US Army Corps
of Engineers®
Walla Walla District

FINAL

Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

APPENDIX E

Existing Systems and Major System Improvements Engineering

February 2002

FEASIBILITY STUDY DOCUMENTATION

	Document Title
Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement	
Appendix A (bound with B)	Anadromous Fish Modeling
Appendix B (bound with A)	Resident Fish
Appendix C	Water Quality
Appendix D	Natural River Drawdown Engineering
Appendix E	Existing Systems and Major System Improvements Engineering
Appendix F (bound with G, H)	Hydrology/Hydraulics and Sedimentation
Appendix G (bound with F, H)	Hydroregulations
Appendix H (bound with F, G)	Fluvial Geomorphology
Appendix I	Economics
Appendix J	Plan Formulation
Appendix K	Real Estate
Appendix L (bound with M)	Lower Snake River Mitigation History and Status
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Appendix N (bound with O, P)	Cultural Resources
Appendix O (bound with N, P)	Public Outreach Program
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Appendix Q (bound with R, T)	Tribal Consultation and Coordination
Appendix R (bound with Q, T)	Historical Perspectives
Appendix S*	Snake River Maps
Appendix T (bound with R, Q)	Clean Water Act, Section 404(b)(1) Evaluation
Appendix U	Response to Public Comments

*Appendix S, Lower Snake River Maps, is bound separately (out of order) to accommodate a special 11 x 17 format.

The documents listed above, as well as supporting technical reports and other study information, are available on our website at http://www.nww.usace.army.mil/lsr. Copies of these documents are also available for public review at various city, county, and regional libraries.

STUDY OVERVIEW

Purpose and Need

Between 1991 and 1997, due to declines in abundance, the National Marine Fisheries Service (NMFS) made the following listings of Snake River salmon or steelhead under the Endangered Species Act (ESA) as amended:

- sockeye salmon (listed as endangered in 1991)
- spring/summer chinook salmon (listed as threatened in 1992)
- fall chinook salmon (listed as threatened in 1992)
- steelhead (listed as threatened in 1997).

In 1995, NMFS issued a Biological Opinion on operations of the Federal Columbia River Power System (FCRPS). Additional opinions were issued in 1998 and 2000. The Biological Opinions established measures to halt and reverse the declines of ESA-listed species. This created the need to evaluate the feasibility, design, and engineering work for these measures.

The Corps implemented a study (after NMFS' Biological Opinion in 1995) of alternatives associated with lower Snake River dams and reservoirs. This study was named the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study). The specific purpose and need of the Feasibility Study is to evaluate and screen structural alternatives that may increase survival of juvenile anadromous fish through the Lower Snake River Project (which includes the four lowermost dams operated by the Corps on the Snake River—Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams) and assist in their recovery.

Development of Alternatives

The Corps' response to the 1995 Biological Opinion and, ultimately, this Feasibility Study, evolved from a System Configuration Study (SCS) initiated in 1991. The SCS was undertaken to evaluate the technical, environmental, and economic effects of potential modifications to the configuration of Federal dams and reservoirs on the Snake and Columbia Rivers to improve survival rates for anadromous salmonids.

The SCS was conducted in two phases. Phase I was completed in June 1995. This phase was a reconnaissance-level assessment of multiple concepts including drawdown, upstream collection, additional reservoir storage, migratory canal, and other alternatives for improving conditions for anadromous salmonid migration.

The Corps completed a Phase II interim report on the Feasibility Study in December 1996. The report evaluated the feasibility of drawdown to natural river levels, spillway crest, and other improvements to existing fish passage facilities.

Based in part on a screening of actions conducted for the Phase I report and the Phase II interim report, the study now focuses on four courses of action:

- Existing Conditions
- Maximum Transport of Juvenile Salmon

- Major System Improvements
- Dam Breaching.

The results of these evaluations are presented in the combined Feasibility Report (FR) and Environmental Impact Statement (EIS). The FR/EIS provides the support for recommendations that will be made regarding decisions on future actions on the Lower Snake River Project for passage of juvenile salmonids. This appendix is a part of the FR/EIS.

Geographic Scope

The geographic area covered by the FR/EIS generally encompasses the 140-mile long lower Snake River reach between Lewiston, Idaho and the Tri-Cities in Washington. The study area does slightly vary by resource area in the FR/EIS because the affected resources have widely varying spatial characteristics throughout the lower Snake River system. For example, socioeconomic effects of a permanent drawdown could be felt throughout the whole Columbia River Basin region with the most effects taking place in the counties of southwest Washington. In contrast, effects on vegetation along the reservoirs would be confined to much smaller areas.

Identification of Alternatives

Since 1995, numerous alternatives have been identified and evaluated. Over time, the alternatives have been assigned numbers and letters that serve as unique identifiers. However, different study groups have sometimes used slightly different numbering or lettering schemes and this has led to some confusion when viewing all the work products prepared during this long period. The primary alternatives that are carried forward in the FR/EIS currently involve the following four major courses of action:

Alternative Name	PATH[1/] Number	Corps Number	FR/EIS Number
Existing Conditions	A-1	A-1	1
Maximum Transport of Juvenile Salmon	A-2	A-2a	2
Major System Improvements	A-2’	A-2d	3
Dam Breaching	A-3	A-3a	4

[1/] Plan for Analyzing and Testing Hypotheses

Summary of Alternatives

The **Existing Conditions Alternative** consists of continuing the fish passage facilities and project operations that were in place or under development at the time this Feasibility Study was initiated. The existing programs and plans underway would continue unless modified through future actions. Project operations include fish hatcheries and Habitat Management Units (HMUs) under the Lower Snake River Fish and Wildlife Compensation Plan (Comp Plan), recreation facilities, power generation, navigation, and irrigation. Adult and juvenile fish passage facilities would continue to operate.

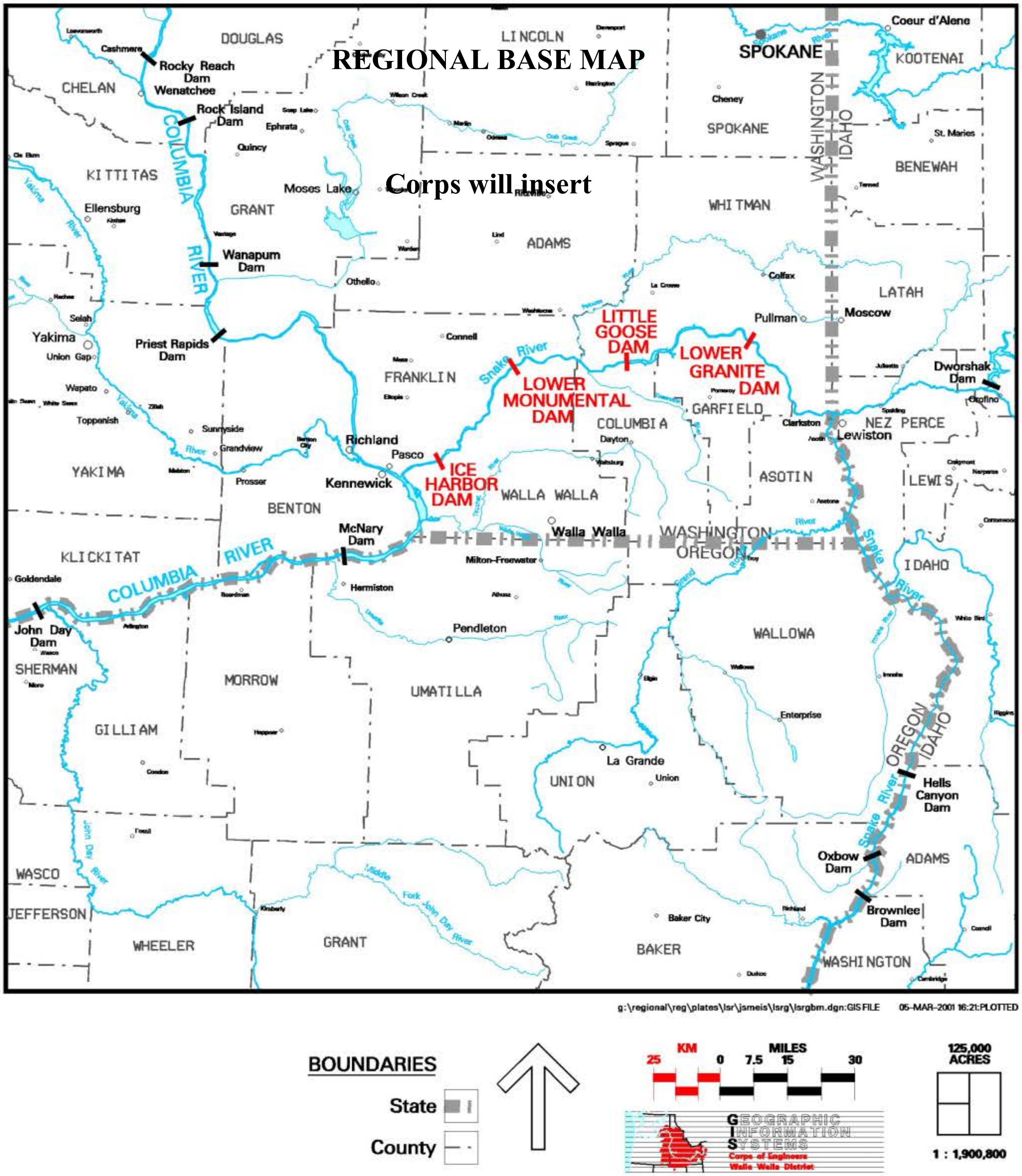
The **Maximum Transport of Juvenile Salmon Alternative** would include all of the existing or planned structural and operational configurations from the Existing Conditions Alternative. However, this alternative assumes that the juvenile fishway systems would be operated to maximize fish transport from Lower Granite, Little Goose, and Lower Monumental and that voluntary spill would not be used to bypass fish through the spillways (except at Ice Harbor). To accommodate this maximization of transport, some measures would be taken to upgrade and improve fish handling facilities.

The **Major System Improvements Alternative** would provide additional improvements to what is considered under the Existing Conditions Alternative. These improvements would be focused on using surface bypass facilities such as surface bypass collectors (SBCs) and removable spillway weirs (RSWs) in conjunction with extended submerged bar screens (ESBSs) and a behavioral guidance structure (BGS). The intent of these facilities would be to provide more effective diversion of juvenile fish away from the turbines. Under this alternative, an adaptive migration strategy would allow flexibility for either in-river migration or collection and transport of juvenile fish downstream in barges and trucks.

The **Dam Breaching Alternative** has been referred to as the "Drawdown Alternative" in many of the study groups since late 1996 and the resulting FR/EIS reports. These two terms essentially refer to the same set of actions. Because the term drawdown can refer to many types of drawdown, the term dam breaching was created to describe the action behind the alternative. The Dam Breaching Alternative would involve significant structural modifications at the four lower Snake River dams, allowing the reservoirs to be drained and resulting in a free-flowing yet controlled river. Dam breaching would involve removing the earthen embankment sections of the four dams and then developing a channel around the powerhouses, spillways, and navigation locks. With dam breaching, the navigation locks would no longer be operational and navigation for large commercial vessels would be eliminated. Some recreation facilities would close while others would be modified and new facilities could be built in the future. The operation and maintenance of fish hatcheries and HMUs would also change, although the extent of change would probably be small and is not known at this time.

Authority

The four Corps dams of the lower Snake River were constructed and are operated and maintained under laws that may be grouped into three categories: 1) laws initially authorizing construction of the project, 2) laws specific to the project passed subsequent to construction, and 3) laws that generally apply to all Corps reservoirs.



LOWER SNAKE RIVER
Juvenile Salmon Migration Feasibility Study

REGIONAL BASE MAP

US Army Corps of Engineers®
Walla Walla District

Final
Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

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Appendix E
Existing Systems and Major System Improvements Engineering

Produced by

U.S. Army Corps of Engineers
Walla Walla District

February 2002

FOREWORD

Appendix E was prepared by staff of the U.S. Army Corps of Engineers (Corps), Walla Walla District. Contributors to this appendix included Jacobs-Sverdrup Engineering, Inc., ENSR Engineering, and Hamilton Engineering. This appendix is one part of the overall effort of the Corps to prepare the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement (FR/EIS).

The Corps has reached out to regional stakeholders (Federal agencies, tribes, states, local governmental entities, organizations, and individuals) during the development of the FR/EIS and appendices. This effort resulted in many of these regional stakeholders providing input and comments, and even drafting work products or portions of these documents. This regional input provided the Corps with an insight and perspective not found in previous processes. A great deal of this information was subsequently included in the FR/EIS and appendices; therefore, not all of the opinions and/or findings herein may reflect the official policy or position of the Corps.

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ACRONYMS AND ABBREVIATIONS

AFEP	Anadromous Fish Evaluation Program
BGS	behavioral guidance structure
BOR	Bureau of Reclamation
CBFWA	Columbia Basin Fish and Wildlife Authority
CBE	combined bypass efficiency
cfs	cubic feet per second
Corps	U.S. Army Corps of Engineers
DGAS	Dissolved Gas Abatement Study
ESA	Endangered Species Act
ESBS	extended submerged bar screen
FGE	fish guidance efficiency
flip lips	spillway flow deflectors
FLE	fish ladder extension
FPE	fish passage efficiency
FR/EIS	Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement
m3/s	cubic meters per second
MOP	minimum operating pool
NMFS	National Marine Fisheries Service
NPPC	Northwest Power Planning Council
O&M	operation and maintenance
PB-2A	Detailed Project Schedule
RPA	reasonable and prudent alternative
RSW	removable spillway weir
SBC	surface bypass collector
SES	spillway extension structure
SRWG	Study Review Work Group
str	structure
STS	submerged traveling screen
SWI	simulated Wells intake
TDG	total dissolved gas
USFWS	US Fish and Wildlife Service

ENGLISH TO METRIC CONVERSION FACTORS

To Convert From	To	Multiply By
LENGTH CONVERSIONS:		
Inches	Millimeters	25.4
Feet	Meters	0.3048
Miles	Kilometers	1.6093
AREA CONVERSIONS:		
Acres	Hectares	0.4047
Acres	Square meters	4047
Square Miles	Square kilometers	2.590
VOLUME CONVERSIONS:		
Gallons	Cubic meters	0.003785
Cubic yards	Cubic meters	0.7646
Acre-feet	Hectare-meters	0.1234
Acre-feet	Cubic meters	1234
OTHER CONVERSIONS:		
Feet/mile	Meters/kilometer	0.1894
Tons	Kilograms	907.2
Tons/square mile	Kilograms/square kilometer	350.2703
Cubic feet/second	Cubic meters/sec	0.02832
Degrees Fahrenheit	Degrees Celsius	(Deg F –32) x (5/9)

Executive Summary

Purpose

The Walla Walla District of the U.S. Army Corps of Engineers (Corps) operates four lock and dam facilities on the lower Snake River. These include the Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams. In response to the National Marine Fisheries Service (NMFS) 1995 Biological Opinion concerning the operation of the Federal hydropower system, the Corps is studying structural and operational alternatives to improve the downstream migration of juvenile salmonids through the four lower Snake River dams. These alternatives will provide improved downstream fish migration while keeping the dams operational.

The alternatives described in this appendix may be compared to each other and to the other alternative identified for investigation under this feasibility study — breaching of the four lower Snake River dams.

The information contained in this appendix will be used to assist in decisions regarding future project modifications and operations of the lower Snake River system.

Fish Passage Strategies

The term "Existing System Upgrades," as used in this appendix, refers to options available for upgrading the existing facilities used for transporting or bypassing downstream migrating juvenile fish. Existing System Upgrades corresponds to Alternatives 1 and 2 in the FR/EIS. The term "Major System Improvements," as used in this appendix, involves the use of surface bypass collectors (SBCs) and other devices to provide a way to collect fish swimming near the surface. Major System Improvements corresponds to Alternative 3 in the FR/EIS.

This appendix utilizes three different fish passage strategies in order to define and evaluate the various alternatives. These strategies include:

- In-River Passage — Keeping the fish in the river during their downstream migration.
- Transport — Collecting and transporting the fish downstream of Bonneville Dam.
- Adaptive Migration — Providing operational alternatives to allow an effective method for either in-river passage or transport.

These strategies were applied to the options for upgrading the existing facilities (Existing System Upgrades) and to the Major System Improvement alternatives. The modifications required for upgrading the existing system include the following:

- Improvement of the effectiveness of the juvenile fish bypass and collection facilities
- Additional barges for fish transportation
- Turbine modifications and improvements made during a major rehabilitation of the powerhouse
- Modification of spillways to reduce dissolved gas levels.

Major System Improvements includes upgrading the existing system, constructing SBC systems, and new extended submerged bar screens (ESBSs) in turbine entrances. Surface bypass and collection systems consist of surface collectors, behavioral guidance structures (BGSs), and modified spillbays.

Unresolved Issues

The development of SBC technology is still underway. As more is learned about the effectiveness of various components of surface bypass and collection systems, designs may be developed that have a higher reliability of success. These designs may differ from those presented in this appendix. However, the SBC alternatives described in this appendix represent effective options for improving the current system of transporting and/or bypassing fish past the dams.

Some of the surface bypass and collection options include modifying a spillbay at each project. This will reduce spillway capacity by as much as 5 percent. If it is decided that a reduction in spillway capacity is not acceptable, an alternate plan to bypass fish via the central non-overflow could be implemented. Alternatively, options that would include methods to pass the 5 percent spillway capacity flow through the powerhouse and/or navigation lock during the rare flood event may be found to be feasible.

Some of the SBC options have the potential of increasing design seismic loading on the existing dam monoliths. Further analysis is required to determine the need for measures to strengthen the structures or increase their stability.

The removable spillway weir (RSW) included with the adaptive migration option, described herein, would require model testing to determine the best shape for providing a fish-friendly bypass. Since the RSW would be resting on top of an existing spillbay, there are limitations on the possible shapes of the weir. Prototype testing would show if an acceptable design could be developed.

Several dissolved gas abatement measures are included herein. These measures include structural modifications to the spillways in an effort to reduce gas levels that are known to be harmful to fish. The improvements are based upon the latest developments in spillway deflector design and have received regional support for rapid installation. The dissolved gas abatement study (DGAS) is a system-wide study that is addressing these measures as well as more extensive measures to reduce total dissolved gas (TDG) supersaturation that forms in both the Snake and Columbia rivers. The need for these more extensive measures will be determined after completion of the system-wide study. Therefore, these more extensive gas abatement measures are not included in this appendix.

Installation of the dissolved gas abatement measures included in this appendix may impact the following: 1) adult fish passage, 2) juvenile fish passage, 3) navigation, and 4) stilling basin and channel erosion. These potential impacts must be evaluated and resolved as necessary prior to implementation of the spillway modifications.

For all alternatives other than a drawdown of the river, a portion of the fish will still be passing through the turbine environment. The Turbine Survival Program is exploring ways to improve passage through the turbines. For the purpose of this study, it was assumed that the fish passage improvements identified in the Turbine Survival Program would be applied to all turbines at the lower Snake River dams. Because of their tremendous costs, the installation of these improvements is assumed to occur during major turbine rehabilitation at that facility.

Summary

The following are summary tables for each of the Existing System Upgrades (Table ES-1) and Major System Improvement (Table ES-2) options investigated in this appendix. The summary tables include 1) costs for lock and dam operations, 2) implementation schedules, 3) fish hatchery costs, and 4) percentage of fish surviving from just upstream of Lower Granite Dam to just downstream of Bonneville Dam.

Table ES-1. Existing System Upgrades: Implementation Costs and Schedules, Hydropower Generation and Fish Survival through the System

Option No./ Description (Spill Condition)	New Construction Costs ($million)	Construction Schedule (Duration–Years)	AFEP Annual Costs for 27 Years ($million)	AFEP Schedule (Duration–Years)	Lock and Dam Routine O & M and Minor Repair Annual Costs ($million)	Major Rehabilitation of Turbines ($million)	Major Rehabilitation of Turbines Schedule (Duration–Years)	Fish Hatcheries O&M and Minor Repair Annual Costs ($million)	BOR Annual Costs ($million)	Fish Survival Through the System (%)
A-1 Adaptive Management strategy (voluntary spill)	89.3	5	5.3	27	36.5	193.6	41	14.5	2.4	83.38
A-1a In-River (voluntary spill)	80.1	5	5.3	27	35.8	193.6	41	14.5	2.4	54.94
A-2a Transport (No voluntary spill except Ice Harbor)	67.9	5	3.6	27	36.5	193.6	41	14.5	2.4	93.11

Notes: AFEP = Anadromous Fish Evaluation Program
O & M = Operation and Maintenance
MW-hr = Megawatts per hour
BOR = Bureau of Reclamation
The duration of these costs varies by cost category and alternative. Therefore, all costs are amortized over a 100-year period for comparability.

Table ES-2. Major System Improvements: Implementation Costs and Schedules, Hydropower Generation and Fish Survival through the System (New Construction Costs Include Existing System Upgrade Costs)

Option No./ Description (Spill Condition)	New Construction Costs ($million)	Construction Schedule (Duration–Years)	AFEP Annual Costs for 27 Years ($million)	AFEP Schedule (Duration–Years)	Lock and Dam Routine O & M and Minor Repair Annual Costs ($million)	Major Rehabilitation of Turbines ($million)	Major Rehabilitation of Turbines Schedule (Duration–Years)	Fish Hatcheries O&M and Minor Repair Annual Costs ($million)	BOR Annual Costs ($million)	Fish Survival Through the System (%)
A-2b Transport (High Cost–No voluntary spill)	270.0	11	7.4	27	38.0	193.6	41	14.5	2.4	95.45
A-2c Transport (Low Cost–No voluntary spill except Ice Harbor)	162.5	7	5.7	27	37.0	193.6	41	14.5	2.4	95.41
A-2d Adaptive Management Strategy (voluntary spill varies)	389.6	10	9.5	27	37.2	193.6	41	14.5	2.4	Not Available
A-6a In-River (Voluntary Spill and No BGS, Higher Flow Augmentation)	316.7	10	9.2	27	35.8	193.6	41	14.5	(See Annex E)	65.87
A-6b In-River (voluntary spill and no BGS, no flow augmentation)	316.7	10	9.2	27	35.8	193.6	41	14.5	28.1	Not Available
A-6d In-River (voluntary spill only at Little Goose, BGS at other dams)	249.2	10	9.0	27	35.4	193.6	41	14.5	2.4	Not Available

Notes:
AFEP = Anadromous Fish Evaluation Program
O & M = Operation and Maintenance
MW-hr = Megawatts per hour
BOR = Bureau of Reclamation

The duration of these costs varies by cost category and alternative. Therefore, all costs are amortized over a 100-year period for comparability.

1. Introduction

1.1 General

The Walla Walla District of the U.S. Army Corps of Engineers (Corps) operates four lock and dam projects on the lower Snake River, including Lower Granite, Little Goose, Lower Monumental, and Ice Harbor. In response to the National Marine Fisheries Service (NMFS) 1995 Biological Opinion concerning the operation of the Federal Columbia River Power System, the Corps is studying structural and operational alternatives to improve the downstream migration of juvenile salmon smolts through the four lower Snake River dams.

For the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study), four alternatives are being studied: Alternative 1—Existing Conditions, Alternative 2—Maximum Transport of Juvenile Salmon, Alternative 3—Major System Improvements, Alternative 4—Dam Breaching.

The term “Existing System Upgrades,” as used in this appendix, refers to options available for upgrading the existing facilities used for transporting or bypassing downstream migrating juvenile fish. Existing System Upgrades corresponds to Alternatives 1 and 2 in the FR/EIS. The term “Major System Improvements,” as used in this appendix, involves the use of surface bypass collectors (SBC) and other devices to provide a way to collect fish swimming near the surface. Major System Improvements corresponds to Alternative 3 in the FR/EIS.

Existing System Upgrades not only covers facilities and project operations as they currently exist and are operated at the dams and reservoirs, but also includes measures to maintain or upgrade present facilities to state-of-the-art design and operation. Depending on the juvenile fish passage strategy (see Section 1.3), this may or may not require voluntary spill. A full discussion of Existing System Upgrades involving dissolved gas, turbines, and other miscellaneous measures is provided in Annexes A, C, and D, respectively.

Major System Improvements includes upgrades to the existing systems plus major system modifications that significantly impact project layout and operations. This includes utilizing surface bypass and collection technology to safely collect and guide fish. Depending on the alternative, voluntary spill may or may not be required. A full discussion of surface collection systems included with Major System Improvements options can be found in Annex B.

Dam Breaching is evaluated in Appendix D, Natural River Drawdown Engineering.

1.2 Purpose

This document presents key engineering and cost information concerning the Existing System Upgrades and Major System Improvements alternatives. In addition, it summarizes biological performance information gathered during prototype testing of surface collector concepts and predicted biological performance data for each of the alternatives included in this appendix. This information will be used in the Feasibility Study where recommendations regarding future project modifications and operations of the lower Snake River system will be made.

1.3 Juvenile Fish Passage Strategies

Existing System Upgrades and Major System Improvements are described in the context of three strategies for aiding in the downstream migration of juvenile fish safely past the dams: 1) In-River Bypass, 2) Transport, and 3) Adaptive Migration Strategy.

In-River Bypass refers to designs and operations that would bypass fish directly to the tailrace via existing spillways or through some type of fish bypass strategy. No trucking or barging of fish would be done. Based on current project operations, this strategy would require voluntary spill.

Transport refers to directing fish to a truck or barge transport system with capabilities to bypass fish to the tailrace in an emergency. This strategy would generally not require voluntary spill.

The Adaptive Migration Strategy would optimize current operational objectives where either in-river or transport strategies can be used. This strategy addresses concerns about the risks and effectiveness associated with bypass only and transport only. The combined overall strategy would be to operate the different facilities so that a spread-the-risk philosophy could be implemented considering the whole river system. This strategy might be used over a relatively short time period (5 to 10 years) until a regional decision is made to select either a transport or in-river passage strategy. The Adaptive Migration Strategy might also be a long-term plan, where transport may be used at certain times and in-river bypass used at other times, depending on varying river conditions. This type of operation may include voluntary spill, but it will depend on whether the fish are kept in the river or transported. Because of its operational flexibility, the Adaptive Migration Strategy is more effective at addressing doubts as to whether fish transportation is better or worse for fish than in-river passage.

1.4 Spill Operations

In this appendix, “voluntary spill” is defined as spill intended to attract juvenile fish to the spillways for in-river passage. Typically, this spill would not have taken place under normal project operations. “Involuntary spill” is defined as spill that is required to pass high river discharge past the project once powerhouse capacities/power requirements have been reached.

As described in the Fish Passage Plan for Corps of Engineers Projects (March 1998), the Corps shall spill for juvenile fish passage according to the NMFS Biological Opinion. As it relates to the lower Snake River dams, during the juvenile spring/summer chinook migration season (April 10 through June 20), the Corps is to spill at all dams (except under certain exceptions) to the gas cap, which has been defined as 120 percent total dissolved gas (TDG) supersaturation. Voluntary spill levels are limited by the resulting TDG levels. If the TDG levels are high enough and fish are exposed to these levels long enough, both adult and juvenile migrants would be harmed.

The decision to include voluntary spill as a portion of any Major System Improvements alternative will depend upon the ability of voluntary spill to help achieve the goals of that alternative.

1.5 Annexes

Annexes to this appendix are included at the back of the appendix. These annexes provide detailed backup information used to develop the main body of the appendix. The reader may wish to refer to the annexes for detailed information not included in the main body of the appendix.

The annexes include the following descriptions:

- Existing system operations (including proposed upgrades to the existing system)
- Surface bypass and collection alternatives
- Dissolved gas abatement measures
- Turbine Survival Program
- Cost and implementation schedules.

2. Background

2.1 General

On March 2, 1995, the National Marine Fisheries (NMFS) issued a biological opinion for the Reinitiation of Consultation on 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years (NMFS, 1995a). The biological opinion established immediate measures necessary for the survival and recovery of Snake River salmon stocks listed under the Endangered Species Act (ESA). In response to the biological opinion, the Corps has been investigating various system improvements to the lower Snake River dams intended to improve the effectiveness of downstream smolt migration. These system improvements represent an alternative to a drawdown of the lower Snake River dams.

2.2 Existing Juvenile Fish System

Since the construction of each of the lower Snake River dams, the Corps has operated adult fish collection and passage facilities at each dam. These facilities were developed in collaboration with the regional fishery agencies to aid in the upstream migration of adult fish. Juvenile fish bypass facilities were developed or installed as the four lower Snake River dams were constructed. Facilities were upgraded as new technology developed.

2.3 Development of Surface Bypass and Collection Technology

The Corps has focused much attention on the development of surface bypass and collection system (SBC) options. These options are intended to collect downstream migrating smolts in the forebay and safely bypass them across the dam (in-river options) or transport them downstream in trucks or barges (transportation option). Objectives for developing SBC systems include: 1) increasing the number of juvenile fish guided for bypass or collection through non-turbine routes; 2) reducing fish stress, injury, and migration delays; and 3) reducing high-spill levels that are associated with dissolved gas problems and lost power generation.

Brainstorming sessions were held in Walla Walla in July 1994 in order to develop and expand surface bypass and collection concepts. Participants in these meetings included private individuals; consulting firm representatives; and state, Federal, and tribal fishery representatives. A prototype surface collector was constructed in 1996 at Lower Granite Dam. The basis for this design was the successful surface-oriented bypass system currently in use at Wells Dam on the mid-Columbia River. Biological performance data of the Lower Granite prototype were collected and evaluated. Modifications were made in 1998 to the Lower Granite prototype to effectively make the collector deeper and to include a behavioral guidance structure (BGS) to guide fish to the SBC entrance. More testing is now underway. A more detailed discussion of the SBC prototype testing is included is Section 4.4 of this appendix.

Preliminary hydraulic model testing of methods for removing most of the water entering the SBC has been completed. Dewatering to a lower flow rate is required for SBCs that allow for fish transportation because the downstream juvenile fish facility cannot handle the large flows used in surface collection. Results of the SBC testing and dewatering modeling have been encouraging. Therefore, further development of SBC options is ongoing.

2.4 Conceptual Level Surface Bypass Collector Designs

The Corps contracted the development of concept level SBC designs for the lower Snake River dams based on the fundamental surface collector concepts being tested at Lower Granite Dam. This effort focused on the development of SBC designs and costs while the prototype testing at Lower Granite was used for evaluating SBC performance.

Once the prototype testing had provided preliminary performance levels for the various concepts and the engineering report had verified feasibility and cost, it was necessary to define combinations of measures that would most reasonably meet the goals of the fish passage strategies (in-river passage, transportation, adaptive migration). A second report was developed investigating various SBC system combinations (refer to Annex B). These alternative combinations are represented in Tables 1 and 2 in the Executive Summary and are more fully described later in this appendix and in Annex B.

2.5 Dissolved Gas Abatement Study

Currently, the Corps is actively involved in the development of methods reducing total dissolved gas (TDG) supersaturation in the lower Snake and Columbia river systems. High levels of TDG supersaturation are known to be harmful to fish. The DGAS does not involve separate investigations of the Snake and Columbia rivers. Instead, the DGAS treats the TDG supersaturation as a system-wide problem. To date, the study has included a Phase I technical report. A Phase II report is currently scheduled for completion in fiscal year 2001.

2.6 Coordination

The Corps coordinated with a large number of fish agencies throughout the northwest and local interest groups in the development of the SBC combinations report and the DGAS. For more detailed information, refer to the annexes at the back of this appendix.

3. Existing System Features

The "Existing System" is defined for this appendix as project features and operations that presently are considered to aid in the migration of juvenile and adult fish on the lower Snake River. Major existing system components are listed below.

- Adult Fish Passage Systems: Includes fish ladders, pumped attraction water supplies, and powerhouse fish collection systems designed to aid upstream migrating adult fish.
- Juvenile Fish Bypass and Collection Systems: Includes turbine intake screen systems.
- Juvenile bypass and collection facilities and transportation facilities intended to aid downstream migrating fish.
- Minimum Operating Pools (MOP): Includes operating the reservoirs at minimum operating pool elevation during the juvenile fish outmigration.
- Turbine Operations: Includes operating the turbines within 1 percent of peak efficiency.
- Spill Operations: Includes voluntary spill to assist in the bypassing of juvenile salmon and steelhead in accordance with the biological opinion. The spill is thought to attract the fish away from the turbines, and towards the spillway.
- Flow Augmentation: Includes the use of upstream storage for flow augmentation. Flow augmentation decreases the duration of downstream migration.
- Spillway Gas Control Measures: Includes the use of spill deflectors to allow an increase in spill flows without exceeding the 120 percent total dissolved gas (TDG) supersaturation.
- Spillway Gas Monitoring: Continued monitoring and control of TDG levels in order to ensure compliance with state standards.
- Fish Hatcheries: Continued operation and maintenance of fish hatcheries.
- Anadromous Fish Evaluation Program (AFEP): Involves biological evaluations of anadromous fish and evaluations of proposed dam modifications to predict resulting impacts to fish.

Refer to Annex A for more detailed information, including the current operations per the 1995 Biological Opinion.

4. Future Development

4.1 Introduction

Measures that have a high potential of increasing the effectiveness and efficiency of getting fish past the dams are discussed below. These measures are combined to form the Existing System Upgrade options (see Section 5) and Major System Improvement options (see Section 6). The information presented in Sections 4.2 and 4.3 provides an overview of key measures that could be used as part of either Existing System Upgrades or Major System Improvements.

4.2 Dissolved Gas Abatement Measures

4.2.1 General

A Dissolved Gas Abatement Study (DGAS) was initiated in 1994 to examine potential methods of reducing total dissolved gas (TDG) produced by spillway operations at the Corps' eight dams on the lower Snake and Columbia rivers. The study was called for by the National Marine Fisheries Service (NMFS) biological opinion on operation of the Federal Columbia River Power System (1995). NMFS prescribed two reasonable and prudent alternatives (RPA 16 and 18) that directed the Corps to address means to measure, evaluate, and prescribe alternatives to reduce TDG in the lower Snake and Columbia rivers.

The DGAS is being completed in two parts: a Phase I reconnaissance-level report and a Phase II feasibility-level report. The Phase I report was completed in April 1996. The Phase II report is scheduled for completion in 2001.

The Phase I report recommended several measures that could be implemented quickly to provide immediate reductions in TDG production. These measures included spillway operational changes and design and construction of spillway deflectors at Ice Harbor and John Day Dams. These measures have been implemented and the associated benefits were observed during the spring of 1998.

The Phase II DGAS studies are complete. Numerous structural measures that hold potential for reducing TDG production have been identified and the system-wide engineering evaluation is complete. The Phase II effort and descriptions of the measures, which could be implemented at the lower Snake River dams, are summarized in Annex C of this appendix.

Various gas abatement improvements are described in this appendix. These DGAS measures will provide water quality benefits by reducing TDG production at the lower Snake River dams. The first DGAS measure described below includes installation of end bay deflectors. This has been proven to be a significant benefit for gas abatement at a relatively low cost. This proposed improvement has received considerable regional support and has been made a part of all alternatives described in this appendix.

The second group of DGAS options described below includes various modifications of the existing deflectors and installation of new pier extensions.

A third level of gas abatement protection may be provided by use of one or more of the major gas improvement measures defined within the gas abatement annex (Annex C). One of these concepts is a powerhouse/spillway divider wall at each dam to reduce the introduction of gas into powerhouse exit flows. This concept is described herein.

The measures described below would be designed to minimize the production of TDG through a range of normal flows under current operating conditions. These would reduce the TDG concentrations resulting from current spill levels. Also, the gas abatement measures would provide the ability to increase spill volumes for fish passage, without exceeding the 120 percent TDG supersaturation level spill cap included in the 1995 Biological Opinion. Other identified measures could eventually be recommended following the system-wide analysis. Refer to Annex C for a more complete description of all the DGAS alternatives.

4.2.2 Additional End Bay Spillway Deflectors

Spillway flow deflectors have been installed at all four of the lower Snake River dams (Table 4-1). Deflectors consist of a 2.4- to 3.8-meter (8.0 to 12.5 feet) horizontal lip placed on the spillway ogee section just below or near the minimum tailwater elevation. "Ogee" refers to the reverse curve shape of the spillway. The deflectors produce a thin discharge jet that skims the water surface of the stilling basin. Though the skimming flow is highly aerated, spillway discharge is prevented from plunging and entraining air deep into the stilling basin. Reducing the depth of plunge, and thus the hydrostatic pressures acting on the aerated flow, reduces the production of TDGs.

Table 4-1. Existing Deflectors

Dam	No. of Spillway Bays	No. of Deflectors	Deflector Elevation (meters)	Deflector Length (meters)	Deflector Transition (meters)
Ice Harbor	10	8	103.0 (338.0)	3.81 (12.5)	4.57 (15.0) radius
Ice Harbor	10	2	101.8 (334.0)	3.81 (12.5)	4.57 (15.0) radius
Lower Monumental	8	6	132.2 (434.0)	3.81 (12.5)	Flat
Little Goose	8	6	162.2 (532.0)	2.44 (8.0)	Flat
Lower Granite	8	8	192.0 (630.0)	3.81 (12.5)	4.57 (15.0) radius

Note: feet in parentheses (feet)

Deflectors have lowered the levels of dissolved gasses generated by conventional spillways by as much as 15 to 20 percent TDG. The construction of additional flow deflectors on non-deflected spillway bays will further reduce TDG production.

The effectiveness of spillway flow deflectors is dependent upon the geometry of the deflector, spillway discharge, and deflector submergence (tailwater elevation minus deflector elevation). Performance is optimized when the elevation of the deflector, associated with a design discharge and tailwater elevation, is set to provide a smooth skimming flow. If the tailwater elevation relative to the deflector is too low, the deflected discharge generates a plunging flow, subjecting aerated flow to higher pressures. If the tailwater elevation is too high, the deflected discharge generates a highly aerated undular flow that will also draw air deep into the basin.

Additional spillway flow deflectors can be installed at some of the lower Snake River dams. The benefit of added deflectors is dependent on the hydraulic performance of the deflector and the ratio of deflected to non-deflected spill flow. Spill patterns developed for each project establish the distribution of spill through deflected and non-deflected spillway bays and influence the generation of TDG. They are designed to maintain acceptable tailrace conditions for adult salmonids seeking upstream passage and juvenile salmonids migrating downstream, and are included in the Corps' annual fish passage plan.

Both Lower Monumental and Little Goose spillways have deflectors on six of the eight spillway bays. Thus, these are the only two facilities with the potential for adding end bay deflectors. Deflectors were not constructed in spillway bays 1 and 8 on these projects because of adult fish passage concerns. Recent studies indicate adult passage rates may not be as sensitive to deflected flow conditions as previously expected. Adding end bay deflectors may further reduce the saturation of TDGs without adverse impacts to adult passage.

4.2.2.1 Design

End bay spillway flow deflectors at Lower Monumental and Little Goose Dams would be designed to provide optimum skimming flow conditions for spillway flows up to 283.2 cubic meters per second (m^3/s) (10,000 cubic feet per second [cfs]) per bay and tailwater elevations up to 135.3 meters (444 feet) at Lower Monumental and 165.2 meter (542 feet) at Little Goose. Based on the performance of the Ice Harbor deflectors and current project operating conditions, deflectors in spillway bays 1 and 8 would be 3.81 meters (12.5 feet) long with a 1.2-meter (15-feet)-radius fillet between the sloped face of the spillway and the horizontal surface of the deflector. The two additional deflectors would include pier nose extensions and would be set at elevation 131.0 meter (430 feet) at Lower Monumental and 161.2 meter (529 feet) at Little Goose, 1.2 meters (4 feet) lower than the existing deflectors. At this elevation the deflectors should provide optimum hydraulic performance for voluntary fish passage spills up to the 120 percent TDG spill levels, which may range from 198.2 to 283.2 m^3/s (7,000 to 10,000 cfs) per bay.

Sectional spillway and general model studies will be required to verify the final deflector design. The influence of the lower deflectors on stilling basin performance and potential impacts to tailrace and stilling basin erosion must be carefully evaluated. Consideration must also be given to adult fish passage and the influence of the flow deflectors on fishway entrance conditions.

4.2.2.2 Total Dissolved Gas Performance

For Lower Monumental, TDG levels of 120 percent are generated with a uniform spill release of 203 m^3/s (7,170 cfs) through each of the six bays with deflectors for a total of 1,218 m^3/s (43,000 cfs). If the two end bay deflectors are constructed and perform similar to the Ice Harbor deflectors, the 120 percent TDG spill cap may increase by 198 to 283 m^3/s (7,000 to 10,000 cfs) per end bay, potentially raising the total 120 percent TDG discharge to between 1,721 and 1,892 m^3/s (60,800 to 66,800 cfs).

For Little Goose, TDG levels of 120 percent are generated with a uniform spill release of 227 m^3/s (8,000 cfs) through each of the six spill bays with deflectors. This is a total for the dam of 1,359 m^3/s (48,000 cfs). If the two end bay deflectors are constructed and perform similar to the Ice Harbor deflectors, the 120 percent TDG spill cap may increase by 198 to 283 m^3/s (7,000 to 10,000 cfs) per end bay. This may potentially raise the total 120 percent TDG discharge to 1,841 m^3/s (65,000 cfs).

4.2.2.3 Operations

If properly designed, end bay deflectors should have no impact on project operations except that they will allow additional spill volumes before the tailrace exceeds the 120 percent TDG cap. This may reduce the amount of water available to pass through the existing powerhouse resulting in reduced power generation.

4.2.3 Modified Deflectors

The effectiveness of a flow deflector will improve if it can be designed to perform over a wider range of spill discharge and tailwater fluctuations. The ideal deflector generates a smooth, stable skimming flow across the water surface of the stilling basin. However, the existing deflectors were designed to perform within a narrow range of tailwater elevations and spill discharges. The deflectors recently constructed at Ice Harbor and John Day appear to perform better than deflectors at other projects in terms of gas production versus spill discharge. The new deflectors are 3.81 meters (12.5 feet) long with a 4.6-meter (15-foot)-radius transition and are set at an elevation that provides optimal performance during the more typical project operations under the current voluntary spill program. The pier walls between spillway bays at Ice Harbor and John Day were also extended to the end of the deflectors. Deflectors at other projects may be modified to perform more like the new John Day and Ice Harbor spillway deflectors. These modifications are relatively inexpensive and could reduce gas levels by a few percentage points.

With the exception of Ice Harbor, current operations at the lower Snake River dams are different from those at the time of the original deflector installation. Projects typically operate at minimum pool elevations as required by the 1995 Biological Opinion. Voluntary spill resulting in up to 120 percent TDG supersaturation is requested to aid fish passage. Turbine discharges are limited to operations within the peak one percent of efficiency, limiting the total powerhouse discharge to less than 3,400 m^3/s (120,000 cfs). Each of these operational measures cause the deflectors to function over a range of tailwater elevations lower than that used for the original design.

The new spillway flow deflectors at John Day and Ice Harbor Dams were constructed with a 4.6-meter (15-foot)-radius transition (fillet) from the spillway ogee to the horizontal surface of the deflector. Lower Granite was also constructed with a 4.6-meter (15-foot) radius and the Bonneville deflectors have a 1.8-meter (6-foot)-radius fillet. The deflectors at Little Goose and McNary Dams do not have a radius fillet. Two deflectors at Lower Monumental have a radius fillet. Model studies and prototype evaluations indicate deflectors with a radius transition generate a smoother and more stable surface jet.

Pier extensions were added at both John Day and Ice Harbor. The pier extensions extend the downstream face of the existing piers flush to the downstream edge of the flow deflector. The pier extensions prevent the sidewall flow from directly impacting the flow deflector and plunging into the basin. The sidewall flow rises from the corners of the spillway gates and rides 1.8 to 2.4 meters (6 to 8 feet) above the surface of the spillway discharge jet. As the sidewall flow reaches the end of the pier walls it expands abruptly. The two jets, one from each side of the wall, converge. The lower portion of the combined jet impacts the exposed section of the deflector immediately below the pier. The upper portion reaches beyond the deflector and plunges into the stilling basin. The extension forces the expansion of sidewall flow to occur further out away from the deflector, where the flow becomes intercepted by the much more dominant deflected surface flow, preventing it from plunging into the basin. The hydraulic performance of pier extensions has been observed in the spillway sectional models of John Day and Ice Harbor, as well as the prototype structures. Though both John Day and Ice Harbor deflectors provide excellent gas reduction benefits, it is difficult to determine the overall influence of the pier extension on the TDG performance of those deflectors. However, it is reasonable to expect that by preventing the sidewall flow from entraining air and plunging deep into the stilling basin, the generation of TDGs will be reduced. In addition to reducing the plunging and aeration of flow, the pier walls were recommended to prevent fish, which may be entrained within the lower portion of the sidewall flow, from directly impacting the exposed section of the spillway flow deflector.

The TDG reduction performance of deflectors set too high or too low, because of outdated operations, may be improved by raising or lowering them accordingly. Project-specific operations for a design range of total river flows must be established to optimize the deflector elevation. Given the percent spill requirement and design range of total river flow, the tail water elevations and unit spill discharges are easily identified. The ideal submergence and deflector elevation can then be determined from physical spillway model studies and prototype evaluations.

4.2.3.1 Design

Deflector modifications could include pier nose extensions, construction of a smooth radius transition, and reconstruction of the deflector at an optimum elevation. Based on the performance of the Ice Harbor deflectors and current project operating conditions, the modified deflectors would be 3.8 meters (12.5 feet) long with a 4.6-meter (15-foot)-radius transition from the sloped face of the spillway to the horizontal surface of the deflector. The new or reconstructed deflectors would be constructed at an elevation providing optimum hydraulic performance for voluntary fish passage spills up to the 120 percent TDG spill levels.

Lowering the existing deflectors would require removal of much of the deflector concrete and reinforcement steel, making it more feasible to remove the entire deflector and construct all new deflectors. However, if the deflectors are not lowered, the radius transitions and pier extensions could possibly be constructed without demolishing the existing deflectors, resulting in significant cost savings.

4.2.3.2 Total Dissolved Gas Performance

The incremental gas abatement improvements of each potential modification are difficult to estimate. Design improvements similar to those implemented at Ice Harbor should produce similar reductions in TDG levels. However, the Ice Harbor tailrace channel is significantly shallower than the Lower Monumental channel. The shallower channel alone may account for gas reduction levels of 2 to 4 percent. It is possible that only a 1 to 2 percent reduction in gas levels may be realized at each dam due to the radius transitions, pier nose extensions, and optimization of the deflector elevation.

4.2.3.3 Operations

Modification of existing deflectors and/or construction of new deflectors will not significantly change or impact project operations. However, the improved deflectors will increase the spill required to reach the 120 percent TDG supersaturation spill cap. Increasing spill will reduce the amount of water available for hydroelectric energy production.

4.2.4 Powerhouse/Spillway Separation Wall

Spill released flows on Lower Snake River projects retrofitted with deflectors will draw flow from the powerhouse into the stilling basin. The entrainment of powerhouse flow is visually evident in general physical hydraulic models of Ice Harbor and Lower Granite. It is also visually evident at the four lower Snake River dams and John Day and McNary Dams. Field tests at Little Goose and Ice Harbor Dams indicate as much as 100 percent of the powerhouse flow can be drawn into the stilling basin under certain operating conditions. Powerhouse flows entrained within in the spillway are exposed to aeration and pressures that saturate this flow to TDG levels typical of the spillway flow itself.

A cutoff wall constructed between the powerhouse and spillway will prevent powerhouse flow from becoming entrained and aerated within the spillway's stilling basin. In addition to the gas reduction benefits of the flow separation wall, the wall will prevent juvenile fish passed through the turbines from being drawn into the spillway. This condition has been observed at McNary Dam during the 1999 turbine survival studies. The separation wall will streamline powerhouse flow and improve current flow patterns below the juvenile fishway out-falls and will reduce or eliminate large eddies that might otherwise delay juvenile fish egress from both powerhouse and spillway tailrace regions.

Both the Lower Granite and Ice Harbor general models were used to establish the wall length necessary to prevent the entrainment of powerhouse flow into the spillway stilling basins. Observations of dye released in the models indicate a wall length of approximately 150 feet extending downstream from the existing powerhouse/spillway training walls will prevent powerhouse flows from becoming entrained within the spillways stilling basin over the entire operating range. The Lower Granite and Ice Harbor general models are 1:80 and 1:55 scale respectively. One to 55 scale general models of Little Goose and Lower Monumental will be completed and available for testing by mid-year 2001. These models can be used to further evaluate the design parameters and benefits of the divider wall at the respective projects.

Two concept level designs were developed. Both designs include two 75-foot long concrete monolithic structures that are post tensioned. The first design concept utilizes sheet pile to construct the wall forms and fills the form with mass tremie concrete. The second design concept utilizes pre-cast concrete cells set in place then filled with tremie concrete. The design and construction of a divider wall at either of the lower Snake River projects could take between 3 to 4 years.

The walls could be added with any of the SBC types included in this appendix. However, more study is required to determine if the separators would be an appropriate addition to the dams. Because of this uncertainty, the walls were not included in any of the Major System Improvements alternatives described herein.

More information about the separation walls is provided in Annex C of this report.

4.2.5 Additional Spillway Bays

Adding more spillway bays at each dam would reduce the generation of TDG by reducing the unit spill discharge requirements and necessary stilling basin depths. Unlike conventional spillways designed to pass and adequately dissipate the energy of flow for the Spillway Design Flood, the additional spillway bays could be designed for much less spill. The spillway would be designed specifically to reduce the saturation of TDG for normal or voluntary spill flows, while improving the spill passage efficiency and survival of juvenile fish.

Additional spillway bays can be constructed in place of the earthen non-overflow embankments of the lower Snake River dams. More information about the additional spillways is provided in Annex C of this appendix.

4.2.6 Combined Dissolved Gas Abatement Measures

Gas abatement measures may be grouped together to form a package of improvements. The improvements cited in the DGAS study are grouped together as alternatives as follows:

<u>Alternative a)</u> - Adding end bay deflectors at Little Goose and Lower Monumental – Total cost about $18 million.

<u>Alternative b)</u> - Adding end bay deflectors at Little Goose and Lower Monumental and powerhouse/spillway separation walls at each dam – Total cost about $94 million to $142 million.

Alternative c) - Adding end bay deflectors at Little Goose and Lower Monumental, separation walls at each dam, and additional spillway bays at each dam – Total cost about $1.4 billion to $2.2 billion.

Alternative "b" provides a higher level of gas abatement than alternative "a", but at a higher cost. Likewise, alternative "c" provides a higher level of gas abatement than alternative "a" or "b", but at a significantly higher cost. A more detailed discussion of this comparison is provided in Annex C, Dissolved Gas Abatement Study.

No recommendations for implementation of powerhouse/spillway separation walls or additional spillway bays at each of the lower Snake River dams is included in this appendix.

More information concerning engineering, implementation and costs for each of the dissolved gas abatement options described above is available in Annex C of this appendix.

4.3 Turbine Measures

4.3.1 General

Under present conditions, direct fish survival through a typical lower Snake River turbine ranges from 89 to 94 percent. Unless the natural river drawdown alternative is selected, it is likely that all of these units will require major repair or rehabilitation in the next 10 to 50 years. The Turbine Passage Survival Program is currently gathering information that will allow an accurate evaluation of fish passage benefits associated with turbine operational changes and changes resulting from the incorporation of improved fish passage turbine design concepts. For the purpose of this appendix, it is assumed that the information from the Turbine Passage Survival Program will be incorporated into the operation and design of the rehabilitated units. The benefits to anadromous fish stocks are potentially significant and cannot be ignored because they will accrue over the life of a rehabilitated turbine, which is estimated to be 35 to 50 years. An approximate schedule for these rehabilitations is given in Annex D.

4.3.2 Improved Turbine Operation (3-D Cams)

The most significant improvement in operation will result from optimizing performance of the turbine units with fish diversion devices installed in the unit. The installation of these devices, including fish screens and surface collection structures, can affect turbine operational efficiency by 1 to 3 percent. Through the use of turbine performance models, new flow measurement technology developed in the Turbine Passage Survival Program, and prototype tests, new optimized turbine performance curves with installed fish diversion devices will be developed. The performance curves relate power output to differential head, flow rates, wicket gate openings, and blade angles. 3-D cams are computer software based upon the turbine performance curves that automatically adjusts the wicket gate openings and turbine blade angle to optimize turbine efficiency. It is widely thought that the stress on fish passing through the turbines is minimized if the turbines are operating at peak efficiency. Therefore, use of the 3-D cams should maximize hydroelectric production efficiency and reduce impacts to fish passing through the turbines.

4.3.3 Other Turbine Improvements

Improvements to turbine passage may be accomplished by modifying the major features of the turbine. Modifications include the following: 1) re-design runners, 2) re-orientation of the wicket gate and stay vanes, 3) use of smooth coatings, 4) minimizing gaps, 5) re-shaping of the hydraulic transitions or surfaces, and 6) extension of the draft tube. Results from the Turbine Passage Survival Program will be used to decide which of these measures will yield significant improvements to fish passage through the turbines. For estimating purposes, it was assumed that the cost for all items included in this section was developed from the costs included in the Ice Harbor Powerhouse Major Rehabilitation Program Report, dated March 1997. As the Turbine Passage Survival Program proceeds, the necessary improvements will be better defined.

4.4 Surface Bypass and Collection Measures

4.4.1 General

SBC measures will improve fish passage conditions by taking advantage of the tendency for juvenile fish to stay in the upper portions of the water column. SBC designs are based on passive fish behavior. Passive fish behavior refers to allowing fish to maintain their natural preferences for horizontal and vertical surface-oriented distribution. As it compares to existing systems, justification for developing SBC systems relates to the following: 1) increasing the number of juvenile fish guided for bypass or collection through non-turbine routes, 2) reducing fish stress, injury, and migration delays, 3) reducing high-spill levels that are associated with dissolved gas problems, and 4) losing power generation. For total system designs, final SBC systems have to consider surface collection, fish bypass/transport, and river outfall components. Refer to Annex B for more detailed information on SBC technology and conceptual designs.

The Corps began brainstorming sessions in July 1994 (receiving input from consultants, fishery agencies, and tribes) and has proceeded with SBC prototype development at several dams. Concepts discussed and being evaluated consist of a variety of both fixed and floating systems used either alone or combined with fish guidance devices (physical and/or behavioral), project operational changes, with and without fish sampling, and with and without transport, etc. Biological and environmental considerations, as well as construction, operational, cost, and schedule elements, all factor into developing realistic surface oriented fishways that would have a high potential of improving passage and survival of juvenile fish migrating past Corps' Snake and Columbia River hydroelectric projects. Immediate SBC objectives have been to collect information on SBC performance, designs, and costs to be used as a basis for comparing SBC systems with other options for improving fish survival in the Lower Snake River Feasibility Study. Future efforts may include continued development and investigation of SBC concepts that appear promising.

The original concept of SBC is founded largely on the successful implementation of 12 years of research and development of a system at Wells Dam on the mid-Columbia River. However, because there are major differences between Corps' projects and the Wells hydrocombine design (as well as differences between Corps' projects themselves), each project design will be site-specific.

4.4.2 Technology Overview

The SBC systems are designed to provide benign, fish-friendly, surface-oriented passage systems that juvenile fish, already distributed high in the water column, can use to pass a dam safely. An example of a highly successful, surface-oriented bypass system currently in use is at Wells Dam on the mid-Columbia River. The Wells Dam system (with its hydrocombine design) is different from any SBC system that might be developed for lower Snake River projects. However, lessons are being learned from the surface bypass efforts at Wells Dam, as well as ongoing SBC work at other projects in the region. Effectiveness and appearance of these designs would vary from project to project on the lower Snake River.

The premise behind the SBC designs is that fish located upstream of a dam generally tend to follow bulk flow into the project. A key assumption of SBC systems is that, even if there are high bulk flows going to deep powerhouse intakes or deep spillway gate openings, fish tend to stay surface oriented (if given the opportunity) and pass through a system at shallower depths. There are several factors that are believed to influence the effectiveness of SBC systems besides bulk flow influences. The factors include the depth of fish in the water column, flownets produced by SBC structures as they relate to turbine and spillway hydraulics, opportunity of discovery for fish to find an SBC fishway entrance prior to using a turbine or spillway flow passage, and SBC fishway entrance conditions (total volume, velocities, horizontal/vertical orientations, etc.).

In the case of a powerhouse-related SBC component with fishway entrance slots (as demonstrated by Wells Dam and by SBC prototype designs at other projects, including the Lower Granite prototype tests), fish will enter SBC fishway entrances with different levels of success if given the option to take this higher passage route. Changes in the 1998 Lower Granite prototype SBC structure incorporated a simulated Wells intake (SWI) design. This SWI design effectively makes the SBC structure deeper and influences flow lines approaching the SBC structure to allow fish a greater chance to discover SBC entrances prior to passing towards the turbine intakes.

The design of a behavioral guidance structure (BGS)-related SBC component is based on the observation that fish tend to guide along physical structures that are generally lined up with river flow. One example of this is at Rocky Reach Dam on the mid-Columbia River where fish follow surface flows passing by operating generating units to congregate in a cul-de-sac at the end of the powerhouse. Another example is at Lower Granite where fish have guided along a relatively shallow trash shear boom. The BGS prototype test design at Lower Granite utilizes this same principle but exaggerates the differences between deep powerhouse intakes and surface-oriented guidance systems. It is believed that a combination of a general, downstream angled flow approach in the forebay, a deep physical barrier with relatively low velocities passing beneath the structure, and strong SBC fishway entrance surface flows at the downstream end of the BGS should provide for passive fish movement toward the entrance.

The Corps and others in the region have been involved in accelerated programs to develop and evaluate different variations of SBC technology for different locations. There are no established criteria for SBC system designs. Preliminary SBC design criteria (fishway entrance configurations, flow requirements, number of fishway slots, structure depths, and water velocities below the BGS, etc.) used as part of the SBC Conceptual Design Report for different design options were developed by the collective judgment of biologists and engineers (Corps and non-Corps personnel). As SBC prototype test results from different test efforts become available, future reevaluation and refinement of SBC designs, as presented in the feasibility study, will be required prior to installation of final SBC systems at the different lower Snake River projects. Additional work, focusing on other projects besides Lower Granite, might include activities such as baseline fish behavior data collection, hydraulic model studies, and site-specific prototype work.

4.4.3 Surface Bypass Collector System Types

4.4.3.1 General

SBC concepts discussed and evaluated in a preliminary SBC Conceptual Design Report consisted of a variety of both fixed and floating systems, used either alone or in combination with fish guidance devices, project operational changes, with and without transport, etc., at Lower Granite. This conceptual design report was used as the basis for the SBC System Combinations Report (see Annex B). A few of the SBC concept options utilized a BGS to guide fish to the spillway or smaller surface collectors. Also, some of the options included a 21.3-meter (70-foot)-deep surface collector, while other options included 16.7-meter (55-foot)-deep surface collectors. Biological and environmental considerations, as well as construction, operational, cost, and schedule elements, all factored into developing realistic, surface-oriented fishways. These designs were used as the basis for the system combination designs.

In the preliminary SBC Conceptual Design Report, ten individual SBC design options for Lower Granite were developed and evaluated. Each of these SBC options was made up of components that worked together to achieve a specific bypass strategy. Some of these components have been tested at the Lower Granite SBC prototype to determine their biological effectiveness, either individually or in combination with each other. Based on the information in the Conceptual Design Report and results of the prototype testing, four SBC types were selected for continued study in the SBC System Combinations Report. Each system combination includes an SBC type at each dam. The four SBC combinations contained in the report and a fifth SBC combination were incorporated into Annex B of this appendix. Four of the five SBC combinations have been selected for further discussion herein.

4.4.3.2 Designs and Operations

General

Each of the Major System Improvements option utilizing SBC system combinations use one or more of seven SBC type designs. (See Annex B for a more detailed explanation of why these seven SBC types were selected.) These designs are combined at the different projects in such a way as to achieve the overall migration strategies for the river, as discussed in Sections 1.3 and 1.4. In some instances, a particular project would not utilize any of these SBC types. Instead, it would use either existing or new extended submerged bar screen (ESBS) intake diversion systems only.

The seven SBC designs are as follows:

- Full-length SBC powerhouse channel with dewatering (Type 1)
- Full-length SBC powerhouse channel bypass without dewatering (Type 2)
- Two-unit SBC powerhouse channel and BGS system, with dual passage options (Type 3)
- Modified SBC spillway bypass at one spillbay (Type 4).
- Two-unit SBC powerhouse channel and BGS system with dewatering and modified spillway bypass at two spillbays (Type 5)
- Full powerhouse length occlusion structure and modified spillway bypass at two spillbays (Type 6)
- Modified SBC spillway bypass at two spillbays (Type 7).

Each one of these SBC design types would look slightly different, depending on which project it would be applied. For illustration purposes, SBC Type 1, 2, and 5 designs, as they would typically be applied at a lower Snake River Dam, are presented below for Lower Granite Dam (Figures 4-1, 4-2, and 4-4, respectively). The SBC Type 4, as it would typically be applied at a lower Snake River dam, is presented for Ice Harbor Dam (Figure 4-3). The SBC Type 6, as it would be applied at Little Goose Dam, is presented in Figure 4-5. The SBC Type 7, as it would typically be applied at a lower Snake River Dam, is presented below for Ice Harbor Dam (Figure 4-6).

SBC Type 3 is not included in this document for further analysis. Refer to Annex B for more information on this SBC type.

Type 1 - Full Length SBC Powerhouse Channel with Dewatering

Overview

The design goal of SBC Type 1 is to provide a surface collector system designed to attract fish away from the turbine intakes across the face of the entire powerhouse. The fish would be directed to the existing juvenile fish bypass gallery inside the dam where they would swim downstream to the juvenile facilities. The design allows for the channel to be used in conjunction with ESBS intake diversion screens. Adequate dewatering of the fish-bearing transport flow is provided in the channel so that the fish entering the SBC can be delivered to the existing juvenile fish gallery inside the dam, where they would be combined with the fish diverted by the intake diversion screens. The gallery is designed to deliver the fish to the fish-handling and transport/release facilities downstream. In addition, in case there is a problem with the dewatering portion of the channel, the design will allow for emergency bypass of the fish collected by the channel directly to the tailrace via a spillway bay.

The SBC Type 1 design would vary slightly depending on where this structure was constructed. For illustration purposes, the SBC Type 1 design is shown in Figure 4-1 as it would be applied at Lower Granite Dam. (Refer to Annex B for a more detailed description of how SBC Type 1 designs would be applied to Lower Granite, Little Goose, and Lower Monumental Dams.)

As with all the designs evaluated in this report, ESBS intake diversion screens would be used in conjunction with the SBC. Screens are already in place at Lower Granite and Little Goose Dams.

Design and Operational Information

<u>SBC Channel</u>

The application of the SBC Type 1 design includes a floating collector channel that would span across the entire upstream face of the powerhouse intake structure. A portion of the channel accommodates the secondary dewatering screen section.

During testing of the prototype SBC channel at Lower Granite Dam, there were indications that migrating fish in the forebay upstream of the spillway were being attracted under the north end of the channel and into the Unit 6 intake. Therefore, as part of this design, a cutoff wall is included below the channel at the end of the powerhouse closest to the spillway in order to preclude fish movement under this end of the channel directly from the spillway area into the closest unit intake.

<u>SBC Entrances, Flows, and Dewatering</u>

Three vertical entrances into the channel would be located along the upstream wall of the channel. The entrances are located close to every second unit joint. Flow into each entrance is 56.6 m^3/s (2,000 cfs) for a total combined SBC attraction flow of 170 m^3/s (6,000 cfs). Each entrance is outfitted with a full-height semicircular trashrack.

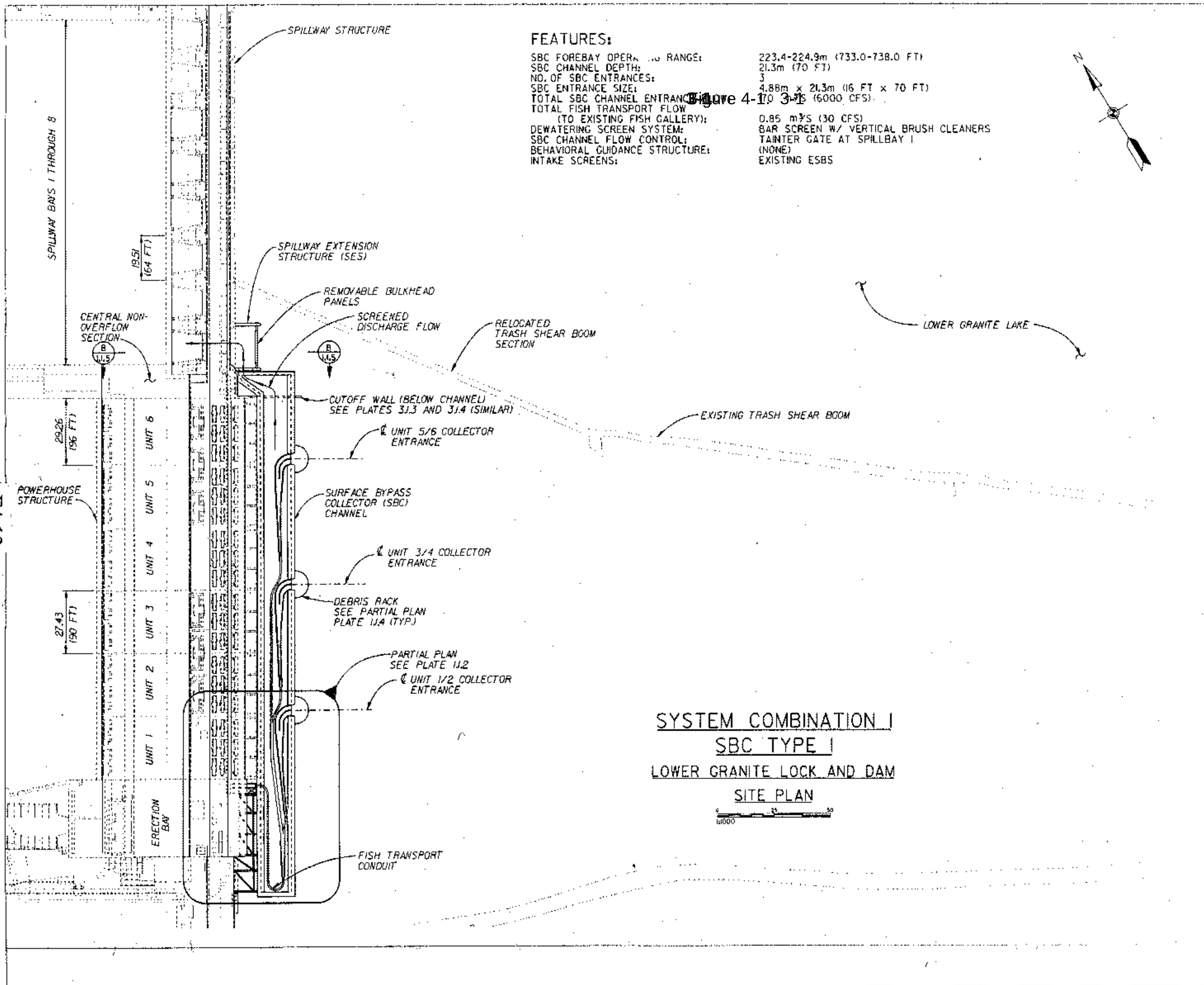

Figure 4-1. Surface Bypass Collector Type 1 Design as Applied at Lower Granite Dam (Plan View)

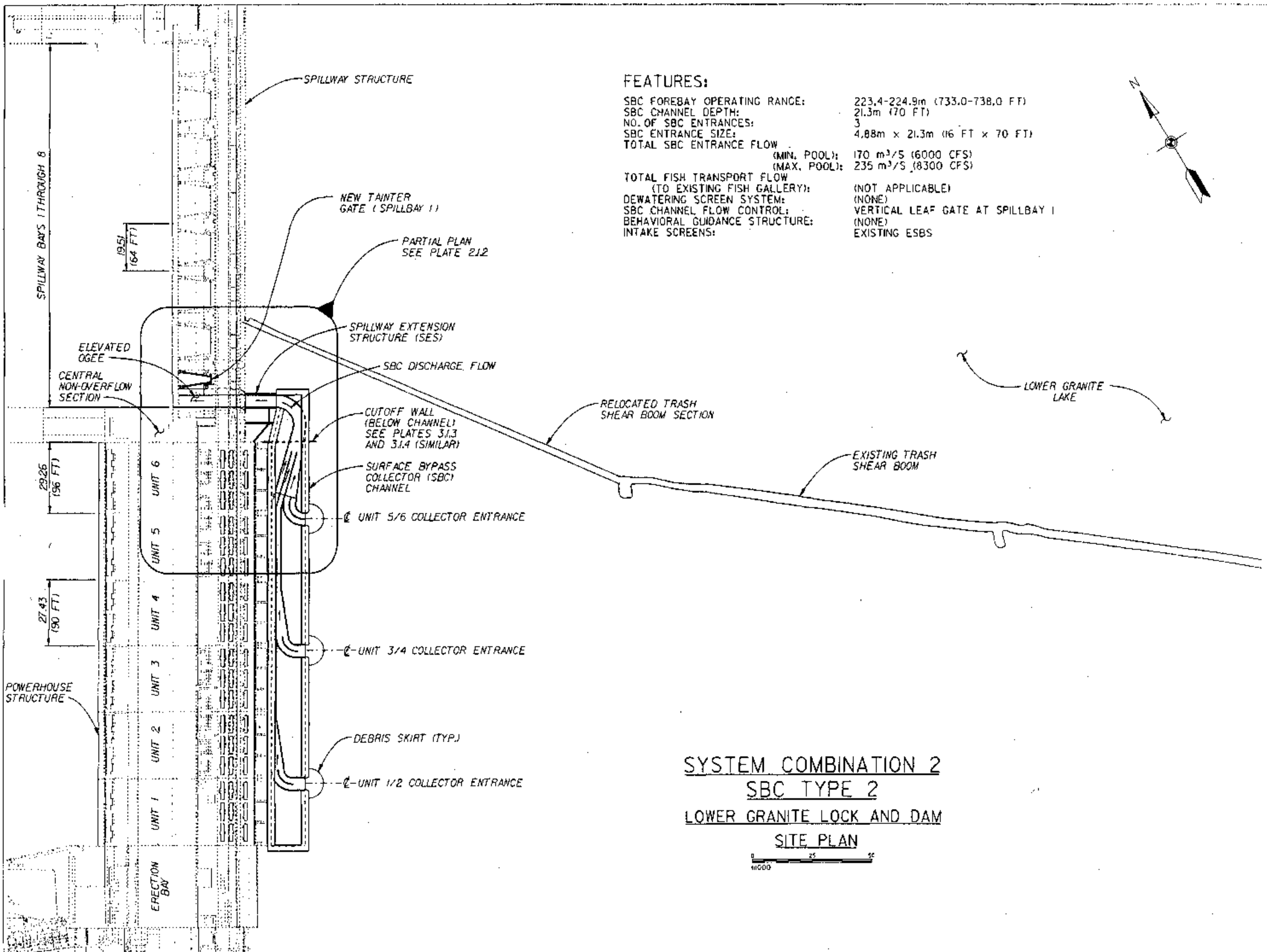

Figure 4-2. Surface Bypass Collector Type 2 Design as Applied at Lower Granite Dam (Plan View)

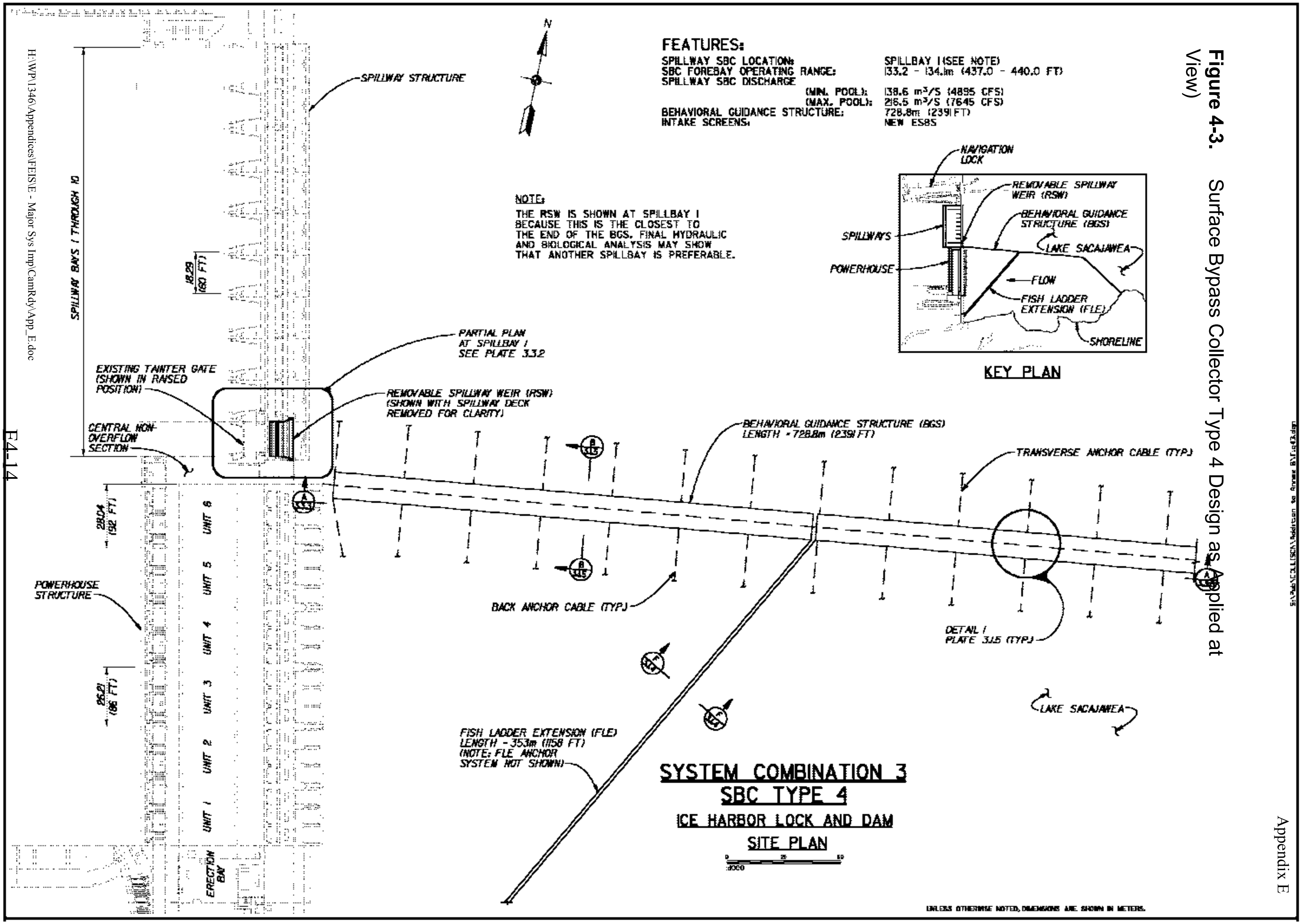

Figure 4-3. Surface Bypass Collector Type 4 Design as Applied at View)

Figure 4-3. Surface Bypass Collector Type 4 Design as Applied at Ice Harbor Dam (Plan View)

E4-14

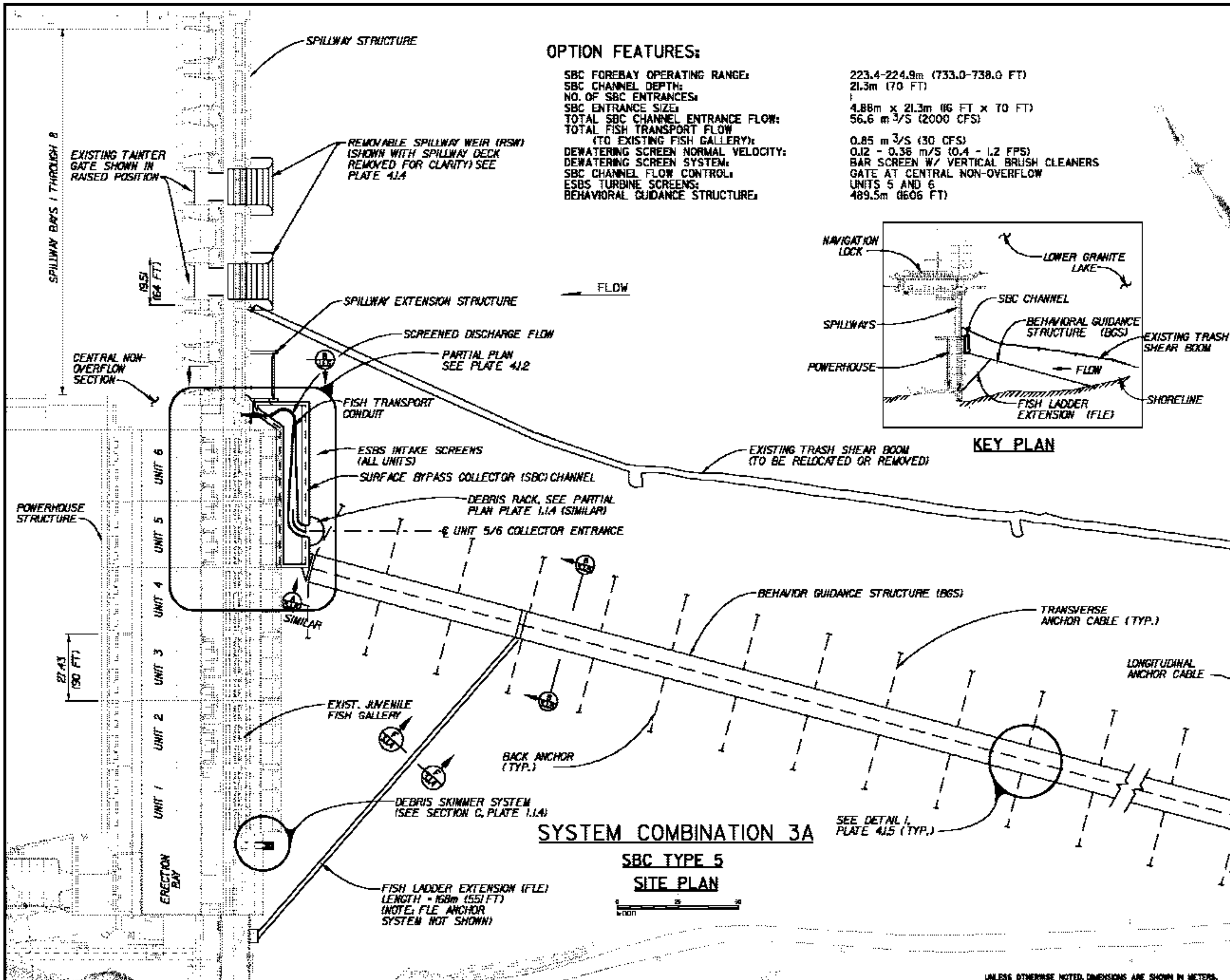

Figure 4-4. Surface Bypass Collector Type 5 Design as Applied at Lower Granite Dam (Plan View)

Figure 4-5. Surface Bypass Collector Type 6 Design as Applied at Little Goose Dam (Plan View)

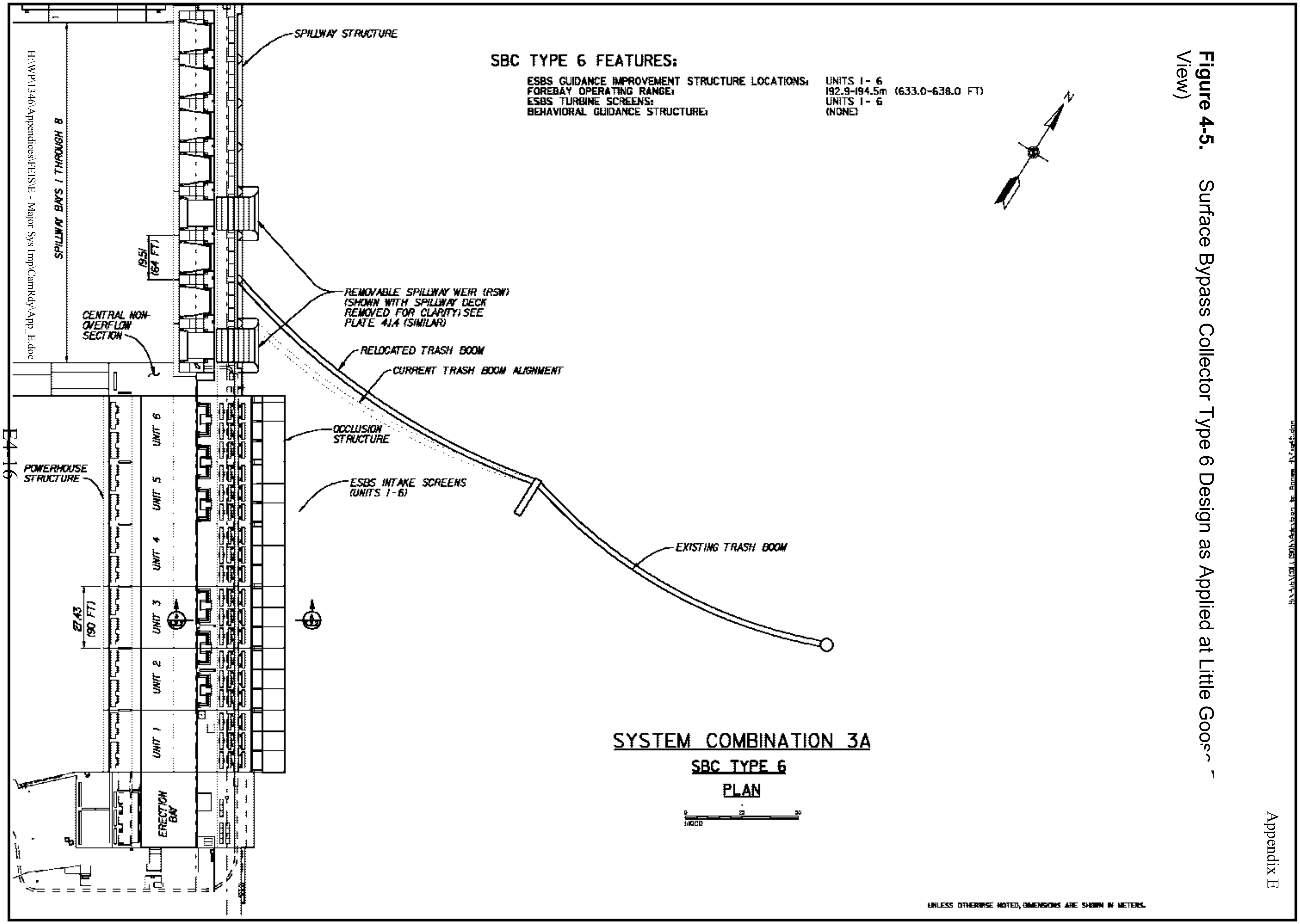

Figure 4-5. Surface Bypass Collector Type 6 Design as Applied at Little Goose Dam (Plan View)

E4-16

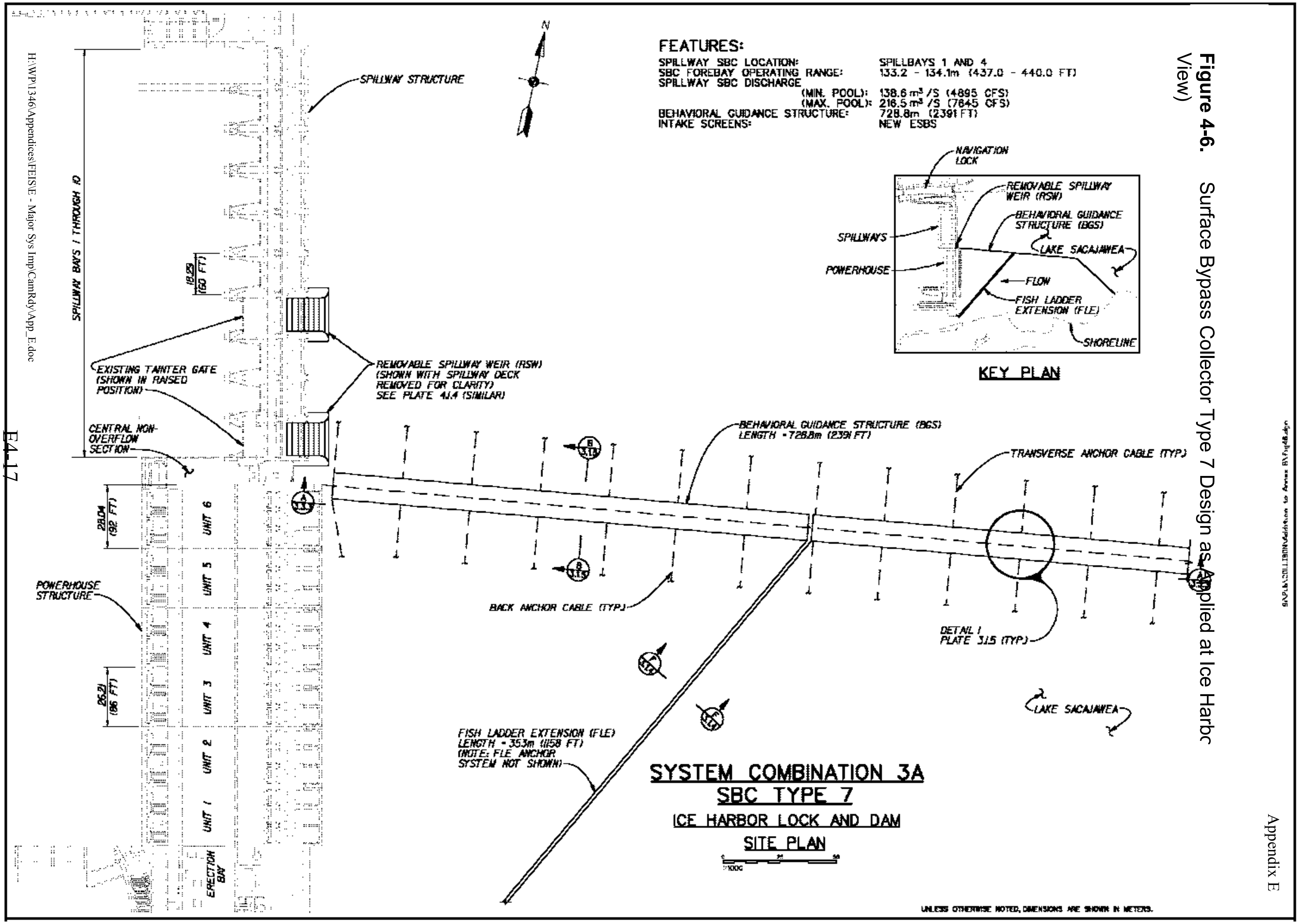

Figure 4-6. Surface Bypass Collector Type 7 Design as Applied at Ice Harbor Dam (Plan View)

Figure 4-6. Surface Bypass Collector Type 7 Design as Applied at Ice Harbc View)

E4-17

Fish enter the channel through one of the three entrances, each of which are 4.88 meters (16 feet) wide. The floor of the channel coincides with the bottom of the entrances located 21.3 meters (70 feet) below the forebay water surface. Each entrance is associated with a transport conduit that includes a primary dewatering section. The primary dewatering is accomplished independently for the flow entering each of the three entrances. After passing through the primary dewatering screen section, the remaining flow in the three individual conduits is progressively combined into a single conduit leading to a common secondary dewatering screen section. The secondary screening reduces the combined flow, which contains the fish from all three entrances, to a quantity that can be added to the existing juvenile gallery, approximately 0.85 m^3/s (30 cfs).

SBC Entrance Operation

Under normal operation, SBC entrances are all fully open. Bulkhead panels are provided which can be slid down into the flow path both upstream and downstream of each of the three primary dewatering sections to shut off the flow to the primary screens. Emergency bypass doors are located in each conduit upstream of the bulkhead guides to allow for direct bypass of fish and flow to the tailrace when the bulkheads are installed. This approach allows for the flow through a single entrance to be bypassed directly to the tailrace in the event the screening section requires maintenance, without impacting the hydraulics of the flow through the remaining entrances. In addition, this design offers increased operational flexibility in that the flow through an individual conduit can be shut off during periods of low river flow when all units are not operating. In the event that the existing juvenile facilities require maintenance or downtime, the flow through all three entrances can be bypassed directly to the tailrace by placing the upstream bulkheads in all three conduits and opening the emergency bypass doors.

Connection to Existing Juvenile Fish Facilities

After all dewatering is accomplished, the remaining transport flow is delivered with the fish to a location at or near the Erection Bay portion of the powerhouse. The transport conduit in the channel is outfitted with a tilting weir control structure so that the final transport flow can be maintained at 0.85 m^3/s (30 cfs). Flow over the control weir spills into a stationary channel attached to the dam. The channel then passes the flow into the juvenile fish gallery inside the dam.

An opening will be excavated in the concrete wall to accommodate the channel and to allow the 0.85 m^3/s (30 cfs) transport flow to pass as an open channel flow into the gallery. This opening will also house a surface skimming cleaner to remove any floating debris that accumulates. Once in the juvenile fish gallery, the fish are transported downstream in a non-pressurized flume to the fish handling facilities for eventual transport or release to the tailrace, dependent upon the project and selected project operations.

Screened Water Discharge to the Spillway

The screened discharge from the four channel dewatering screen sections (three primary and one secondary) passes from the screens into the main portion of the floating channel, which forms a common discharge channel. This screened flow travels to a spillway extension structure (SES) attached to the upstream face of the nearest spillbay piers. The SES forms a well upstream of this spillbay so that the Tainter gate can be used to regulate and pass the SBC screened flow. The SES is a concrete-filled steel shell forming two walls and a floor bolted to the upstream face of this spillbay. The upstream end of the structure is closed off by means of removable steel stop logs. This design allows for removal of the stop logs so that the full spillway flood discharge capability of this spillbay can be maintained. With the maximum flood of record being less than half the combined discharge capacity of eight spillbays, it is anticipated that this procedure would be required extremely infrequently. However, if this were to be necessary, one additional step would be to install a closure panel over the opening between the channel and the SES to hydraulically separate the two structures. This would be required to prevent the large spill flow passing through the SES from creating a dangerously large head differential between the forebay and the inside of the channel.

Type 2 - Full Length SBC Powerhouse Channel Bypass without Dewatering

Overview

Like the SBC Type 1 design, the goals of the SBC Type 2 channel include providing a surface collector system at the powerhouse designed to attract fish away from the turbine intakes. However, unlike the SBC Type 1, the operational goal of this channel is to deliver the fish with the full flow directly to the tailrace, with no dewatering of the flow taking place (i.e., no dewatering screens). An additional goal of this design is to provide a discharge for the channel that is a surface withdrawal (rather than a pressurized release) and that also minimizes the impact on the ability of the project to pass flood flows.

The SBC Type 2 design would vary slightly between projects. For illustration purposes, the SBC Type 2 design is shown in Figure 4-2 as it would be applied at Lower Granite Dam. (Refer to Annex B for a more detailed description of how SBC Type 2 designs would be applied to all of the projects.)

As with all the designs evaluated in this appendix, ESBS intake diversion screens would be used in conjunction with the SBC. The screens are already in place at Lower Granite and Little Goose Dams.

Design and Operational Information

SBC Channel

This full-flow bypass design (SBC Type 2) includes a floating SBC channel that spans across the entire upstream face of the powerhouse intake structure. The channel is 21.3 meters (70 feet) deep by 14.0 meters (46 feet) wide with three collector entrances along the upstream wall, similar to the Type 1 design. The channel extends from the far end of powerhouse to the middle of the closest spillbay.

The fish enter the channel through the entrances, which are 4.87 meters (16 feet) wide and 21.3 meters (70 feet) high. The exception to this is at Ice Harbor where the entrances are 16.8 meters (55 feet) high. The floor of the channel coincides with the bottom of the entrances. After entering the channel, the fish are diverted 90 degrees towards the spillway. Each entrance is associated with an individual transport conduit. The width of each individual conduit narrows down to 1.83 meters (6 feet) and is maintained at this constant width up to the part of powerhouse closest to the spillway where all three conduits combine together to form a single conduit 6.1 meters (20 feet) wide. The floor of the conduits slopes up through the section where the conduits come together. The combined conduit then gradually converges to a width of 4.88 meters (16 feet) in front of the central non-overflow section of the dam where the conduit makes a 90-degree turn toward the west and joins the fixed SES attached to the upstream face of the closest half of the nearest spillbay. All the flow that enters through the collector entrances travels through the transport conduits, into the SES, and ultimately over the overflow ogee to the tailrace. This is different than a normal spillway (and different than Wells Dam on the mid-Columbia River) because fish are not exposed to the high velocities and abrupt pressures changes that would be associated with an underflow spillway gate.

Like the SBC Type 1 channel, a cutoff wall has been included below the channel at the end closest to the spillway in order to preclude fish movement beneath the end of the channel near the spillway. The wall design would be similar to that described for the SBC Type 1 channel.

SBC Entrances and Flows

The SBC channel has three vertical entrances through the upstream wall. The entrances are located near every second unit joint. Flow through each entrance is approximately 56.6 m^3/s (2,000 cfs), for a combined SBC collection flow of 170 m^3/s (6,000 cfs), when the forebay is at the minimum operating pool (MOP). For this design, the entrances do not have full-height debris racks because most debris entrained in the flow would simply pass though the system to the tailrace. A debris skirt is placed in front of the entrance to minimize floating debris entering the channel. Similar to the Type 1 trashrack, this is a semicircular shape, but rather than being the full entrance height, it extends only about 1.5 meters (5 feet) deep.

SBC Channel to Spillway Connection and Spillway Modification

The floating structure connects to a fixed spillway extension structure (SES) extending from the face of the nearest spillbay. This spillbay is modified to form a 4.88-meter (16-foot)-wide overflow ogee for surface withdrawal from the SBC channel. Half of the spillbay is preserved at its full depth and will function in the same manner as the other seven spillbays, except at about half the discharge. Modifications of the spillbay include construction of a new 2.74-meter (9.0-foot)-wide pier and trunnion block at approximately the middle of the spillbay to define the extent of the full depth spillbay leaving a 7.6-meter (25-foot)-wide full depth spillbay. Half of the spillway will be filled with concrete to define the new higher ogee crest.

A new underflow vertical leaf gate is provided at the elevated ogee for on/off control of the SBC channel discharge. During normal operation of the channel, the leaf gates are hoisted out of the flow path, allowing free overflow at the weir within the normal SBC operating range that corresponds to normal pool fluctuations. At forebay elevations above normal pool, the leaf gates would either close completely or throttle flow. Presumably, forebay elevations higher than normal pool would be outside the operating window of the SBC fish passage requirements, and passage of flow through the SBC during these periods would be strictly for the purpose of adding spill capacity during flood discharge.

To accommodate the narrower spillway at half of the nearest spillbay, the existing Tainter gate would be removed and replaced with a new, narrower tainter gate sized to fit the reduced spillbay width of 7.6 meters (25 feet). At project flood forebay elevations, it is anticipated that the closest spillbay in its modified condition, in combination with the SBC capacity, would be able to pass about 60 percent of its pre-modified capacity. For the entire spillway, the modifications to the closest spillbay would result in a total discharge capacity over 95 percent of the unmodified project capacity. The portion of this total project capacity released through the SBC would be approximately 340 m^3/s (12 kcfs).

Raising the spillway crests would reduce the total capacity of the spillway to pass the standard project flood by about 3.8 percent at Ice Harbor and 5 percent at Lower Granite, Little Goose, and Lower Monumental Dams. If no approval to reduce spillway capacities by the amount shown above is provided, alternative methods of bypassing fish or high flows may be implemented. Refer to Section 8.4.3 and Annex B for more detailed discussions of this issue.

Type 4 - Modified SBC Spillway Bypass

Overview

The goal of the SBC Type 4 design is to provide an SBC facility at the spillways to divert fish away from the powerhouse and toward the spillway. One or more spillbays would be modified so each provides an overflow spill of approximately 170 m^3/s (6,000 cfs) at the surface of the forebay in order to attract and safely pass the fish directly to the tailrace. A removable spillway weir (RSW) would be used to serve this function at Ice Harbor.

The SBC Type 4 design has been developed conceptually in this appendix just for Ice Harbor Dam (refer to Annex B). However, it is likely that similar designs could be applied successfully at Lower Monumental and Lower Granite Dams. For illustration purposes, the SBC Type 4 design is shown in Figure 4-3 as it would be applied at Ice Harbor Dam. A Type 4 design utilizing a straight line BGS would not be used at Little Goose Dam because a straight BGS would block navigation. Where full bypass to a spillway is the desired goal, a full powerhouse Type 1 SBC design would be more appropriate for Little Goose Dam.

As with all of the designs evaluated in this report, the turbine intakes located behind the BGS will be outfitted with ESBS intake diversion systems that would divert fish passing below the BGS into the existing juvenile gallery and eventually to the juvenile facilities downstream. In the case of Lower Monumental and Ice Harbor Dams, the intakes are currently outfitted with an STS diversion screen system that would be removed and replaced with a new ESBS system. ESBS systems are already in place at Lower Granite and Little Goose Dams.

Removable Spillway Weir

The RSW is a removable steel ogee-shaped structure that is inserted into the existing spillbay, creating a raised overflow weir above and upstream of the existing concrete ogee crest. No modifications, except the addition of support brackets, would be required to the existing spillway to accommodate the RSW. The elevation of the new crest is designed to pass approximately 170 m^3/s (6,000 cfs) in an uncontrolled, open-channel flow condition at the average operating pool elevation. The flow would be either on or off, determined by whether the tainter gate is in a fully open or fully closed position. Because the flow is essentially uncontrolled, the flow rate would vary depending on the forebay water surface elevation. Discharge would be greater when the forebay is at maximum operating pool and smaller when at the MOP.

The RSW is supported vertically on hinges attached to the spillway. During high river flows, the RSW is rotated off the spillway by gradually filling flotation tanks within the RSW with water. This reduces the buoyancy of the RSW, causing it to rotate upstream. Filling continues until the RSW is lowered onto a landing pad resting on the bottom of the river. This restores the hydraulic spillway capacity. After the river flows drop to an acceptable level, the tanks are gradually filled with air, displacing the water. This causes the RSW to rotate back into position on top of the spillway.

The best shape of the downstream portion of the RSW to provide a fish-friendly bypass would have to be determined from prototype testing.

Behavioral Guidance Structure

A BGS is included in the forebay to guide fish away from the powerhouse and toward the spillway. The basic design and function of the BGS is the same as was described for the Type 3 design. However, for the Type 4 design, the downstream end of the BGS would be located between the powerhouse and the spillway. Because the entire powerhouse flow for all six turbines must pass below the BGS in this case, the BGS must be considerably longer than the Type 3 BGS. The Type 4 BGS would extend 729 meters (2,391 feet) upstream at Ice Harbor.

Type 5 - Two-Unit SBC Powerhouse Channel and BGS System with Dewatering and Modified Spillway Bypass at Two Spillbays

Overview

The goal of SBC Type 5 is to provide an effective method for collecting juvenile fish for downstream transportation and to provide an effective method for bypassing fish over the spillway. Therefore, this SBC type allows for varying the fish migration operational strategy.

The design goal of the SBC Type 5 surface collector is to provide a surface collection channel that achieves the operational objectives of the SBC Type 1 design. That is, the floating channel includes a screened flow operation, which passes the fish into the existing juvenile gallery for downstream transportation. Unlike the Type 1 and Type 2 designs, the SBC Type 5 channel extends over only two units at the spillway end of the powerhouse. This design includes a collection channel extending across the front of two powerhouse units located at the end of the powerhouse nearest the spillway. To guide fish away from the other units, a BGS is located in the forebay. The BGS would guide fish to the entrances in the SBC. The channel includes one entrance.

SBC Type 5 would also include the addition of two RSWs to the existing spillway. When the operational strategy involves keeping the fish in the river (not transporting), the surface collector would be closed off. The BGS would guide fish across the surface collector, to the RSWs. When this mode of operation is selected, the RSWs would create an effective method of bypassing the juvenile fish over the spillway when it is decided not to use the SBC for fish transportation. When the fish migration strategy is to transport fish, the RSWs would be made inoperable by closing the existing tainter gates that allow flow over the RSWs. The surface collector would then be operated to collect the fish.

The SBC Type 5 design would vary slightly depending on where this structure is constructed. For illustration purposes, the SBC Type 5 design is shown in Figure 4-4 as it would be applied at Lower Granite Dam. (Refer to Annex B for a more detailed description of how SBC Type 5 designs may be applied at Lower Granite and Lower Monumental Dams.) A Type 5 design utilizing a straight line BGS would not be used at Little Goose Dam because a straight BGS would block navigation. Instead, a vee-shaped BGS would be needed in the forebay requiring two fishway entrances and related features. As with all the designs evaluated in this report, ESBS intake diversion screens would be used in conjunction with the SBC. The screens are already in place at Lower Granite and Little Goose Dams. Fish diverted by the ESBS would be delivered to the juvenile fish facilities where they would be collected for transport or returned to the river.

SBC Channel, SBC Entrances, Flows, and Dewatering

Many of the SBC channel features for the SBC Type 5 design are similar (with a few subtle differences) to those previously described for the Type 1 design. These features include a floating channel with an internal fish conduit, a cutoff wall below the channel at the end closest to the spillway, dewatering, and connection to the existing juvenile fish facilities for the transport route, as well as a channel attachment to a stationary SES located at the closest spillbay.

Each of the two entrances is 4.88 meters (16 feet) wide by 21.3 meters (70 feet) deep, with the bottom of the channel coinciding with the invert of the entrances. Discharge would be controlled by the existing tainter gate in the spillbay adjacent to the surface collector. This design would be similar to the design described for SBC Type 1 previously discussed. The system is designed to pass a relatively constant entrance flow of 56.6 m^3/s (2,000 cfs). Following dewatering, the flow into the juvenile collection channel would be about 0.85 m^3/s (30 cfs).

The design includes passing screened water through the spillway extension structure and over the spillway. Because this water is not used for fish passage, it may prove to be cost effective and feasible to pump the screened water back into the forebay rather than passing it over the spillway. This would allow an RSW to be placed in spillbay 1, which is probably the most desirable location on the spillway for an RSW. Also, it would allow the screened water to be used for hydropower production. If this SBC type is selected for further study, this pumpback option will be investigated in more detail.

BGS and Fish Ladder Extension

The downstream end of the BGS is located at the end of the channel, near the unit joint between the two units closest to the spillway. The structure extends from this location upstream about 489.5 meters (1,606 feet) at Lower Granite Dam and 556 meters (1,824 feet) at Lower Monumental Dam to reach the shore. The upstream end of the BGS is closed off to preclude juveniles from entering the excluded area behind the BGS. An FLE structure has been added to the existing south-bank fish ladder exit to a point approximately one quarter of the distance along the BGS. This ladder extension effectively relocates the ladder exit from the face of the dam to a location on the upstream side of the BGS and gives adult fish a direct path from behind the BGS to points upriver.

Removable Spillway Weir

SBC Type 5 includes two RSWs. An RSW is a removable steel ogee-shaped structure that is inserted into an existing spillbay, creating a raised overflow weir above and upstream of the existing concrete ogee crest. No modifications, except the addition of support brackets, would be required for the existing spillway to accommodate each RSW. The elevation of the new crest is designed to pass approximately 170 m^3/s (6,000 cfs) per RSW in an uncontrolled, open-channel flow condition at the average operating pool elevation. The flow would be either on or off, determined by whether the tainter gate is in a fully open or fully closed position. Because the flow is essentially uncontrolled, the flow rate would vary depending on the forebay water surface elevation. Discharge would be greater when the forebay is at maximum operating pool and smaller when at the MOP.

The SBC Type 5 design includes a BGS in the forebay to guide fish away from the powerhouse and toward the modified spillway.

The RSW is supported vertically on hinges attached to the spillway. During high river flows, the RSW is rotated off the spillway by gradually filling flotation tanks within the RSW with water. This reduces the buoyancy of the RSW, causing it to rotate upstream. Filling continues until the RSW is lowered onto a landing pad resting on the bottom of the river. This restores the hydraulic spillway capacity. After the river flows drop to an acceptable level, the tanks are gradually filled with air, displacing the water. This causes the RSW to rotate back into position on top of the spillway.

The best shape for the downstream portion of the RSW to provide a fish-friendly bypass would have to be determined from prototype testing. Prototype testing at Lower Granite is planned for 2001.

Type 6 - Full Powerhouse Length Occlusion Structure and Modified Spillway Bypass at Two Spillbays

Overview

SBC Type 6 is intended to improve in-river passage over the spillway at Little Goose Dam. No major system improvements for transportation are included. The strategy of SBC Type 6 is to reduce the flow patterns that attract fish to the turbine intakes by installing a large box shaped structure called an occlusion structure in front of the powerhouse. The flow and fish would then be directed to RSWs placed in spillbays 1 and 4. The RSWs are similar to those described for SBC Type 5.

It is uncertain that this strategy would work well. If model testing shows that an occlusion structure is not likely to divert a high percentage of fish to the RSWs, a full powerhouse surface collector (SBC Type 2) could be installed that would collect fish and bypass them through Spillbay 1 or the central non-overflow. Alternatively, a bypass through the north non-overflow section could be considered. However, this option has not been investigated yet. The occlusion structure is included herein to show a possible alternative to a surface collector at Little Goose. Use of a BGS and a two unit surface collector is not possible because the BGS would have to cross the navigation lock in order to be effective.

With this SBC type, ESBS intake diversion screens would be used to divert fish away from the turbines. Fish diverted by the ESBS would be delivered to the juvenile fish facilities where they would be collected for transport or returned to the river.

Installation of an RSW in spillbay 1 would require moving the trash boom. A potential location is shown on Figure 4-5. The relocated trash boom would have to be analyzed and possibly strengthened to account for different loading due to its new location.

Occlusion Structure

A large box shaped occlusion structure would be placed in front of the powerhouse. This structure would block downward flow that now is directed towards the powerhouse intakes. The theory is that fish in the upper portions of the water column would not experience the large downward flows that draw them into the turbine intakes. Instead, with the RSWs operating, lateral flow patterns would be created, drawing the fish to the RSWs.

The structural system for the occlusion structure consists of braced structural steel support frames located at the piers with stiffened steel plate panels spanning approximately 9.1 meters (30 feet) between the frames. The panels make up the bottom of the structure and a partial height front wall.

The mechanical system requirements for the occlusion structure center on the intake trash rake access door and door-opening system. The doors are required in the otherwise solid bottom panel of the guidance structure located just above and upstream of the intake openings across the length of the powerhouse. The doors allow the trash rake to access the trash racks below. The proposed door opening system is a low-tech solution to the problem. A system of winches and cables is installed with the winches located on the parapet wall at deck level, the cables being attached to the doors through a series of fixed pulleys or blocks.

Fish Guidance Efficiency Improvements

Observations during the prototype SBC channel testing at Lower Granite Dam seemed to show that the presence of the SBC improved the fish guidance efficiency (FGE) of the existing ESBS intake diversion screens. The occlusion structure could potentially influence FGE of the diversion screens either by improving fish guidance from higher in the forebay to the turbine intake and/or by locally improving flow conditions and fish guidance within the turbine intake, across the screens, and into the bulkhead slots. These flow features could likely be evaluated or confirmed through use of the existing models. Modeling should be pursued if further development of this option is proposed.

Removable Spillway Weir

An RSW would be placed in spillbays 1 and 3. Design and operation considerations for the RSWs at Little Goose Dam would be similar to those for Lower Granite Dam (SBC Type 5). The shape of the spillway and piers are similar. However, additional spillbay and forebay modeling is necessary to determine the optimal flow patterns in the forebay and along the RSW.

As described above, the goal of this SBC Type is to divert flow in the upper portions of the water column from heading towards the turbine intakes. The RSWs would create a surface flow towards the RSWs. The fish would then pass over the RSWs. Operation of the powerhouse would likely have a significant effect on flow patterns near the powerhouse.

Fish north of the RSWs would likely be attracted to the RSW in spillbay 3, and not experience the effects of the powerhouse flow.

Type 7 – Modified SBC Spillway Bypass at Two Spillbays

The goal of the SBC Type 7 design is to provide an SBC facility at the spillway to divert fish away from the powerhouse and toward the spillway in a manner similar to SBC Type 4. Two spillbays would be modified to each and provide an overflow spill of approximately 170 m^3/s (6,000 cfs) at the surface of the forebay to attract and safely pass the fish directly to the tailrace. Two RSWs are proposed to serve this function. SBC Type 7, as it is proposed for Ice Harbor, is depicted in Figure 4-6.

The SBC Type 7 is similar to SBC Type 4, except two RSWs are installed instead of one. RSWs would be placed in spillbays 1 and 4. Two RSWs would provide twice as much attraction flow, increasing the chances that fish would pass over an RSW. Refer to Section 8.4 and 9.1 for detailed information concerning the RSW. The BGS is the same as included for SBC Type 3 and is described in Section 8.1 and 8.4.

SBC Type 7 includes the use of ESBS. Fish diverted by the ESBS would be delivered to the juvenile fish facilities where they would be collected for transport (except at Ice Harbor) or returned to the river.

4.4.4 Lower Granite Prototype Tests and Predicted Future Surface Bypass Collector Performance

4.4.4.1 Background

Lower Granite Dam was selected for prototype development because it is at the upper end of the system where large numbers of juvenile salmon and steelhead pass, and because of concern for stocks listed as endangered under the ESA. Efforts at other projects have fed into SBC prototype development efforts at Lower Granite.

The first SBC prototype test (a three-unit SBC) at Lower Granite was conducted in 1996. A repeat of the same structure, with varying SBC gate and project operations, was completed in 1997. Test results showed that a surface-oriented juvenile fish system could safely collect fish in significant numbers. However, in order to more closely approach or exceed the high performance observed at Wells Dam, further development and testing was completed. In 1998, an SWI was inserted into the turbine intakes to work in conjunction with the original SBC structure in order to more closely simulate flow conditions that occur at Wells Dam. In addition, a BGS was tested in 1998. The BGS test was to evaluate the concept of a deep physical barrier with relatively low velocities passing beneath the structure, working in combination with a general downstream angled river flow to keep fish away from turbine units behind the BGS.

4.4.4.2 Predicted Fish Performance for Different SBC Types Based on 1998 Lower Granite Prototype Test Results

The Lower Granite SBC underwent a series of tests from 1996 through 2000. Generally, entrance configurations and project operations were not similar between test years. Results were highly variable between test years and between monitoring techniques (primarily hydroacoustics and radiotelemetry). Preliminary results from 1998 SBC/BGS prototype tests were used to develop estimates of what performance might be expected from a permanent SBC system at a dam. These estimates use hydroacoustic fish passage data gathered during the 1998, 1999 and 2000 juvenile salmonid outmigration at Lower Granite Dam on the Snake River. Hydroacoustics provides a measure of the run-at-large, with relatively large sample sizes. Radio-telemetry was also used in 1998 and 2000 to assess the performance of the SBC and BGS. Radiotelemetry provides species specific information, but uses relatively small sample sizes, so variability is increased. The data from the two studies comport fairly well; however, radiotelemetry estimates of SBC passage for spring chinook and wild steelhead were generally lower than those for hydroacoustics. Conversely, some passage estimates using radiotelemetry for hatchery steelhead were higher than hydroacoustic estimates.

SBC passage estimates for the various SBC types were all derived from a value of 50 percent for R(4 to 5). This represents somewhat of an average for the last 3 years of testing, in which the BGS and SWI were both in place. This means that 50 percent of the fish passing through the SBC or units 4 and 5 or the screened bypass system actually passed through the SBC. The FGE value of 82 percent was used for all units with all SBC types. While different FGE values were measured for different units and different groups of units under different configurations of the SBC and BGS, 82 percent represents an overall FGE value for the entire powerhouse.

For a SBC Type 1 or 2 (full powerhouse with or without dewatering), it is estimated that 50 percent of the fish passing the powerhouse would pass through the SBC. Of the remaining 50 percent, approximately 41 percent would be guided by the screens (FGE value used for these analyses is 82 percent), leaving

9 percent of the fish passing through the turbines. As a system, this gives a combined bypass efficiency (CBE) for SBC and screens of 91 percent. The SBC, in this case, provides a 9 percent increase in fish passage efficiency (FPE).

For an SBC Type 3 (partial powerhouse with a BGS), the analysis becomes more complicated. Of 100 fish approaching the dam, 78 percent of those fish approaching units 1 through 4 would be diverted over to units 5 and 6. If we assume the initial distribution of fish to be equal at all six units (with no BGS in place), this means that approximately 85 percent of the fish are now in front of units 5 and 6, where the SBC is located. Fifty percent, or 43 fish, enter the SBC while 42 fish enter the turbine intakes, where 34 of them are guided by the screens and 8 pass through the turbines. The remaining fish at units 1 through 4 total 15. Twelve of these are guided and 3 pass through the turbines. To summarize, 43 fish pass through the SBC, 46 are guided by the screens and 11 pass through turbines. CBE is 89 percent, with the SBC providing a 7 percent increase over screens alone in FPE.

An SBC Type 4 consists of a BGS leading to a modified spillway entrance. There is no SBC associated with the powerhouse. For purposes of this discussion, it is assumed that a BGS to the spillway will divert fish at a similar rate as the prototype BGS which covered only the south half of the powerhouse. While the diversion probability of the BGS (and thus the overall FPE also) would probably be lower under this condition, it reflects the only measurement that is available: what was measured on the prototype in 1998. This being the case, 78 percent of the fish approaching the powerhouse would be diverted to the spillway. The remaining 22 percent would enter the turbine intakes with 18 being diverted by the screens and 4 passing through the turbines. This gives an FPE (or CBE) of 96 percent. The BGS with spillway passage provides a 14 percent increase over screens alone. This system has no provisions for transport of fish.

SBC Type 5, would have a BGS with a partial powerhouse surface collector for transport only and RSWs in spillbays 3 and 5. These structures would be used in combination with ESBSs. It is assumed that the RSWs would be operated during times that it is desirable to have fish migrating in the river, while the surface collector would operate during times that transportation was the preferred fish migration tool. When operating with just the surface collector, performance would be similar to a SBC Type 3. Because we have no information on the performance of RSWs at this time, it is impossible to try and predict what percentage of fish will pass over them under various conditions. It will be assumed for this analysis that the performance will be similar to a partial powerhouse SBC. FPE should be similar for both of these options (partial powerhouse SBC and two RSWs, with BGS).

SBC Type 6 consists of an occlusion structure in front of the powerhouse together with two RSWs. There is some evidence that an occlusion structure in front of a powerhouse may positively influence FGE, although the exact mechanism is not known. This has not been definitively tested and the tests which seem to show this, at Lower Granite in 1998 and 2000, were confounded by the presence of the BGS in front of the units that did not have the occlusion (the SBC in this case). Also, as stated in the previous section, there are currently no test results for the RSW and it is unknown what the FPE and effectiveness of this type of structure will be. Given these caveats, we can speculate that the occlusion device will result in a small increase in FGE for the ESBSs and may tend to discourage fish from entering the turbine intakes. This would tend to increase the effectiveness of the spillway in general, and the RSWs in particular. Spillway effectiveness has been measured at Lower Granite in recent years in conjunction with SBC testing, with values usually between 1 and 1.5.

Table 4-2. Surface Bypass Collector Performance Data Presented as a Percentage of All Fish Approaching the Powerhouse (Not Spilled)

SBC Type	FGE and CBE			Fish Passage Route			
	FGE Alone %	CBE %	Increase %	Screened Bypass %	SBC %	Turbine %	Project Survival* %
Type 1, 2	82	91	9	41	50	9	98.6
Type 3	82	89	7	43	46	11	98.3
Type 4	82	96	14	18	78	4	99.1

* Survival Number Assumptions: SBC=99.5%, Screened Bypass=99.5%, Turbine=89%

SBC Type 7 includes a BGS to the spillway with RSWs in spillbays 1 and 3. This option would most likely be used at Ice Harbor. Again, without any test results for the RSW, it is difficult to predict how this combination would perform. It is, however, very similar to SBC Type 4, and performance would probably be similar if BGS diversion were as high as with the prototype at Lower Granite.

4.4.5 Rationale Used for Development of Surface Bypass Collector Types Used for Different Surface Bypass Collector System Combinations

4.4.5.1 General

An SBC Conceptual Design Report completed in 1998 included ten SBC options for Lower Granite Dam. The options were compared to one another to determine the best transportation, bypass, and adaptive migration strategy options for future consideration at the lower Snake River facilities. The goal was to develop several rational SBC systems to be investigated further. Several meetings were held by Corps biologists and engineers to discuss which SBC options should be used for development of the SBC system combinations. The Corps coordinated with regional specialists to achieve a consensus on the SBC system combinations to be studied.

The SBC combinations selected are described in detail in the Surface Bypass and Collection System Combinations Conceptual Design Report (SBC Combinations Concept Report). The report was completed in December 1998 and is included in full in Annex B. The Major System Improvements options included in this appendix are based upon this report. The following sections reference the SBC Combinations Concept Report.

Because there is currently no widespread regional agreement on whether transporting the juvenile fish is better or worse than keeping the fish in-river, it was decided to develop several system combinations. Two SBC system combinations that keep fish in-river for downstream migration will be investigated in this appendix. Also, there are two SBC combinations investigated that utilize a fish transportation system with one combination at a significantly reduced cost. Finally, there is another system combination studied in this appendix that allows for both transportation and in-river bypass.

4.4.5.2 SBC Structure with SWI Component

The preliminary data from the SBC prototype testing indicated that the SWI and ESBS worked well together to achieve a high collection rate. Because of this, 21.3-meter (70-foot)-deep surface collectors were selected over 16.7-meter (55-foot)-deep surface collectors for further consideration at Lower Granite, Little Goose and Lower Monumental Dams. At Ice Harbor Dam, the forebay depth is considerably shallower and the powerhouse structure is configured such that a 16.7-meter (55-foot)-deep surface collector would appear more appropriate for working together with the ESBS. Use of ESBS intake diversion screen systems is assumed for each SBC type, at each project, for each system combination.

4.4.5.3 SBC Structure with BGS Component

The performance data for the BGS were inconclusive at the time of development of the SBC combinations. Also, as described in Annex B, the cost for a deep full powerhouse surface collector with dewatering is only about 15 percent higher than for a deep partial powerhouse surface collector with dewatering and a BGS. Also, it was felt that if a full powerhouse surface collector were feasible then a partial powerhouse surface collector with a BGS would also be feasible. The reason for this is that the most challenging aspect of development of a full powerhouse SBC is the large scale dewatering, assumed to be about 170 m^3/s (6,000 cfs). A partial powerhouse surface collector would have much less dewatering, approximately 56.6 m^3/s (2,000 cfs). Also, development of a BGS was found to be feasible in the SBC Combinations Conceptual Report. For the reasons stated above, it was felt that a reasonable choice for the bypass and transport SBC system combinations would include full powerhouse surface collectors. If it is later found conclusively that the BGS testing is indeed successful, then it is likely that less expensive partial powerhouse surface collectors with BGSs could be developed in lieu of full powerhouse surface collectors to collect fish for transportation. Also, the BGSs could be used in lieu of full powerhouse surface collectors to guide fish directly to a spillbay for bypass. However, concern was raised regarding the complete exclusion of BGSs from the SBC Combinations Concept Report. It was agreed that it was inappropriate to exclude consideration of this emerging technology prior to the completion of prototype testing. Consequently, it was decided to include BGSs in the Adaptive Migration Strategy System Combination described in the SBC Combinations Concept Design Report. That way, BGS technical and cost issues would be included in the report.

The most recent results from the prototype testing indicate the BGS is effective at guiding fish. Because of this, a Major Systems Improvements option, not contained in the SBC Combinations Concept Design Report, is included in this appendix (Option A-6d). This additional option includes use of BGSs to guide fish to the spillway.

4.4.5.4 Dewatering

The SBC Combinations Conceptual Design Report for Lower Granite Dam included a dewatering system for a full powerhouse surface collector utilizing conventional dewatering criteria. Conventional criteria includes a 0.12 m/s (0.4 ft/s) screen approach velocity component, as defined by NMFS, for screen applications where salmonid fry may be present. Also, the conceptual design report included several full and partial powerhouse surface collector options utilizing more progressive dewatering criteria. The criteria includes a higher screen approach velocity, varying gradually between 0.36 m/s (1.2 ft/s) in the upstream portion of the dewatering channel to the NMFS mandated 0.12 m/s (0.4 ft/s) in the downstream portion of the channel. Preliminary dewatering model testing utilizing the progressive criteria has been completed and has provided promising results. However, more model testing and, eventually, full-size prototype testing would be required to determine the full effects of various dewatering scenarios on fish. Use of the conventional dewatering criteria would result in a much larger and more expensive surface collector. Also, the fish entrances would be further upstream, and the fish would experience a longer travel time through the surface collector. For all these reasons, it was decided that the surface collectors developed for the SBC Combinations Concept Report would utilize "progressive" dewatering criteria.

Although not evaluated as part of this report, energy conservation measures related to excess flows removed during dewatering will be evaluated in future studies. This may mean that excess SBC discharge may be routed to a turbine to capture the energy that would be lost, or water may be added to adult collection systems in order to take the place of flow currently provided by pumps or fishwater turbines.

4.4.5.5 Spillway Fish Bypass Structure

Regional experts, including Corps biologists and engineers, compared methods of bypassing fish over the spillway. One method included in the SBC Combinations Concept Report utilized a chute structure to guide fish over the spillway. With the chute design, the fish would experience a high-velocity free plunge from the end of the chute into the spillway tailwater. This would be a near-vertical, drop-off at the end of the chute, as opposed to a spillway-type flow that is supported by the spillway concrete and guided into the tailwater. This free plunge was seen as possibly being detrimental to the fish. Another method developed in the report included raising the spillway crest. This method was seen as likely causing less fish stress because it would discharge the fish into the tailwater in the same way the existing spillway does and would include no free plunging water. Consequently, the in-river bypass and adaptive migration strategy SBC system combinations contained in the SBC Combinations Concept Report include raised or modified spillbays.

4.5 Miscellaneous Measures

4.5.1 General

Miscellaneous measures to upgrade present facilities to state-of-the-art designs and operations are assumed to consist of items listed in the following sections. A description of how these improvements may be grouped together to improve the existing system's effectiveness for bypassing and/or transporting fish is included in Section 5 of this appendix.

4.5.2 Adult Fish Attraction Modifications

The adult fish attraction water at selected projects would be modified in order to ensure an adequate water supply for the fish ladders in the event of a pump failure. This may include electrical upgrades to provide a more reliable source of electrical power to the attraction water pumps, upgrading existing pumps, adding new pumps, or adding a gravity feed system for the attraction flow.

4.5.3 Upgrade to Lower Granite Juvenile Fish Facilities

Lower Granite Dam is the first dam downstream that migrating juvenile fish pass on the lower Snake River. Under a fish transportation operating scenario, without in-river bypass, the highest percentage of fish transported downstream from the lower Snake River would be transported from Lower Granite Dam. Under an in-river, bypass-only operating scenario, all downstream migrating fish would pass Lower Granite Dam. Therefore, it is important to incorporate improvements to minimize fish stress and to optimize the effectiveness of the juvenile fish facility at Lower Granite Dam. Listed below are potential improvements to the Lower Granite facility. The selection of specific items for implementation depends upon whether the facility would be used for fish transport, bypass, or both. The proposed modifications are derived from improvements in fish facility technology gained in recent years. Upgrading the juvenile fish facilities at Lower Granite would include the following:

- Replacing the thirty-six (36) 254-millimeter (10-inch) orifices extending from the bulkhead slots to the juvenile fish collection gallery with thirty-six (36) 305-millimeter (12-inch) orifices. Each orifice would be equipped with an air operated knife valve, and an air back-flush system for dislodging debris. The valves would be automated and controlled with a programmable logic control computer so they could be cycled to prevent clogging.
- Mining the gallery to a 2.7-meter (9-foot)-width so orifice flow would not strike the far wall. The gallery is currently 1.8 meters (6 feet) wide.
- Mining an exit channel from the dam out to daylight, and installing a non-pressurized flume system to the fish collection facility.
- Installing a dewatering system to reduce the flow from 7.08 m^3/sec (250 cfs) to 0.85 m^3/sec (30 cfs), similar to the design at Little Goose Dam, and routing the excess water to the adult fish collection facility.
- Installing a size separator to separate smaller (primarily salmon) from larger (primarily steelhead) smolts so smaller and larger smolts can be transported in separate truck or barge compartments.
- Upgrading raceways and distribution flume systems at the collection facility.
- Upgrading direct barge loading facilities.

4.5.4 Additional Fish Barges

Additional barges would be constructed to allow direct loading (thus reducing fish stress) at collector dams. Five additional 22,700-kilogram (50,000-pound) barges would be required to allow direct loading at lower Snake River collector dams and to replace two existing barges. The two barges being replaced are old hulls (over 50 years old) approaching the end of their serviceable life.

4.5.5 Modified Fish Separators

If prototype testing proves successful, fish separators would be modified to improve fish separation and to reduce fish stress, delay, and mortality at existing juvenile fish facilities. The new separators would be installed at Little Goose and Lower Monumental Dams and would be included in an upgrade of the Lower Granite Juvenile Fish Facility.

4.5.6 Cylindrical Dewatering Screens

If prototype testing proves successful, cylindrical dewatering screens may be added to existing juvenile fish facilities in order to improve dependability, and debris handling capabilities, as well as to reduce fish stress. A cylindrical dewatering screen design is under consideration that may be an improvement over existing stationary screen designs. If testing shows the cylindrical dewatering screens are beneficial, they would likely be installed at Little Goose, Lower Monumental, Ice Harbor Dams, and included in an upgrade of the Lower Granite Juvenile Fish Facility.

4.5.7 Trash Shear Boom at Little Goose Dam

A new trash shear boom would be constructed in the forebay of Little Goose Dam to capture more of the debris before it can get to the juvenile fish facilities. This debris creates maintenance problems, such as plugging of orifices, which can lead to additional stress on the fish.

4.5.8 Modified Extended Submersible Bar Screens at Turbine Intakes

Submersible bar screens at Lower Granite and Little Goose Dams would be modified to improve their operability and longevity. Modifications might include reducing vibration that causes steel fatigue and cracking and better sealing underwater mechanical equipment to prevent water intrusion. Currently, facilities do not exist at the dams to perform large-scale maintenance. The extended submerged bar screens (ESBS) would have to be moved off site to perform this work.

4.5.9 Additional Flow Augmentation

Currently, additional flow from upstream storage in Idaho is used to increase the total river flow in order to speed downstream migration of juvenile fish. This is a requirement of the 1995 Biological Opinion. Many of the options for operating the river described later in this appendix assume the continued use of flow augmentation or an increased amount of flow augmentation.

4.5.10 Anadromous Fish Evaluation Program

There will be continued monitoring and biological evaluations of anadromous fish due to any significant changes made in the dam facilities and operations. The biological evaluations are conducted in three phases: 1) identification of the problem, 2) evaluation of proposed modifications to the facilities or operations to address the problem, and 3) evaluation of post-construction/operation performance.

5. Existing System Upgrades

5.1 Introduction

Juvenile fish presently pass the dams through turbines, fish bypass systems, or over spillways. In accordance with the 1995 Biological Opinion NMFS issued for operation of the Federal Columbia River Power Systems, the Corps also implements flow augmentation and increased spill measures to help migration. Intake screens are used to guide most of the fish away from turbines and into bypass systems. Juvenile fish are then routed back to the river or into barges or trucks for transport downriver. The 1995 Biological Opinion currently states that about 50 percent of the juveniles are to be transported.

Existing Systems (see Section 3) consist of continuing present fish passage facilities and operations that were in place or under development at the time the feasibility study was initiated. This includes non-fish-related items as well, when considering operation and maintenance costs. Items to be added to present systems (i.e., Existing System Upgrades) are considered important measures to upgrade existing facilities to state-of-the-art designs and operations. Depending upon the alternative being evaluated, ongoing improvements would include such things as modified turbine intake screens, additional fish transport barges, additional end bay flow deflectors on spillways, turbine modifications, and others.

Proposed upgrades to the existing system vary somewhat depending upon the assumed method of aiding fish migration (i.e., whether the fish are transported or bypassed). Various upgrades are grouped together as options to improve the effectiveness of these operational scenarios. These options and the corresponding upgrades are described below.

5.2 Option A-1a: In-River Passage with Voluntary Spill

5.2.1 General

Option A-1a assumes that the juvenile fishway systems will be operated to maximize in-river fish passage and that voluntary spill will be used to bypass fish through the spillways.

Measures for Option A-1a that would likely be used to upgrade existing systems are identified in the following sections.

5.2.2 Dissolved Gas Abatement Measures

Because the fish would remain in the river and voluntary spill would be used to attract the fish to the spillway, it is important to implement dissolved gas abatement improvements. Dissolved gas abatement measures are listed below.

- Spillway gas monitoring for all projects would be continued.
- Two end-bay deflectors would be added at Lower Monumental and Little Goose Dams. The added deflectors would include smooth radius transitions and pier nose extensions. See Section 4.2.2 for further information related to additional end-bay deflectors.
- The existing deflectors at Lower Monumental, Little Goose, and Lower Granite Dams would be modified. See Section 4.2.3 for further information related to modified deflectors.

5.2.3 Turbine Measures

Because of the tremendous costs of implementing major changes to the turbines, it is assumed that improvements to the turbines to improve fish passage will be incorporated in the scheduled turbine rehabilitation for each project. The exact nature of this modification has not yet been determined. For the purpose of this study, a minimum gap runner design will be installed in each turbine. This will approximate the cost of incorporating fish passage measures with existing turbines.

5.2.4 Miscellaneous Measures

Unless specifically identified, the existing features, improvements to existing features, and new features that are listed below would apply to all four lower Snake River projects. (See Section 4.5 for additional discussion related to these items.) The items include the following:

- Existing adult fish passage systems with upgraded adult fish passage modifications
- Existing juvenile fish bypass and collection systems with upgrades to the Lower Granite Juvenile Fish Facilities (less separator, raceway, distribution flume, and direct barge loading upgrades at Lower Granite Dam)
- Minimum operating pools (MOP) with 527 million cubic meters (427,000 acre-feet) flow augmentation from upstream storage in Idaho. Refer to Section 7 in Annex A for more information
- New cylindrical dewatering screens
- Trash shear boom at Little Goose Dam
- Modification of the existing extended submerged bar screens (ESBS) at Little Goose and Lower Granite dams
- Continued operation of the fish hatcheries
- Continuation of AFEP evaluations.

5.3 Option A-2a: Maximizing Transport

5.3.1 General

Option A-2a assumes that the juvenile fishway systems will be operated to maximize fish transportation. Under this option, fish would be bypassed only at Ice Harbor Dam. Therefore, voluntary spill is included only for Ice Harbor Dam.

Measures for Option A-2a that would likely be used to upgrade existing systems are identified in the following sections.

5.3.2 Dissolved Gas Abatement Measures

Because most fish would be transported and voluntary spill is used only at Ice Harbor Dam, it was decided that modifying the existing deflectors was not necessary. However, additional end-bay deflectors at Lower Monumental and Little Goose Dams, as described for Option A-1a, were included in this option. Also, spillway gas monitoring would be continued.

5.3.3 Turbine Measures

For this alternative, improvement to the turbine designs that will improve fish passage will likely be incorporated during the scheduled turbine rehabilitation for the particular project. This is the same assumption as is included for Option A-1a.

5.3.4 Miscellaneous Measures

Unless specifically identified, the existing features, improvements to existing features, and new features that are listed below would apply to all four lower Snake River projects. This is the same list of improvements as is included for Option A-1a, except for the following: 1) new barges, 2) new separators at Lower Granite, Little Goose and Lower Monumental Dams, and 3) the existing juvenile facility at Lower Granite Dam would have more extensive modifications to improve juvenile fish transportation operations. See Section 4.5 for additional discussion related to these items. The list of items for this option include the following:

- Existing adult fish passage systems with upgraded adult fish passage modifications
- Existing juvenile fish bypass and collection systems with upgrades to the Lower Granite Juvenile Fish Facilities
- MOP with 527 million cubic meters (427,000 acre-feet) flow augmentation from upstream storage in Idaho
- Additional fish barges
- Modified fish separators at Little Goose, Lower Monumental, and Lower Granite Dams
- New cylindrical dewatering screens
- Trash shear boom at Little Goose Dam
- Modification of the existing ESBSs at turbine intakes at Little Goose and Lower Granite Dams
- Continued operation of the fish hatcheries
- Continuation of AFEP evaluations.

5.4 Option A-1: Adaptive Migration Strategy with Voluntary Spill

5.4.1 General

Option A-1 assumes that the juvenile fishway systems will be operated in a manner that will balance the passage of fish between in-river and transport methods. This is the current operational strategy for the lower Snake River dams per the 1995 Biological Opinion. Voluntary spill will still be used to bypass more fish through the spillways.

Bypassing and transporting fish is the current operating strategy for the lower Snake River dams.

Measures for Option A-1 that would likely be used to upgrade existing systems are identified in the following sections.

5.4.2 Dissolved Gas Abatement Measures

This option includes bypassing some of the fish over the spillway and utilizing voluntary spill, approaching the gas cap, to attract the fish to the spillway. These measures are similar to that included for Option A-1a. Therefore, dissolved gas abatement measures proposed for Option A-1 are the same as those included with Option A-1a. These measures include the following: 1) continuation of spillway gas monitoring, 2) additional end bay deflectors and pier extensions at Lower Monumental and Little Goose Dams, and 3) modification of existing deflectors at Lower Monumental, Little Goose, and Lower Granite Dams.

5.4.3 Turbine Measures

As is included for Options A-1a and A-2a, improvements to turbines to aid fish passage are assumed to occur during a future major rehabilitation of the turbines.

5.4.4 Miscellaneous Measures

The improvements listed in Section 5.3.4 are the same as the miscellaneous improvements that would be appropriate for Option A-1. These measures would improve both the existing transportation and bypass systems. Refer to Section 5.3.4 for a list of these measures.

6. Major System Improvements

6.1 Introduction

Major System Improvements consist of measures beyond previously mentioned Existing System Upgrades that have a high potential of increasing the effectiveness and efficiency of juvenile fish passage around the dams. Based upon current information, the only future development that is included in this category for this report is SBC-related alternatives. SBC alternatives would provide a new method of collecting and/or bypassing fish.

Each Major System Improvements option would include various Existing System Upgrade options, as described in Section 4 of this appendix. The major system improvements would act in concert with upgraded existing systems to provide a significantly improved overall strategy for aiding downstream fish passage. Refer to Section 4.4.3 and Annex B for a more detailed description of the SBC types referenced herein.

6.2 Option A-6a: Major System Improvements—In-River Passage

6.2.1 General

Option A-6a assumes that the juvenile fishway systems will be operated to maximize in-river fish passage utilizing upgrades to the existing system and major system improvements.

Also, 1,760 million cubic meters (1,427,000 acre-feet) of flow augmentation from upstream storage is included in Option A-6a, compared to 527 million cubic meters (427,000 acre-feet) of flow augmentation included with Option A-1a.

Voluntary spill would be used at each dam to attract fish away from the powerhouse, towards the spillway.

Measures for Option A-6a that would be used to improve fish passage conditions significantly, focusing on actions that will particularly facilitate in-river fish passage operations, are identified in the following sections. Refer to Annex B for a more detailed discussion of SBC options related to the in-river passage strategy.

6.2.2 Existing System Upgrades

All Existing System Upgrade measures identified with Option A-1a, as described in Section 5.2, are included with Major Systems Improvements Option A-6a, except for flow augmentation, as described in Section 6.2.1 above.

6.2.3 Surface Bypass Collectors

The migration strategy for Option A-6a is to focus on effective diversion of the fish away from the turbines for in-river migration. For this combination, all four projects would be outfitted with a SBC Type 2 design. See Section 4.4.3 and Annex B for more detailed information. This means each dam would have a full-length powerhouse SBC channel without dewatering screens. Fish would be passed directly downstream to the tailrace through modified spill flow. To maximize effective diversion away from the turbines, ESBS intake diversion systems would be used in conjunction with the SBC channels at all four dams to divert fish that might pass under the channels and into the turbine intakes. Fish diverted by the ESBS systems would continue to be directed to the juvenile fish facilities where these fish could be delivered directly into the tailrace at that location.

As previously described, Lower Granite and Little Goose Dams already have ESBS systems, and these would continue to be used in conjunction with the new SBC channels. The STS systems at Lower Monumental and Ice Harbor Dams would be removed and replaced with new ESBS systems.

Table 6-1 below summarizes the SBC types at each project that would make up the SBC system combination for Option A-6a.

Table 6-1. Summary of Surface Bypass Collector Types for Option A-6a

System Combination No.	Lower Granite	Little Goose	Lower Monumental	Ice Harbor
Options A-6a: In-River with voluntary spill	**Type 2** (Six-unit Bypass Channel)	**Type 2** (Six-unit Bypass Channel)	**Type 2** (Six-unit Bypass Channel)	**Type 2** (Six-unit Bypass Channel)

6.3 Option A-6b

Option A-6b is identical to Option A-6a, except no flow augmentation is assumed.

6.4 Option A-6d: Alternate In-River Major System Improvement Option

6.4.1 General

Option A-6d assumes that the juvenile fishway systems will be operated to maximize in-river fish passage. This is the same fish passage strategy for Option A-6a except that it uses different SBC components to accomplish the objective. Option A-6d includes the use of a BGS and RSW (SBC Type 4) in lieu of a surface collector at each dam, except Little Goose Dam. A full-powerhouse, bypass-only surface collector (SBC Type 2) system is included for Little Goose Dam.

This option was added late in the study because performance of the BGS was not known at the time a preferred in-river passage alternative was selected to be studied and included in the SBC Combinations Report (reference Annex B). At that time, it was decided to select Option A-6a to be included in the report. However, the most recent data from the prototype testing of the BGS and surface collector at Lower Granite Dam indicate that more fish would be guided to a spillway by a BGS than would be collected with a surface collector. Option A-6d was selected for study during the latter stages of development of this appendix when these data become available. Therefore, inadequate time existed to develop drawings and text in the detail included in Annex B. However, Option A-6d is described in sufficient detail herein by including appropriate references to Annex B.

Option A-6d includes 527 million cubic meters (427,000 acre-feet) of flow augmentation from upstream storage.

Measures for Option A-6d that would be used to significantly improve fish passage conditions, focusing on actions that will particularly facilitate in-river fish passage operations, are identified in the following sections. Because this alternative was added late in the study, this SBC system combination is not evaluated in Annex B. However, a detailed discussion of SBC Types 2 and 4 are included in Annex B. This information was used as a basis for determining estimated costs and an implementation schedule for this option.

6.4.2 Existing System Upgrades

Most of the Existing System Upgrade features identified with Option A-1a in Section 4.2 would be included with Option A-6d. Modification of the existing deflectors at Little Goose Dam is included in Option A-6d because it is assumed Little Goose will have voluntary spill. None of the other projects is assumed to have voluntary spill. Therefore, no modifications to the deflectors are included for the other dams in this option.

6.4.3 Surface Bypass Collectors

The migration strategy for Option A-6d is to focus on effective diversion of the fish away from the turbines for in-river migration. For this combination, Lower Granite, Lower Monumental, and Ice Harbor Dams would have SBC Type 4 systems. At these dams, a BGS would extend upstream from the interface of the powerhouse and spillway. A removable raised spillway weir would be placed on the spillbay adjacent to the powerhouse to provide a more fish-friendly bypass over the spillway. SBC Type 4 systems are described in more detail in Section 4.4.3. There would be no need for voluntary spill at these dams because the BGS is expected to divert about 78 percent of the fish away from the powerhouse, towards the spillway. Refer to Section 4.4.4 for more information on BGS performance.

At Little Goose Dam, an SBC Type 4 would not be used because a BGS would block navigation. Instead, an SBC Type 2 would be employed. See Table 6-2 for a summary of SBC types. Therefore, Little Goose Dam would have a full-length powerhouse SBC channel that would not include dewatering screens. Fish would be collected in the SBC, guided to the spillbay adjacent to the powerhouse, and passed over a raised spillbay, downstream to the tailrace. Voluntary spill would be used to increase the percentage of fish passed over the spillway. Refer to Section 4.4.4 for the effectiveness of SBC.

The existing ESBS intake system at Lower Granite and Little Goose Dams would be used to divert fish that pass under the channel and into turbine intakes. Fish diverted by the ESBS systems would continue to be directed to the juvenile fish facilities, where they would be delivered into the tailrace at that location.

A new ESBS system would be installed in the turbine intakes at Ice Harbor and Lower Monumental Dams to divert fish from the turbines.

Table 6-2. Summary of Surface Bypass Collector Types for Option A-6d

System Combination No.	Lower Granite	Little Goose	Lower Monumental	Ice Harbor
Options A-6d: In-River Passage With BGS Structures (No voluntary spill except at Little Goose)	**Type 4** (Removable Spillbay Weir with BGS)	**Type 2** (Six-unit Bypass Channel)	**Type 4** (Removable Spillbay Weir with BGS)	**Type 4** (Removable Spillbay Weir with BGS)

6.5 Option A-2b: Major System Improvements with Maximized (High Cost) Transport System

6.5.1 General

Option A-2b assumes that the juvenile fishway systems will be operated to maximize fish transport and that voluntary spill will not be needed.

Option A-2b includes 527 million cubic meters (427,000 acre-feet) of flow augmentation from upstream storage.

Measures for Option A-2b that would be used to upgrade existing systems and significantly improve the effectiveness of fish collection and transportation are identified in the following sections. Refer to Annex B for a more detailed discussion of SBC options used for improving fish transportation.

6.5.2 Existing System Upgrades

Existing System Upgrade features identified with Option A-2a in Section 5.3 would be included with this Major Systems Improvements Option A-2b.

6.5.3 Surface Bypass Collectors

The migration strategy for Option A-2b is to maximize the number of fish collected and delivered to the transportation facilities located at Lower Granite, Little Goose, and Lower Monumental Dams. Ice Harbor Dam is not included because fish can only be bypassed. Fish collection would be accomplished by constructing a full-length powerhouse SBC channel at each of the three upstream projects (SBC Type 1). The channels would contain dewatering screens to concentrate the fish in a small enough flow that they could be delivered into the existing juvenile bypass channels inside each dam. Emergency bypass openings would also be provided to allow the collected fish to bypass the dewatering screens and pass downstream directly through the spillway if there is a problem with either the dewatering screens or the transportation facilities. The SBC channels would be used in conjunction with ESBS located in the turbine intakes. Fish diverted by the ESBS would also be delivered into the existing juvenile bypass channels. All fish collected would be delivered to the transportation facilities and either trucked or barged downstream. The number of fish continuing downstream by in-river passage through the projects (either through the turbines or spillways) would be minimized and would drop significantly at each consecutive project.

Lower Granite and Little Goose Dams currently have ESBS installed in the turbine intakes. These would continue to be used. However, the intakes at Lower Monumental are currently outfitted with submerged traveling screens (STS). These would be removed and replaced with ESBS to increase the screen diversion efficiency and to further reduce the number of fish passing through the turbines.

At Ice Harbor Dam, the turbine intakes are also currently outfitted with STS. As at Lower Monumental Dam, these would be removed and replaced with ESBS to increase the diversion efficiency of the screening system. However, no SBC channel would be installed at Ice Harbor Dam. If the combination of the SBC channels and the ESBS diversion systems function as anticipated at the upper three projects, there should be so few freely migrating fish left in the river reaching Ice Harbor Dam, that construction of an SBC system would not be necessary. This approach is further justified by the fact that no fish enter the Snake River between Lower Monumental and Ice Harbor.

Table 6-3 summarizes the SBC types at each project that make up the system combination for Option A-2A).

Table 6-3. Summary of Surface Bypass Collector Types for Option A-2b

System Combination No.	Lower Granite	Little Goose	Lower Monumental	Ice Harbor
Option A-2b:	Type 1	Type 1	Type 1	None
Transport (High Cost) with no voluntary spill	(Six-unit Screened Channel)	(Six-unit Screened Channel)	(Six-unit Screened Channel)	

6.6 Option A-2c: Major System Improvements with Low Cost Transport System

6.6.1 General

Option A-2c assumes that the juvenile fishway systems will be operated to maximize fish transport and that voluntary spill will be needed only at Ice Harbor Dam to aid in bypassing fish over the spillways.

Option A-2c includes 527 million cubic meters (427,000 acre-feet) of flow augmentation from upstream storage.

Measures for Option A-2c that would be used to upgrade existing systems and significantly improve the effectiveness of fish collection and transportation are identified in the following sections. Refer to Annex B for a more detailed discussion of SBC options used for improving fish transportation.

The juvenile fish passage strategies for Options A-2b and A-2c are the same. However, there are significant differences in designs and project operations between these two options.

6.6.2 Existing System Upgrades

Existing System Upgrade features identified with Option A-2a in Section 5.3 would be included with this major systems improvements option.

6.6.3 Surface Bypass Collectors

Option A-2c is a reduced-scale version of Option A-2b, requiring significantly reduced initial and operating costs.

A key justification for implementing Option A-2c is that the majority of juvenile salmon coming down the Snake River starts upstream of Lower Granite Dam. If the combined SBC and ESBS systems to be utilized at Lower Granite function as effectively as anticipated, there would be few migrating fish left in the river below the dam. Considering the potential effectiveness of upgrading the intake screen systems, construction of large, expensive SBC systems may not be justified downstream of Lower Granite Dam.

The migration strategy for Option A-2c, like Option A-2b, is to maximize the number of fish collected and delivered to the existing or upgraded transportation facilities. However, this option relies more heavily on the intake diversions screen systems because an SBC system would only be used at Lower Granite Dam.

Like Option A-2b, Option A-2c includes an SBC Type 1 at Lower Granite. This would include the construction of a full-length powerhouse SBC channel with dewatering to be used in conjunction with the existing ESBS system. At the lower three projects (Little Goose, Lower Monumental, and Ice Harbor Dams) only ESBS intake diversion systems would be used. Because ESBS already exist at Little Goose, there would be no required modifications at this project, and the existing diversion/bypass facilities would continue to be used. At Lower Monumental and Ice Harbor Dams, the existing STS intake diversion systems would be replaced with ESBS systems, but no additional SBC channels would be constructed to augment these systems.

If it is decided that transportation is the migration strategy for the river, Options A-2b and A-2c actually form a transportation package, which could be initiated prior to a decision between which of the two combinations would constitute the final design. This is because everything involved in Option A-2c would be required in Option A-2b. In fact, the most prudent way to install Option A-2b would be to install Option A-2c first and test the SBC/ESBS collection facility at Lower Granite Dam. Any unanticipated bugs could then be worked out of the SBC design. If, after testing of Option A-2c, it is decided that Option A-2b is justified, lessons learned for the SBC Type 1 design at Lower Granite Dam could be applied at Little Goose and Lower Monumental Dams.

Table 6-4 below summarizes the SBC types at each project. These SBC types make up Option A-2c.

Table 6-4. Summary of Surface Bypass Collector Option A-2c

System Combination No.	Lower Granite	Little Goose	Lower Monumental	Ice Harbor
Option A-2c:	Type 1	None	None	None
Transport (Low Cost) with Voluntary Spill at Ice Harbor only	(Six-unit Screened Channel)			

6.7 Option A-2d: Major System Improvements—Adaptive Migration Strategy

6.7.1 General

Option A-2d assumes that the juvenile fishway systems will be operated in a manner that will balance the passage of fish between in-river and transport fish passage methods. The Adaptive Migration Strategy would optimize current operational objectives where either in-river or transport strategies can be used. This strategy addresses concerns about the risks and effectiveness associated with bypass-only and transport-only. Because of its design, this option would have the flexibility to allow operational changes to be made within a migration season if necessary.

This is similar to the fish passage strategy included for the Existing System Upgrade Adaptive Migration Strategy (Option A-1). See Section 5.4 for details.

Option A-2d includes 527 million cubic meters (427,000 acre-feet) of flow augmentation from upstream storage.

Actions required to implement Option A-2d are identified in the following sections. Refer to Annex B for a more detailed discussion.

6.7.2 Existing System Upgrades

Existing System Upgrade measures included with Option A-1, as described in Section 5.4, would be included with Option A-2d.

6.7.3 Surface Bypass Collectors

The migration strategy for Option A-2d allows for either fish-friendly transportation or in-river migration. At Lower Granite and Lower Monumental dams, SBC Type 5 systems would be installed. Surface collectors could then be used to collect fish at these two dams for downstream transportation. Lower Granite is a logical location for collecting fish for transport because it is the furthest upstream dam. It was decided to use a surface collector at Lower Monumental to allow collection of 1) fish not collected at Lower Granite, 2) fish entering the Snake River from the Tucannon River and 3) fish released from the Lyons Ferry Hatchery.

When in transport mode, the surface collectors in front of Turbine Units 5 and 6 at Lower Granite and Lower Monumental would collect downstream migrating fish and pass them through a dewatering section in the surface collector, delivering them to the existing juvenile fish collection channel within each dam. To guide fish away from Units 1 through 4, a BGS would be constructed in the forebay.

When it is desired to keep the fish in the river, the surface collector would be shut off and the fish would be guided by the BGS past the surface collector to two RSWs. The RSWs would provide a surface attraction flow and a less stressful method of bypassing fish than is now used for spillway passage.

As with the other system options, ESBS intake diversion systems would be used in conjunction with these two-unit SBC channels. At Lower Granite Dam, the existing ESBS would be used, whereas at Lower Monumental Dam there would be new ESBS to replace the existing STS. ESBS would be located in the turbine intakes of all six units of both powerhouses to bypass fish that pass around or under the BGS.

At Little Goose Dam, a SBC Type 6 system would be installed. The Type 6 system consists of a full-length powerhouse occlusion structure. The occlusion structure is expected to improve the performance of the ESBS and to increase the guidance of fish away from the turbine intakes and towards the spillway. An RSW would be placed in spillbays 1 and 3 to bypass fish. The goal is to provide an effective bypass for juvenile fish. Also, each turbine unit at Little Goose Dam would have an existing ESBS in place. Fish diverted by the ESBS would be directed to the juvenile fish facilities where they would be collected for transport or returned to the river.

At Ice Harbor, a SBC Type 7 system would be constructed. A BGS would extend upstream from the interface of the powerhouse and spillway. Two removable raised spillway weirs would be installed, one on spillbay 1 and the other on spillbay 3. The RSWs would provide attraction flow to the spillways and would provide a less stressful method of bypassing fish over the spillway than the current method. New ESBS would replace the existing STS at Ice Harbor. They would be installed in the turbine intakes to offer a bypass for fish passing around or under the BGS. Table 6-5 summarizes the SBC types for Option A-2d.

Table 6-5. Summary of Surface Bypass Collector Option A-2d

System Combination No.	Lower Granite	Little Goose	Lower Monumental	Ice Harbor
Options A-2d:	Type 5	Type 6	Type 5	Type 7
Adaptive Migration Strategy	Two-Unit Screened Channel/BGS/Two RSWs – (Transport or Bypass SBC)	Occlusion Structure/Two RSWs – (Bypass SBC)	Two-Unit Screened Channel/BGS/Two RSWs (Transport or Bypass SBC)	Two Removable Spillbay Weirs with BGS- (Bypass SBC)

6.7.4 Voluntary Spill

When operating in bypass mode, there would be a need for voluntary spill over the RSW at each dam. However, each of the SBC types described previously is anticipated to improve the effectiveness of fish attraction, guidance and bypass across each spillway, while spilling less water than required for current spillway passage (see Section 4.4.4 for more information). In other words, it is anticipated more fish can be bypassed with less spill using RSWs. Full scale testing is required to verify this. However, it may be necessary to have additional spill across other spillbays to improve tailrace egress conditions for juvenile fish. Hydraulic model tests specific to each dam would be needed to determine requirements for additional training flows.

When transporting fish, there would be no need for voluntary spill at Lower Granite, Little Goose, or Lower Monumental Dams because fish are transported from these dams. At Ice Harbor, fish must be bypassed across the dam. Therefore, voluntary spill is required for the RSWs and may be necessary at other spillbays to improve training flow at Ice Harbor.

7. Impacts to Hydropower

7.1 General

As discussed in Section 1.4, the Corps is currently required to spill at all lower Snake River dams to attempt to achieve an FPE target of 80 percent. Also, voluntary spill is assumed for some of the Upgraded Existing System options and Major System Improvement options. Voluntary spill results in less water available for hydropower production. Use of SBC options also requires water to be passed over the spillway. This results in lost hydropower as well.

Each transportation option (Options A-2a, A-2b, and A-2c) and Option A-2d (Adaptive Migration) assumes substantially reduced or eliminated voluntary spill, resulting in reduced hydropower losses. When compared to the current operating procedure, which includes voluntary spill, the loss of hydropower due to the use of surface collectors for fish transportation (Options A-2a and A-2c) is offset partially or completely by the reduced voluntary spill. For instance, Option A-2c utilizes one 170 m^3/s (6,000 kcfs) surface collector that reduces hydropower economic benefits by about $4.5 million per year. However, hydropower benefits are increased by about $9.6 million per year over the current operating procedure due to the elimination of voluntary spill at Lower Granite, Little Goose, and Lower Monumental Dams. The net effect for Option A-2c is an increase in hydropower economic benefits of $5.1 million over the current operating procedure (reference: "Technical Report on Hydropower Costs and Benefits," developed by the Drawdown Regional Economic Workgroup: Hydropower Impact Team).

It is likely that a pumpback system or turbine generator could be installed to recoup most of the hydropower benefits that would otherwise be lost due to use of an SBC. Such a system would likely require an SBC with a dewatering system to separate the fish from the water that is either pumped back into the reservoir or passed through a turbine generator. The in-river passage options (Options A-6a, A-6b, and A-6d) do not have SBC dewatering systems. These options would likely have to be reconfigured to include SBC dewatering if pumpback systems or turbine generators were included. If any option using an SBC were selected for implementation, more detailed investigation of an energy conservation system would be required.

7.2 Voluntary Spill Caps

Table 7-1 summarizes existing and new projected voluntary spill caps as they currently are operated and illustrates how they could be operated in the future if gas abatement measures associated with upgraded existing systems were implemented. This includes additional end-bay deflectors and modification of existing deflectors. New gas abatement measures used with current flow levels would result in TDG supersaturation levels of about 112 percent to 115 percent. Alternatively, new gas abatement measures would allow a higher amount of flow without exceeding the limit of 120 percent TDG supersaturation. However, increased spill would reduce hydropower benefits. The lost hydropower benefits due to current and potential increased spill flows has not been determined. Spill flows are summarized for the two spill conditions, assuming spill to the 120 percent TDG supersaturation limit.

Table 7-1. Approximate Voluntary Spill Caps, Existing System, and Existing System Upgrades

	Ice Harbor 1,000 m^3/s (1,000 cfs)	**Lower Monumental 1,000 m^3/s (1,000 cfs)**	**Little Goose 1,000 m^3/s (1,000 cfs)**	**Lower Granite 1,000 m^3/s (1,000 cfs)**
Existing System	3.11 (110)	1.2 (43)	1.4 (48)	1.3 (45)
Existing System Upgrades*	3.11 (110)	1.9 (68)	1.9 (68)	1.9 (68)

* Includes additional endbay deflectors and modified deflectors where appropriate.
Note: Voluntary spills based on 120 percent TDG supersaturation limit.

8. Unresolved Issues

8.1 General

Included below is a description of unresolved issues concerning dissolved gas abatement measures, turbine modifications, and SBC technology development. Resolution of these issues could impact the implementation schedules and costs included in this appendix.

8.2 Dissolved Gas Abatement Measures

8.2.1 General

The impacts of any spillway modifications on juvenile and adult fish passage, navigation and channel erosion must be considered. The addition or modification of spillway flow deflectors may potentially affect any or all of these items. In addition, as discussed in Section 4.2.1, there are still uncertainties associated with the ongoing Phase II DGAS studies.

There are other gas abatement measures not included in any of the Existing System Upgrades or Major System Improvements options, but which are included in Annex C. These measures hold potential for significantly reducing TDG production. The engineering evaluation of these options is complete. However, biological evaluations have yet to be completed.

8.2.2 Adult Fish Passage

Model studies and prototype evaluations have shown deflectors in the outside spillway bays may create strong cross-currents (or lateral flows) immediately downstream of the adult fishway entrances. Tailrace conditions altered by additional deflectors may disorient and delay adult fish seeking passage through the fishway entrances adjacent to the spillways.

The effect of additional or modified flow deflectors on adult passage must be evaluated on a project-by-project basis, accounting for differences in project configurations, such as relative location of fishway entrances, channel bathymetry, and the existence of guide walls separating the entrances from the spillway stilling basin. Hydraulic model studies would be required. Modifications to the existing deflectors at Lower Granite Dam are not expected to affect adult fish passage.

If model studies indicate potential problems, it is anticipated that physical changes such as training wall extensions or changes in the deflector design would resolve the problem. Also, spillway operational changes resulting in modified spill patterns could be implemented. It is worth noting that similar spillway modifications have been installed at Ice Harbor and John Day Dams without any apparent serious impacts to adult fish migration.

8.2.2.1 Lower Monumental Dam

Although not anticipated, if end-bay deflectors were to cause adult fish passage delays, discharge through these bays could be restricted during daylight hours with no impact to adults. These bays then could be operated throughout the night for additional gas reduction benefits.

8.2.2.2 Little Goose Dam

Conventional type deflectors in spillbays 1 and 8 should have minimal impacts on adult fish passage.

8.2.3 Juvenile Fish Passage

The hydraulic flow conditions generated by deflected spill flow may directly impact survivability of juvenile salmonids migrating downstream. Increased turbulence in the vicinity of stilling basin baffle blocks and the end sill may increase with additional or modified deflectors. Increased turbulence in the vicinity of these structures may result in increased mechanical injury. Though many of the projects are similar, the influence of spillway modifications on juvenile fish passage must be evaluated on a project-by-project basis.

If problems are discovered, then changes to spillway operations resulting in modified spill patterns could be implemented to minimize impacts to juvenile fish.

8.2.4 Navigation

Flow deflectors decrease the amount of energy dissipated within the stilling basin, increasing the velocity of flow in the downstream channel. The extent that deflectors influence navigation conditions downstream of the lock entrances depends on the channel configuration, bathymetry, and the relative location of the navigation lock to the spillway. Increased velocity and cross-channel flows may make it difficult for tow operators to maintain proper alignment and speed as they approach and exit the downstream lock entrance. Potential impacts of additional or modified deflectors on navigation must also be evaluated on a project-by-project basis. Modifications to the existing deflectors at Lower Granite Dam are not expected to affect navigation.

8.2.4.1 Lower Monumental Dam

The navigation lock at Lower Monumental Dam is located near the south non-overflow embankment and is separated from the spillway by the south shore fish ladder. Surface skimming flow deflected from spillbay 1 may increase channel velocities below the downstream lock entrance. Higher velocities could create problems for tows exiting and entering the downstream lock approach.

Hydraulic modeling would be used to determine the impacts of any spillway modifications. If problems are discovered, changes could be made to the spill patterns. Also, cellular cofferdams, similar to those at Ice Harbor Dam, could be installed, or the guide wall could be extended. This would provide a physical barrier to the spillway flows adjacent to the downstream approach to the lock.

8.2.4.2 Little Goose Dam

Conventional type deflectors in spillbays 1 and 8 and existing deflector modifications at Little Goose Dam should have no adverse impacts on navigation. The peninsula downstream of the dam provides a suitable barrier to the spillway flows.

8.2.5 Stilling Basin and Channel Erosion

The ability of the spillway and stilling basin to adequately dissipate the energy of spillway design flows must not be compromised by any spillway modifications. If the primary energy from the spillway can be contained within the stilling basin, no damage will occur to the structure. Model studies show the standard 3.8-meter (12.5-foot)-long flow deflectors at Lower Monumental and Lower Granite Dams will not cause a hydraulic jump to occur downstream of the stilling basin, regardless of the flow rate. However, standard length deflectors at Little Goose Dam may cause problems with energy dissipation because of the roller bucket.

8.2.5.1 Lower Monumental Dam

Due to erosion, large holes have been created in the Lower Monumental stilling basin because the construction of flow deflectors in the center six spillbays. The erosion has occurred near the toe of the spillway below spillbays 1, 2, 7, and 8. Because of the location of the holes it is believed that the erosion has been caused by hydraulic conditions created by the interaction of deflected and non-deflected spillway flows. Adding flow deflectors to spillbays 1 and 8 may reduce the potential for continued erosion. However, due to the severity of the problem, stilling basin conditions must be thoroughly investigated before a recommendation of additional deflectors can be made.

8.2.5.2 Little Goose Dam

Extending the existing deflector lengths to 3.8 meters (12.5 feet) may result in insufficient energy dissipation of the project design flows, forcing the hydraulic jump and high-energy flow into the downstream channel and potentially causing erosion of the downstream channel and shoreline. Likewise, adding similar size deflectors to the end bays may also compromise the roller bucket's ability to dissipate the energy of high spillway flows and may increase the potential for tailrace channel erosion. Model studies will be needed to assess the potential impact.

8.3 Turbine Measures

Unless dam breaching is selected, it is likely that all of the generating units will require major repair or rehabilitation in the next 10 to 50 years. Now, the exact nature of turbine related modifications and associated fish benefits are not specifically known. However, benefits to anadromous fish stocks are potentially significant because they will accrue over the life of a rehabilitated turbine, estimated to be 35 to 50 years. The current Turbine Passage Survival Program is yielding information to allow an accurate evaluation of fish passage benefits associated with turbine operational changes and modifications. This evaluation is expected to be complete in about 10 years.

8.4 Surface Bypass Collector Measures

8.4.1 Surface Bypass Collector Performance

Present SBC performance numbers are based on SBC prototype testing conducted at Lower Granite Dam between 1996 and 1998 (see Section 4.4.4). In the case of SWI and BGS components of SBC, these features have undergone just one year of testing. Given the nature of the prototype tests and the limited test duration, predictions of how SBC systems might perform for full-system designs at Lower Granite Dam and other lower Snake River projects can only be projected. However, it is believed that prototype type test results thus far do provide a conservative prediction of how full-scale production systems would perform. It is believed that with continued SBC research and development there is a high likelihood that significant gain in SBC fishway performance can still be realized.

8.4.2 Dewatering

Several of the current options for SBC development (see Sections 4.4.3 and 4.4.5) would require the use of large-scale dewatering systems that would be substantially larger than any screen system used on any project to date. Large-scale dewatering systems discussed in this report are needed for all transport-related options. In-river options do not have dewatering. In-river designs, however, may also eventually require dewatering if some form of sampling and fish tag evaluations is ever required, or if it is desired to reduce large fish attraction flows down to an amount that can be economically handled.

The original study plan for dewatering was to perform field investigations, conduct literature searches, develop design criteria, concept designs, complete large scale hydraulic model studies, and design, construct, and test a prototype dewatering structure in conjunction with a SBC prototype. Progress was made on all of these items, except for detailed design, construction, and testing of a dewatering prototype structure. For a variety of reasons, such as budgetary constraints, design criteria uncertainties, uncertainties as to how well SBC technology would perform, and a general aversion by many to dewatering, the goal to complete a dewatering prototype test structure in time to provide input to the feasibility study was dropped.

A variety of critical issues have to be answered before large-scale dewatering can be used with a high degree of confidence. A physical hydraulic model study of a dewatering prototype test structure indicated that more progressive dewatering screen criteria with a specially shaped channel floor and sidewall design would be feasible from a hydraulics perspective. Because the model performed well hydraulically, the consensus is that it would likely perform well from a biological perspective. However, large scale dewatering, as it relates to biological performance and project operations/reliability concerns, can only be answered with certainty by evaluating the results from a prototype test structure. Until such a prototype structure is tested, which would also require additional detailed hydraulic modeling, uncertainties about large-scale dewatering will exist.

The final design criteria used for development of a permanent dewatering structure would be based upon the results of the prototype test.

8.4.3 Reduced Spillway Capacities

Some of the SBC options impacting existing spill bays reduce original spillway flow capacities by as much as 5 percent. For these options to be completed using these designs, approval will be required from a higher authority to reduce spill levels authorized for original projects. If approvals for reduced spill levels are not given, alternative plans involving higher cost designs could be used. Some alternative plans to address the reduced spillway capacity include the following:

- Routing SBC flows to the tailrace via modified portions of non-overflow sections of dams. Refer to the appendix at the end of Annex B for more information.
- Modifying some of the other spillbays to increase their spill capacity. This option would likely be very expensive.
- Passing excess flood flows through the turbines. Perforated bulkheads installed upstream and/or downstream of the turbines would be required to reduce the large head differential enough to avoid damaging the turbines. However, this option has not yet been studied in detail.
- Passing excess flood flows through the navigation lock culverts and into the lock, to exit downstream through the open downstream lock gate. However, this option has not yet been studied in detail.

8.4.4 Structural Design Issues Related to Modifications to Existing Spillways and Central Non-Overflow Sections

Additional seismic structural stress analysis of key existing structures would be required for some of the options due to the addition of SESs and RSWs to the spillway and central non-overflow monoliths. These analyses would be especially important at Ice Harbor Dam where design ground accelerations are high. A stability analysis of the spillway at Ice Harbor Dam would be required before attaching any structures to it. If the stability of any monolith is compromised, or concrete design stresses are found to be excessive, additional concrete and/or post-tensioning may be added to bring the structure(s) into compliance with current design criteria.

8.4.5 Removable Spillway Weir

The RSW included with SBC Type 4, 5, 6, and 7 systems would require model testing to determine the best shape for development of a full-size prototype. Prototype testing would show whether an acceptable design could be developed that does not harm fish. Because the RSW would be resting on top of an existing spillbay, there are limitations on the possible shapes of the RSW. However, it is currently anticipated that a successful design could be developed.

8.5 Miscellaneous Measures

Some of the miscellaneous measures to upgrade present facilities, as discussed in Section 4.5, involve issues related to either uncertainties surrounding effectiveness of the improvement or its specific design layout.

Examples of features that are either being researched now or soon will be, include cylindrical dewatering screens and modified fish separators. The results of the research and testing will determine if these items are to be implemented. Also, the results will be used in developing the final design of the upgrades to the Lower Granite Juvenile Fish Facilities. The decision on whether or not to install an SBC at Lower Granite Dam would also affect the design of the juvenile facility upgrade.

9. Implementation Costs and Schedules

9.1 General

Implementation costs and schedules for each of the options evaluated in this appendix have been developed and are summarized in Tables 9-1, 9-2, and 9-3 and in Figure 9-1, contained herein. Included are costs for construction, operation, and maintenance, as well as other specific federal requirements for each of the options. The costs were developed as comparison type costs, for use in the economic studies and option selecting. Costs do not include escalation and are not intended to be used as program funding estimates. These costs are based on the scope of work, assumptions, and methodology presented in the "Detailed Project Schedule PB-2A" (PB-2A) and Engineering Annexes A through D of this appendix. Engineering, design and construction supervision, and administration costs are included in new construction costs. Also, all costs include contingencies. More detailed cost and implementation information can be found in Annex E. Final cost comparisons will take place in Appendix I, Economics.

Costs are tabulated for each of the eight options for operating the four lower Snake River dams as shown in Table 9-1.

Table 9-1. Options Included in the Cost Estimates

Option Number	Existing System Upgrade or Major System Improvement	River Operational Strategy
A-1	Existing System Upgrade	Adaptive Management Strategy
A-1a	Existing System Upgrade	In-River Operation
A-2a	Existing System Upgrade	Maximizing Transport
A-2b	Major System Improvement	Maximizing Transport with SBC (high-cost option)
A-2c	Major System Improvement	Maximizing Transport with SBC (low-cost option)
A-2d	Major System Improvement	Adaptive Migration Strategy with SBC
A-6a and A-6b	Major System Improvement	In-River Passage with SBC and without BGS
A-6d	Major System Improvement	In-River Passage with BGS

9.2 Methodology for Development of Implementation Cost

This report includes concept level cost estimates. Estimates were developed for each of the nine options. Costs are developed based on a 100-year life cycle analysis. All costs are at a price level October 1, 1998 (start of the fiscal year). For comparison purposes, no allowance is included for inflation to cover construction time. A period extending from 2001 to 2045 is included in the graphs. After 2045, annual costs are fairly constant.

Construction and acquisition costs are short point-in-time values, based on PB-2A, Conceptual Design Reports, and supporting documents. These budgetary costs include costs for contracts, construction, prototypes, testing and development, feasibility studies, real estate, cultural resources, engineering and design, construction management, and project management. It has been assumed for cost development that fish passage around the dams will not be impacted during construction. Therefore, in-water construction work will be allowed only during normal in-water work windows. Other assumptions and costs are documented in the annexes. The cost for construction and acquisition occur for a short period during these economic studies.

Anadromous fish evaluation program annual costs are for testing, research, development, and evaluation of the effects of dam improvements on migrating fish. These study-costs occur for approximately the first 25 years of the construction and rehabilitation improvements.

Operations and maintenance (O&M) annual costs are based on historical records received from Programs Management Branch within the Corps. They are tabulated and broken out per work breakdown structure and separated into O&M costs for each dam. Minor and major rehabilitation costs, such as costs for navigation locks, spillways, fish transportation, dredging and miscellaneous costs, are included in the O&M cost data. However, costs for major rehabilitation of the powerhouse are not included with O&M costs.

Costs for minor repair are shown as an annual cost based upon an assumed percentage of O&M costs. An additional percentage was used to cover the cost of aging equipment and increased dredging. When minor repairs and routine operation and maintenance costs are combined, the result is the complete cost of operating and maintaining the four lower Snake River dams, except for major rehabilitation of the dam turbine and generator units. Routine operation, maintenance, and minor repair costs are included for the full duration of the economic study.

Major rehabilitation costs are short point-in-time costs for completely rehabilitating all 24 turbine and generator units at the lower Snake River dams. This includes rehabilitation of the turbines, the turbine blades (six blades per turbine), rewinding generators, and miscellaneous work. Because of the time spanned by the economic study, more than one rehabilitation will be required. The second group of turbine rehabilitations is not shown in the table or on the graphs because they would occur very far in the future, but the second group of rehabilitation costs is included in the economic studies report. These major repair and rehabilitation costs are assumed to occur during various short periods within the economic study life.

Fish hatchery annual costs are for operating, repairing, and rehabilitating the fish hatcheries. The costs for operating and maintaining the fish hatcheries are assumed to occur for the full duration of the economic study.

Bureau of Reclamation (BOR) water acquisition annual costs include obtaining additional water for flow augmentation to aid downstream migrating fish. Average costs for water acquisition were used in the development of these costs. The water is purchased from natural (irrigator) flow rights, changes in lower Snake River reservoir operations, and additional water from BOR storage reservoirs. These water purchase costs occur for the full duration of the economic study.

9.3 Uncertainties

The yearly costs profile graphs show the funds needed to accomplish the work on schedule (without inflation). However, final schedules and project costs depend upon funding limitations and will be adjusted accordingly. The schedules assume that work will start in FY 2001 (Oct 1, 2000).

Because various aspects of the fish mitigation program are in the early stages of development, certain requirements may change and costs may vary. There were no additional costs included for future improvements to the existing fish facilities that may occur upon completion of research.

The 24 lower Snake River dam turbine units have an approximate life span of 35 to 50 years. It is assumed that approximately 10 years is required to rehabilitate the six turbine units at each dam, and only one turbine unit can be rehabilitated at a time, in order to maintain consistent power production. Also, it is assumed that rehabilitation will occur at just one dam at a time due to anticipated funding limitations. The schedule assumes the final turbine unit rehabilitation at each dam will be completed 10 years after the end of its estimated 50-year life span (see schedule). This method is a conservative approach to rehabilitation of the turbine units.

Schedules, concept costs, and the fish mitigation program are under development and are subject to change as direction and funding are made available. All annual costs are an approximation of fluctuating costs and funding and are subject to change over time.

9.4 Summary Tables and Graphs

Tables 9-2 and 9-3 and Figure 9-1 provide a summary of costs and implementation schedules for each of the options described in Section 9.1. More detailed information is available in Annex E.

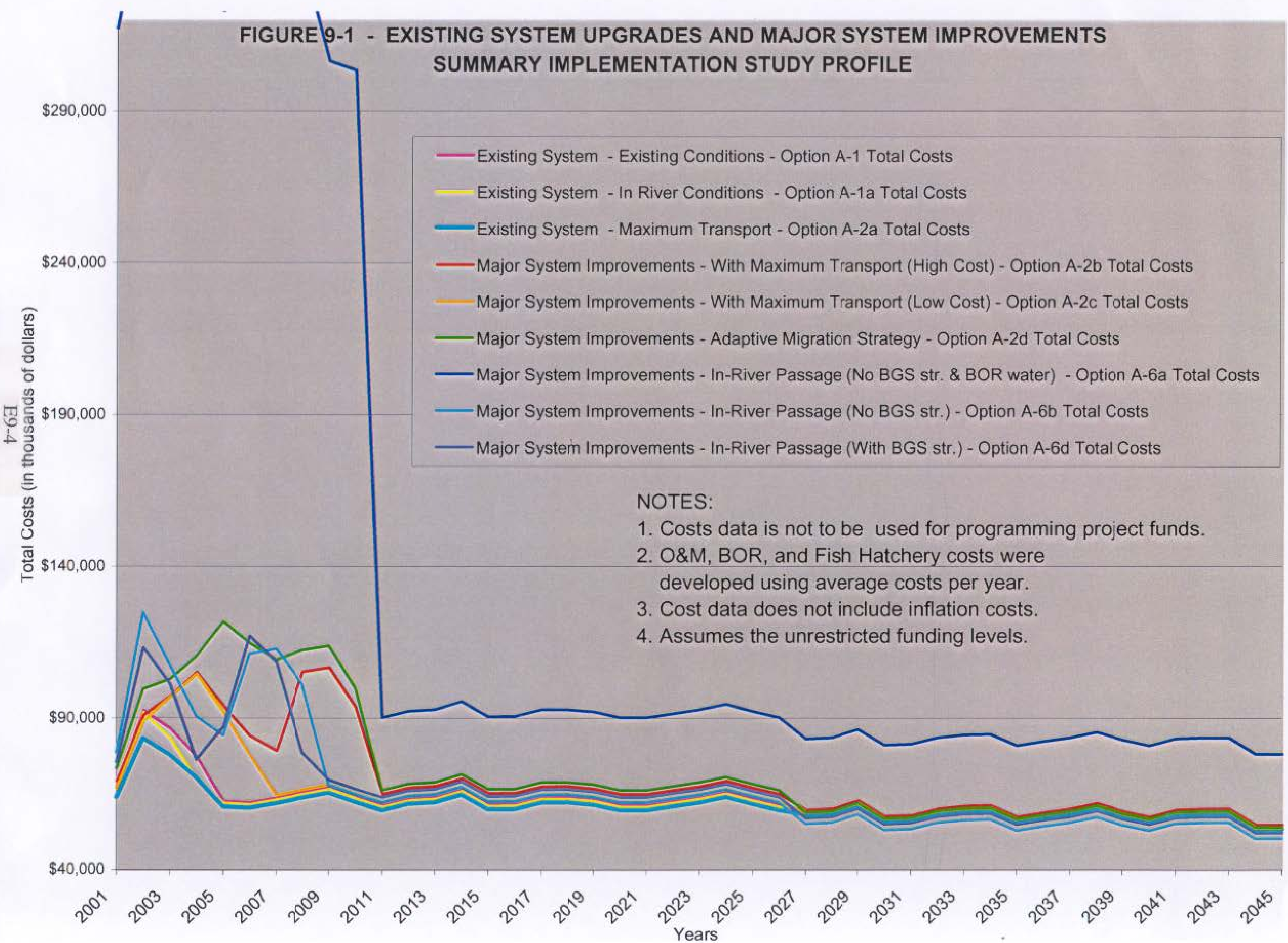
FIGURE 9-1 - EXISTING SYSTEM UPGRADES AND MAJOR SYSTEM IMPROVEMENTS
SUMMARY IMPLEMENTATION STUDY PROFILE
Existing System - Existing Conditions - Option A-1 Total Costs
Existing System - In River Conditions - Option A-1a Total Costs
Existing System - Maximum Transport - Option A-2a Total Costs
Major System Improvements - With Maximum Transport (High Cost) - Option A-2b Total Costs
Major System Improvements - With Maximum Transport (Low Cost) - Option A-2c Total Costs
Major System Improvements - Adaptive Migration Strategy - Option A-2d Total Costs
Major System Improvements - In-River Passage (No BGS str. & BOR water) - Option A-6a Total Costs
Major System Improvements - In-River Passage (No BGS str.) - Option A-6b Total Costs
Major System Improvements - In-River Passage (With BGS str.) - Option A-6d Total Costs
NOTES:
1. Costs data is not to be used for programming project funds.
2. O&M, BOR, and Fish Hatchery costs were developed using average costs per year.
3. Cost data does not include inflation costs.
4. Assumes the unrestricted funding levels.
Total Costs (in thousands of dollars)
$290,000
$240,000
$190,000
$140,000
$90,000
$40,000
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
2041
2043
2045
Years

Table 9-2. Summary Table of Implementation Costs and Schedules for Existing System Upgrade Options

Option No./ Description (spill condition)	Construction Costs ($million)	Construction Schedule (Duration–Years)	Anadromous Fish Evaluation Program (AFEP) annual costs for 27 years ($million)	AFEP Schedule (Duration–Years)	Routine O & M and Minor Annual Repair ($million)	Major Rehabilitation of Turbines ($million)	Major Rehabilitation of Turbines Schedule (Duration–Years)	BOR Annual Costs ($million)
Existing System Upgrades								
A-1 Adaptive Management Strategy (voluntary spill)	89.3	5	5.3	27	36.5	193.6	41	2.4
A-1a In-River (voluntary spill)	80.1	5	5.3	27	35.8	193.6	41	2.4
A-2a Transport (No voluntary spill except Ice Harbor)	67.9	5	3.6	27	36.5	193.6	41	2.4

Table 9-3. Summary Table of Implementation Costs and Schedules for Major System Improvement Options (Construction costs includes Existing System Upgrades)

Option No./ Description (Spill Condition)	Construction Costs ($million)	Construction Schedule (Duration–Years)	Anadromous Fish Evaluation Program (AFEP) annual costs for 25 years ($million)	AFEP Schedule (Duration –Years)	Routine O & M and Minor Annual Repair ($million)	Major Rehabilitation of Turbines ($million)	Major Rehabilitation of Turbines Schedule (Duration–Years)	BOR COSTS ($million)
Major System Improvements								
A-2b Transport (High cost–no voluntary spill)	270.0	11	7.4	27	38.0	193.6	41	2.4
A-2c Transport (Low cost–no voluntary spill except Ice Harbor)	162.5	7	5.7	27	37.0	193.6	41	2.4
A-2d Adaptive Management Strategy (Voluntary spill varies)	389.6	10	9.5	27	37.2	193.6	41	2.4
A-6a In-River (Voluntary spill and no BGS, higher flow augmentation)	316.7	10	9.2	27	35.8	193.6	41	(See Annex E)
A-6b In-River (Voluntary spill and no BGS, no flow augmentation)	316.7	10	9.2	27	35.8	193.6	41	28.1
A-6d In-River (Voluntary spill only at Little Goose, BGS at other dams)	249.2	10	9.0	27	35.4	193.6	41	2.4

10. Glossary

3-D cams: Computer software based upon the turbine performance curves that automatically adjusts the wicket gate openings and turbine blade angle to optimize turbine efficiency.

Adaptive Migration Strategy: This strategy allows for the use of either in-river bypass and/or transportation of juvenile fish.

Anadromous Fish: Fish, such as salmon or steelhead trout, which hatch in fresh water, migrate to and mature in the ocean, and return to fresh water as adults to spawn.

Anadromous Fish Evaluation Program (AFEP): Involves biological evaluations of anadromous fish and evaluations of proposed dam modifications to predict resulting impacts to fish.

Behavioral guidance structure (BGS): Long, steel, floating structure designed to simulate the natural shoreline and guide fish toward the surface bypass collection system by taking advantage of their natural tendency to follow the shore.

Collection channel: A channel within the powerhouse that downstream migrating fish enter after being guided away from the turbines with turbine intake screens or a surface collector. The fish travel down the channel to a juvenile fish facility where they are transported downstream of Bonneville dam.

Combined bypass efficiency (CBE): Refers to the total number of fish guided by the screens or collected by a surface collector, as a percentage of the total number of fish approaching the powerhouse.

Cylindrical dewatering screens: A structure used for reducing the flow of water to the juvenile fish facilities. Cylindrical dewatering screens may be an improvement over existing dewatering screens, but need to be tested using a prototype before implementation.

Dewatering: The process of removing excess water from a surface collector or the juvenile fish collection system in order to have reduced flow that the juvenile fish facilities can handle.

Dissolved gas supersaturation: Caused when water passing through a dam's spillway carries trapped air deep into the waters of the plunge pool, increasing pressure and causing the air to dissolve into the water. Deep in the pool, the water is "supersaturated" with dissolved gas compared to the conditions at the water's surface.

Existing System: The existing hydrosystem operations under the National Marine Fisheries Service's 1995 and 1998 Biological Opinions. The Corps would continue to increase spill and manipulate spring and summer river flows as much as possible to assist juvenile salmon and steelhead migration. Juvenile salmon and steelhead would continue to pass the dams through the turbines, over spillway, or through the fish bypass systems. Transportation of juvenile fish via barge or truck would continue at its current level.

Existing System Upgrades: Changes implemented to improve the effectiveness of the current fish collection/bypass facilities.

Extended submerged bar screens (ESBS): Screens extending in front of the turbines to guide fish away from the turbines, up to the juvenile fish collection channel inside the dam. These are an alternative to submerged traveling screens.

Fish collection/handling facility: Holding area where juvenile salmon and steelhead are separated from adult fish and debris by a separator and then passed to holding ponds or raceways until they are loaded onto juvenile fish transportation barges or trucks.

Fish guidance efficiency (FGE): Percent of juvenile salmon and steelhead diverted away from the turbines by submerged screens or other structures.

Fish Hatcheries: Hatcheries operated to compensate for reduced numbers of anadromous fish.

Fish Ladder: A structure designed to provide safe adult fish passage from the downstream to the upstream side of each dam.

Fish passage efficiency (FPE): Portion of all juvenile salmon and steelhead passing a facility that do not pass through the turbines.

Fish Separators: Structures that separate juvenile salmon from juvenile steelhead.

Flow Augmentation: Includes the use of upstream storage for flow augmentation. Flow augmentation decreases the duration of downstream migration of juvenile fish.

In-River Bypass: Operations that bypass fish directly to the tailrace via existing spillways or through some type of fish bypass system.

Involuntary Spill: Spill that is required to pass high river discharge past the project once powerhouse capacities/owner requirements have been reached.

Juvenile fish transportation system: System of barges and trucks used to transport juvenile salmon and steelhead from the lower Snake River or McNary dam downstream of Bonneville dam for release back into the river.

Minimum Operating Pool (MOP): The bottom one foot of the operating range for each reservoir. The reservoirs normally have a 3-foot to 5-foot operating range.

Removable spillway weir (RSW): A removable steel structure that is attached to the forebay of an existing spillbay, creating a raised overflow weir above and upstream of the existing spillway crest.

Simulated Wells intake (SWI): Modified turbine intake that draws water from below the surface so that the surface is calmer and juvenile fish are less influenced by turbine flows. This allows juvenile fish more opportunity to discover and enter the SBC.

Spill Operations: Includes voluntary spill to assist in the bypassing of juvenile salmon and steelhead over the dam spillways. The spill is thought to attract the fish away from the turbines, and towards the spillway.

Spillway extension structure (SES): A structure attached to the upstream face of the spillway to aid in passing water from the surface collector over the spillway.

Spillway flow deflectors (flip lips): Structures that limit the plunge depth of water over the dam spillway, producing a less forceful, more horizontal spill. These structures reduce the amount of dissolved gas trapped in the spilled water.

Submerged traveling screen (STS): Structures with a moving (traveling) screen extending in front of the turbines to guide fish away from the turbines, up to the juvenile fish collection channel inside the dam. These are an alternative to extended submerged bar screens.

Surface bypass collector (SBC) system: Structures designed to divert fish at the surface before they dive and encounter the existing turbine intake screens. SBCs collect the juvenile fish and guide them downstream, either over the dam spillway or to the juvenile fish transportation system.

Transport: Directing fish to a truck or barge transport system with capabilities to bypass fish to the tailrace in an emergency.

Trash Boom: A floating structure in front of the dam to collect floating debris. The trash boom prevents trash from getting into the juvenile fish collection system and causing damage to fish, clogging of screens, etc.

Voluntary Spill: Bypassing water over the spillway intended to attract juvenile fish to the spillways for in-river passage.

ANNEX A

EXISTING CONDITIONS

TABLE OF CONTENTS

FIGURES

1. General

This annex provides a detailed description of the elements of the existing conditions. This description includes not only the facilities that currently exist at the dams and reservoirs on the lower Snake River, but also future improvements to those facilities that are considered to be reasonable and prudent.

The existing conditions consist of continuing the fish passage facilities and operations that were in place or under development at the time the feasibility study was initiated. The existing conditions include:

- adult fish passage systems including fish ladders, pumped attraction water supplies, and powerhouse fish collection systems operated as specified in the 1995 and 1998 Biological Opinion and Supplemental Biological Opinion
- juvenile fish bypass/collection systems at the lower Snake River dams. This includes collecting and transporting a portion of the juvenile fish outmigration as specified in the 1995, 1998 Supplemental Biological Opinion, and the ESA Section 10 Permit (No. 895) for the Juvenile Fish Transportation Program (JFTP)
- operating the lower Snake River reservoirs at minimum operating pool (MOP) during the outmigration as specified in the 1995 and 1998 Biological Opinions
- operating turbines within 1 percent of peak efficiency at the dams
- providing spill to bypass juvenile salmon and steelhead
- using upstream storage for flow augmentation as required in the Biological Opinion and Supplemental Biological Opinion for operation of the Federal Columbia River Power System
- completing the installation of gas control measures at the dams
- monitoring and controlling total dissolved gas levels to state standards
- providing or operating and maintaining fish hatcheries for compensation for dam caused fish losses.

2. Adult Fish Facilities

Since the construction of each dam, the Corps has operated adult fish collection and passage facilities at each lower Snake River dam. These facilities were developed in collaboration with the fishery agencies of the region. Although facilities differ at each dam, they have certain common features. Each dam is comprised of the powerhouse, spillway, navigation lock, and an earth fill section. The position of each element with respect to one another varies from dam to dam. In development of each dam, hydraulic models were used to select the best location for adult fish facilities. Typically, there is a set of main fishway entrances near the far end of the spillway, between the spillway and powerhouse, and at the near end of the powerhouse. Two entrances are typically used at each location. Additional smaller entrances (floating orifice gates) are provided across the face of the powerhouse. At Ice Harbor and Lower Monumental Dams, there is one fish ladder on the spillway side and one on the powerhouse side to allow fish passage over the dam. At Little Goose and Lower Granite Dams, fish entering the spillway entrance pass under the spillway through a tunnel. The tunnel connects to the powerhouse fish collection system. Fish entering the north powerhouse entrances, fish entering through floating orifices along the face of the powerhouse, and fish entering the south powerhouse entrances, all pass over the dam via one fish ladder on the south abutment of the dam. Adult fish facilities are operated in accordance with the Corps' Fish Passage Plan as prescribed in the 1995 and 1998 Biological Opinions. Studies are underway to improve facilities and operations in accordance with the Biological Opinions. Modifications to the adult fish attraction water system are being considered for all adult fishways at each lower Snake River dam per the 1995 Biological Opinion. This may include electrical upgrades to provide a more reliable source of electrical power to the attraction water pumps, upgrading existing pumps, adding new pumps or adding a gravity feed system for the attraction flow. These measures will ensure an adequate water supply for the fish ladders in the event of a pump failure.

Figure 1. Fish Ladder at Little Goose Dam

3. Juvenile Fish Bypass/Collection Systems

Juvenile fish bypass facilities were developed or installed as the four lower Snake River dams were constructed. Facilities were upgraded as new technology developed. In 1987, the Columbia River Fish Mitigation Program (CRFMP) was initiated. Under CRFMP, juvenile fish bypass/collection facilities were to be upgraded at all of the lower Snake River dams, as well as at McNary, John Day, The Dalles, and Bonneville Dams on the lower Columbia River. On the lower Snake River, facilities were upgraded at each dam. A typical, modern facility consists of existing and new features as described below:

Turbine intakes

Each generating unit at the lower Snake River dams has three turbine intakes (funnel shaped entrances that allow water into the turbine). Each intake is protected by a trash rack (steel grating) that has openings 6 inches wide by 6 feet high. Juvenile and adult fish pass through these trash racks when they enter the turbines. With three intakes per turbine, and six turbines per lower Snake River Dam, there are 18 openings where fish enter the powerhouse. Turbine intakes are similar at the four dams except that they are slightly smaller at Ice Harbor Dam where the turbines are smaller.

Turbine intake screens

Standard length traveling fish screens (STSs) are devices that are lowered into the turbine bulkhead slots, tilted out to a 55 degree angle, and divert fish from the turbine intake up the bulkhead slot. The screened area is 6 meters (20 foot) high and 6 meters (20 foot) wide. The screen is a continuous belt that travels around the frame like a conveyer belt. A perforated plate between the front and back of the screen creates a sort of hydraulic cushion at the upstream face of the screen, preventing fish from becoming impinged on the screen. The flow is diverted upwards, carrying the fish to the bulkhead slot. The screen revolves so that debris collected on the front face is carried over to the back side where it is washed off by the flow through the screen. Standard traveling screens have been replaced with extended submersible bar screens (ESBSs) at Lower Granite and Little Goose Dams. These screens are 12 meters (40 foot) long and 6 meters (20 foot) wide. They have a stainless steel bar screen face with a trash brush that carries debris up the face and over the top of the screened area. Like the STSs, the ESBSs have a perforated plate behind the screen to create a hydraulic cushion to guide the fish. STSs are still used at Lower Monumental and Ice Harbor Dams.

Bulkhead slots and orifices

Fish guided into the bulkhead slot swim or are carried upward by the flow deflected by the fish screen. A vertical barrier screen allows most of the flow to go into the operating gate slot downstream of the bulkhead slot. Typically, there is 0.31 m^3/s (11 cfs) to 0.71 m^3/s (25 cfs) of flow exit from the bulkhead slot into a collection channel within the powerhouse. There are typically two 12-inch orifices per bulkhead slot. One or two orifices are operated, depending on the elevation of the reservoir. If the reservoir is full, one orifice is operated. If it is at MOP, two orifices may be operated. Orifices at Lower Granite Dam are 0.25 meters (10 inches) in diameter pending an upgrade, which is discussed later.

Collection gallery

At Lower Granite Dam, a collection gallery was constructed in the dam. It is a tunnel 1.8 meters (6 feet) wide and 3.7 meters (12 feet) high running from the north end of the powerhouse to the south end. Orifices from the bulkhead slots and fish screen slots (upstream of the gallery, but abandoned because they did not work) empty into the collection channel. Enough orifices are operated to maintain approximately 6.85 m^3/s (242 cfs) flow in the gallery. At the south end of the powerhouse, the gallery turns downward into a funnel shaped downwell for 20 meters (65 feet) before entering a 1,066-millimeter (42-inch) pipe. At Little Goose and Lower Monumental Dams, which were constructed with imbedded pipelines for juvenile bypass systems, subsequent modifications resulted in mining of tunnels similar to the gallery at Lower Granite Dam. At Ice

Harbor Dam, a collection channel was constructed in the ice/trash sluiceway along the upper face of the powerhouse.

Bypass pipe or flume

As mentioned above, Lower Granite Dam has a 1,066-millimeter (42-inch) pipeline from the powerhouse to the juvenile fish facility approximately 762 meters (2,500 feet) downstream. There is 20 meters (65 feet) of head on the water and fish that are released at the juvenile fish facility when the water upwells at the fish separator. Research conducted by the National Marine Fisheries Service (NMFS) and University of Idaho researchers have identified the pressurized pipe as the most stressful part for fish within the bypass system. Therefore, when the juvenile fish facilities were upgraded at Little Goose (1989), Lower Monumental (1991), and Ice Harbor (1995) Dams, non-pressurized flumes were constructed to get fish from the collection channel/gallery to the fish collection/handling facilities.

Fish collection/handling facilities

Fish arriving at the juvenile fish facilities by pipe or flume are separated from adult fish and debris by a wet separator. Juvenile fish swim down through bars spaced so that adult fish and debris are passed over the end and back to the river. The juvenile fish exit the separator via a flume where several samples per hour are diverted into a sample handling tank. Most (usually around 97 percent of the annual collection) are either loaded directly into a barge or are passed to holding ponds or raceways where they are held until being loaded into a truck or barge. The sampled fish are anesthetized, and handled by state fishery agency biologists to obtain species composition, size, weight, mark, descaling, injury, and mortality data necessary for operation of the transportation program. At Little Goose and Lower Monumental Dams, the separator separates smaller salmon from larger steelhead. These fish are then handled and transported separately. At Ice Harbor Dam where fish are not transported, a sample of fish is diverted to obtain fish species and composition information, but the majority of fish are bypassed directly to the tailrace below the dam.

Transportation

Collection at Lower Granite Dam starts March 25 per the 1998 Biological Opinion, and a few days later at Little Goose and Lower Monumental Dams. One or two 13.2-m^3 (3500-gallon) fish tanker trucks operate from each dam. Fishery agency criteria require that fish cannot be held more than 48 hours once collected at the dams, nor can transport to the release site below Bonneville Dam take more than 48 hours. Per fish agency barging criteria of 60 kilogram/m^3 (½ pound per gallon), up to 794 kilograms (1,750 pounds) of fish can be transported in a fish tanker. At 22 fish per kilogram (10 fish per pound), a truck could haul up to 17,500 fish. Early in the season, daily collection at Lower Granite Dam is very low (less than 100 fish per day). As the spring begins, the fish begin to migrate. By the second week of April, fish collection may reach 20,000 fish per day. Fish are trucked from all three dams with fish being released at a facility on Bradford Island at Bonneville Dam.

Figure 2. Fish Transportation Truck

A typical truck trip takes about 8 hours from Lower Granite to Bonneville Dam (slightly less time from the other dams that are further downstream). When counts reach about 20,000 fish per day at Lower Granite Dam, barging begins. When barging starts, fish are loaded at Lower Granite, then the barge stops at Little Goose, and Lower Monumental Dams to pick up more fish. Thirty to 40 hours after leaving Lower Granite Dam, the fish are released from the barge below Bonneville Dam. Eight barges are used: two 326 m^3 (86,000 gallon) barges holding 10,400 kilograms (23,000 pounds) of fish, two 379 m^3 (100,000 gallon) barges holding 22,700 kilograms (50,000 pounds) of fish, and four 568 m^3 (150,000 gallon) holding 34,000 kilograms (75,000 pounds) of fish. When spill is not excessive, barges may be moored at the Lower Granite and Little Goose facilities, and fish are loaded into the barges without passing through the raceways. This eliminates the stress of loading from the raceways. Early in the season, a barge leaves Lower Granite every other day. As collection numbers approach 100,000 fish per day, barging is increased to every day. Except during the peak of the migration, barges are not fully loaded. With a record peak of 893,100 fish in one day at Lower Granite Dam, barge capacity can be exceeded. In that case, fish must be bypassed back to the river to avoid exceeding holding criteria. Transportation peaked in 1990 when over 22 million fish were collected and over 21 million were transported. Since then, numbers transported have declined because wild and hatchery production have fluctuated, spring transport from McNary Dam has been curtailed, and the fishery agencies and tribes have imposed a spread-the-risk policy that uses spill to keep more fish in the river. Currently, the goal is to transport half of the Snake River salmon and steelhead. About 15 million fish are collected and about 13 million fish are transported.

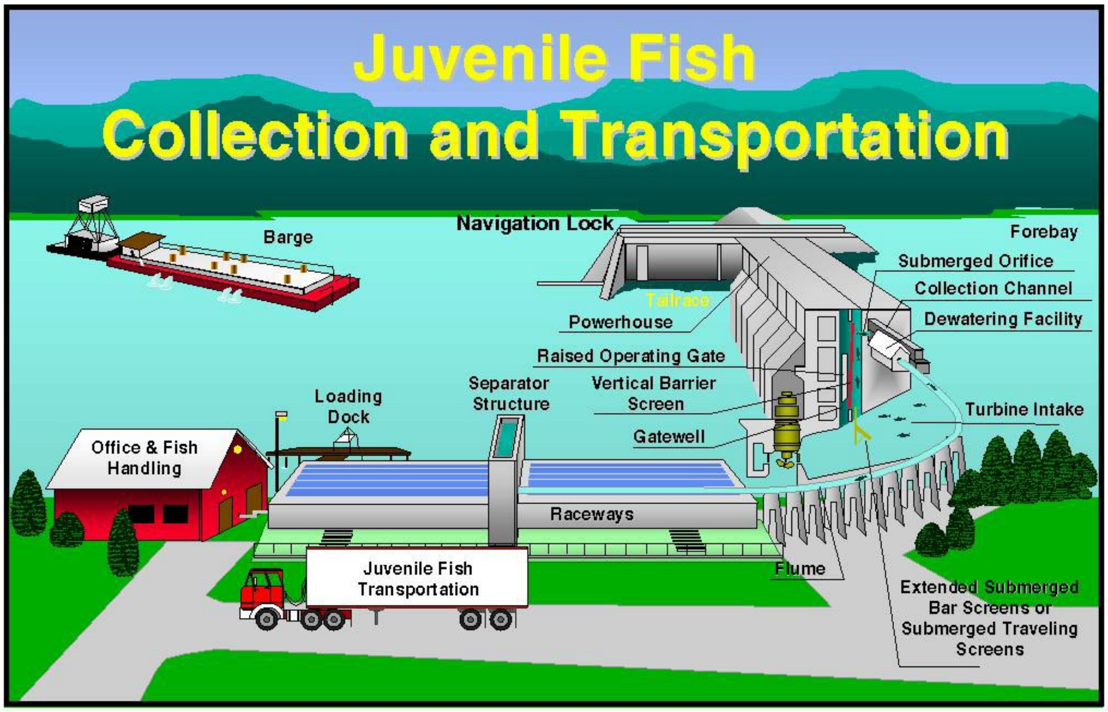

Figure 3. Elements of a typical Juvenile Fish Collection Facility

Upgrading fish collection/transportation facilities at Lower Granite

As mentioned above, juvenile fish facilities were upgraded through the CRSMP . Upgrading the Lower Granite facility was postponed in response to a request by the Columbia Basin Fish and Wildlife Authority until the Feasibility decision is made in 1999. The rationale for postponement was that the current facility provides high survival (99.5+percent), and the cost of replacing the facility to eliminate known stress problems might be lost if a decision is made to breach the dam. Therefore, if the decision is to continue current operations, replacing this facility would be an element of that action. The Corps had completed a Decision Document, dated August 1995, for a new facility at Lower Granite Dam. According to that document, upgrading the Lower Granite Juvenile Fish Facility would include:

- Replacing the thirty-six (36) 254-millimeter (10-inch) orifices from the bulkhead slots to the juvenile fish collection gallery with thirty-six (36) 305-millimeter (12-inch) orifices. Each orifice would be equipped with an air operated knife valve, and an air back-flush system for dislodging debris. The valves would be automated and controlled with a programmable logic control computer so they could be cycled to prevent clogging.
- Mine the gallery to a 2.7-meter (9-foot) width so orifice flow would not strike the far wall. The gallery is currently 1.8 meters (6 feet) wide.
- Mine an exit channel from the dam out to daylight and install a non-pressurized flume system to the fish collection facility. Install a dewatering system to reduce the flow from 7.08 m^3/sec (250 cfs) to 1.70 m^3/sec (60 cfs), similar to the design at Little Goose Dam and route the excess water to the adult fish collection facility.

- Install a size separator to separate small (primarily salmon) from larger (primarily steelhead) smolts so smaller and larger smolts can be transported in separate truck or barge compartments.
- Upgrade raceways and distribution flume systems at the collection facility.
- Upgrade direct barge loading facilities.

Additional barges

The existing conditions include providing additional barges and facilities to allow direct loading at collector dams. A reconnaissance level report completed in 1996 recommended that a total of five 34,000-kilogram (75,000-pound) capacity barges would be needed to allow direct loading at all times at Lower Granite Dam. Four 22,700-kilogram (50,000-pound) capacity barges would be required at Little Goose Dam, three at Lower Monumental Dam, and two at McNary Dam if spring transport resumed. Since that study was conducted, turn-around time for the towboats has improved. Currently, a total of four 34,000-kilogram (75,000-pound) capacity barges at Lower Granite, four 22,700-kilogram (50,000-pound) barges at Little Goose, three 22,700-kilogram (50,000-pound) barges at Lower Monumental, and two at McNary are required for maximizing direct loading. Four 34,000-kilogram (75,000 pound barges), two 22,700-kilogram (50,000-pound) barges, and two 10,400-kilogram (23,000 pound) barges are currently available. The 10,400-kilogram (23,000-pound) barges need to be replaced. The hulls are over 50 years old, and the metal is too thin for continued safe use. Therefore, seven additional 22,700-kilogram (50,000 pound) barges would be required to replace the two retired barges and to provide the necessary barges for direct loading at all collector dams. If current transport criteria continued, five barges would be needed because there would not be spring transport from McNary Dam. The addition of these extra barges would require the expansion of barge storage facilities at Lower Granite Dam, or at other locations selected by the Corps.

Figure 4. Fish Transportation Barge

Modifying Fish Separators

In accordance with the 1995 Biological Opinion, studies are underway to improve fish separators. The improved separators would provide for separation of the fish by species at a relatively high water velocity within the fish flumes instead of separation at a lower velocity in a separation tank, as is the current practice. The improved separators would reduce fish stress, delay, and mortality. Also, the separators would be more effective at separating fish. The new separators would be installed at Little Goose and Lower Monumental Dams and included in an upgrade of the Lower Granite Juvenile Fish facility.

New Cylindrical Dewatering Screens

Design studies are also planned for improving the dewatering systems for the juvenile fish collection system. A cylindrical dewatering screen design is under consideration that may be an improvement over existing stationary screen designs. A cylindrical dewatering system would provide a more effective method of monitoring plugging of the screens and removing trash. This reduces fish mortality. The cylindrical dewatering screens would be installed at Little Goose, Lower Monumental and Ice Harbor Dams and included in an upgrade of the Lower Granite Juvenile Fish facility.

New Trash Shear Boom

At Little Goose Dam, a large amount of debris has blocked the orifices at the collection gallery, and significant fish losses have occurred within just a few hours. Therefore, a new debris shear boom is scheduled to be installed in the forebay of Little Goose Dam to capture more of the debris before it can get to the orifices.

Improvements to the ESBSs

It is planned to modify the ESBSs at Lower Granite and Little Goose to improve their operability and longevity. One modification is to reduce vibration that causes steel fatigue cracking. Also, underwater mechanical equipment must be sealed better to prevent water intrusion. The mechanical equipment is required for operation of the screen cleaners.

Figure 5. An ESBS

Anadromous Fish Evaluation Program (AFEP)

The AFEP program provides continued monitoring of fish behavior and stress levels. The monitoring is especially important when there are additions or modifications to the juvenile fish collection/bypass system or changes to project operations.

4. Operating Reservoirs at Minimum Operating Pool (MOP)

The concept of drawing down reservoirs to increase water velocity and decrease the travel time of juvenile salmon emerged in the late 1980s. The fishery agencies and tribes asked to have the Snake River reservoirs operated in the bottom 0.305 meter (1 foot) of the operating range. The reservoirs have a 0.91-meter (3-foot) or 1.52-meter (5-foot) normal operating range, although Lower Granite Reservoir can be drawn down approximately 6 meters (20 feet) if a major flood flow threatens to overtop the levees at the confluence of the Clearwater and Snake rivers in the Lewiston/Clarkston area. With the listing of the Snake River salmon in 1991 and 1992, NMFS required operation of the lower Snake River reservoirs at MOP during the juvenile salmon outmigration. Theoretically, the slight decrease in migration time resulting from this operation increases the survival of inriver migrants, although there has never been any definitive research to prove this theory.

5. Operating Turbines within 1 percent of Peak Efficiency

In 1981, based on model studies of turbine efficiency, researchers proposed that operating turbines within 1 percent of peak efficiency would maximize survival of juvenile salmon passing through the turbines (Bell, 1981). Since the mid-1980s, the Corps has made every effort to operate turbines within 1 percent of peak efficiency range. With the listing of the Snake River salmon, the NMFS made this a requirement. Research prior to this operational change typically showed about 15 percent mortality to juvenile salmon from passage through turbines (Bell, 1986). Since the change in operation, numerous studies have shown turbine mortality to be less than 7 percent (Normandeau Associates, 1992, 1994, 1996). This change in operation has the potential of increasing survival of fish passing through the eight dam system by almost 20 percent.

6. Spill for Juvenile Fish Passage

Spilling water over the spillways at lower Snake and Columbia river dams to bypass fish around the turbines was proposed by the fishery agencies in the 1980s. The premise is that the spillways at 98 percent survival are safer than the turbines at 85 percent survival (the old regionally accepted value). However, spill causes gas supersaturation in the water, a condition that is harmful and can be fatal to the fish. Also, when spill occurs, fish that could be collected and transported around a series of dams are bypassed downstream to the next reservoir and whatever dams are left to pass. Contrary to popular thought, spilling of water does not speed downstream fish migration because water not spilled would be passed through the turbines. The total downstream flow rate would always be the same. Analysis of the existing data indicates that by keeping fish inriver, they are subjected to additional reservoir and dam mortality that could be avoided by collecting and transporting them around the dams and reservoirs. On the other side of the issue, there are many who believe the transportation process is stressful and causes additional direct or delayed mortality to the transported fish. The fishery agencies and tribes have adopted a spread-the-risk policy that attempts to keep half the fish in-river and allows half to be transported. This is the policy currently being followed as a result of NMFS incorporating the spread-the-risk policy in the 1995 and 1998 Biological Opinions. At collector dams, the percentage of fish collected is controlled by spilling water up to the adjusted total dissolved gas cap administered by the states of Oregon and Washington. The standard of 110 percent has been waived to 115 percent in the forebay and 120 percent average in the tailrace of each Dam. With better monitoring systems being developed in the past couple of years, the amount of spill has been increased since the 1995 Biological Opinion, and the Supplemental Biological Opinion requires spill to the gas cap, not specified levels as were used in the 1995 Biological Opinion. Increasing the percentage of spill has decreased the percentage of fish collected by the juvenile fish bypass systems. Currently, the NMFS and CBFWA are requesting that spill be utilized to keep at least half of the Snake River outmigration in the river. As part of the Feasibility Study, the Corps has been studying Surface Bypass Technology at Lower Granite Dam since 1996. This has been done for the major system improvements pathway, so it is not part of the existing condition pathway. However, it is mentioned here because it has been instrumental in bypassing fish over the spillway, decreasing the percentage of fish transported from Lower Granite Dam, and increasing the numbers being bypassed to Little Goose and Lower Monumental Dams.

7. Flow Augmentation

The original Fish and Wildlife Program of the Northwest Power Planning Council included in a Water Budget, an amount of upstream storage to be controlled by the fishery agencies and tribes to simulate the natural spring freshet for the juvenile salmon outmigration (NPPC, 1984). The Fish Passage Center was established to manage the water budget that included 2,020 million cubic meters (1.64 million-acre feet) in the Snake River Basin. Since that time, the fishery agencies have been using and shaping flows in the Snake and Columbia rivers to aid the salmon outmigration. The 1995 Biological Opinion called for the use of an addition 527 million cubic meters (427,000-acre feet) from upstream storage in Idaho. The 1998 BO calls for studies to increase that amount, perhaps by another 1,200 million cubic meters (1.0 million-acre feet). Although there has been considerable controversy over the value of flow augmentation, it has been adopted by the NMFS as a requirement in the Biological Opinions.

8. Completion of Gas Abatement Measures

When gas supersaturation emerged as a major threat to the survival of the Snake and Columbia river salmon runs in the late 1960s, a major effort was made to modify the Corps dams to reduce the problem. Measures taken were: 1) completion and use of upstream storage to minimize spill, 2) installation of turbines in skeleton bays at the lower Snake and Columbia river dams, and 3) installation of spillway deflectors in the spillbays at the lower Snake and Columbia river dams. Lower Granite Dam was under construction at the time. Spillway deflectors were installed in all eight spillbays. Deflectors were installed in six of eight bays at Little Goose and Lower Monumental Dams. Studies by fishery agency experts indicated that deflectors should not be added in the end bays because plunging flows from these bays were necessary to confine the skating flow created by the deflectors. Spillway deflectors were not recommended at Ice Harbor Dam because of concerns over adult fish passage, and because it was only a few miles to low supersaturated waters in the Columbia River coming from the free flowing Hanford Reach. Deflectors were installed in 18 of 22 spillbays at McNary Dam with the two end bays on either end retained to provide plunging flow for adult fish as described above. Similarly, 14 of 18 spillbays were equipped with deflectors at Bonneville Dam. John Day and The Dalles Dams had the largest generating capacities in the system, so more water could pass through turbines, and deflectors were not considered necessary. Since that time, spill policy has changed. Before, spill was minimized to prevent gas supersaturation. Later, it was decided to spill up to a level of 120 percent gas supersaturation to keep fish inriver for the spread-the-risk policy. Also, gas capability has improved significantly since the 1970s, and knowledge about the effects of spill and gas supersaturation has increased a great deal. Consequently, the fishery agencies and NMFS have required more spill, and want more gas control so more spill can be used. As a result, in 1996 and 1997, spillway deflectors were added to eight of 10 spillbays at Ice Harbor Dam, and to all 20 spillbays at John Day Dam. At the Dalles Dam, the spillway is configured such that deflectors are not considered necessary, although recent studies have shown that the required 64 percent spill there may be causing higher fish mortality. As required by the 1995 and 1998 Biological

Opinions, studies are continuing to evaluate installation of spillway deflectors in bays where they have not been installed. Other measures such as raising stilling basins and installing alternate methods of passing water are under consideration. The existing condition assumes that additional deflectors, modifications to existing spillway deflectors, and pier wall extensions will be added at Lower Granite, Little Goose, and Lower Monumental Dams. Additional deflectors and a pier extension are currently being added at Ice Harbor. These improvements are expected to further reduce gas levels in the river.

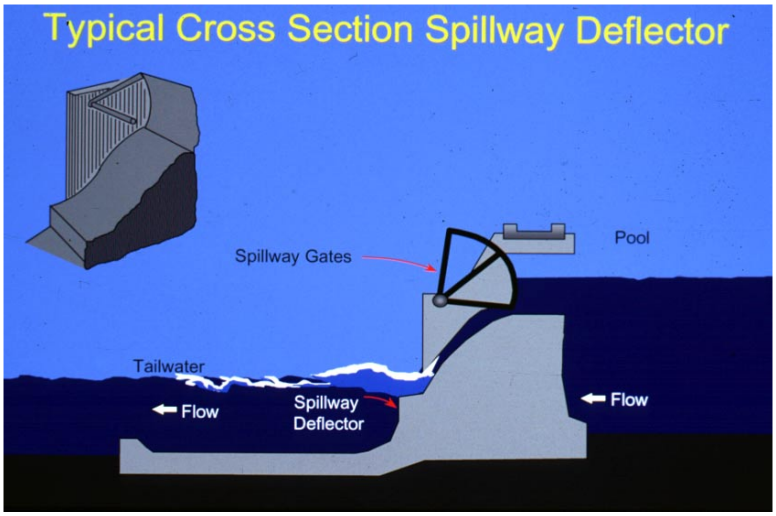

Figure 6. Typical Spillway Deflector

9. Monitoring and Controlling Dissolved Gas Levels

As stated above, the technology of monitoring dissolved gas levels has greatly advanced in the past 30 years. Sensing equipment has been greatly improved, and a network of stations has been established above and below each major dam, and at major points of interest throughout the Federal Columbia River Power System. Remote sites have been linked through satellite and phone communication systems. Real-time monitoring of the effects of spill at nearly all locations is a reality. As a result, the Fish Passage Center (who are charged with monitoring dam operations for the fishery agencies and tribes) and the NMFS have immediate access to gas supersaturation information throughout the system. As a result, dam operations are closely controlled to maximize spill to the 120 percent state standards throughout the juvenile salmon outmigration. Control is implemented through the Technical Management Team that was established by the 1995 Biological Opinion.

10. Fish Hatcheries for Dam Mitigation

The Lower Snake River Fish and Wildlife Compensation Plan was authorized to mitigate for fish and wildlife losses caused by construction and operation of the four lower Snake River Dams. Based on 15 percent mortality per dam (cumulative mortality of 47 percent), hatcheries were sized to produce about 28 million juvenile spring, summer, and fall chinook salmon, and steelhead trout.

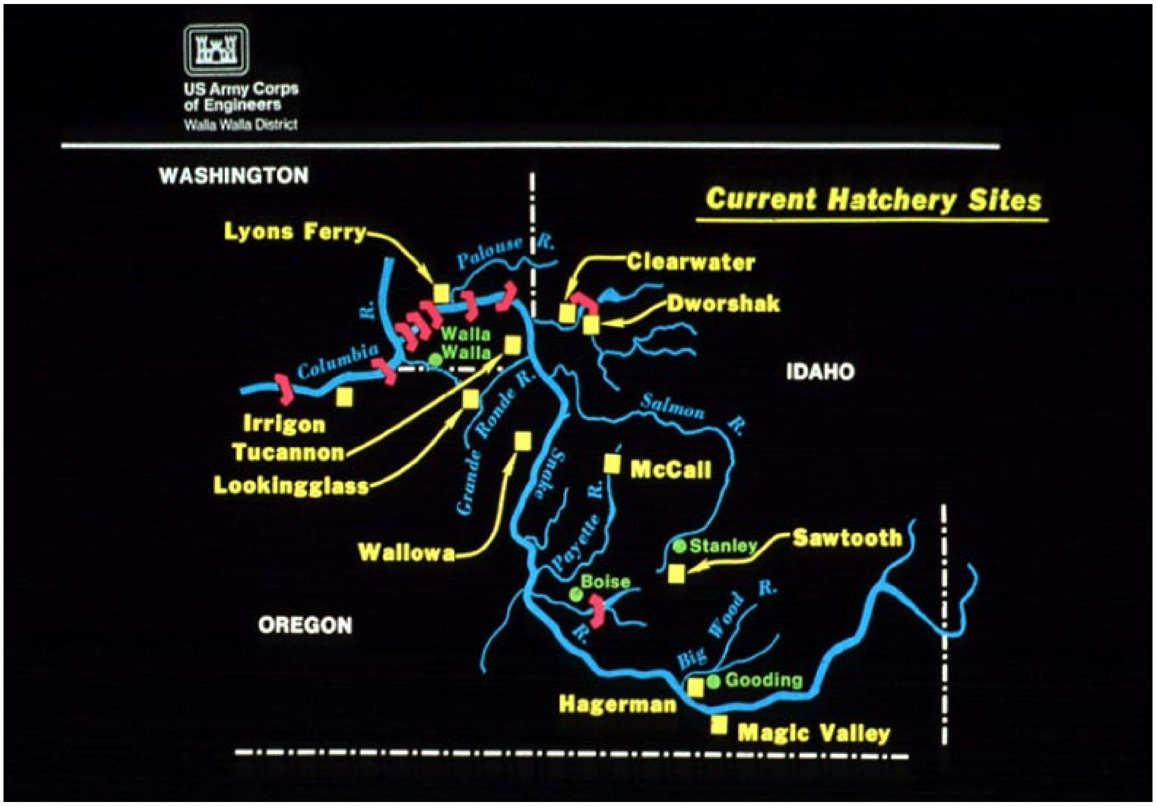

Figure 7. Lower Snake River Fish and Wildlife Compensation Plan Hatcheries

Eleven hatcheries were modified or constructed along with a number of collection facilities for gathering adults and acclimation ponds for acclimating juveniles to water sources where they would return as adults. In all, over $200 million in hatchery facilities were constructed. As specified in the Compensation Plan, these facilities are operated by the state fishery agencies or US Fish and Wildlife Service (USFWS). Recently, additional facilities have been constructed and are operated by the Nez Perce and Confederated Tribes of the Umatilla Indian Reservation. Dworshak National Fish Hatchery was constructed to compensate for steelhead and resident fish losses associated with the construction of Dworshak Dam. Dworshak hatchery was later modified to include chinook production under the Lower Snake River Fish and Wildlife Compensation Plan. Although hatchery compensation for coho and sockeye were not included in the Lower Snake River Fish and Wildlife Compensation Plan, subsequent Endangered Species Act listing of the sockeye has resulted in a captive broodstock program that is funded by the Bonneville Power Administration. Also, the Nez Perce Tribe has been transporting coho from the lower Columbia River to the Clearwater Basin in an attempt to re-establish runs of these salmon.

11. Modifications to Hydropower Turbines

New Turbine Cams

The cams that control the turbine blades and wicket gates may be modified to increase the hydraulic efficiency of the turbines with ESBS in place. The increased hydraulic efficiency of the turbines will likely reduce fish mortality for those juvenile fish passing through the turbines. The existing condition assumes the modified cams would be added to all turbines at all projects.

New Turbine runners

Studies are currently underway to develop turbine runners that reduce fish stress and mortality for those juvenile fish passing through the turbines. It is assumed for the existing condition that these turbine runners would only be incorporated into turbines requiring future major rehabilitation. It is also assumed for the existing condition that eventually all turbine runners at each of the four lower Snake River dams will require rehabilitation and, therefore, new fish friendlier turbine runners. Also, other structural changes in the vicinity of the turbine runners may be found to improve hydraulic flow conditions for the fish and may be incorporated into a major rehabilitation of the turbines.

12. Other Project Operations

The continued operation of the dams under the existing condition scenario includes many non-fish related expenses. For purposes of developing an economic analysis, a 100-year life is assumed for each of the lower Snake River facilities. It is assumed that in addition to routine operation and maintenance costs that additional costs would result from the eventual replacement or rehabilitation of major dam features. A list of those features is provided below. These features apply to each of the four lower Snake River facilities.

- Major Rehabilitation of the turbines and generators
- Re-roofing of the powerhouses
- Replacement of the extended submersible bar screens and vertical bar screens
- Replacement of the spillway gates
- Replacement of navigation lock gates, timber bumpers, and valves
- Replacement of fish ladder pumps
- Rehabilitation of roads adjacent to the projects

13. Operation and Maintenance Costs

The continued operation of all features of the Lower Snake River facilities, whether they exist or are proposed under the existing condition, will have operation and maintenance (O&M) requirements. Existing operations include navigation, hydropower, recreation, wildlife mitigation, river dredging, adult and juvenile fish migration, and miscellaneous dam operations. The O&M costs are included in the cost estimate annex.

14. Installation Costs for New or Modified Project Features

The cost for planning, design, and construction of each new or modified project feature assumed for the existing condition is included in the cost estimate annex.

15. Implementation Schedule

The assumed date for midpoint of construction and the construction duration for each task is included with the cost estimate annex.

16. Anadromous Fish Evaluation Program

16.1 Biological Evaluations

16.1.1 Biological Research Coordination

Biological evaluations conducted for anadromous fish go through a process of research development, review, and regional coordination. This process is facilitated by the Northwestern Division's Anadromous Fish Evaluation Program (AFEP). Representatives from federal, state, and tribal fish agencies participate in the AFEP process through two technical work groups; the Fish Facility Design Review Work Group and the Study Review Work Group (SRWG).

The purpose of the Fish Facility Design Review Work Group is to provide a technical review process for the development of new or modified structures that affect fish passage, specifically for anadromous salmon and steelhead trout of the Snake and Columbia basins, including engineering designs, construction activities, and pre- and post-construction evaluations. This review ensures that the best biological information available is incorporated into the structure's design criteria.

The SRWG is focused on providing study development and a review process for research proposals that ensures the objectives of the studies meet the goals of the region, and that the study's experimental design and scientific assumptions are technically sound. Results from these evaluations are incorporated into the operation or the design of new structures to enhance fish passage around hydro-projects.

Both of these technical working groups are comprised of multi-agency participants from the Division and District offices of the Corps, NMFS, USFWS, U.S Geological Survey – Biological Resources Division, Bonneville Power Administration, Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, Idaho Department of Fish and Game, and tribal representation through the Columbia River Inter-Tribal Fish Commission. Together these technical working groups combine the engineering and biological components to develop the goals and objectives of each sub-program under the Columbia River Fish Mitigation Program for beneficial fish passage on the Snake River.

16.1.2 Pre- and Post- Construction/Implementation Evaluations

All work, regardless of its origin (construction or operation), that has the potential to impact salmon as they pass through the hydroprojects on the Snake River is evaluated. The biological evaluations for this type of work are conducted in three phases: problem verification; pre-construction/operation development; and post-construction/operation performance confirmation. In general, the phases that biological evaluations go through reflect the phases of engineering and operation design development that will ultimately lead to the final product.

The detail and extent of biological evaluations in the first phase can vary depending on the extent of information available about the problem. Usual investigations in the first phase of evaluations are those that identify or confirm the known or suspected problem to fish passage, survival, or injury. In cases when the work being conducted is for non-fish purposes a biological component to the evaluations may not be necessary. Under these conditions the first phase of evaluations may be entirely devoted to design or operation investigations.

Biological investigations in the second phase of evaluations are usually closely related with the engineering and design improvements, and development of experimental operation conditions. The ultimate goal of these evaluations is to provide information that supports the selection and implementation decisions of new or modified structures and operations for the benefit of fish passage, condition and survival.

The final phase of biological evaluations includes studies to verify that new or modified structure for fish passage or changes to project operations perform as designed and planned, and also, that these changes do not impact fish passage, condition, and survival. Results from these studies often lead to further refinement of the design or to operations specific to the unique condition found at each hydro-project.

16.1.3 Duration of Biological Research

The time frame in which each phase of biological evaluation is conducted is dependent on the objectives. The average duration for a biological evaluation can be estimated based on typical past evaluations. The first evaluation phase, problem identification, usually requires less than two years to conduct and is highly dependent on the nature of the problem being assessed. Pre-construction biological investigations in the second phase of evaluations are closely linked to the engineering and operational development. Often, during the course of the engineering and biological investigations, problems arise that require further investigations. Work in the second phase evaluation usually takes three or more years to resolve. Examples of studies taking more than three years to complete the pre-construction evaluations are those for the extended screens, surface bypass/collection, debris management, and juvenile fish facility improvements.

The post-construction phase of evaluation occurs following implementation of full project improvement or construction (such as the juvenile fish facilities). When the new designs or operations perform as expected based on the prototype tests or when these changes have no negative impact to fish passage, condition, or survival, these confirmation evaluations usually require no more than two years to complete. However, due to the uniqueness of various aspects of each hydro-project, there is usually clean up work that may extend post-construction evaluations past the usual two years. The project differences may result in the start of new biological and engineering investigations at the second phase of pre-construction evaluations.

Following major hydro-project construction, improvements, or major operational changes a project survival study is conducted for approximately three sequential years (the duration of these studies is designed to reduce the chance of a poor fish outmigration masking the benefits of the expected project improvement or performance). These types of studies identify the benefits or impacts that have been provided to fish passage efficiencies, and direct and indirect survival by the hydro-project improvement. When a series of major improvements are planned at one hydro-project the subsequent survival studies are consolidated into one study to reduce costs. It should be noted that the regional fishery agencies do not usually support years of delay between major hydro-project changes/improvements and a project survival study. Therefore, multiple project studies for one project may be scheduled when more than five years occurs between major hydro-project improvements.

16.2 Types of Biological Evaluations

Although biological evaluations cannot be predicted for every condition or unforeseen problems in the future, the objective of the work can be generically identified. The broad category of studies for evaluation of modifications to existing systems and for major system improvements and can be broken down into the following groups.

- Studies that evaluate passage performance of a structure (compared to the expected performance of specific project operations or structures based on the designs or modeling results). For each of these types of studies there will be a passage component that compares the relative passage rates to the various passage routes available at the hydro-project. There may be various experimental configurations or operation patterns in which the passage performances are compared for each juvenile chinook salmon and steelhead trout.
- Studies that determine the injury and direct impact (i.e. descaling) to juvenile fish condition. This includes evaluations of direct and indirect mortality influenced by passage through or near new structures or passage structures. Included in these types of studies are the evaluations of changes to predation pressures on juvenile salmonids as a result of hydraulic changes to the environment as a result of a new or modified structure.
- Evaluation of the impact of new or modified structures, or operations on adult upstream passage success. Major structural or operational changes will require investigations to determine their effects on adult passage delays and rates of adult fallback.
- Project survival studies for juvenile chinook salmon and steelhead trout are conducted following all major hydro-project improvements.

ANNEX B

SURFACE BYPASS AND COLLECTION SYSTEM COMBINATIONS

LOWER SNAKE RIVER

[This annex contains a report prepared for other purposes and includes word tenses that are outdated for this FR/EIS. This report is incorporated into Appendix E simply because of its applicability.]

TABLE OF CONTENTS

FIGURES

TABLES

ABBREVIATIONS AND ACRONYMS

ACI	American Concrete Institute
AGMA	American Gear Manufacturers Association
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
BGS	behavioral guidance structure
CDR	Conceptual Design Report
cfs	cubic feet per second
Corps	U.S. Army Corps of Engineers
ESBS	extended submersible bar screens
Feasibility Study	Lower Snake River Juvenile Salmon Migration Feasibility Study
FGE	fish guidance efficiency
FLE	fish ladder extension
ft	feet
ft^2	square feet
g	gravitational acceleration (9.807 m/s^2)
hr	hour
IEEE	Institute of Electrical and Electronics Engineering
kcfs	thousand cubic feet per second
kg	kilogram
kip	1,000 pounds
km	kilometer
kN	kilonewton
kPa	kilopascal
ksi	kip per square inch
kVA	kilovoltampere
kW	kilowatt
lb	pound
m	meter
m/s	meter per second (velocity)
m^2	square meter (area)
m^3/s	cubic meters per second (flow rate)
MCC	motor control center
mg/l	milligram per liter

ABBREVIATIONS AND ACRONYMS

mm	millimeter
MOP	minimum operating pool
MPa	megapascal
mph	miles per hour
N	newtons
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NMFS	National Marine Fisheries Service
O&M	operation and maintenance
PLC	programmable logic controller
psf	pounds per square foot
ROV	remotely operated vehicle
RSW	removal spillway weir
s	seconds
SBC	surface bypass collector or surface bypass and collection
SES	spillway extension structure
STS	submerged traveling screen
SWI	Simulated Wells Intake
TDG	total dissolved gas
tonne	1,000 kilograms (metric ton)
UBC	Uniform Building Code
UL	Underwriters Laboratories, Inc.
VBS	vertical barrier screens
VOC	volatile organic compound
WES	U.S. Army Corps of Engineers Waterways Experiment Station
yd^3	cubic yard

Executive Summary

The Walla Walla District of the U.S. Army Corps of Engineers (Corps) operates four lock and dam projects on the lower Snake River including Lower Granite, Little Goose, Lower Monumental, and Ice Harbor. In response to the National Marine Fisheries Service (NMFS) 1995 Biological Opinion concerning the operation of the federal Columbia River power system, the Corps is studying structural alternatives to improve the downstream migration of juvenile salmon smolts through the four lower Snake River projects. As part of that study, this report summarizes an investigation of the engineering feasibility of installing surface bypass collector (SBC) systems to improve the efficiency of turbine bypass and fish collection. This report is the second of two reports investigating SBC development on the lower Snake River. It is a follow-up to the first report, *Lower Granite Lock and Dam, Surface Bypass and Collection System Options, Conceptual Design Report*, which investigated a variety of SBC designs as they would apply to Lower Granite Lock and Dam.

The Corps has been testing a prototype SBC system at Lower Granite since the spring of 1996. The basis for this design was the highly successful surface oriented bypass system currently in use at Wells Dam on the mid-Columbia River. In 1998, additional components were added to the prototype to gather more information about the factors which could optimize a surface collection approach to effective bypass. Based on the results of this testing, and the engineering feasibility and cost information compiled in the first report, SBC system combinations were developed for investigation in this report. Each system combination includes a bypass and/or collection facility located at each of the four projects which are designed to work together toward achieving a system-wide migration goal. These goals include maximizing the effectiveness of fish transportation, maximizing inriver migration, and an adaptive migration strategy which allows for transportation or inriver migration.

The purpose of this report is to investigate, from an engineering perspective, each of the system combinations developed for review. The investigation includes discussions of alternatives for achieving the design goals; engineering feasibility assessment for the chosen alternatives; criteria and requirements concerning hydraulic, structural, mechanical and electrical design; discussions of construction and operation and maintenance (O&M) issues; and conceptual level cost estimates for engineering design, construction and annual O&M. The following are brief descriptions of each of the system combinations:

Maximizing Effectiveness of Fish Transportation

<u>System Combination 1:</u> In System Combination 1, migrating juvenile salmon would be collected at the three upstream projects and transported downstream using barges and trucks. The goal of System Combination 1, maximizing the number of fish collected for transporting, would be accomplished by constructing full length powerhouse SBC channels at each of the three upstream projects. The channels would contain dewatering screens to concentrate the fish in a small enough flow so that they could be delivered into the existing juvenile bypass galleries inside each dam. The turbine intakes behind the channels would be outfitted with extended length submerged bar screen (ESBS) diversion systems which would also divert fish into the existing juvenile bypass galleries. At Lower Granite and Little Goose these ESBS diversion systems are already present and functioning. At Lower Monumental the existing submerged traveling screen (STS) diversion system would need to be removed and replaced with a new ESBS system. Ultimately, fish collected by both the SBC channels and the ESBS diversion systems would be combined and delivered to the transportation facilities and either trucked or barged downstream.

At Ice Harbor, the most downstream of the four projects, the existing STS diversion system would be replaced with a new ESBS system, but no new SBC channel or other modifications would be added. This reduced approach at Ice Harbor is based on the fact that no migrating fish are added to the river between Lower Monumental and Ice Harbor, and with the collection enhancements described at the three upstream projects there should be very few inriver migrating fish approaching Ice Harbor.

<u>System Combination 1A:</u> System Combination 1A also emphasizes the continued and enhanced use of the fish transportation facilities. However, the goal in this combination is to construct enhanced collection facilities for the existing transportation infrastructure at a significantly reduced initial and operational cost, relative to System Combination 1. To facilitate this approach, the same SBC channel facilities described for System Combination 1 at Lower Granite would be constructed. At the remaining three projects, downstream of Lower Granite, only ESBS intake diversion systems would be used. The basis for this strategy is that the majority of juvenile salmon coming down the Snake River are coming from above Lower Granite. If the combined SBC and ESBS systems to be utilized at Lower Granite function as effectively as anticipated, there would be few migrating fish left in the river below Lower Granite and construction of large, expensive SBC systems could not be justified. System Combination 1A also could serve as a prudent first-build approach to achieving a system based on maximizing effectiveness of the transportation infrastructure. It would allow for operation of a production SBC channel at Lower Granite to assess the benefits of installing similar systems at Little Goose and Lower Monumental, and provide valuable information which could be used to optimize the design of any subsequent SBC channels.

Emphasis on Inriver Passage

<u>System Combination 2:</u> The migration strategy for System Combination 2 is to focus on effective diversion of the fish away from the turbines while emphasizing inriver migration, and de-emphasizing transportation. For this combination, all four projects would be outfitted with full length powerhouse SBC channels. However, these channels would not include dewatering screens and the fish collected by the channels would be passed directly downstream to the tailrace through modified spill flow. As with System Combination 1, ESBS intake diversion systems would be used in conjunction with the channels at all four projects. Fish diverted by the ESBS systems would continue to be directed to the juvenile transportation facilities where a reduced transportation program could still be operated, or these fish could be delivered directly into the tailrace at that location. As previously described, Lower Granite and Little Goose already have ESBS systems, and these would continue to be used in conjunction with the new SBC channels. The STS systems at Lower Monumental and Ice Harbor would be removed and replaced with new ESBS systems.

Adaptive Migration Strategy for Transportation and Bypass

<u>System Combination 3:</u> This approach applies a migration strategy which allows for adaptive flexibility between transportation and inriver migration. At Lower Granite and Lower Monumental, partial powerhouse length SBC channels would be constructed which would allow for either direct bypass to the tailrace or a screened flow mode which directs the fish into the existing juvenile galleries. In this way it would combine features of the SBC channels described for System Combinations 1 and 2. Therefore, fish collected by the SBC could be directed to transport facilities or inriver migration. To guide fish away from in front of Units 1 through 4, a behavioral guidance structure (BGS) would be constructed in the forebay. This BGS would include an extension to the adult fish ladder so that adult fish passing the

project would be discharged on the upstream side of the BGS. At Little Goose, a full length powerhouse SBC channel without dewatering, would collect and pass fish directly to the tailrace, as described for System Combination 2. At Ice Harbor, a unique, removable, spillway SBC would be constructed at Spillbay 1, the spillbay closest to the powerhouse. A BGS would be included in the forebay to direct fish toward the modified spillbay and away from the powerhouse. Fish collected by the spillway SBC would be passed directly to the tailrace via the modified spillbay. As with the other system combinations, ESBS intake diversion systems would be used in conjunction with each of the four SBC installations.

System Combination 3A: This alternative also allows for adaptive flexibility between transportation and in-river migration, but uses SBC components differently than System Combination 3. At Lower Granite and Lower Monumental, partial powerhouse surface collectors would be installed to collect fish for transportation (no in-river bypass of fish that enter these surface collectors). A BGS would be installed at both Lower Granite and Lower Monumental to guide fish away from Turbine Units 1 through 4. The BGS would include an extension to the fish ladder to facilitate adult fish passage. Two removable spillway weirs would be installed at each dam to bypass fish across the spillway to the tailrace. New ESBS would be installed at Lower Monumental to replace the traveling screens. At Little Goose, an occlusion structure would be placed in front of the powerhouse to divert fish away from the powerhouse towards the spillway. Also at Little Goose, two removable spillway weirs would be installed to bypass fish across the spillway to the tailrace. At Ice Harbor, a BGS with two removable spillway weirs would be installed to provide fish bypass across the spillway. New ESBS would be installed at Ice Harbor to replace the existing traveling screens. Each of the dams would then have ESBSs in the turbine intakes to be used for fish collection.

Cost estimates are provided in the report for the engineering design and construction associated with each of the components of the system combinations. Detailed calculations supporting these estimates are provided in the appendices. Additionally, annual operations and maintenance costs are also estimated. A summary of the estimated costs is provided below:

Summary of Costs for System Combinations

System Combination	**Engineering Design and Construction**	**Annual O&M**
1: Maximizing Effectiveness of Fish Transportation	$202,102,000	$1,481,200
1A: Fish Transportation at a Reduced Cost	$94,565,000	$530,600
2: Emphasis on Inriver Passage	$208,057,000	$611,900
3: Adaptive Migration Strategy for Transportation and Bypass	$243,472,000	$982,800
3A: Adaptive Migration Strategy for Transportation and Bypass	$300,388,000	$693,000

It is apparent from these cost estimate summaries that the differences in initial engineering design and construction costs for System Combinations 1, 2, and 3 are not very significant. System Combination 3A has the largest initial engineering design and construction costs. However, the annual O&M costs do vary significantly, with System Combination 1 being most expensive. The reduced cost of System Combination 1A, as compared to System Combination 1, is very significant; this is true for both initial cost and annual O&M expenses.

1. Introduction

1.1 General

The Walla Walla District of the U.S. Army Corps of Engineers (Corps) operates four lock and dam projects on the lower Snake River in Washington State. The most upstream of these projects is Lower Granite Lock and Dam, located 173.0 kilometers (107.5 miles) upstream of the Snake River's confluence with the Columbia River. Progressing downstream from Lower Granite, the remaining three lock and dam projects are Little Goose, Lower Monumental, and Ice Harbor. Each project includes a powerhouse containing six turbine/generator units, a navigation lock, a multiple-bay Tainter-gate controlled spillway, an earthen embankment, and either one or two upstream adult passage fish ladders. The turbine intakes at each of the projects are currently fitted with intake diversion screens for diverting downstream migrating juvenile salmon smolts from passage through the turbines. At Lower Granite and Little Goose, these intake screens are extended length submerged bar screens (ESBS), while at Lower Monumental and Ice Harbor the intakes include standard length submerged traveling screens (STS). Details concerning the existing project features at each of the four projects are included in Section 3.2.

In response to the National Marine Fisheries Service (NMFS) 1995 Biological Opinion concerning the operation of the federal Columbia River power system, the Corps is studying structural alternatives to improve the downstream migration of juvenile salmon smolts through the four lower Snake River projects. As part of that study, this report summarizes a feasibility investigation concerning four surface bypass and collection (SBC) system combinations involving structural modifications at each of the projects. Each combination applies a different fish passage approach to the river as a whole, and includes specific modifications at each project designed to incorporate that approach.

The Corps began design of a prototype SBC system for bypassing juvenile salmon at Lower Granite in 1995. The basis for this design was the highly successful surface oriented bypass system currently in use at Wells Dam on the mid-Columbia River. However, Wells Dam is unique in that the powerhouse is located entirely beneath the project spillbays. Thus, all project flows (and downstream migrants) are concentrated in the combined powerhouse/spillway area. By making convenient use of the spillbays, the Wells bypass system creates a flow condition in the forebay which tends to guide the smolts into the spillbays and away from the turbine intakes located directly below. In contrast, the four lower Snake River projects are of a more conventional design with the spillbays located adjacent to the powerhouses.

To apply the SBC concept at the Lower Granite powerhouse, a large prototype channel was attached to the upstream face of the powerhouse to act as a collector and transport conduit for the fish. The fish collected by this prototype channel are transported to the first spillbay for discharge into the tailrace. Construction of the prototype SBC channel was completed and testing began in 1996. Additional testing continued through the 1997 and 1998 migration seasons. Results of the testing has been encouraging enough to justify a feasibility level investigation of permanent production SBC systems at the four lower Snake River projects.

The information presented in Sections 1 and 2 of this report provides an overview and discussion of current SBC design strategies and alternatives being evaluated in the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study). Additionally, a general discussion is presented concerning the basic assumptions used in the layout of the system combinations and the logic behind the specific designs incorporated into each of the combinations.

Lower Granite Lock and Dam was used in the Corps, Walla Walla District, *Lower Granite Lock and Dam, Surface Bypass and Collection System Options, Conceptual Design Report, 1998* (SBC Conceptual Design Report) to evaluate, from an engineering perspective, various SBC designs, costs, and schedules as they might appear for a final system application. In this report, *Surface Bypass and Collection System Combinations, Conceptual Design Report* (System Combinations CDR) versions of some of those design options are applied at each of the lower Snake River dams to create the river system combinations investigated. The design perspective information presented in the SBC Conceptual Design Report was considered in conjunction with the biological results gathered from the 3 years of prototype testing at Lower Granite to develop the system combinations with the greatest potential for successful safe fish migration through the river. Each of the combinations has a different goal or approach to better facilitating successful migration.

1.2 SBC Engineering Concept Reports

The SBC development is one of the major system improvement options being considered in the Feasibility Study. Two SBC-related engineering reports have been prepared and will be used to develop an engineering appendix to be included in the Feasibility Study report. This report is the second of the two reports. These reports are as follows:

1. The Corps' SBC Conceptual Design Report summarizes an investigation of the engineering feasibility of installing various SBC systems at Lower Granite. This investigation includes reviews and comparisons of 10 SBC options as they might apply, specifically, to Lower Granite. This investigation has been completed and the final report was submitted in May 1998.
2. The Corps' lower Snake River SBC System Combinations Conceptual Design Report (this report) is a follow-up study to the SBC Conceptual Design Report. It evaluates how the different options developed in the first report may be applied to each of the lower Snake River projects. Selection of system components was made based on how well the different components are predicted to perform and on fish-related, operational strategies selected for the river system.

Information from the two SBC-related engineering reports will be used in economic and performance-related evaluations in later stages of the Feasibility Study that will be completed in 1999.

1.3 SBC Prototype Testing at Lower Granite

The Corps has been testing an SBC prototype at Lower Granite since 1996. In 1998, two major features were added to the prototype, a Simulated Wells Intake (SWI) and a behavioral guidance structure (BGS). The SWI was placed below the SBC prototype channel to test its ability to increase the percentage of fish being directed into the SBC entrances. The 1,100-foot long BGS was located in the forebay upstream of the powerhouse to test its ability to divert fish away from Units 1 through 3. (See Section 2.2.2 for additional discussion on the results of this testing.)

Information gained by evaluating the SWI and BGS (as part of a 1998 Lower Granite SBC prototype test) is critical in evaluating SBC technology. This technology has the potential of significantly improving fish survival through the lower Snake River system. The immediate SBC prototype development objective (through 1999) is to collect information on SBC performance, designs, and costs. This information will be used as a basis for comparing SBC systems with other options for improving fish survival in the lower Snake River in the ongoing Feasibility Study. Efforts beyond 1999 may involve design and construction of concepts selected for implementation by regional decision makers.

1.4 Fish Migration Strategies

Two primary strategies were evaluated in the SBC Conceptual Design Report to pass juvenile fish past Lower Granite: 1) SBC designs that would direct fish to truck or barge transport systems with capabilities to bypass fish directly to the tailrace in an emergency, or 2) inriver passage bypassing fish directly to the tailrace via SBC designs including powerhouse collector channels, similar to the prototype, and modified or existing spillbays. The first system combination reviewed in this report (System Combination 1) utilizes the first strategy, while System Combination 1A represents a reduced-cost version of this same strategy. System Combination 2 utilizes the second strategy emphasizing inriver migration.

A third strategy, being investigated in this System Combinations CDR, is a “Spread the Risk” approach. This is identified as System Combination 3: Adaptive Migration Strategy for Transportation and Bypass. This strategy optimizes current operational objectives where both inriver and transport strategies are used concurrently to pass fish through the projects. This system combination attempts to address concerns about the risks and effectiveness associated with transport only and bypass only. The combined overall strategy is to operate the different projects so that a “Spread the Risk” philosophy could be implemented considering the river system as a whole.

Specific functional goals and design approaches for each of the system combinations are described in Section 2.3. More detailed discussions concerning the hydraulic, structural, mechanical, electrical, construction, and operation and maintenance issues or requirements are presented in Sections 5.0 through 8.0, along with drawings and preliminary cost estimates for the individual facilities proposed for each project.

2. Developmental Background

2.1 SBC Technology Overview

The SBC systems are designed to provide benign, fish-friendly, surface oriented passage systems that juvenile fish, already distributed high in the water column, can use to safely pass a dam. Justification for developing SBC systems relates to the following: Increasing the number of juvenile fish guided for bypass or collection through non-turbine routes, reducing fish stress, injury, and migration delays, and reducing high-spill levels that are associated with dissolved gas problems and lost power generation.

An example of a highly successful surface oriented bypass system currently in use is at Wells Dam on the mid-Columbia River. The Wells Dam system (with its hydrocombine design) would be different from any SBC system that might be developed for lower Snake River projects. However, lessons are being learned from the surface bypass efforts at Wells Dam, as well as ongoing SBC work at other projects in the region. How effective, and how these designs will look, would vary from project to project on the lower Snake River.

The premise behind the SBC designs is that fish located upstream of a dam generally tend to follow bulk flow into the project. A key assumption behind SBC systems is that, even if there are high-bulk flows going to deep powerhouse intakes or spillway gate openings, fish tend to stay surface oriented (if given the opportunity) and pass through a system at shallower depths. There are several factors that are believed to influence the effectiveness of SBC systems besides bulk flow influences. The factors include the depth of fish in the water column, flownets produced by SBC structures as they relate to turbine and spillway hydraulics, opportunity of discovery for fish to find an SBC fishway entrance prior to using a turbine or spillway flow passage, and SBC fishway entrance conditions (total volume, velocities, horizontal/vertical orientations, etc.).

In the case of a powerhouse-related SBC component with fishway entrance slots (as demonstrated by Wells Dam and by SBC prototype designs at other projects, including the Lower Granite prototype tests), fish will enter SBC fishway entrances with different levels of success if given the option to take this higher passage route. Changes in the 1998 Lower Granite prototype SBC structure incorporated an SWI design. This SWI design effectively makes the SBC structure deeper and influences flow lines approaching the SBC structure to allow fish a greater chance to discover SBC entrances prior to passing towards the turbine intakes.

The design of the BGS-related SBC component is based on the observation that fish tend to guide along physical structures that are generally lined up with river flow. One example of this is at Rocky Reach Dam on the mid-Columbia River where fish follow surface flows passing by operating generating units to congregate in a cul-de-sac at the end of the powerhouse. Another example is at Lower Granite where fish have guided along a relatively shallow trash shear boom. The BGS prototype test design at Lower Granite utilizes this same principle but exaggerates the differences between deep powerhouse intakes and surface oriented guidance systems. It is believed that a combination of a general, downstream angled flow approach in the forebay, a deep physical barrier with relatively low velocities passing beneath the structure, and strong SBC fishway entrance surface flows at the downstream end of the BGS should provide for passive fish movement toward the entrance.

The Corps and others in the region have been involved in accelerated programs to develop and evaluate different variations of SBC technology for different locations. There are no established criteria for SBC system designs. Preliminary SBC design criteria (fishway entrance configurations, flow requirements, number of fishway slots, structure depths and water velocities below the BGS, etc.) used as part of the SBC Conceptual Design Report for different design options were developed by the collective judgment of biologists and engineers (Corps and non-Corps personnel). As SBC prototype test results from different test efforts become available, future re-evaluation and refinement of SBC designs, as presented in Feasibility Study, will be required prior to installation of final SBC systems at the different lower Snake River projects. Additional work, focusing on other projects besides Lower Granite, might include activities such as baseline fish behavior data collection, hydraulic model studies, and site specific prototype work.

2.2 Basis for Selection of System Combinations

Each of the lower Snake River system combinations described in this report consists of four individual collection and bypass designs (one to be constructed at each of the four projects.) These designs are combined in such a way as to achieve the overall migration strategies for the river, as discussed in Section 1.4. In the earlier SBC Conceptual Design Report, ten individual SBC design options were conceptually developed and evaluated as they would relate to Lower Granite. Each of these SBC options was made up of components which worked together to achieve a specific bypass strategy. A number of these components have been tested at the Lower Granite SBC prototype to determine their biological effectiveness, either individually or in combination with each other. Based on the information in that report and results of the testing, four of the ten options evaluated have been furthered in this report to create the SBC design types which together create the river system combinations. The four SBC types include a full length powerhouse channel with dewatering (Type 1), a full length powerhouse channel bypass without dewatering (Type 2), a shorter two-unit powerhouse channel with bypass or dewatering capabilities (Type 3), and a modified spillway bypass (Type 4). In some instances a particular project would not utilize any of these SBC types, but would instead utilize either existing or new ESBS intake diversion systems only. In this section, the basis and methodology used to develop these combinations is discussed.

2.2.1 Conclusions from the SBC Conceptual Design Report

Concepts discussed and evaluated in the SBC Conceptual Design Report consisted of a variety of both fixed and floating systems used either alone or in combination with fish guidance devices, project operational changes, with and without transport, etc., at Lower Granite. Biological and environmental considerations, as well as construction, operational, cost, and schedule elements all factor into developing realistic, surface oriented fishways. These SBC concepts are anticipated to have a high potential of improving passage and survival of juvenile salmon migrating past Corps lower Snake and Columbia Rivers hydroelectric projects.

A few of the SBC options utilized a BGS to guide fish to the spillway or smaller surface collectors. Also, some of the options included a 21.3-meter (70-foot)-deep surface collector while other options included 16.7-meter (55-foot)-deep surface collectors. The report addressed the engineering feasibility, constructability, and operational procedures for each SBC option. Also, the costs for construction, operation, and maintenance for each SBC option are included in the report. The options were all developed to be feasible from an engineering, construction, maintenance and operations perspective. Costs varied between options. For instance, the construction costs for a full powerhouse deep surface collector with dewatering were found to be about 15 percent higher than for a partial powerhouse surface collector with a BGS ($51 million versus $44.3 million). The construction costs for the 21.3-meter (70-

foot)-deep surface collector options were only slightly higher than the shallower 16.7-meter (55-foot) options. For a full listing of costs, refer to the SBC Conceptual Design Report.

2.2.2 Results from 1998 Prototype Testing at Lower Granite

The goal of testing of the prototype SBC channel and BGS at Lower Granite was to establish a rational basis for advancing, or not advancing, surface collector technology at the lower Snake River dams. There were two primary means of measuring performance of the SBC channel and BGS in 1998 at Lower Granite: 1) hydroacoustics, which samples thousands of fish passing the dam, but cannot distinguish between species, and 2) radiotelemetry, which provides species-specific information on fish movement and passage but relies on only 200 to 400 fish, a very small sample size. At this time, all results are preliminary and subject to change as the data undergo further analysis. For the BGS, radiotelemetry showed that for fish that would normally have passed the dam via Unit Intakes 1 through 3, 69 percent of the hatchery chinook, 86 percent of the hatchery steelhead, and 65 percent of the wild steelhead were diverted to the SBC, Unit Intakes 4 through 6, or the spillway. The hydroacoustic estimate of this BGS diversion efficiency was 78 percent.

For the SBC, the best estimate of performance is probably the percentage of fish passing through the SBC relative to those passing into the turbine intakes of Units 4 through 6, above which the SBC is located. For radio-tagged fish, this $R_{(4-6)}$ value was 29 percent, 49 percent, and 28 percent for chinook, hatchery steelhead and wild steelhead, respectively. In other words, of all the radio-tagged chinook that entered either turbines 4 through 6 or the SBC, 29 percent passed through the SBC. The hydroacoustic SBC passage estimate was from 50 percent to 54 percent, depending on entrance configuration. The passage efficiency for the SBC and ESBS in combination was about 90 percent for the whole powerhouse, as measured with hydroacoustics. For the different species, the combination of ESBS and SBC at Units 4 through 6 was 83 percent, 98 percent, and 87 percent for chinook, hatchery and wild steelhead, respectively. All SBC passage indices increased substantially from previous test seasons, sometimes doubling or tripling, presumably because of the addition of the SWI.

Although the BGS diverted a high percentage of fish away from the south half of the powerhouse, many of these diverted fish apparently did not enter the SBC, but rather passed into Turbine Intakes 4 through 6, or over the spillway. The BGS only slightly increased the percentage of total fish passing through the SBC. If testing and development of surface bypass concepts continue, entrance configurations and conditions will be a focal point to attract more of these fish into the SBC.

2.2.3 System Combination Selection Process

The SBC options contained in the SBC Conceptual Design Report for Lower Granite were then compared to one another to determine the best transportation and bypass options for future consideration at other lower Snake River facilities. The goal was to develop several rational SBC systems to be further investigated. Several meetings were held by Corps biologists and engineers to discuss what SBC options should be used for development of the SBC system combinations. The Corps coordinated with regional specialists to achieve a consensus on the SBC system combinations to be studied. Because there is no current wide spread regional agreement on whether transporting the juvenile fish is better or worse than keeping the fish in river, it was decided to develop several system combinations. One SBC system combination will be investigated which keeps fish inriver, two which utilize a fish-friendly transportation system (one at a significantly reduced cost), and a yet another system combination which allows for both fish-friendly transportation or inriver bypass.

The first SBC combination emphasizing fish collection and transportation utilizes surface collectors at Lower Granite, Little Goose, and Lower Monumental Dams in an effort to maximize use of surface collection and existing transportation. Ice Harbor currently has fish bypass facilities with no transportation capability. Since most fish would likely be collected for transport upstream of Ice Harbor, it was decided to assume only a new ESBS system at Ice Harbor to collect fish for inriver bypass via the juvenile fish facility.

The second SBC combination emphasizing transportation utilizes surface collection only at Lower Granite Dam. No new surface collectors or inriver bypass measures are assumed for Little Goose, Lower Monumental, and Ice Harbor Dams. Fish not collected at Lower Granite, including those that enter the Snake River further downstream, would not be collected with any surface collector. Instead, they would either bypass the dam and not be available for collection and transportation, or be collected for transport via ESBS systems extending in front of the turbine entrances. This SBC combination was selected for study because it represents a much less expensive alternative to the previously described SBC combination, although it may not be as effective at collecting fish.

One alternative was selected for investigation in this report representing an inriver bypass strategy. This SBC combination utilizes surface collectors at all four dams to guide the fish over a modified spillbay. This alternative was selected for study because it represents an effective method for keeping the fish inriver by guiding them to a more fish friendly spillbay at each dam.

Another SBC combination allowing for optimized transportation or inriver bypass is the Adaptive Migration Strategy alternative. This SBC combination utilizes a surface collector at Lower Granite Dam which provides either collection or inriver bypass opportunities. A surface collector allowing for inriver bypass only is used at Little Goose because no fish enter the Snake river between Lower Granite and Little Goose Dams. A surface collector allowing either collection or inriver bypass is again included at Lower Monumental Dam to primarily collect fish entering the river between Little Goose and Lower Monumental dams from the Tucannon River and Lyons Ferry Hatchery. A BGS leading to a modified spillbay is used at Ice Harbor since there are no fish transportation facilities there. This SBC combination was selected for study because it represents an effective method to either bypass or transport fish. This alternative allows for the most flexibility in selecting fish passage strategies after implementation. SBC systems which utilize a BGS were included to demonstrate how a BGS might be used as part of an SBC system combination.

New ESBS systems at Ice Harbor and Lower Monumental are assumed for each SBC combination because they are more effective than the existing submerged traveling screens at guiding fish away from the turbines and to the existing juvenile fish facilities.

The preliminary data from the SBC prototype testing indicated that the Simulated Wells Intake and ESBS worked well together to achieve a high collection rate. Because of this, 21.3-meter (70-foot)-deep surface collectors were selected over 16.7-meter (55-foot)-deep surface collectors for further consideration at Lower Granite, Little Goose, and Lower Monumental. At Ice Harbor, the forebay depth is considerably shallower and the powerhouse structure is configured such that a 16.7-meter (55-foot)-deep surface collector would appear more appropriate for working together with the ESBS. Use of ESBS intake diversion screen systems is assumed for each SBC type at each project for each system combination.

The performance data for the BGS were inconclusive at the time of development of the SBC combinations. Also, as described above, the cost for a deep full powerhouse surface collector with dewatering was only about 15 percent higher than for a deep partial powerhouse surface collector with dewatering and a BGS. Also, it was felt that if a full powerhouse surface collector were feasible, then a partial powerhouse surface collector with a BGS could likely be developed. The reason for this is that the most challenging aspect of development of a full powerhouse SBC is the large scale dewatering, assumed to be about 170 cubic meters per second (m^3/s) (6,000 cubic feet per second [cfs]). A partial powerhouse surface collector would have much less dewatering, approximately 56.6 m^3/s (2,000 cfs). Also, development of a BGS was found in the SBC Conceptual Design Report to be feasible. For the reasons stated above, it was felt that a reasonable choice for the bypass and transport SBC system combinations would include full powerhouse surface collectors. If it is later found that the BGS testing is indeed successful, then it is likely that less expensive partial powerhouse surface collectors with BGSs could be developed in lieu of full powerhouse surface collectors to collect fish for transportation. Also, the BGSs could be used in lieu of full powerhouse surface collectors to guide fish directly to a spillbay for bypass. However, concern was raised regarding the complete exclusion of BGSs from the System Combinations CDR. It was agreed that it was inappropriate to exclude consideration of this emerging technology prior to the completion of prototype testing. In fact, prototype testing may yet show the BGS to be very effective at guiding fish. Consequently, it was decided to include BGSs in the Adaptive Migration Strategy System Combination. That way, BGS technical and cost issues may be included in the report.

The SBC Conceptual Design Report for Lower Granite included a dewatering system for a full powerhouse surface collector utilizing "conventional" dewatering criteria (Option 1). Conventional criteria includes a 0.12 meters per second (m/s) (0.4 feet per second [ft/s]) screen approach velocity component, as defined by NMFS for screen applications where salmonid fry may be present. Also, the conceptual design report includes several full and partial powerhouse surface collector options utilizing more progressive dewatering criteria. These criteria include a higher screen approach velocity, varying gradually between 0.36 m/s (1.2 ft/s) in the upstream portion of the dewatering channel to the NMFS mandated 0.12 m/s (0.4 ft/s) in the downstream portion of the channel. Dewatering model testing utilizing the progressive criteria is on-going and, so far, appears to be promising. However, more model testing and, eventually, full size prototype testing would be required to determine the full effects on fish from various dewatering scenarios. The conventional dewatering criteria result in a much larger and more expensive surface collector. Also, the fish entrances are further upstream and the fish experience a longer travel time through the surface collector. For the reasons stated above, it was decided that the surface collectors developed for the System Combinations CDR would utilize "progressive" dewatering criteria.

Regional experts including Corps biologists and engineers compared methods of bypassing fish over the spillway. One method included in the SBC Conceptual Design Report utilized a chute structure to guide fish over the spillway. With the chute design, the fish would experience a high velocity free plunge from the end of the chute into the spillway tailwater. This would be a near vertical drop off the end of the chute, as opposed to a spillway type flow which is supported by the spillway concrete and guided into the tailwater. This free plunge was seen as possibly being detrimental to the fish. Another method developed in the report included raising the spillway crest. This method was seen as likely causing less fish stress since it would discharge the fish into the tailwater in the same way the existing spillway does and would include no free plunging water. Consequently, the inriver bypass and adaptive migration strategy SBC system combinations contained in the System Combinations CDR will include raised or modified spillbays.

2.3 System Combination Descriptions

Each of the system combinations is designed to apply a particular migration strategy to the river as a whole. At each of the four projects, one of the SBC designs evaluated in the SBC Conceptual Design

Report, and/or ESBS intake diversion systems, would be utilized to facilitate the desired strategy. Brief descriptions of the strategy and functional approach for each combination are provided in this section.

Detailed descriptions of the proposed bypass and collection facilities for each project are provided in Sections 5 through 8. In some cases, similar or even identical facilities would be used at a particular project for different system combinations. In these cases, descriptions of project facilities, or components, which have previously been described would not be repeated, rather the previous description in another section is referenced. Therefore, much of the information, which is generic to all combinations and designs, especially concerning structural and mechanical issues, is presented once in Section 5.

2.3.1 System Combination 1: Maximizing Effectiveness of Fish Transportation

The goal of System Combination 1 is to maximize the number of fish collected and delivered to the existing or upgraded transportation facilities located at each project. This would be accomplished by constructing a full length powerhouse SBC channel at each of the three upstream projects (SBC Type 1). The channels would contain dewatering screens to concentrate the fish in a small enough flow that they could be delivered into the existing juvenile bypass channels inside each dam. Emergency bypass openings would also be provided to allow the collected fish to bypass the dewatering screens and pass downstream directly through the spillway in the event there is a problem with either the dewatering screens or the transportation facilities. The SBC channels would be used in conjunction with ESBS located in the turbine intakes. Fish diverted by the ESBS would also be delivered into the existing juvenile bypass channels. Ultimately, fish collected by both bypass structures would be combined and delivered to the transportation facilities, and either trucked or barged downstream. The number of fish continuing downstream by inriver passage through the projects (either through the turbines or spillways) would be minimized, and would significantly reduce at each consecutive project.

The upper two projects (Lower Granite and Little Goose) currently have ESBS installed in the turbine intakes. These would continue to be used in System Combination 1. However, the intakes at Lower Monumental are currently outfitted with STS. These would be removed and replaced with ESBS to increase the screen diversion efficiency, and further reduce the number of fish passing through the turbines.

At Ice Harbor the turbine intakes are also currently outfitted with STS. As at Lower Monumental, these would be removed and replaced with ESBS to increase the diversion efficiency of the screening system. However, no SBC channel would be installed at Ice Harbor. If the combination of the SBC channels and the ESBS diversion systems function as anticipated at the upper three projects, there should be so few freely migrating fish left in the river at Ice Harbor that construction of an SBC system and a transportation facility would not appear to be justified. This approach is further justified by the fact that no fish enter the Snake River between Lower Monumental and Ice Harbor.

Detailed descriptions of the specific bypass and collection facilities at each project which make up System Combination 1 are presented in Section 5.

2.3.2 System Combination 1A: Fish Transportation at a Reduced Cost

System Combination 1A also emphasizes the continued and enhanced use of the fish transportation facilities. However, the goal in this combination is to construct enhanced collection facilities for the existing transportation infrastructure at a significantly reduced initial and operational cost, relative to System Combination 1. To facilitate this approach, the same collection facilities as described for System Combination 1 at Lower Granite would be constructed (SBC Type 1). This would include the construction of a full-length powerhouse SBC channel to be used in conjunction with the existing ESBS system. At the lower three projects only ESBS intake diversion systems would be used. Since ESBS already exist at Little Goose there would be no modifications required at this project, and the existing diversion/bypass facilities would continue to be used. At Lower Monumental and Ice Harbor the existing STS intake diversion systems would be removed and replaced with ESBS systems, but no additional SBC channels would be constructed to augment these systems.

The basis for this strategy is that the majority of juvenile salmon coming down the Snake River are coming from above Lower Granite. If the combined SBC and ESBS systems to be utilized at Lower Granite function as effectively as anticipated there would be few migrating fish left in the river below Lower Granite, and construction of large, expensive SBC systems could not be justified. This is the same reasoning behind utilizing only the ESBS system at Ice Harbor in System Combination 1.

If it should be decided that transportation is the migration goal for the river, System Combinations 1 and 1A actually form a transportation package which could be initiated prior to a decision on which of the two combinations would constitute the final design. This is because everything involved in Combination 1A would be required in Combination 1. In fact, the most prudent way to install Combination 1 would be to install Combination 1A first and test the production SBC/ESBS collection facility at Lower Granite to ensure its efficiency, and potentially work any unanticipated bugs out of the SBC channel design. If after testing of Combination 1A it is decided that Combination 1 would be justified, all that would be required is to construct Type 1 SBC channels at Little Goose and Lower Monumental, with the advantage of experience at Lower Granite to guide a more efficient design for the subsequent SBC channels.

Detailed descriptions of the specific bypass and collection facilities at each project which make up System Combination 1A are presented in Section 6.

2.3.3 System Combination 2: Emphasis on Inriver Passage

The migration strategy for System Combination 2 is to focus on effective diversion of the fish away from the turbines while emphasizing inriver migration, and de-emphasizing transportation. For this combination, all four projects would be outfitted with a full length powerhouse SBC channel. However, these channels would not include dewatering screens and the fish would be passed directly downstream to the tailrace through modified spill flow (SBC Type 2). To maximize effective diversion away from the turbines, ESBS intake diversion systems would be used in conjunction with the channels at all four projects (as described for the SBC installations in Combination 1). Fish diverted by the ESBS systems would continue to be directed to the juvenile transportation facilities where a reduced transportation program could still be operated, or these fish could be delivered directly into the tailrace at that location.

As previously described, Lower Granite and Little Goose already have ESBS systems, and these would continue to be used in conjunction with the new SBC channels. The STS systems at Lower Monumental and Ice Harbor would be removed and replaced with new ESBS systems.

Detailed descriptions of the specific bypass and collection facilities at each project which make up System Combination 2 are presented in Section 7.

2.3.4 System Combination 3: Adaptive Migration Strategy for Transportation and Bypass

System Combination 3 applies a migration strategy which allows for adaptive flexibility between transportation and inriver migration. At Lower Granite and Lower Monumental, partial powerhouse length SBC channels would be constructed at Turbine Units 5 and 6 (SBC Type 3). These two-unit SBC channels would have two side-by-side entrances. One entrance would pass the fish through a dewatering section so that they could be delivered into the existing juvenile bypass channel, and ultimately to the transportation facilities, similar to the SBC channels in System Combination 1. The other entrance would not contain dewatering screens and would pass the fish directly to the tailrace through modified spill flow, similar to the SBC channels in System Combination 2. Therefore, fish collected by the SBC could be directed to transport or inriver migration. To guide fish away from in front of Units 1 through 4, a BGS would be constructed in the forebay.

As with the other system combinations, ESBS intake diversion systems would be used in conjunction with these two-unit SBC channels. At Lower Granite the existing ESBS would be used, whereas at Lower Monumental there would need to be new ESBS. The ESBS would be located in turbine intakes at all six units, including Units 1 through 4 to offer a bypass for those fish which may pass around or under the BGS.

At Little Goose, a full length powerhouse SBC channel without dewatering, would collect and pass fish directly to the tailrace (SBC Type 2). This is the same system as described for Little Goose in System Combination 2, and would utilize the existing ESBS intake diversion systems in all unit intakes.

At Ice Harbor, a spillway SBC would be constructed at Spillbay 1 (SBC Type 4), the spillbay closest to the powerhouse. The spillway SBC would consist of a removable raised ogee crest to be placed between the upstream portions of the spillbay piers spanning the entire spillbay width with the downstream remainder of the spillbay to remain at its existing elevation. A BGS would be included in the forebay to direct fish toward the modified spillbay and away from the powerhouse. Fish collected by the spillway SBC would be passed directly to the tailrace via the modified spillbay. New ESBS intake diversion screens would be incorporated into the turbine intakes to offer a bypass for any fish which do pass around or under the BGS.

Detailed descriptions of the specific bypass and collection facilities at each project which make up System Combination 3 are presented in Section 8.

Table 2.1 summarizes the SBC types at each project which make up the system combinations investigated in this report.

Table 2.1. Summary of System Combinations

System Combination No.	Lower Granite	Little Goose	Lower Monumental	Ice Harbor
1 – Emphasis on transportation	**Type 1** (screened channel)	**Type 1** (screened channel)	**Type 1** (screened channel)	**New ESBS** (intake diversion screen system)
1A – Transportation at reduced cost	**Type 1** (screened channel)	**Existing ESBS** (intake diversion screen system)	**New ESBS** (intake diversion screen system)	**New ESBS** (intake diversion screen system)
2 – Emphasis on inriver migration	**Type 2** (bypass channel)	**Type 2** (bypass channel)	**Type 2** (bypass channel)	**Type 2** (bypass channel)
3 – Adaptive migration strategy	**Type 3** (2-unit dual channel)	**Type 2** (bypass channel)	**Type 3** (2-unit dual channel)	**Type 4** (removable spillbay weir)

3. Design Criteria and Project Data

3.1 General

The SBC designs used at each of the four projects to create the system combinations were first developed and evaluated in the SBC Conceptual Design Report. One of the goals of that report was to compare the impacts of different design criteria on the complexity and cost of resulting structures. Because there are no production bypass systems that dewater the magnitudes of flow being considered for these SBC designs, there was no precedent from which to establish tried and "proven" criteria. Therefore, one of the options in the SBC Conceptual Design Report incorporated traditional fisheries and hydraulic design parameters and conventional dewatering screen velocity criteria. These are criteria which have been approved and utilized successfully on much smaller facilities. The constructability, operation and maintenance (O&M) issues, and costs associated with the resulting design were compared to other options utilizing a progressive set of fisheries and hydraulic design parameters which have been utilized in prototype SBC facilities at other dams, and developed by engineers and biologists familiar with fisheries requirements. In addition, these progressive criteria included higher dewatering screen velocities which are currently being developed by the Corps and reviewed by agency personnel. For the SBC designs making up the system combinations in this report, it is the progressive criteria which have been utilized. These design criteria and the existing project data for the four lower Snake River projects are listed below.

3.2 Existing Project Data

3.2.1 Snake River

<u>Hydrologic Data:</u>	
(Based on streamflow data near Clarkston, Washington)	
Mean annual river flow	1,424 m^3/s (50.3 thousand cfs [kcfs])
Average annual peak daily flow	332 m^3/s (188.3 kcfs)
Minimum discharge of record (September 1958)	187 m^3/s (6.6 kcfs)
Maximum discharge of record (June 1894)	11,600 m^3/s (409 kcfs)
Spillway design flood (all four projects)	24,100 m^3/s (850 kcfs)

3.2.2 Lower Granite

<u>General:</u>	
River location (from confluence with Columbia River)	173.0 kilometers (km) (107.5 miles)
Number of generating units	6
Output capacity (nameplate rating)	810,000 kilowatts (kW)
Number of spillbays	8
Intake diversion screen type	ESBS
Number of adult fish ladders	1
<u>Dimensions:</u>	
Powerhouse overall length	199.9 m (656 ft)
Unit width (Units 1 to 5)	27.43 m (90 ft)
Unit width (Unit 6)	29.26 m (96 ft)

Erection Bay width	33.53 m (110 ft)
Spillway overall length	156.1 m (512 ft)
Spillbay center-to-center spacing	19.51 m (64 ft)
Spillbay gate width	15.24 m (50 ft)
Spillbay gate height (above spillway crest)	17.98 m (59 ft)

<u>Elevations:</u> (referenced to mean sea level)

Maximum pool (design flood condition)	227.5 m (746.5 ft)
Maximum operating pool	224.9 m (738.0 ft)
Minimum operating pool (MOP)	223.4 m (733.0 ft)
Minimum flood control pool	220.7 m (724.0 ft)
Top of tainter gates (closed)	225.6 m (740.0 ft)
Spillway crest	207.6 m (681.0 ft)
Maximum flood tailwater (24,100 m^3/s)	202.1 m (662.9 ft)
Normal maximum tailwater (9,630 m^3/s)	196.7 m (645.5 ft)
Tailwater at maximum powerhouse flow (3,680 m^3/s)	194.8 m (639.2 ft)
Normal tailwater	194.5 m (638.0 ft)
Minimum tailwater (zero flow)	192.9 m (633.0 ft)
Intake deck	228.9 m (751.0 ft)

3.2.3 Little Goose

<u>General:</u>

River location (from confluence with Columbia River)	113.1 km (70.3 miles)
Number of generating units	6
Output capacity (nameplate rating)	810,000 kW
Number of spillbays	8
Intake diversion screen type	ESBS
Number of adult fish ladders	1

<u>Dimensions:</u>

Powerhouse overall length	199.9 m (656 ft)
Unit width (Units 1 to 5)	27.43 m (90 ft)
Unit width (Unit 6)	29.26 m (96 ft)
Erection Bay width	33.53 m (110 ft)
Spillway overall length	156.1 m (512 ft)
Spillbay center-to-center spacing	19.51 m (64 ft)
Spillbay gate width	15.24 m (50 ft)
Spillbay gate height (above spillway crest)	17.98 m (59 ft)

<u>Elevations:</u> (referenced to mean sea level)

Maximum pool (design flood condition)	197.1 m (646.5 ft)
Maximum operating pool	194.5 m (638.0 ft)
Minimum operating pool	192.9 m (633.0 ft)
Top of tainter gates (closed)	195.1 m (640.0 ft)
Spillway crest	177.1 m (581.0 ft)
Maximum flood tailwater (24,100 m^3/s)	172.0 m (564.4 ft)
Maximum normal tailwater	164.6 m (540.0 ft)

Minimum normal tailwater ([MOP] at Lower Monumental)	163.7 m (537.0 ft)
Intake deck	198.4 m (651.0 ft)

3.2.4 Lower Monumental

General:	
River location (from confluence with Columbia River)	66.9 km (41.6 miles)
Number of generating units	6
Output capacity (nameplate rating)	810,000 kW
Number of spillbays	8
Intake diversion screen type	STS
Number of adult fish ladders	2
Dimensions:	
Powerhouse overall length	199.9 m (656 ft)
Unit width (Units 1 to 5)	27.43 m (90 ft)
Unit width (Unit 6)	29.26 m (96 ft)
Erection Bay width	33.53 m (110 ft)
Spillway overall length	156.1 m (512 ft)
Spillbay center-to-center spacing	19.51 m (64 ft)
Spillbay gate width	15.24 m (50 ft)
Spillbay gate height (above spillway crest)	17.98 m (59 ft)
Elevations: (referenced to mean sea level)	
Maximum pool (design flood condition)	167.1 m (548.3 ft)
Maximum operating pool	164.6 m (540.0 ft)
Minimum operating pool	163.7 m (537.0 ft)
Top of tainter gates (closed)	165.2 m (542.0 ft)
Spillway crest	147.2 m (483.0 ft)
Maximum flood tailwater (24,100 m^3/s)	141.8 m (465.1 ft)
Maximum normal tailwater	134.1 m (440.0 ft)
Minimum normal tailwater (MOP at Ice Harbor)	133.2 m (437.0 ft)
Intake deck	168.6 m (553.0 ft)

3.2.5 Ice Harbor

General:	
River location (from confluence with Columbia River)	15.6 km (9.7 miles)
Number of generating units	6
Output capacity (nameplate rating)	603,000 kW
Number of spillbays	10
Intake diversion screen type	STS
Number of adult fish ladders	2
Dimensions:	
Powerhouse overall length	204.5 m (671 ft)
Unit width (Units 1 to 5)	26.21 m (86 ft)
Unit width (Unit 6)	28.04 m (92 ft)
Erection and service bay width	45.42 m (149 ft)

Spillway overall length	182.9 m (600 ft)
Spillbay center-to-center spacing	18.29 m (60 ft)
Spillbay gate width	15.24 m (50 ft)
Spillbay gate height (above spillway crest)	15.54 m (51 ft)

Elevations: (referenced to mean sea level)	
Maximum pool (design flood condition)	136.1 m (446.4 ft)
Maximum operating pool	134.1 m (440.0 ft)
Minimum operating pool	133.2 m (437.0 ft)
Top of tainter gates (closed)	134.7 m (442.0 ft)
Spillway crest	119.2 m (391.0 ft)
Maximum flood tailwater (24,100 m^3/s)	114.0 m (374.0 ft)
Maximum normal tailwater	103.6 m (340.0 ft)
Minimum normal tailwater	102.7 m (337.0 ft)
Intake deck	138.1 m (453.0 ft)

3.3 Design Criteria

3.3.1 Fisheries and Hydraulic Criteria

Fisheries and hydraulic design criteria for juvenile fish bypass systems are interrelated. They usually consist of allowable velocities, depths of flow, duration of exposure to dewatering screens, flow boundary conditions, screen materials, etc. intended to provide protection to fish passing through a structure. NMFS has published general criteria for design of juvenile fish screening and bypass systems [1]. These were intended to be "worst-case default criteria" to be applied throughout the region. Site-specific data and considerations may be used to adjust the criteria. In this report, the fish bypass systems have been developed using these criteria where they are clearly applicable. However, one exception to this is the higher dewatering screen approach velocities applied to the upstream portions of the dewatering screens in the SBC channel designs. Approach velocity is defined by NMFS as the component of the water velocity which is perpendicular to the face of the screen as measured at a location approximately three inches in front of the screen face. These "progressive" dewatering criteria were investigated in the SBC Conceptual Design Report, and would appear to be more appropriate for the unprecedented large flows and conduit widths present in the SBC channel designs. In some cases other criteria which have been applied in the region were applied where the NMFS criteria do not cover a situation.

The conditions and criteria considered in the designs of the various components of the SBC fish bypass systems include:

Behavioral Guidance Structure (BGS) Design Criteria

Flow velocity under (perpendicular to) the BGS	$<$ 0.61 m/s (2.0 ft/s)
Flow velocity along (parallel to) the face of the BGS	$>$ 0.61 m/s (2.0 ft/s)

The criteria presented here represent the use of "best judgment" to prevent attraction or entrainment under the BGS. Results from the 1998 BGS prototype, and hydraulic modeling studies, would be used to further refine these criteria prior to final design.

Surface Collection Channel

Criteria and design parameters presented here represent a best judgment approach based on results of the prototype testing at Lower Granite, the Wells Dam juvenile bypass system, and experience at other projects. The criteria listed here are used consistently for the channel designs at all four projects, with the following qualifications:

Some of the surface collection channel designs evaluated for Lower Granite, Little Goose, and Lower Monumental include dewatering screens to facilitate delivery of the fish into the existing juvenile bypass facilities. In each of these cases there would be ESBS intake diversion systems also contributing orifice flow to these same bypass facilities. To prevent overloading of these facilities, the flow contribution from the SBC channel is limited to 0.850 m^3/s (30 cfs) at each of these three projects. This limitation was defined solely for the purposes of this conceptual evaluation. During final design of SBC channels for these projects, the actual flow capacity and ESBS contribution should be investigated for each project so that designs can be optimized for the specific project.

The only surface collection channel being evaluated for Ice Harbor is a full-flow bypass channel being utilized in System Combination 2. This channel would not contain dewatering screens. The depth of the forebay at Ice Harbor is approximately 36.5 meters (120 feet), whereas at the other three projects it is approximately 42.7 meters (140 feet). Therefore, the channel design evaluated for Ice Harbor is shallower than for the other three projects so as to create the same projection downward in front of the turbine intakes as at the other projects. Prior to a final design of a channel at Ice Harbor, it is suggested that model studies be performed to investigate how far down this projection could go without negatively impacting the turbine operations or the efficiency of the ESBS system.

Flow per SBC entrance	56.6 m^3/s (2,000 cfs)
Entrance width	4.88 m (16 ft)
Invert depth of entrance (Lower Granite, Little Goose, and Lower Monumental)	21.3 m (70.0 ft)
Invert depth of entrance (Ice Harbor)	16.8 m (55.0 ft)
Minimum transport conduit width	0.61 m (2.0 ft)
Trapping velocity	≥ 2.13 m/s (7 ft/s)
Floor slopes	≤ 45 degrees
Horizontal convergence slopes of solid walls	≤ 13 degrees
Horizontal divergence slopes of solid walls	≤ 5.0 degrees
Horizontal convergence slopes of screen faces	≤ 9.0 degrees
Screen depth	[No limit]
Dewatering screen approach velocity based on effective screen area:	
Upstream 1/3 of primary screen length	≤ 0.36 m/s (1.2 ft/s)
Middle 1/3 of primary screen length	≤ 0.24 m/s (0.8 ft/s)
Downstream 1/3 of primary screen length	≤ 0.12 m/s (0.4 ft/s)
Secondary screens	≤ 0.12 m/s (0.4 ft/s)
Ratio effective to gross screen area to account for structural Members and cleaner tracks	75 percent
Total maximum flow from SBC to juvenile gallery	0.850 m^3/s (30 cfs)
Centerline radius of open channel conduit bends:	
Large conduits upstream of dewatering	≥ 2 times conduit width
Small conduits downstream of dewatering	≥ 5 times conduit width

Time for sweeping flow to pass screen face	≤ 60 seconds
Maximum energy dissipation concentration	1077 joules/s-m^3 (22.5 ft-lb/s-ft^3)

Ability to allow for emergency bypass directly to tailrace

Transport velocity constant or mildly accelerating up to trapping velocity*

* Mildly accelerating flow is defined as a flow which is not likely to cause a startle response from the fish. An actual criterion to be used as a maximum is still in a stage of development. Rather than a true "acceleration" which is defined as an increase in velocity at a single location over a period of time, the parameter which is generally focused on in these types of applications is "velocity increase" defined as a change in velocity per linear length of conduit. Where reasonably achievable, these designs keep the velocity increase below 0.1 m/s per meter of conduit (0.1 ft/s per foot). In certain local cases, such as immediately upstream of the tilting weirs, this limitation would likely be difficult to achieve due to the required transition length. However, in no case should the velocity increase exceed 0.5 m/s per meter of conduit (0.5 ft/s per foot).

<u>Spillway SBC – Ice Harbor System Combination 3 only:</u>

Flow per top flow spillbay at average operating pool	170 m^3/s (6,000 cfs)

3.3.2 Structural Criteria

Maximum pressure differential on channel walls	
Channel designs with dewatering screens	14.9 kilopascal (kPa) (312 pound per square foot [psf])
Channel designs without dewatering screens	8.96 kPa (187 psf)
Ice load (at top of upstream wall)	73.0 kilonewtons (kN)/m (5 kips/ft)
Design wind speed	113 km/hr (70 mph)
Fetch length for wave development	
Lower Granite	3.21 km (2.0 miles)
Little Goose	10.5 km (6.5 miles)
Lower Monumental	5.63 km (3.5 miles)
Ice Harbor	2.41 km (1.5 miles)
Load rejection pressure (on downstream wall)	2.99 kPa (62.4 psf)
Yield strength of steel pipe	290 megapascals (MPa) (42 kip per square inch [ksi])
Yield strength of structural steel tube	317 MPa (46 ksi)
Yield strength of other steel components	345 MPa (50 ksi)
Existing concrete strength	20.7 MPa (3.0 ksi)
New concrete strength	27.6 MPa (4.0 ksi)
Yield strength of steel reinforcing bars	414 MPa (60 ksi)
Bedrock acceleration from max. credible earthquake	
Lower Granite, Little Goose, Lower Monumental	0.10 gravitational acceleration (g)
Ice Harbor	0.38 g

The maximum pressure differential on the channel walls for the SBC channels with dewatering screens is based on a maximum water surface differential from the outside to the inside of the channel of 1.52 meters (5.0 feet). This is assumed to be a conservative value to be used as a design maximum for structural purposes and does not represent a normal operating differential. This value is based on the high-head dewatering screen design and the potentially coarse flow adjustment characteristics of the Tainter gate. Design of the high-head dewatering screens and the advantages of this design are discussed in Section 5.1.1. Since the screens are not included in the designs without dewatering (SBC Type 2), the maximum pressure differential used for design of these channels is reduced to 0.914 meter (3.0 feet).

Structures are to be designed for wave loading based on the Corps' Shore Protection Manual [2] with the assumption that the design wind is sustained for a length of time adequate to fully develop the available fetch lengths as listed above. This results in a wave heights and lengths as shown below:

Project	Wave Height	Wave Length
Lower Granite	0.88 m (2.9 ft)	13 m (43 ft)
Little Goose	1.62 m (5.3 ft)	28 m (93 ft)
Lower Monumental	1.19 m (3.9 ft)	20 m (65 ft)
Ice Harbor	0.79 m (2.6 ft)	11 m (36 ft)

Detailed calculations of the design waves and load distributions on the structures are provided in Attachment A.

Load rejection pressure is based on actual load rejection tests performed at Lower Granite, and is assumed to be similar for all four projects.

For earthquake design, the horizontal bedrock acceleration is applied to large monolithic structures attached to the bedrock, such as the dam, and any large components attached directly to the dam. Other structures could have greater or lesser seismic loads applied to them depending on their design which would be determined through the use of the Uniform Building Code (UBC). The water confined within the channel and the spillway extension structure (SES) is treated as a solid mass with an associated inertial force resulting from a horizontal acceleration equal to the bedrock acceleration. A review of the likely actual loads resulting from this water sloshing (convective loading) during an earthquake revealed that the solid mass assumption is slightly conservative for structures with depth to width ratios of those found in these structures.

Structural designs shall be in accordance with the following references:

Shore Protection Manual [2]

Strength Design for Reinforced-Concrete Hydraulic Structures [3]

Design of Hydraulic Steel Structures [4]

Gravity Dam Design [5]

Seismic Design for Buildings [6]

American Concrete Institute (ACI)

American Institute of Steel Construction (AISC)

UBC

3.3.3 Mechanical Criteria

Mechanical designs shall be in accordance with the following references:

American Gear Manufacturers Association (AGMA)
American National Standards Institute (ANSI)—Safety Standards for Overhead Cranes
American Society of Mechanical Engineers (ASME)
Department of Defense Federal Specification
Department of Labor Code of Federal Regulations - Occupational Safety and Health Administration Standards
National Fluid Power Association
Washington Administrative Code - General Safety and Health Standards

3.3.4 Electrical Criteria

Electrical and control design for electrical components shall be in accordance with the 1996 National Electrical Code (NEC), National Electrical Manufacturers Association (NEMA) and applicable Institute of Electrical and Electronics Engineering (IEEE) and ANSI standards.

Panelboards	NEMA (PB 1)
Programmable Logic Controllers (PLC)	NEMA (ICS 2)
Transformers, fused switches, switchboards	ANSI (C37.121)
Conduit	Underwriters Laboratories, Inc. (UL) Listed (UL-6)
Motors, operators	NEMA (ICS 6, WC-7, WC-8, MG1)
Wiring devices, luminaires	UL Approved

4. Methodology

4.1 Design

The system combinations evaluated in this report incorporate surface bypass and/or collection facilities to be constructed at each of the four lower Snake River projects. These facilities are designed to work in combination with each other to achieve a desired migration strategy for the river as a whole. The individual facilities to be located at the projects are referred to in this report as SBC Types (SBC Types 1 through 4). Each of the designs involves the interaction of a number of components. The goal of the designs is to incorporate these components in such a way as to efficiently and effectively guide juvenile fish from the forebay and deliver them safely to a desired location downstream of the dam, while ensuring that the structural and hydraulic requirements of the dam are not compromised.

To accomplish this goal, experience with the design of SBC juvenile fish passage facilities at other projects in the region was utilized to develop designs based on the best information currently available. The approach was to develop conceptual designs which meet the most current criteria for fish passage structures and which could be constructed given appropriate final design and financing. As this report is a feasibility level study and not a final design memorandum, the designs were not developed through to the stage of final design. Therefore, the descriptions and drawings presented do not include details required for construction such as member sizing, detailing of equipment requirements, or other detail design features. Hydraulic analysis was limited to calculations of gross flow cross-sectional areas, velocities, screen areas, and estimates of head losses, etc. Detailed analyses of head losses and water surface profiles were not performed, unless noted.

The conceptual design analysis performed for each SBC Type design included, but was not necessarily limited to, the following items:

- description of the interaction between each component and how the design is intended to guide fish and transport them to a desired location downstream
- methods for discharging and controlling the excess channel flow
- ability to maintain flood discharge capability at the spillway
- suggested methods of support for each component while accounting for the stability requirements of the existing dam structures
- discussion of the constructability and construction concerns
- hydraulic issues to consider for additional study and/or modeling
- operation and maintenance concerns including screen cleaning and debris removal
- estimate of the probable construction duration
- estimate of the probable construction cost
- estimate of the anticipated annual operations and maintenance cost.

Many of the issues which must be addressed during the design, construction and operation of the SBC systems presented in this report are typical to most (or all) of the designs. This is especially true for structural, mechanical and maintenance issues. Typically, a number of alternatives for solving a particular problem common to many of the designs were investigated before choosing a design approach. Where applicable, this approach is subsequently applied throughout the entire report. Examples of this are the attachment of large heavy objects to the dams without compromising the stability of the structures; effective methods for keeping the dewatering screens clean; and long-term corrosion protection for permanently submerged objects. Descriptions of the alternatives investigated and design decisions in cases such as these are given in Section 5.1 for the Lower Granite Type 1 design and should be assumed to be applied to all other designs in this report, unless stated otherwise.

4.2 Cost Estimates and Construction Durations

Construction Cost Estimates

Since these are conceptual level designs, developed without a high degree of design detail, the probable construction cost estimates were developed from estimated unit costs derived from the actual construction costs of similar facilities (including the existing Lower Granite prototypes), vendor input for large components, standard industry cost guides [7], and in the case of the ESBS (turbine intake screen) systems actual costs from construction of similar systems at other dams. This method was used since adequate detail is not included in these designs to perform a detailed cost estimate based on exact material quantity and fabrication/installation labor expenses. Separate cost estimates have been prepared for each project within each of the system combinations and are presented in spreadsheet format in the system combination descriptions. A combined total estimate for each system combination is included at the end of each system combination section. The development of the unit costs and an accounting of quantities shown in the estimates are included in Attachment A.

Because fully developed production SBC systems like those presented in this report do not exist, and because these designs are conceptual in nature, a construction contingency of 25 percent has been added to all cost estimates. Additionally, a 15 percent design cost has been included in each estimate as part of the 22.5 percent planning and engineering line item. Other costs associated with the planning and engineering cost include project management and value engineering studies. A construction management cost of 12.5 percent is also added to each cost estimate. Finally, a single line item of $1 million has been added to each system combination total estimate to cover feasibility studies (including, for example, the cost of this study and the SBC Conceptual Design Report done previously).

Given the untested nature of some of these design concepts, a significant level of hydraulic modeling and/or prototyping may be required before final implementation of any of these designs. However, as with the construction costs, adequate detail concerning the actual modeling or prototyping needs cannot be developed at this stage of design to accurately estimate these costs individually for each SBC type. Although adequate funding should exist within the assumed design costs to cover the expenses of some of the smaller modeling requirements, especially where an existing model can be utilized, costs for large extensive modeling and prototyping requirements are not included in these estimates. To assist in future decisions concerning modeling and/or prototyping, recommendations are made in the report concerning areas where hydraulic and prototyping investigations may be warranted.

Operations and Maintenance Costs

Development of annual operations and maintenance costs is similarly constrained by the absence of detail, typical at a conceptual design level. For this reason, O&M costs were estimated based on percentages of construction costs (excluding planning, design, construction management, and the contractor's mobilization and O&P costs). Due to their relatively higher maintenance requirements, O&M costs for mechanical and electrical systems such as gates, screen cleaners, cranes, hoisting equipment, and controls, etc., were assigned an annual cost equal to 6 percent of their construction cost. These costs include the annualized cost of periodic replacement or rehabilitation of components.

Structural elements such as floating channels, internal conduits, removable screen panels, behavioral guidance structures, SESs, etc., were assigned an annual O&M cost equal to 1/2 percent of their construction cost and typically reflect periodic inspection, refurbishing and other maintenance activities. Because the proposed corrosion protection system for large submerged items is a thermal spray system which is expected to exhibit an excellent service life (as much as 50 years), the maintenance of most of the structural steel is anticipated to be primarily an inspection activity to confirm the integrity of the structure. It is assumed that inspection of these items would be performed mostly by divers. A cost of $3,000 per day was assigned to an inspection dive team resulting, for example, in a three-week inspection of underwater components costing an estimated $45,000.

Separate O&M cost estimates have been prepared for each project within each system combination and are presented along with the system combination descriptions in the report. As with the construction cost estimates, individual project O&M cost estimates are totaled at the end of the system combination section to provide an O&M estimate for the combination as a whole. Cost calculations for O&M are presented in Attachment A. O&M costs associated with the operation of the ESBS intake diversion screens, either existing or new, and costs associated with the operation of existing juvenile facilities downstream of the ESBS (including actual transportation costs) are not included. Since these costs are existing system costs it was decided that they should not be included as part of the SBC O&M cost. Review of maintenance records revealed that O&M costs associated with the existing STS diversion systems at Ice Harbor and Lower Monumental were similar to costs associated with the ESBS systems at Little Goose and Lower Granite. Therefore, changing out the existing STS with new ESBS should not result in a significant change in the diversion screen O&M costs at these two projects. Juvenile facilities and transportation costs should be included for a true comparison of O&M costs for each system combination, but are beyond the scope of this report. When assessing an estimate for these costs it should be understood that the different system combinations utilize transportation and existing transportation facilities to varying degrees, and at differing locations. For example, in the case of System Combination 1, which relies most heavily on transportation, it will not be known in advance to what extent transportation facilities will be utilized at each project. If the Type 1 SBC system at Lower Granite is very efficient at collecting fish, a very large percentage of the total number of migrating fish could be removed from inriver migration at this location, resulting in very small (if any) transportation costs at Little Goose or Lower Monumental.

Construction Durations

A similar approach using experience with the development of existing prototype facilities was used in the development of construction duration estimates. Estimated durations are identified in the text of the report along with other construction issues for each design type.

4.3 Hydraulic Modeling Issues

Final development of any of these options, or any combination of the components into a new design, would require some level of hydraulic analyses and modeling. There are a number of specific areas where it is anticipated that model studies would assist in addressing hydraulic design issues. These areas are grouped as follows (Note that the design components referenced in this list are described in detail in Sections 5 through 8):

<u>Forebay and Approach Flow</u>

1. Zone of influence of collector entrances versus collector flows and locations and plant operations
2. BGS alignment, velocities, and loading during normal operations
3. BGS velocities, loading, and movement during spill and load rejection

<u>Turbine Intake</u>

4. SBC impact on turbine performance
5. SBC impact on intake diversion screen (ESBS) hydraulics and potential FGE impact
6. VBS performance and influence of flow rates and turbulence intensities on gate well hydraulics

<u>Surface Bypass Channel</u>

7. Conduit alignments and geometry
8. Primary screen porosity design
9. Secondary screen porosity design
10. Gallery connection hydraulics
11. Emergency bypass mode operations hydraulics for Type 1 SBC
12. Hydraulic loads during normal operation and load rejection

<u>Spillbay Modifications</u>

13. SES design details
14. Removable spillway weir (RSW) design details
15. Elevated ogee design details
16. Spillway gate rating during normal operations and flood passage
17. Downstream conditions for juvenile and adult migration
18. Effectiveness of the existing spillway deflector under new flow conditions

Depending on the site, many of these issues can be addressed using and modifying existing hydraulic models at the Corps Waterways Experiment Station (WES) and the turbine model in Austria. However, additional models may be required to address site specific details. Required models and their suggested modeling scales are listed here:

	Approximate Scale
A. Turbine Model	1:12
B. Single Turbine Intake Model	1:12
C. SBC Model	1:15
D. Spillway Sectional Model	1:20
E. Powerhouse Sectional Model	1:25
F. Forebay Model	1:40
G. Spillway Sectional Model	1:55
H. General Model	1:70

To assist in the planning stages for further development, a matrix relating hydraulic design issues to the various design components and the appropriate modeling tool for resolving each issue is provided in Table 4.1.

4.4 Prototype Studies and Baseline Data Collection Issues

Suggested prototype and baseline data collection studies are identified in this report as the specific design features and issues are discussed. However, detailed study plans with time and cost estimates have not been included. The primary design feature which could benefit from a prototype investigation is dewatering. The engineering issues that could be addressed by prototype dewatering screen tests are:

1. Progressive Velocity Screen Criteria—Hydraulic modeling efforts which have been conducted are showing that design of screens that comply with the progressive velocity criteria is possible. There are, however performance uncertainties including establishing appropriate transport velocities, exposure times, determining fouling characteristics, and generally documenting fish response; which should be evaluated through prototype studies. Exposure time and consequently screen length in the direction of flow is a key parameter. The prototype test facility should represent the full length of the SBC Types 1 and 3 primary screens. It would not be necessary to include the full screen depth. Fish species, life stage, size, and condition; and debris type and concentration are also key parameters that should be correctly represented in the prototype evaluation. As a consequence, conducting the prototype tests at one of the proposed sites would be appropriate.
2. Screen Cleaning—Cleaning technologies for the deep vertical screen panels are largely unproven (with the exception of traveling screen technology), particularly in a strong sweeping velocity field. The proposed cleaning devices should be evaluated on the actual screen material with representative approach and transport velocities, and debris loading. The screen test panels should extend the full proposed depth. Performance features evaluated might include cleaning effectiveness, cleaning head stability in the crossing flow, workability of the drive mechanism, and potential for debris removal at the cleaner. The last feature is important in addressing the cleaner's ability to reduce debris loading in transport conduits and at the juvenile facilities downstream. Influence of bar screen orientation (vertical or horizontal bars) on fouling and cleaning could also be considered. Because of the importance of correctly representing debris type and concentration, these tests would best be conducted at one of the proposed sites.
3. Debris Characterization—Screen fouling and cleaning is potentially the single largest maintenance issue associated with dewatering. Fouling and cleaning characteristics are strongly dependent on debris type and concentration. Both to select appropriate screen material and cleaner designs, and to allow extension of the prototype results to other sites, debris types and concentrations should be well documented. Prototype studies would be most informative if performed at the site with the highest potential for debris accumulation. This would likely be Lower Granite, since it is the most upstream site, however, Lower Monumental has been reported to have unique debris problems associated with wheat straw entering the system from the Palouse and Tucannon Rivers. The influences of the trash racks on the screen debris loading should also be estimated.

These studies might best be accommodated in a prototype of a complete primary screen module.

Table 4.1. Hydraulic Modeling Issues

SBC Type	Modeling Requirements: (N) = New Model, (E) = Existing Model, (+) = Model required if installed in bay with deflector																	
	1*	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Type 1																		
Lower Granite	F** (E)			A(E), B(E)	B(E)		C(N)	C(N)	C(N)	C(N)	C(N)	E(E)	D(N), F(E)			D(N), F(E)	H(E)	D(N), G(E)
Little Goose	F(N)			A(E), B(N)	B(N)		C(N)	C(N)	C(N)	C(N)	C(N)	E(E)	D(N), F(N)			D(N), F(N)	H(N)	
Lower Monumental	F(N)			A(E), B(N)	B(N)	B(N)	C(N)	C(N)	C(N)	C(N)	C(N)	E(N)	D(N), F(N)			D(N), F(N)	H(N)	
Type 2																		
Lower Granite	F(E)			A(E), B(E)	B(E)		C(N)					E(E)	D(N), F(E)		D(N), F(E)	D(N), F(E)	H(E)	D(N), G(E)
Little Goose	F(N)			A(E), B(N)	B(N)		C(N)					E(E)	D(N), F(N)		D(N), F(N)	D(N), F(N)	H(N)	
Lower Monumental	F(N)			A(E), B(N)	B(N)	B(N)	C(N)					E(N)	D(N), F(N)		D(N), F(N)	D(N), F(N)	H(N)	
Ice Harbor	F(N)			A(N), B(N)	B(N)	B(N)	C(N)					E(N)	D(N), F(N)		D(N), F(N)	D(N), F(N)	H(E)	+D(N), G(E)
Type 3																		
Lower Granite	F(E)	F(E)	F(E)	A(E), B(E)	B(E)		C(N)	C(N)		C(N)		E(E)	D(N), F(E)		D(N), F(E)	D(N), F(E)	H(E)	D(N), G(E)
Lower Monumental	F(N)	F(N)	F(N)	A(E), B(N)	B(N)	B(N)	C(N)	C(N)		C(N)		E(N)	D(N), F(N)		D(N), F(N)	D(N), F(N)	H(N)	
Type 4																		
Ice Harbor	F(N)	F(N)	F(N)			B(N)								D(N)			H(E)	+D(N), G(E)
New ESBS																		
Lower Monumental						B(N)												
Ice Harbor						B(N)												

* MODELING ISSUES:
1. Zone of influence of collector entrances versus collector flows and locations and plant operations
2. BGS alignment, velocities, and loading during normal operations
3. BGS velocities, loading, and movement during spill and load rejection
4. SBC impact on turbine performance
5. SBC impact on intake diversion screen (ESBS) hydraulics and potential FGE impact
6. VBS performance and influence of flow rates and turbulence intensities on gate well hydraulics
7. Conduit alignments and geometry
8. Primary screen porosity design
9. Secondary screen porosity design
10. Gallery connection hydraulics
11. Emergency Bypass mode operations hydraulics for Type 1 SBC
12. Hydraulic loads during normal operation and load rejection
13. SES design details
14. RSW design details
15. Elevated ogee design details
16. Spillway gate rating during normal operations and flood passage
17. Downstream conditions for juvenile and adult migration
18. Effectiveness of the existing spillway deflector under new flow conditions

** MODELS:		Scale
A.	Turbine Model	1:12
B.	Single Turbine Intake Model	1:12
C.	SBC Model	1:15
D.	Spillway Sectional Model	1:20
E.	Powerhouse Sectional Model	1:25
F.	Forebay Model	1:40
G.	Spillway Sectional Model	1:55
H.	General Model	1:70

5. System Combination 1—Maximizing Effectiveness of Fish Transportation

The goal of System Combination 1 is to maximize the number of fish collected and delivered to the existing transportation facilities located at each project. This would be accomplished by constructing a full length powerhouse SBC channel at each of the three upstream projects (Lower Granite, Little Goose, and Lower Monumental). This design is referred to as SBC Type 1. The channels would contain dewatering screens to concentrate the fish in a small enough flow so that they could be delivered into the existing juvenile bypass channels inside each dam. The SBC channels would be used in conjunction with ESBS located in the turbine intakes. Fish diverted by the ESBS would also be delivered into the existing juvenile bypass channels. Ultimately, fish collected by both bypass structures would be combined and delivered to the transportation facilities, and either trucked or barged downstream. The number of fish continuing downstream by inriver passage through the projects (either through the turbines or spillways) would be minimized, and would be significantly reduced at each consecutive project.

The upper two projects (Lower Granite and Little Goose) currently have ESBS systems installed in the turbine intakes. These would continue to be used in System Combination 1. However, the intakes at Lower Monumental are currently outfitted with STS. These would be removed and replaced with ESBS to increase the screen diversion efficiency, and further reduce the number of fish passing through the turbines.

At Ice Harbor the turbine intakes are also currently outfitted with an STS system. As at Lower Monumental, these would be removed and replaced with an ESBS system to increase the diversion efficiency of the screening system. However, no SBC channel would be installed at Ice Harbor. If the combination of the SBC channels and the ESBS diversion systems function as anticipated at the upper three projects, there should be so few freely migrating fish left in the river at Ice Harbor that construction of an SBC system and a transportation facility would not appear to be justified.

Detailed descriptions of the specific bypass and collection facilities at each project which make up System Combination 1 are presented in the following text. In some cases issues or designs described for the facilities in System Combination 1 are the same for other designs throughout this report. In these cases, the discussions in this section will be referenced in later sections, as applicable.

5.1 Lower Granite: Full Powerhouse SBC (with Existing ESBS) – SBC Type 1

The design goal of SBC Type 1 is to provide a surface collector channel across the face of the entire powerhouse designed to attract fish away from the turbine intakes and deliver them to the existing juvenile fish bypass gallery inside the dam where they would be transported downstream to the juvenile facilities. The concept is based on the bypass system at Wells Dam on the mid-Columbia River, and on prototype testing performed at Lower Granite since 1996. The design allows for the channel to be used in conjunction with the existing ESBS intake diversion screens. Adequate dewatering of the fish-bearing transport flow is provided in the channel so that the fish entering the SBC can be delivered to the existing juvenile fish gallery inside the dam, where they would be combined with the fish diverted by the intake diversion screens. The gallery is designed to deliver the fish to the fish-handling and transport/release facilities downstream. In addition, in case there is a problem with the dewatering portion of the channel, the design will allow for emergency bypass of the fish collected by the channel directly to the tailrace via a Spillbay.

The application of the SBC Type 1 design to Lower Granite includes a floating collector channel which spans across the entire upstream face of the powerhouse intake structure. Plans and details of this design are provided on Plates 1.1.1 through 1.1.6, in Section 5.6. The channel extends from the north end of the central non-overflow section (south edge of Spillbay 1) to a location about 16.8 meters (55 feet) south of the erection bay (see Plate 1.1.2). This southern portion of the channel accommodates the secondary dewatering screen section. At this position, the southern end of the channel extends in front of the existing adult fish ladder exit. At Lower Granite there is an adult fish ladder exit chute that is used when the forebay is below elevation 223.4 meters (733 feet). During the final design of a Type 1 SBC, a review of this chute will need to be performed to determine if the chute needs to be modified or replaced to accommodate the channel and its support structure bracing. During operation within the normal operating pool range, it is felt that the channel is far enough upstream of the fish ladder exit as not to present an obstacle to the passage of adult fish upstream into the forebay. Additionally, this section of channel is only 10.7 meters (35 feet) deep, or half as deep as the main channel section, which will further minimize any potential blockage problem.

Three vertical entrances into the channel are located along the upstream wall of the channel. The entrances are located near the unit joints between Units 1 and 2, 3 and 4, and 5 and 6. In this text, each entrance is identified by the unit numbers near which it is located (e.g., Entrance 1/2 is the entrance near the joint between Units 1 and 2). Flow into each entrance is 56.6 m^3/s (2,000 cfs) for a total combined SBC attraction flow of 170 m^3/s (6,000 cfs). Each entrance is outfitted with a full-height semi-circular trash rack with a vertical bar spacing of 0.305 meter (1.0 foot). Although the semi-circular trash rack may be more complicated to clean than a flat rack, the rounded rack is assumed to have advantages from a fish behavior perspective. These issues are discussed in Sections 5.1.1 and 5.1.3.

Fish enter the channel through one of the three entrances, each of which are 4.88 meters (16 feet) wide. The floor of the channel coincides with the bottom of the entrances located 21.3 meters (70 feet) below the forebay water surface. Each entrance is associated with a transport conduit which includes a primary dewatering section. The primary dewatering is accomplished independently for the flow entering each of the three entrances. After passing through the primary dewatering screen section, the remaining flow in the three individual conduits is progressively combined into a single conduit leading to a common secondary dewatering screen section. The secondary screening reduces the combined flow, which contains the fish from all three entrances, to a level which can be added to the existing juvenile gallery, approximately 0.85 m^3/s (30 cfs).

Bulkhead panels are provided which can be slid down into the flow path both upstream and downstream of each of the three primary dewatering sections to shut off the flow to the primary screens. Emergency bypass doors are located in each conduit upstream of the bulkhead guides to allow for direct bypass of fish and flow to the tailrace when the bulkheads are installed. This approach allows for the flow through a single entrance to be bypassed directly to the tailrace in the event the screening section requires maintenance without impacting the hydraulics of the flow through the remaining entrances. In addition, this design offers increased operational flexibility in that the flow through an individual conduit can be shut off during periods of low river flow when all units are not operating. In the event that the existing juvenile facilities require maintenance or downtime, the flow through all three entrances can be bypassed directly to the tailrace by placing the upstream bulkheads in all three conduits and opening the emergency bypass doors. Specific details concerning the hydraulics and dimensional layout of the SBC Type 1 system, are defined in Section 5.1.1.

After all dewatering is accomplished, the remaining transport flow is delivered with the fish to a location at the south non-overflow section of the dam and above the existing south auxiliary water port of the juvenile fish gallery system. The transport conduit in the channel is outfitted with a tilting weir control structure so that the final transport flow can be maintained at 0.85 m^3/s (30 cfs). This adjustable weir would also be capable of rising to an elevation above the water surface to facilitate its use as a shut-off gate for the conduit downstream of the dewatering sections. Flow over the control weir spills into a stationary channel attached to the dam which delivers the flow into the juvenile gallery inside the dam (see Plate 1.1.4). An opening will be excavated above the existing auxiliary water port in the erection bay wall to accommodate the channel and to allow the 0.85 m^3/s (30 cfs) transport flow to pass as an open channel flow into the existing downwell portion of the gallery. This opening will also house a surface skimming cleaner to remove any floating debris which accumulates in the downwell area. Once in the juvenile fish gallery, the fish are transported downstream via existing fish piping to the fish handling facilities for eventual transport or release into the tailrace. The existing (modified) auxiliary water port below the opening provides make-up water to the gallery. A new slide gate is installed over the existing port to replace the control gate which will be removed with the existing caisson.

The screened discharge from the four channel dewatering screen sections (three primary and one secondary) passes through the screens into the main portion of the floating channel, which forms a common discharge channel. This screened flow travels north to a SES attached to the upstream face of the Spillbay 1 piers (see Plate 1.1.5). The SES forms a well upstream of Spillbay 1 so that the Tainter gate can be used to regulate and pass the SBC screened flow. The SES is a concrete filled steel shell forming two walls and a floor bolted to the upstream face of Spillbay 1. The upstream end of the structure is closed off by means of removable steel stop logs. This design allows for removal of the stop logs so that the full spillway flood discharge capability of Spillbay 1 can be maintained. With the maximum flood of record being less than half the combined discharge capacity of eight spillbays, it is anticipated that this procedure would be required extremely infrequently. However, if this were to be necessary, one additional step would be to install a closure panel over the opening between the channel and the SES to hydraulically separate the two structures. This would be required to prevent the large spill flow passing through the SES from creating a dangerously large head differential between the forebay and the inside of the channel.

The presence of the SES at Spillbay 1, and the attachment of the channel to the SES, will necessitate the relocation of the downstream end of the existing trash shear boom. This is depicted on Plate 1.1.1. Since the trash boom will then be located directly upstream of some of the spillbays, the design of the boom and anchorage system will need to be reviewed and possibly modified to assure adequate strength and flexibility for this new position in the event of a design flood discharge. It may be necessary to remove the section of the boom upstream from the spillway prior to major spill events.

Because the channel is floating and the SES is stationary, the connection between these two components will need to allow for relative vertical motion between the structures. This is also true of the connection between the fish transport conduit and the short stationary channel attached above the auxiliary water port at the south end of the channel.

The turbine intakes at Lower Granite are currently outfitted with ESBS. These intake diversion screens will be used in conjunction with the SBC to divert and collect fish which may pass below the SBC channel and into the turbine intakes. The ESBS are 12.2 meters (40 feet) long and located in the upper portion of the turbine intake at an angle of 55 degrees up from vertical. In this way, the screens occupy the upper two thirds of the turbine intake at a plane through the upstream tip of the screen (see Plate 1.1.3). The upstream face of the screen consists of fixed bar screen material, while the downstream face has porosity control plates to control the flow rates and velocities along the face and through the screen. The screens divert fish entering the upper portion of the turbine intake into the gatewell slot, where they follow the flow up the slot and into bypass orifices. The orifices deposit the fish from the gatewells into the juvenile gallery, where they will be combined with the fish collected by the SBC. For the purposes of this report, at projects where ESBS systems are currently in place, like Lower Granite, only O&M related issues related to the systems will be addressed.

During testing of the prototype SBC channel at Lower Granite there were indications that migrating fish in the forebay upstream of the spillway were being attracted under the north end of the channel and into the Unit 6 intake. Therefore, as part of this design a cutoff wall is included below the channel at the north end of the powerhouse to preclude fish movement under this end of the channel directly from the spillway area into the Unit 6 intake. The wall is a two-panel telescoping design allowing for vertical movement of the floating channel (see Plates 3.1.3 and 3.1.4). The upper panel is attached and braced to the under side of the channel. This panel would move up and down with the floating channel. The lower panel is attached at its base to rock-bolted concrete footings at the bottom of the forebay. The top of the lower panel is laterally supported by the upper panel, but is free to slide up and down relative to the upper panel (much like the connection of an extension ladder). Structural issues related to the cutoff wall are presented in Section 5.1.2.

5.1.1 Hydraulics

Floating Structure Issues

The hydraulic advantages of the SBC channel being a floating structure are that the invert elevations of the flow conduits and controls, such as tilting weirs, will automatically adjust with pool elevation. As a result, the areas of screens, flow conduit cross sections, and the flows and velocities that they define, will remain constant as pool elevation varies. So, once the facility is started and the desired operating conditions established, the controls will not have to be adjusted in response to pool elevation changes.

The hydraulic disadvantages of the floating structure include the complexity of the connections between the floating channel and the fixed dam structures, and the need to provide adjustable flow control to maintain hydraulic gradeline relative to the floating channel invert at the connections. This will occur at two locations:

- the south end of the floating channel, where the fish transport conduit connects to the dam through the new opening in the forebay wall, as shown on Plates 1.1.2 and 1.1.4
- the north end of the channel, where the floating channel connects to the fixed SES at Spillbay 1, as shown on Plates 1.1.1 and 1.1.5.

The fish transport conduit passes through the float on the downstream side of the channel and attaches to guides on the fixed steel caisson, which forms an entrance channel into the existing fish gallery. The guides allow the floating channel to move vertically relative to the fixed caisson. The water surface level in the caisson would be controlled from downstream at the existing gallery flow control. This movable connection is sealed against leakage with rubber seals in the same manner as a movable gate would be. A small amount of leakage would be anticipated at these seals and is considered to be acceptable.

The connection of the north end of the channel to Spillbay 1 is made by attaching the channel to guides on the SES. The SES is designed to allow Spillbay 1 to function either as a control for the SBC channel or in its full capacity for flood discharge. Hydraulic control of the channel flow will be effected by manipulation of the radial Tainter gate. As with the connection at the south end of the channel, this connection could be sealed against leakage, however, small leakage into the SES would not have significant impact on the channel flow and could be tolerated. The design of the SES and the use of the Tainter gate for channel flow control are described later in this section.

An additional hydraulic concern with the floating channel is the fact that at the minimum flood control pool of 221 meters (724 feet) the bottom of the channel will nominally be at elevation 199 meters (654 feet). At this elevation the channel will block slightly more than 25 percent of the turbine intake openings. Field tests and/or modeling studies at Rocky Reach, The Dalles and Wanapum Dams, all of which have similar large vertical Kaplan turbine units, have shown that this level of blockage should not result in significant power loss or damage to the turbines. Moreover, this condition is not considered to be a normal operating condition for the project and thus is of diminished concern in the overall operations of the plant. However, prior to constructing an SBC channel as described here it would be prudent to perform model and field studies specific to Lower Granite to confirm that this level of blockage would not represent a problem. This concern is maximized at Lower Granite in that it is the only one of the four projects at which the forebay pool could be drawn down (below the minimum operating pool elevation) for flood control. Although SBC blockage of the turbine intakes is less pronounced at the other projects, potential influences on turbine performance should be further evaluated in support of design development.

Collector Entrances

Each of the three collector entrances is 21.3 meters (70 feet) deep by 4.88 meters (16 feet) wide. The attraction flow entering each entrance is 56.6 m^3/s (2,000 cfs) at a velocity of 0.55 m/s (1.8 ft/s). A semi-circular trash rack is provided at each entrance to preclude large entrained debris from entering the channel where it could potentially do damage. The trash rack has a radius of 6.10 meters (20 feet) and is centered in front of the entrance. Vertical bars are spaced at 0.305 meter (1.0 foot) on center. A semi-circular rack was used, as opposed to a flat rack, to minimize the approach velocity at the location of the rack and reduce hydraulic effects of the rack bars on the flow. Experience with trash racks and louver systems has shown that if a series of bars or slats placed in a flow path create a detectable hydraulic disturbance then fish may tend to avoid the area. With the rack bars located a considerable distance upstream of the entrance, this disturbance should be minimized. Below the channel flotation cells there are solid plate walls extending back at about 45 degrees from the two ends of the trash rack to the outside of the channel wall (see Plate 1.1.4). These are included to seal off this area and to lead fish which might be traveling along the wall toward the trash rack. The area at the bottom of the trash rack could be either open or closed. If the area is left open there would be potential for large debris to pass up under the trash rack and into the channel where it would need to be removed, however, it is anticipated that this would be a somewhat rare occurrence. Closing off this area with a solid plate would prevent this problem but would also preclude flow up through this route which could eliminate one means of attracting some of the deeper fish up into the SBC. A final alternative might be to close the opening with a trash rack at an adverse angle, sloping away from the structure with increasing elevation. It would not be possible to rake this rack. However, when the entrance is not operating and no flow is being drawn up through the rack, debris will tend to drift off of it. This would be a decision for final design.

Immediately downstream of each entrance, the flow passes through approximately a 90-degree bend including a centerline guide wall which helps maintain a uniform flow distribution. Use of the guide wall yields centerline radius to conduit width ratios of about 2 and 3 for each half of the conduit through the bend. The conduit will remain constant depth, but walls of the conduit will converge to a 2.89-meter (9.5-foot)-width to accelerate flow to 0.92 m/s (3.0 ft/s). The acceleration combined with the low Froude Number (0.10) will prevent flow separations (potential fish holding areas) from forming at the inside walls of the conduit bend.

During emergency operations, fish can be bypassed directly into the flow behind the dewatering screens to Spillbay 1 in case of screen plugging or other malfunctions. Gates for this purpose are provided in the approach conduit walls positioned immediately upstream of the dewatering screen as shown on Plate 1.1.2. The average velocity through these doors would be about 1.8 m/s (6.0 ft/s) when they are in the emergency bypass mode. The emergency doors are controlled with slide gates to provide an added level of control over the flow rate. Since the head differential across the doors will control the velocity, adjustment of the gates will control the total open area, and therefore the flow rate, to prevent the operation of the emergency doors at one entrance from “robbing” flow from the other entrances which might still be operating in the standard screening mode. It is anticipated that individual stacks of four slide gates would be connected to a single operator. Guides are provided to install bulkheads both upstream and downstream of the primary dewatering screens to prevent fish and flow from entering the primary screen section of conduit when in the bypass mode.

The size of the channel relative to the channel flow rates is large resulting in low velocities through most of the emergency bypass system. Prior to the flow passing under the Tainter gate, the largest velocity would be approximately 1.22 m/s (4.0 ft/s) occurring in two locations. These locations would be where the flow passes between the back wall and the Entrance 5/6 conduit bend and again where the flow passes through the opening between the channel and the SES. Although the hydraulic conditions in the main channel environment may allow for numerous locations which could represent potential holding and/or delay areas, this is only an emergency bypass operating condition with infrequent or unlikely usage. Therefore, for the purposes of this report the designs of the SBC channels were focused on maximizing the favorable hydraulic conditions of the normal operating scenario. If fish passage directly to the tailrace via the emergency bypass system is foreseen to be a more common operating scenario, a number of modifications could be made to the design to increase the effectiveness of this system. These would include use of internal training walls or screens within the channel to move the flow and fish more directly to the SES and preclude fish from entering dead zones within the channel, and relocation of some or all of the emergency bypass doors to more effectively move the fish rapidly to the SES. These modifications would add cost or in some instances would necessitate changes to the internal fish conduit components which could diminish the hydraulic effectiveness of the normal operating condition. Decisions to include additions or modifications such as these would need to be made based on a cost-benefit analysis and a weighing of the likelihood of “emergency” bypass operation.

Control of Screened Flow

Control of flow through the dewatering screens may be separated into two distinct issues:

- establishing a uniform distribution of flow and velocity through an individual screen section
- controlling the flow rates through different screen sections.

Uniform distribution of flow through a screen may be achieved by any of the following methods:

- Varying the porosity of the screen over its area to compensate for small spatial variations in the head differential available to drive flow through the screen. This approach would be required in designs where the driving mechanism for the flow is only capable of producing relatively small head differentials, such as a turbine driven venturi. Disadvantages of this type of design are its susceptibility to velocity hot spots and the potential for significant variations in the flow rate in response to temporal variations in the driving head differential.

- Controlling the head differential by compartmentalizing the area downstream from the screen into small sub areas, each with its own discharge control, such as a weir or control gate. This type of design offers greater control over the flow distribution through the screen, but involves greater cost and control maintenance complexity. It also requires a greater head differential to drive flow through both the screen and the control device.

- Uniformly reducing the effective porosity of the screen to increase its loss coefficient so small differences in the driving head over the screen area will not noticeably affect the flow distribution. This method of flow control offers the most maintenance free design for controlling the distribution of velocity across the screen face. However, it requires a relatively large design head differential so that the inevitable small variations in differential are insignificant by comparison.

Since the spillway is capable of providing large driving head differentials, the last strategy can be used. This has the advantage of simplicity in control (no adjustments required during operation), fabrication (uniform screen porosity), and maintenance (screen panels are interchangeable). The effective porosity reduction can be achieved by using a higher porosity upstream screen face (40 or more percent) and sandwiching the screen support framework between this upstream plate and a low porosity downstream plate. The low porosity plate would be designed to control the screen flow and approach velocity with a driving head on the order of 0.46 meter (1.5 feet), which should ensure reasonably uniform distribution even in the presence of small spatial or temporal variations in the head differential.

Three materials are typically used for dewatering screens in this type of application. These are perforated plate, bar screen (profile bar or wedge wire), and wire mesh. It is proposed that for this application the upstream screen surface be stainless steel bar screen. While higher in initial cost, bar screen has a number of advantages for this application. It is preferred by agencies in applications where fish contact is possible. Bar screen material is compatible with brush-type cleaning systems. Experience at other dewatering facilities has shown that perforated plate panels with relatively high porosity and long structural spans tend to vibrate when exposed to the types of hydraulic conditions being proposed. Finally, assuming the more expensive material is a conservative approach in a conceptual evaluation to reduce the potential for costs to rise during final design.

The hydraulic and debris handling performance of bar screen will vary depending on whether the bars are oriented vertically or horizontally. Depending on the site-specific debris characteristics, fouling may be substantially reduced, or cleaning improved, by orienting the bars one way or the other. Preliminary indications from application of bar screen by others indicate that orientation of the bars perpendicular to the flow direction may reduce the potential for fouling. Final selection of the bar orientation should be achieved through prototype testing with appropriate debris loading. Such testing would also define hydraulic characteristics of the screen and assist in evaluation and development of cleaning devices.

The downstream screen face is proposed to be a heavy gauge perforated plate. Although the porosity of the perforated plate would be less, the actual opening size would be larger than the openings on the upstream screen panel so that small debris passing through the upstream screen face would pass readily through the perforated plate on the downstream side.

Thus, in a complete screen system, this double-sided screen design consists of individual rectangular panels with bar screen material on the upstream side and perforated plate on the downstream side. The panels stack in guides as required to form discrete screen stacks located side-by-side along one wall of the dewatering section. Three different open area percentages would be required on the downstream sides of the panels to create the three dewatering screen approach velocities (see Section 3.3.1) while operating under a common differential driving head. Screen cleaning is accomplished with vertically operating brush bar cleaners. The size of the panels would likely be based on a practical limit for effective length of the cleaning equipment and the capacity of the hoisting equipment available at the site. Screen cleaning and hoisting issues are discussed in Section 5.1.3. The screen panel stacks would be removable to facilitate more extensive infrequent cleaning which may be required. This would likely only be needed about once a year and could be done during the months the system is not in use.

Control of the total combined flow rate passing through the dewatering sections is regulated by the size of the Tainter gate opening at Spillbay 1. How this flow distributes itself between the six screen sections is defined by the effective porosity of the screen panels at each section. The design driving head differential at each screen section, and the corresponding porosity required, would be determined through hydraulic modeling. Once these porosities are established, the total screened flow defined by the Tainter gate opening should distribute evenly between the dewatering sections so long as the screens are kept relatively clean. In the case that one or more of the entrances is not operating, the Tainter gate will regulate the correct total flow through the remaining entrance(s). The porosity control on the individual screens will still maintain the correct relative differential across the screens for the operating collector entrance(s), within a few percent. The remaining transport flow after dewatering is held constant by tilting weirs located in each conduit.

Head losses through the main channel body transporting flow to the SES will be a maximum of 0.31 meter to 0.46 meter (1 foot to 1.5 feet). This combined with screen and other miscellaneous system losses will result in an operating level in the SES upstream from the Spillbay 1 Tainter gate on the order of 1.0 meter (3.3 feet) lower than the pool level. To establish the desired channel flow would require that the Tainter gate be open approximately 0.91 meter (3.0 feet) when the forebay level is within the normal operating pool range.

Since the bypass system would be operated throughout the migration season, regardless of tailwater conditions or levels, the effects downstream from spilling up to 170 m^3/s (6,000 cfs) through Spillbay 1 at a variety of tailwater conditions should be investigated. These effects would include total dissolved gas (TDG) and influences on adult fish attraction either toward or away from the fish ladder entrances. Some modifications to the existing spillway deflector may be warranted, however, for the purposes of cost estimating in this report it is assumed that the existing deflector would be adequate. Further, it is anticipated that any local TDG effects from spilling through a single spillbay would be diluted downstream by the powerhouse flow. The geometry of the deflector and resulting tailrace hydraulics should be investigated in a hydraulic model to determine the need for modification to address TDG issues. The tailrace flow pattern should also be investigated in a model to ensure satisfactory conditions for adult migration. This would be true for any SBC designs that may impact the current spill release patterns.

Dewatering Screen Sections

To facilitate the simultaneous operation of the SBC channel and the ESBS intake diversion system, which both pass fish into the existing juvenile gallery, the fish transport flow from the SBC must be reduced from 170 m^3/s (6,000 cfs) to 0.85 m^3/s (30 cfs) before it is released into the gallery. This is accomplished in a two-stage dewatering process. The primary dewatering is accomplished individually for each of the three entrance conduits, reducing the 56.6 m^3/s (2,000 cfs) to 1.81 m^3/s (64 cfs), resulting in a combined flow from the three entrances of 5.44 m^3/s (192 cfs). This combined flow is then further reduced in a common secondary dewatering section to the required 0.85 m^3/s (30 cfs).

The primary screens were designed using the screening criteria defined in Section 3.3.1. These include screen approach velocity components which vary from 0.36 m/s (1.2 ft/s) in the upstream third of the screen length, to 0.24 m/s (0.8 ft/s) in the middle third, to the conventional fry criterion of 0.12 m/s (0.4 ft/s) in the downstream third. The screen areas were sized assuming that approximately 75 percent of the gross screen area would be effective (the rest being blocked by structural supports, screen panel framing, and vertical brush cleaning equipment).

In the previous SBC Conceptual Design Study for Lower Granite Dam, several layouts of a dual-wall primary screen section in a “V” configuration were tried. These required using the steepest possible floor slope of 45 degrees to bring the floor up from the 21.3 meters (70 feet) depth. The velocity criteria resulted in a screen that was short enough that, even with a steep floor slope, the conduit cross section at the end of the screen was a narrow “keyhole,” 0.61 meter (2 feet) wide by 12.2 meters (40 feet) deep. With this cross-sectional area the transport velocity falls well below a reasonable minimum of 0.61 m/s (2.0 ft/s), resulting in significant deceleration in the conduit. In short, all of the layouts resulted in a conduit that was excessively deep and narrow and transport velocities that were too low. Therefore, a single-wall screen section was developed, as shown on Plate 1.1.2. This allowed all primary screening to be performed in a single section contained within the length of two powerhouse units.

Each primary dewatering screen section is made up of three areas with different approach velocities, as shown on Plate 1.1.2. This layout is the same for all three primary dewatering screen sections. The first area consists of two stacks of 5.33-meter (17.5-foot)-wide screen panels, one each with depths of 16.0 meters and 10.7 meters (52.5 feet and 35.0 feet). This is followed by two more 5.33-meter (17.5-foot)-wide stacks, one each with depths of 7.77 meters and 4.88 meters (25.5 feet and 16 feet). The final area includes two 7.32-meter (24-foot)-wide screen panel stacks, one each with depths of 3.35 meters and 1.83 meters (11.0 feet and 6.0 feet). This is a conceptual arrangement and represents one of many possible layouts. Panel widths and depths would likely be optimized in the final design to best accommodate the screen cleaning equipment. The 0.36-m/s (1.2-ft/s) criterion is applied over the upstream two stacks, the 0.24-m/s (0.8-ft/s) criterion over the middle two stacks and the 0.12 m/s (0.4 ft/s) over the downstream two stacks. This results in the lower velocities being applied more conservatively to greater than one third of the screen length (40.7 percent). The gross and effective net screen areas are 248 m^2 and 186 m^2 (2,665 ft^2 and 1,999 ft^2), respectively. The conduit width varies linearly from 2.89 meters to 1.52 meters (9.5 feet to 5.0 feet) over the upstream two stacks, 1.52 meters to 0.91 meter (5.0 feet to 3.0 feet) over the middle two stacks, and 0.91 meter to 0.61 meter (3.0 feet to 2.0 feet) over the downstream two stacks. The screen face alignment is straight with the variation in conduit width and rate of convergence being achieved through changes in alignment of the opposite wall. The floor rises through this section with the conduit depth reducing to 2.44 meters (8.0 feet) at the end of the primary screens. The transport (or sweeping) velocity through the primary screen section increases from 0.91 m/s (3.0 ft/s) at the upstream end to 1.22 m/s (4.0 ft/s) at the downstream end. This will result in a transit time past the screen of about

33 seconds for fish moving at the transport velocity. Through the narrowest portion of the screen transport conduit, where the fish are more concentrated, the fish are exposed to the more conservative fry criterion screen approach velocity component of 0.12 m/s (0.4 ft/s).

Downstream of each primary screen section the 1.81-m^3/s (64-cfs) fish transport flow passes through a 0.61 meter (2.0 feet) wide by a 2.4-meter (8.0-foot)-deep open channel transport conduit. Transport velocities through the conduits are sustained at 1.2 m/s (4.0 ft/s). Maintenance of the 1.2-m/s (4.0-ft/s) velocity allows the 2.4-meter (8.0-foot)-deep section to be sustained to the secondary dewatering section, thus minimizing fish exposure to variations in the flow section and flow velocity.

Low tilting weirs are included in the transport conduits to allow balancing of the discharge contribution from each primary screen. Balancing is required in that the length of the transport conduits from each primary screen is substantially different. Additionally, the weirs could be operated to generate fish capture sections. A drop of 160 millimeters (0.53 foot) would provide a trapping velocity of 2.1 m/s (6.9 ft/s) at the weir for Entrance 5/6. Corresponding drops over the succeeding weirs for Entrances 3/4 and 1/2 would be 230 millimeters (0.75 foot) and 251 millimeters (0.82 foot), respectively. For this operation, critical flow with an undular water surface would develop at and below both the Entrance 3/4 and Entrance 1/2 weirs.

As an alternative, if minimizing head loss through the conduits was required, tilting weirs could be limited to the transport conduits from Entrances 3/4 and 1/2 only. With this configuration, the approximate drop over the tilting weirs would be 70 millimeters (0.23 foot) and 91 millimeters (0.30 foot), respectively. The weirs would be fully submerged with adequate control achieved while maintaining subcritical flow. As a consequence, hydraulic jumps would not occur. However, with only two weirs there would be somewhat less control over the system flow conditions.

The bypass conduits are realigned and merged in such a manner that flow disruption is minimized. Upstream of where the conduits merge, centerline conduit bend radii in most cases were held to at least ten conduit widths. The dividing wall between the merged conduits is sustained well downstream of the parallel alignment point to supply flow guidance and stabilization. Merged conduits were held at the 2.4-meter (8.0 feet) depth and merged velocities sustained at 1.2 m/s (4.0 ft/s). Ultimately, the merged conduit has a width of 1.8 meters (6.0 feet) at the entrance to the secondary screening section.

To minimize secondary screen length, a dual wall “V” configured layout was used. The developed screen walls on either side of the section are each 15.2 meters (50.0 feet) long. The transport velocity of 1.2 m/s (4.0 ft/s) is sustained through the dewatering section as the channel converges to a width of 0.612 meter (2.0 feet) and depth of 1.14 meters (3.75 feet). In that fish are concentrated as they pass through the secondary section, screens are sized based on the NMFS fry approach velocity criteria of 0.12 m/s (0.4 ft/s). Effective screen area was evaluated as 75 percent of the gross face area. Each wall of the secondary screen is comprised of five 3.0-meter (10.0-foot)-wide screen stacks (Plate 1.1.2) with progressively decreasing depths of 2.2 meters, 1.9 meters, 1.7 meters, 1.4 meters, and 1.1 meters (7.15 feet, 6.30 feet, 5.45 feet, 4.60 feet, and 3.73 feet). Both of the screen walls and the floor converge linearly through the dewatering section.

Variable flow control for the secondary dewatering screens may be required to compensate for reduced flow rates when not all entrances are in operation. Control may be provided by installing solid plates in slots downstream from the dewatering screen panels for achieving necessary closure (blockage) of the screen panel openings. Selected panels may be installed, reducing effective screen area and maintaining the design head difference and flow distribution. Alternately, a gated porosity control structure could be installed around the entire secondary dewatering section allowing the full section to be utilized at a lower screen velocity. In either case, bulkheads must be provided to block the conduit at either end of a non-operating primary dewatering section to prevent flow from the entrance or back flow from the other entrances from entering the section.

Fish Transport Conduit

Downstream from the last stack of secondary dewatering screens the conduit floor continues to rise from 1.14 meters (3.75 feet) to 0.914 meter (3.0 feet) deep over a length of 3.05 meters (10 feet). This results in a velocity increase to 1.52 m/s (5.0 ft/s). After this point the cross section remains constant, 0.914 meter (3.0 feet) deep by 0.61 meter (2.0 feet) wide. The floor of this conduit would be sloped mildly downward (approximately 1:400) to maintain a constant velocity of 1.52 m/s (5.0 ft/s). All bend centerline radius to channel width ratios equal or exceed 5. Flow and water level in the conduit are controlled by a tilting weir located at the downstream end. Total headloss from the forebay to the tilting weir will be less than 0.3 meter (1.0 foot). The tilting weir consists of a vertical weir with a hinged sloping plate attached to the upstream side. Along the hinged sloping plate, velocity increases to critical depth and velocity, 0.582 meter and 2.39 m/s (1.91 feet and 7.85 ft/s) near the crest of the weir. Although the slope of the tilting plate would vary slightly with the height of the weir, the slope would always be less than 45 degrees up from horizontal.

After passing over the weir, the flow spills into a receiving pool and channel created by a caisson attached to the dam face above the location of the existing auxiliary water port into the juvenile fish gallery. Since the control weir is integral with the floating channel it floats up and down with the structure and should not need to be adjusted in response to varying pool levels. The water level within the caisson would be hydraulically controlled by the conditions in the existing fish gallery. This control is based on the water level head at the inlet to the existing downwell. During current operation of the fish gallery the water level at the downwell is about elevation 221.9 meters (728 feet). It is anticipated that the SBC system would be run with the water in the caisson at about this same level, resulting in drop heights varying between 1.2 meters (4 feet) and 2.7 meters (9 feet) at low- and high-operating pool levels, respectively. The receiving pool was sized to comply with energy dissipation criteria that considers both the maximum drop and the discharge. A submerged ramp and fillets have been included in the pool to minimize the size of eddy zones and to turn and direct the flow downstream. The plunge depth would be about 3.0 meters (10.0 feet). These conditions themselves should not create a biological problem, however flow patterns in the caisson flow should be addressed through hydraulic modeling during final design with the caisson designed to minimize any problems associated with turbulence.

The plunging action into the receiving pool creates a potential for gas transfer and generation of supersaturated TDG levels. Based on mean pressure in the 3.0-meter (10.0-foot)-deep pool, supersaturation levels of at most 1.15 atmospheres (115 percent) could be generated. Degassing would then occur as the flow exits the plunge pool. TDG levels would then be substantially diluted by mixing with the gallery flow. Exposure time to the elevated TDG would be less than one minute based on the flow volume exchange rate.

ESBS Performance

The presence of the SBC will modify velocity magnitudes and distribution in the turbine intake. This will result in modification of the velocity field intercepted by the ESBS. There is a potential that an upward velocity component will be added along the intake crown. Observations, such as those made during the

1996 SBC prototype study at Lower Granite indicate that this may actually improve ESBS performance, increasing fish guidance efficiencies. Changes in the velocity field across the ESBS and flow balance along the height of the vertical barrier screens (VBS) will likely be modified. Influence of the SBC on ESBS performance should be evaluated in a single turbine intake model. Changes in ESBS and VBS porosities may be required.

Cutoff Wall

The cutoff wall is located where flow on one side accelerates into the turbine intake and there are relatively static flow conditions on the other side. This will generate a differential pressure loading on the wall. This loading should be evaluated through use of a powerhouse sectional hydraulic model.

Influence on Spillway Capacity

The SES was designed so that there was no loss of effective crest length when operating in the full spill condition, with the bulkhead panels removed. However, the SES may have minor influences on the discharge coefficient for Spillbay 1. Assuming that during large flood spill events Spillbay 1 would be used in conjunction with significant release through the adjoining spillbay, there should be no re-entrant effect associated with the north SES wall. The influence of the SBC wall should eliminate any effect from the south wall. Proper treatment of the design of the bottom of the SES entrance could eliminate negative re-entrant effects of the SES floor. A short 'false' wall extending down from the floor at the SES entrance is shown on Plate 1.1.5 as a possible means of mitigating this effect. With hydraulic modeling, an SES design could be developed that would have no influence on spill capacity.

5.1.2 Structural Design

Cross sections of the components making up the Lower Granite Type 1 channel design are shown on Plates 1.1.3 through 1.1.5. The channel includes two flotation cells at the top, one on the upstream side and one on the downstream side. The fish conduits described in Section 5.1.1 are located inside the channel between the flotation cells. The main portion of the channel, outside the fish conduits, forms the screened discharge channel which carries the screened flow north to the SES attached to Spillbay 1. Based on the normal operating water surface differential between the forebay pool and the inside of the SBC, a maximum design head differential across the walls and floors of the channel and SES components is conservatively assumed to be 1.52 meters (5.0 feet) for structural design and cost estimating purposes.

To help protect against these components being overloaded it is recommended that the Tainter gate be electrically limited to a specific maximum opening during operation of the SBC. Additionally, the head differential should be monitored and the Tainter gate closed automatically if it becomes excessive. A further measure to protect the channel from possible hydraulic overload would be the inclusion of a pressure relief panel(s) in the channel walls. Since the discharge capacity of the Tainter gate is far in excess of the 170 m^3/s (6,000 cfs) design flow capacity of the channel, and since an unrestricted release of water under the gate would generate a severe pressure overload on the channel, and possibly lead to collapse of the structure, the relief panels should be sized for the design headloss of the channel, but with a total discharge well in excess of 170 m^3/s (6,000 cfs). Assuming a Tainter gate discharge of, for example, 340 m^3/s (12,000 cfs), at a 1.52-meter (5.0-foot) head differential and a conservative 0.60 orifice coefficient, the required panel opening size would be approximately 104 square meters (m^2) (1,115 square feet [ft^2]). A single 9.2-meter by 12.2-meter (30-foot by 40-foot) panel at one end of the channel could provide this relief. Shear pin closures could secure the panel and would be designed to fail at the desired head differential.

The steel caisson attached to the erection bay above the fish gallery auxiliary water port would be designed for a fully dewatered condition to facilitate maintenance of the gallery system.

Floating Channel Issues

The structural advantage of a floating channel is that external support for the vertical dead weight of the structure is not required. Although the channel still needs to be held in place horizontally, these attachments are significantly less substantial than would be required if the channel weight needed to be supported. Additionally, supporting the weight of the channel structure directly off the dam face would have negative impacts on the seismic stability of the powerhouse monoliths. This concern will be addressed in more detail later in this section.

The fact that the channel is floating presents some structural design considerations which must be addressed. Wave dynamics must be considered when dealing with any floating structure. If the draft is small relative to the wave size, the structure can experience a significant heaving motion. However, the 21.3 meters (70 feet) draft of the SBC channel should effectively eliminate any concern with heaving of the channel. Waves can also create differential pitching motions between segments of the channel if the structure is hinged or articulated. This type of motion can place extreme fatigue loads into the connections between segments. An additional source of fatigue loading at the connections, if the channel were to be segmented, would be differential buoyancy between the segments. Given the operating conditions, especially the difference between the on and off conditions, there will be variation in buoyancy over both time and length of the channel. Therefore, the channel should be designed as a continuously rigid structure which floats and pitches as a monolithic unit. At the locations of the entrance openings this will require bracing across the opening to maintain stiffness. Bracing will also be required to provide rigidity across the discontinuities in the flotation cells where the transport conduit passes through the west wall.

Because the channel is supported from the flotation cells, the final design will need to include adequate internal structural bracing to ensure that the channel shape is maintained over all loading conditions. Internal bracing is shown conceptually on the accompanying plates depicting the channel. Actual size and location of the structural components, including this bracing, would be defined in the final design. The anticipated design approach would involve a structural system utilizing an internally braced frame at each of the pier locations supporting wall and floor panel systems. The load path would be from the panels to the braced frames to the channel support attachments. Systems such as this have been developed successfully for prototype SBC channels at other projects. Alternatives to the braced frame design would include a moment frame design at the pier locations, however, it is felt that excessive deflections likely from such a system would compromise the critical alignment requirements of internal walls and equipment, and would result in excessive weight of the channel due to the great depth of the members to transfer the moments.

Some structural bracing members at the channel frames, and possibly within the dewatering screen sections, are anticipated in the flow path, but these will be minimized to the extent possible and will be hydrodynamically shaped. This will be done for fish protection, to minimize debris build up, and to minimize headlosses in the channel. The proposed screen cleaner system utilizes vertically sweeping brush bar cleaners, as opposed to horizontally sweeping brush bar cleaning. Because each individual screen stack would have a dedicated brush bar, there is no specific restriction to including cross-conduit pipe braces at strategic locations within the dewatering section. This could contribute to overall reductions in support steel for the screen walls. As with the channel frame bracing, the extent of cross-conduit bracing would be minimized to reduce biological concerns. The vertically sweeping-brush bar cleaners are described in Section 5.1.3.

Horizontal Restraint and Dam Stability

Although the SBC channel is floating and supported in the vertical direction, horizontal restraint is required in the transverse (upstream/downstream) and longitudinal (along the axis of the dam) directions. The existing prototype SBC channel is restrained by guides attached to the powerhouse intake structure. Concern was expressed early in this study that a direct attachment of the channel to dam mounted guides, as done for the prototype at Lower Granite, might compromise the structural stability of the dam during a seismic event due to the additional inertial force which would need to be overcome to mobilize the mass of the channel. Since there was no comprehensive stability review available for the Lower Granite powerhouse, a review was performed of the original Lower Monumental powerhouse stability analysis, an identical powerhouse with a slightly lower pool level. Although this review was cursory, and not a recalculation of the full stability analysis, it was concluded that there is adequate cause for concern at Lower Granite that if any additional horizontal seismic loading is considered (beyond the current design loads) a full stability analysis documenting the safety of the structure should be performed.

Because the stability review was inconclusive concerning the magnitude of any additional horizontal loads which could be applied safely to the powerhouse, a number of different horizontal support alternatives were investigated for the purpose of comparison. The approach was to investigate alternatives which could support the transverse and longitudinal loads associated with the channel while reducing or eliminating any additional seismic loading imparted on the powerhouse structure. These alternatives included a direct guide attachment to the dam, a damped connection, a stand-alone structure in the forebay, a cable moored design, and a fused attachment to the dam. Calculations and sketches from these investigations are included in Attachment A.

Attaching the channel directly to a dam mounted guide was investigated as a baseline to determine the magnitude of the increased loads which would be applied on the dam, assuming no special measures were taken to isolate the channel loads. As compared to the combined hydrostatic and hydrodynamic loads the forebay would impart to the dam during a design seismic event (whether the channel was present or not), a direct attachment would result in an increase of about 3.3 percent in downstream horizontal loading applied to the upstream face of the powerhouse. Because the channel occupies the upper half of the water column, this load has a somewhat greater effect on the applied overturning moment, representing an increase of about 7.1 percent. Although there is cause for concern about any additional loading, it is recommended that a full stability analysis be performed to determine if this increase is significant or not. If the additional load satisfies the design requirements, then the complexity and maintenance issues associated with the channel attachment might be reduced.

Seismic dampers are commonly produced for installation in building structures to decrease member stresses experienced during an earthquake. If seismic dampers are placed within this type of attachment they would function more like automobile shock absorbers than building dampers. This type of damping can reduce the additional loading but can not eliminate it. Determining the magnitude of the reduction which could be accomplished by a damped connection would be an extensive calculation based on assumptions about the damping characteristics of the equipment, the arrangement of the attachment, and the magnitude of the design earthquake ground deflection and cycle period. This level of investigation would only be justified if it was pre-determined that the full additional load could not be tolerated but some defined reduction target would be acceptable. Therefore, as part of the recommended stability analysis it is suggested that a magnitude be defined for the maximum allowable additional load which could be applied to the upstream face of the powerhouse monolith during a design seismic loading condition if the load was centered 10.7 meters (35 feet) below the water surface. If the full additional load can not be applied, but a realistically achievable reduction is acceptable (e.g. less than a 50 percent reduction), then a design incorporating conventionally manufactured seismic dampers may represent a relatively low-cost installation with minimal maintenance requirements.

Two design alternatives involving full external support for the transverse channel loads were investigated. The first alternative involved a series of fixed tower support structures mounted on the bottom of the forebay on the upstream side of the channel. The second alternative involved a more flexible support system consisting of a series of long heavy cables which would moor the channel to anchors mounted upstream on the bottom of the forebay. Both of these designs were determined to be excessively large and expensive. Additional detail on these designs can be found in the calculations located in Attachment A.

If no additional seismic loading can be applied to the upstream face of the dam, in excess of those which would exist in the absence of the channel, then the proposed support alternative is a fused attachment to guides mounted on the powerhouse piers. The concept behind this design is that up to a designed maximum load the attachment of the channel to the guides would act as a rigid attachment. During an earthquake, a rigid attachment would force the dam and the channel to move and accelerate together monolithically. The portion of the hydrodynamic forebay load (Westergaard forces) which occurs over the top 21.3 meters (70 feet) of the water column would be applied to the upstream face of the channel, rather than the dam face. This portion of the load would then be transferred into the dam via the attachments, along with the inertial loads from the horizontal acceleration of the channel structure and the water contained within it. If the attachments are designed to disconnect when the applied compression load exceeds the hydrodynamic load the dam would experience without the channel, then the dam would not experience an increase over the current design loading. The proposed connection would be made with a series of high-strength steel shear pins acting as the fuse mechanism. This concept is feasible because the design shear load resulting from the maximum hydrodynamic effects of the forebay over the top 21.3 meters (70 feet) would be approximately 3.5 times the ice or wave loading, which represent the next highest naturally occurring design loads. Therefore, no source of loading other than a major earthquake could apply loads large enough to shear the fuse pins, and at the instant of shear during an earthquake the dam structure would not be experiencing loads greater than those it has already been designed for in the transverse (upstream/downstream) direction. A system of fuse pins would also be incorporated into the longitudinal attachment locations to prevent motions in the north/south direction from overstressing the pier noses. Once failure at the fused connection were to occur, the channel would be free to float within the confines of the guide system constrained by compressible stops to prevent the channel from drifting. Calculations and sketches of a possible design are included in Attachment A. It should be noted that regardless of the eventual outcome of the recommended comprehensive stability review of the powerhouse, a fused connection may make economic sense since the overall size of attachment members and anchors would be reduced to the size of the failure force, not the full inertial force of the channel.

Spillway Extension Structure

The SES is attached to the upstream face of Spillbay 1 and extends upstream into the forebay. The effects of this structure on the stability of the spillway monolith were reviewed and it was determined that the presence of the SES increases the stability of the monolith under all design loading conditions, including seismic. This is due to the fact that the SES is proposed to be a concrete-filled steel structure which is rigidly attached to the upstream face of the monolith. At this location, the added weight of the extension structure applies a large stabilizing moment to the monolith which more than compensates for any destabilizing loads the structure and the water it contains would impart during a seismic event. In addition to stability issues, horizontal shear and torsional loading in the spillway structure due to the additional horizontal loads was reviewed. From this review, the spillway structure appears to be fully capable of carrying these loads. The stability review calculations are included in Attachment A.

The one spillway component that would warrant a more detailed review is the Tainter gate itself. Additional loads applied to this structure appear to increase the loading by as much as 4 percent. Because this review was somewhat conservative, and because a detailed investigation of the gate was not performed, the increase may be within the reserve capacity of the gate and may be justified in final design. If the gate does require structural modifications to support this increase they would be relatively minor compared to constructing an alternative outlet for the flow. The advantage of maintaining the ability to utilize Spillbay 1 up to its full flood discharge capacity would justify the small modification costs and the SES design as shown.

Although not shown in the drawings, the structural system of the SES is assumed to include a bracing system in the top plane of the structure to support the tops of the walls. Also, since the structure spans the contraction joint between the non-overflow/half spillbay monolith and the first full spillbay monolith, the floor of the SES would likely also require a similar joint. Bracing of the floor panel on either side of the joint from below may be required to provide support to the panel. A detailed investigation should be performed, possibly including hydraulic modeling, to determine the full extent of the loads experienced by the SES components in both the operating and full spill conditions. These would need to include the thrust loads due to the water flow inside the SES and differential pressure between the inside and outside. Structural loads on the SES during full spill operation in some areas may exceed the operating design loads. This may be especially true in the area of the SES floor and lower walls. Final design should utilize criteria which fully incorporate these full spill loads.

Floating/Fixed Structure Conduit Connections

As was noted, the floating channel structure is proposed to be attached to the powerhouse with a system of fused attachment arms and vertical guides which will allow for vertical movement but restrict horizontal (upstream/downstream) movement under normal operating conditions. During maximum design seismic events, however, these fuses would shear preventing the channel from transferring full inertial loads to the concrete dam. Since the floating channel conveys water to the powerhouse juvenile gallery and the SES, sliding connections capable of allowing vertical movement must be provided at these locations which can pass the conduit flow with a minimal amount of leakage. Moreover, since the proposed channel horizontal support system at the powerhouse is fused, and designed to allow differential horizontal movement between the channel and the dam under extreme seismic loading, these water passage connections must not only slide vertically under normal operations, but also must accommodate horizontal movement of the channel under design seismic loads. A fused connection design would also be appropriate for these connections. Failure of the connections could involve the shearing of pins, the crumpling of steel in designed crumple zones, or a flexible sliding connection that would compress. Selection of a design approach and detailing of the attachments would be issues for final design.

Channel Cutoff Wall

The cutoff wall component of the SBC system is intended to prevent the fish from entering the Unit 6 intake via a path under the north end of the SBC channel. In this sense, the wall is a behavioral structure only. Despite this, the wall could be subjected to relatively significant loads which need to be considered in the design. These loads include the differential water load caused by the velocity of the water entering the turbine intakes of approximately 0.12 meter (0.4 foot) of water, the pressure load caused by load rejection events from the turbines of approximately 0.31 meter (1 foot) of water which acts in an opposite direction from the velocity head-induced loads, gravity loads from the wall itself, and finally, and most significantly, the hydrodynamic Westergaard loads induced by seismic events which push the wall through the water. The Westergaard loads, calculated to be equivalent to approximately 3.23 meters (10.6 feet) of water, are as much as ten times the magnitude of the other out-of-plane loads.

The structural design philosophy of the cutoff wall is proposed to be similar to that of the SBC channel attachment to the dam. That is, to utilize a load limiting system to minimize the structure size and cost. Much like the fused pin connections on the channel, it is proposed that the wall be designed for loads which would be experienced on a relatively frequent basis, and allow failure of various components to occur when confronted with the very infrequent larger loads resulting from large seismic events. This will limit the structural requirements for the cutoff wall itself, and will also limit the loads the wall can transfer into the channel. The channel will need to be reinforced locally in the cutoff wall attachment area to accommodate the normal design loads, and the fused attachment of the channel to the dam will need to be capable of supporting these north-south loads.

For the cutoff wall, it is proposed that the panel framing members and their support points to the channel above and concrete footings below, be designed for approximately 1.52 meters (5 feet) of equivalent water load, well below the Westergaard loads, and that the actual failure components (bolts holding an array of blow-out panels making up the face of the wall) fail under approximately 0.91 meter (3 feet) of water load. This will allow for a substantially more cost efficient structure design and also limit the transfer of loads to the support points for the wall. A conceptual design for this wall is presented in Attachment A.

As an additional complication, the wall needs to accommodate the floating SBC channel to which it is attached on the top. To achieve this, a telescoping wall joint is proposed allowing for the 6.86-meter (22.5-foot) fluctuation in elevation of the floating channel required at Lower Granite. A smaller upper fixed panel section, braced back to the bottom of the channel and able to move vertically with the channel, would in turn provide support, through a sliding connection, to the larger lower panel section which is also supported at the bottom of the forebay. Moreover, the wall is proposed to be isolated from the dam by a sealed moveable joint to a small wall section bolted to the north side of Unit 6.

The bottom of the wall is assumed to be supported by large concrete footings rock-anchored to competent material underlying the forebay.

5.1.3 Mechanical Requirements

Screen Cleaner Systems

Although the trash shear boom in the forebay and the trash racks located at each entrance should effectively prevent large debris from entering the channel, most of the smaller floating debris entrained in the flow entering the SBC entrances will pass into the channel. Since most of this flow passes through the dewatering screens (only a relatively small portion is carried as transport flow to the juvenile facilities), a majority of the smaller debris will become impinged on the dewatering screens. Therefore, automated mechanical screen cleaning equipment is provided for all dewatering screen sections. Development of an effective screen cleaning system is perhaps one of the more significant challenges in the development of all SBC systems that dewater flow. Not only must the system be effective in cleaning, it must be reliable over periods of sustained usage. The criticality of this issue is so great that a prototype dewatering facility has been proposed for the existing prototype SBC channel at Lower Granite. This facility, if constructed, would include many, if not all, of the cleaner designs described below with the goal of assessing effectiveness and reliability.

The challenge associated with keeping vertical fish screens clear of debris is one that has been met in several different ways in the region. In general, screen cleaning systems fall into three groups:

- brush cleaner systems that physically remove accumulated debris from the screen face
- traveling screen systems that trap accumulated debris on a vertically moving continuous looped screen belt relying on water flow to backwash accumulated debris as the belt passes around and back into the flow on the downstream side
- water or air backwash systems that use pressurized jets located behind the screen to blow debris off the screen face and back into the sweeping flow path of the conduit.

Each of these types of systems have been used successfully at various screening facilities, including several operated by the Corps. The challenge of adapting these types of cleaning systems to the SBC channel is primarily a problem of scale. The large volume of water being screened in these facilities is far beyond any typical applications and in many ways, stretches existing technologies to their limits. Not only is the overall area of screens large, but the depth of the screens below the water surface is well beyond where most standard screen cleaning technologies exist. For example, commercially available horizontally sweeping brush cleaners, common on many shallower screen facilities less than 6.1 meters to 7.6 meters (20 feet to 25 feet) deep, are of questionable feasibility on screens that might extend to depths of 16.8 meters (55 feet), as proposed, because of the extreme length of the brush arm. The exception to this is self-cleaning traveling screens which have been installed at screening facilities up to 30.5 meters (100 feet) deep. Each of the major screen types will be discussed briefly.

Brush Cleaners

Brush cleaning systems are the most common. A stiff (typically nylon-type plastic) bristle brush is attached to a steel member which is mobilized in a sweeping motion across the face of the screen. Vortices around the bristles are thought to achieve most of the cleaning action, as opposed to the physical scraping of debris off the face. Impinged material is moved by the brush along face of the screen to a remote location where it either accumulates, is swept downstream by the sweeping velocity of the main conduit flow, or is pulled from the flow for disposal. Brushes move either horizontally or vertically, or in some cases in wide sweeping circles. When bar screen material is used, experience suggests that brush motion perpendicular to the bar screen orientation cleans fibrous material (i.e., grass or straw) more effectively than motion parallel to the bars. Brush cleaner effectiveness is sensitive to screen panel deviation from flatness, requiring relatively close tolerances and construction oversight of panel installation. The main components of brush cleaners are drive motors, shafts and bearings, cables or chains, tracks, brushes, brush bars and framework.

Vertical brush cleaning systems have horizontally oriented brushes moving up and/or down along the face of the screen. Motion is often achieved by pulling the brush with cables or chains along tracks. The sliding contact of the bristles with the screen and the vortices created dislodges debris. The ESBS in use at many of the Corps projects on the Snake and Columbia rivers (including Lower Granite) utilize this type of vertically sweeping brush cleaner. For these structures, the bar sweeps vertically along the face of the screen and is driven by a chain drive system recessed in the support structure on either side. Specific advantages of this type of system include the virtually unlimited depth to which these systems could be designed. Stacks of 3.66-meter (12-foot)-wide screen panels, with a depth up to 16.8 meters (55 feet), fitted with a single vertically sweeping brush bar could be developed for use on the SBC channels. In the design of this type of cleaner for the SBC channels, the cleaner would clean in an upward direction pushing material up and out of the flow where a spray system would flush the material to the downstream side of the screen and out of the channel with the screened flow. A cam or linkage type mechanism would hold the bristles against the screen during the upward movement, and hold the bristles away from the screen during downward travel. To cover the full length of a dewatering screen section, a series of these cleaners would be employed, each dedicated to a single screen panel stack. The stored position of the vertical brush cleaner would be at the bottom of the screen panels either directly in the flow path or in a shielded enclosure. The removable screen panel design proposed for the SBC channels would enable the entire mechanical system for the cleaners to be removed for maintenance or inspection along with the stack of screens.

Commercially available vertically sweeping brush systems have been developed for depths up to 21.3 meters (70 feet) and are currently in use at facilities in Northern California [8]. Rather than being integral to each screen panel, these systems use a track-mounted dual-telescoping boom system with a 1.8-meter (6-foot)-wide horizontal brush attached at the bottom, and would clean the screens in the same manner by pulling debris up and over the top of screen stacks. Cleaning would progress down the wall of screens stopping every 1.8 meters (6 feet) for the entire length of the screens. Budgetary pricing for a machine like this mounted on a 22.9-meter (75-foot)-long track would be about $250,000. Depending on the rate of cleaning required, one or more machines might be required for each wall of screens.

The ability to remove debris from the flow path is a significant advantage for the vertical brush cleaners, a consideration that will lead to lower maintenance costs at subsequent dewatering sections further downstream, pinch points within the conduit where the debris may get hung up, at the juvenile fish gallery downwell, and at the downstream juvenile facilities.

For vertically sweeping cleaners, there is some concern about the trapping of fish above the bar during the upward sweeping motion. Whether this is a real or perceived problem should be investigated in a prototype dewatering facility.

Horizontal brush cleaner systems, on the other hand, have long, vertically oriented brushes attached to steel (or aluminum) arms that are swept horizontally along the face of the screens with the current, then pulled out of the water (or simply away from the screen face) to reset for another pass or for storage. This is a fairly standard design which offers the advantage of a history of reliable service and can be characterized as proven technology in these applications. However, no standard applications of this technology could be found in a review of regional screening facilities for applications as deep as those proposed in this report. Commercially available cleaners of this type have been developed for screens up to 6.1 meters to 7.6 meters (20 feet to 25 feet) deep. Because these cleaners rely on a rigid vertical arm to support the brushes, there is a practical limit to the length (depth) that these cleaners could be designed considering spatial and functional requirements (e.g., their presence in the flow path across the entire height of the screens, the sloping bottoms of many of the proposed designs, as well as the overall size of the vertical arm). For screens located at shallower, constant depth (or mildly sloped) floors, this type of system is convenient since a single brush mounted on a motorized or cable trolley located on a track at the top of the screens could clean a relatively long section of screen, perhaps limited only by the cleaning cycle requirements for the screens. Unlike the vertical brush systems, this cleaning method does not remove the debris from the conduit at the point of cleaning, rather it pushes the debris downstream. Therefore, horizontally sweeping brushes are typically used in applications where the fish and flow would be swept directly downstream to the tailrace with the debris. However, in this application the debris would be swept further down the channel, and ultimately into the juvenile gallery, where it will need to be dealt with again, possibly multiple times.

Commercial application of horizontally sweeping brush cleaners for screen depths over 7.6 meters (25 feet) are rare at best. Discussions with manufacturers of this equipment indicate that while technically feasible, there is a question about the economic justification of doing so, noting that a vertically sweeping system (as described above) could be constructed at a lesser cost.

<u>Traveling Screens</u>

Traveling screens are utilized widely in the screening of water to divert fish and debris. The Corps utilized traveling screen technology in the development of their STS used in turbine intakes along the Snake and Columbia Rivers. These applications are complicated by the fact that the drive machinery is submerged. Conventional traveling screens, with the drive machinery in the dry, are currently used at McNary Lock and Dam to screen the fish ladder water supply on the south side of the project [9]. The basic premise is that the screen face material is a continuous belt and debris caught on the upstream face of the screen will travel on this belt to be flushed off with a spray system, or as proposed for this project, around to the reverse side where it will be flushed off by the action of the water moving through the screen. In this sense, they are self-cleaning. A motor drives the belt which in the case of the STS systems was a flexible plastic mesh, while in other applications it is a series of rigid screen panels connected by pivots into a chain. Sprockets at the top and bottom turn the screen over backwards to the water flow. In most applications the screen travels continuously. Main components of the system are: drive motor, shafts and bearings, chains, tracks, screen belt and framework.

From a mechanical perspective, the application of traveling screens for the SBC channel is a relatively direct one. Commercially available screens are currently fabricated for depths up to 30.5 meters (100 feet) [10]. Screens up to 24.4 meters (80 feet) deep are currently in use on the Ohio and Mississippi Rivers. Widths up to 4.57 meters (15 feet) are common, however, widths of about 3.05 meters (10 feet) are most economical. Typical screen material for applications utilizing rigid panels is wire mesh, but other materials such as profile bar screen or perforated plate could likely be adapted with some level of design modification. Traveling screen systems are manufactured in individual, self-contained units and can be removed completely if desired. Normal maintenance occurs from the deck level where most of the mechanical drive systems are located. While the typical screen is a low-head design, a head loss component generating the desired 0.31 meter to 0.46 meter (1 foot to 1.5 feet) of head loss (see Section 5.1.1) could be incorporated into the screen through the use of a low porosity center plate.

Considerable initial cost is a consideration for vertical traveling screens and perhaps represents its greatest disadvantage. Budgetary pricing for a conventional 3.05-meter by 21.3-meter (10-foot by 70-foot) screen is about $150,000, or over $2,150/m^2 ($200/ft^2). Modifications to substitute stainless steel bar screen for the standard wire mesh panels (if desired) and add the low porosity center plate would drive costs up considerably. These costs are considerably in excess of the estimated costs for a vertical brush system. Periodic overhauling of these screens would be required (typically after 10 to 15 years of service) and the annualized cost for this maintenance is considerable. Traveling screens also require the most machinery of the various cleaner types and are typically quite heavy with larger units weighing as much as 18,200 kilograms (40,000 pounds). A traveling screen system offers maintenance advantages in that the entire system can be removed as a unit and worked on out of the water or replaced as a unit. Also, if spare traveling screen units were purchased and lengths of screens were standardized, screens requiring maintenance could be removed and spare units installed without taking entire dewatering screen sections down for extended maintenance periods. The ability to visually inspect the screen as it clears the water surface would be a significant maintenance advantage to verify that screens are operating successfully and are not damaged.

Backwash Systems

Backwash cleaning systems use pressurized jets of water or air to dislodge debris. The nozzles are aimed upstream at the downstream (back) side of the screen. Typically, the nozzles would be mounted on bars which travel in a circular or linear motion across the back face of the screen. Circular motion nozzle bars are often self-propelled. Linear motion nozzle bars require a drive system. These systems require a supply of pressurized water or air and plumbing to get it to the nozzles. The main system components are: pumps, piping, motion actuators, and motion bearings.

Backwash systems are typically applied in facilities with high sweeping velocities and where conduit geometry precludes the use of brush systems. The high sweeping velocities are required to keep debris from reattaching to the screen face after being blown off. For the relatively low conduit velocities found in the SBC channels, appropriate sweeping velocities may not be achievable to accomplish effective screen cleaning. Additionally, since the proposed design of the dewatering panels introduces a multi-layer porosity control (porosity is controlled by both the upstream screen and, to a much larger degree, the low-porosity downstream plate), a backwash system for these panels would require a fixed piping system integrated into the screen panels (i.e., upstream of the low-porosity back plate). Fixed spray systems are typically uneconomical on large screens due to the large amount of flow required and the complex piping, valving and control systems required. The removable sandwich panel screens proposed in this study would be particularly difficult to plumb and connect for the moving parts of the backwash system. Additionally, a complication with a backwash system for an application this large is that quite a few nozzles could plug and become ineffective before a noticeable reduction in the total spray flow would be detected. This could present an on-going maintenance problem.

Like the horizontal brush systems described earlier, backwash systems leave all of the debris in the fish conduit, however, they do have the advantage of not putting any structural features in the path of the fish.

Proposed Screen Cleaning System

Based on the cost, maintenance and operational advantages discussed above, vertical brush bar cleaners are proposed for Type 1 SBC channel. This approach would also be used for the Type 3 SBC channel described in Section 8. The brush bar would be guided vertically in tracks incorporated into guide frame, with the drive machinery located at the top of the screen panel stack. Each screen stack would have an individual brush bar, drive motor and guide frame.

The screen layout depicted on Plate 1.1.2 (and described in Section 5.1.1) is based on the initial hydraulic analysis to fulfill the design requirements and represents one of many possible arrangements. Actual screen panel widths and stack heights would be determined during final design based on a number of factors, including the most economical structural size for the panels and requirements of the cleaning equipment. For the purpose estimating the complexity and cost of a vertical sweeping brush bar system it was felt that use of individual brush bars as long as 7.32 meters (24 feet) was not a sufficiently conservative assumption in the absence of more detailed design and layout. Therefore, rather than the six screen stacks shown it is conservatively assumed that ten separate brush bar cleaners would be required for each of the three primary dewatering sections. This would be accomplished with screen stack widths and brush bar lengths of approximately 3.66 meters (12 feet). The common secondary dewatering section is 15.24 meters (50 feet) long with screens on both sides. This secondary screen cleaning could be accomplished with eight 3.81-meter (12.5-foot)-wide bars, or ten 3.05-meter (10-foot)-wide bars. It is conservatively assumed for cost estimating that this section would utilize ten individual bar cleaners (five on each side). This results in a requirement for the Type 1 channel of 40 individual brush bar cleaners and frames.

The brush bars would be stored at the bottom of the screen stacks when not in use to prevent debris from building up below the brush and being pushed down when the cleaner is deployed. The screen panels would be designed in sections to allow removal with existing cranes at the project. The cleaner itself would be comprised of a separate frame which again could be removable for maintenance of the mechanical systems. A spare cleaner frame could be installed in this event to allow for continued use, or more cost-effectively a temporary bulkhead could be placed in the screen guides to allow for continued operation at a slightly reduced entrance flow. A discussion of the characteristics of this type of cleaner is presented earlier in this section. A sketch of a conceptual design for this cleaner is included in Attachment A.

Water Control Gates

The primary water flow control gate for the Type 1 SBC channel is the existing Tainter gate at Spillbay 1. Although there are no modifications proposed for the Tainter gate structure, unless final design analysis dictates minor structural upgrades, modifications would be required to the control system for the gate to ensure that proper flow rate and differential head are maintained in the system. Specific control requirements for the system are described in Section 5.1.4.

Control of the water surfaces and transport flow rates in the fish conduits would be accomplished with tilting weir gates located downstream of the primary dewatering sections and just prior to the flow entering the powerhouse at the fixed caisson. The weir gates would be designed with a sloping follower plate on the upstream side of the weir (see Section D on Plate 1.1.4 and Section B on Plate 1.1.2). Very little adjustment should be required on these gates since the design discharge would be constant and the water depth inside the conduits should not vary significantly. However, unanticipated problems, such as a piece of debris lodged in the conduit, could alter the water level quickly and significantly. To maintain the design flow rates it is proposed that the weirs be adjustable to maintain a pre-set depth over the weir crest. The adjustment could possibly be automated to prevent a problem from going unnoticed for a significant period of time.

Debris Management Systems

SBC Entrance Racks

From late winter to mid spring, large releases of debris material may be collected at the dam. These events last between a few days to a week. During these events small and large debris may bypass the trash shear boom and collect at the entrances of the SBC channel. To prevent the larger material (which could plug the conduits) from entering the SBC, there will be a steel trash rack at each of the SBC entrances. Periodically there will be enough accumulation of debris on these racks that removal of the debris becomes imperative. Use of a mechanical trash rake is proposed for removing debris from the trash racks.

The design criteria for the SBC entrance trash rakes would include the following minimum requirements:

- All components must be capable of cleaning a semi-circular trash rack with a radius of 6.07 meters (20 feet) and a depth of 21.3 meters (70 feet). This will require the trash rake to boom out at its furthest point 6.07 meters (20 feet) beyond the SBC structure.
- All components must be capable of operating in extreme weather conditions.
- Each system must lend itself to integration with a debris removal system.
- All components must be adequately protected against corrosion.
- If hydraulic machinery is included, environmentally safe fluid must be used.
- If the collection of debris requires the removal of large material, extraordinary measures should not be needed.

Development of a trash rake system for the SBC entrance racks was determined to be most efficient by investigation and adaptation of the relatively large number of commercial systems available. There are a number of different types of trash rakes currently available on the market. Most of these mechanisms fall into three main categories. The first is the boom type. One or more booms have a scraping device attached to one end. This end is lowered into the water and dragged along the trash rack dislodging the debris pulling it topside with the scraper. Some booms are articulated and others rigid or telescopic. Relatively large forces will be exerted against the rack by the cleaning action. The second type would be a scraper or bucket suspended with cables. The bucket is hoisted topside with the debris and deposited on the deck. The bucket will exert relatively small forces on the rack. The last type would be the continuous belt scraper. Scrapers are attached to a flexible link chain. Driven by sprockets, the chains form a continuous loop. This type of machine is generally used with lighter loads and smaller material. In all, ten different trash rake manufacturers were consulted about this project, with only two exceptions, all declined to recommend their product for this application. The most cited reason was the difficulty in cleaning such a large semi-circular trash rack. The remaining two suppliers will require extensive modifications to their products to meet the design criteria. Although the equipment should be fairly reliable, since it will be developed specifically for this application, it should be assumed that the development cost and lead time for delivery would be greater than for a typical flat trash rack.

The recommended trash rake for this application would feature a telescoping boom as depicted on Plate 1.1.4. Machines such as this are available but would need to undergo modification, either by the supplier or another company, to meet the specific requirements of this installation. One of the modifications needed would add to the machine the ability to rotate about a vertical axis. There are two possible mounting arrangements which could be used in this application. The first would be a dedicated fixed machine at each of the SBC entrances. The second approach would be a single rail mounted traveling trash rake capable of cleaning all three entrances. The traveling rake is the selected approach for the Type 1 channel. The first approach would be less complex than the rail mounted traveling version, however it has the disadvantage of being more expensive overall (due to the number of units). The disadvantage of the second approach is that it requires a more complex and heavy machine, including rails and an additional drive motor for travel. A budgetary estimate for the fixed location machines is $482,000 each, while the rail mounted version would be approximately $659,000. The nominal lifting capacity of the machine would be 1,130 kilograms (2,500 pounds).

Once the debris has been removed from the rack, a means to transport the material to a convenient location for loading onto trucks for disposal must be provided. There are a number of different concepts which may be utilized for this task. Most have significant technological or financial drawbacks. Concepts considered included: a continuous belt or drag conveyor, loading of the material directly from the rake into dumpsters which would be then transported by crane, and loading of material into a rail car (muck car). The conveyor belt approach will not be feasible for this application due in large part to the inability of a reasonably sized conveyor to handle large pieces of material, large logs for example. Additionally, the conveyor would need to be located on top of the channel, since the rake rails will already be occupying the top of the upstream flotation cells. In this location the conveyor would be blocking access to critical channel components like the dewatering screens. The second option is impractical because of the required crane boom length. A rail mounted muck car is the recommended method for disposal of debris. The muck car would have a nominal capacity of approximately 4,530 kilograms (5.0 tons) and would travel on the same rails as the rake. The muck car would use a car puller to transport the car along the length of the SBC. A new small mobile crane or boom truck would be procured to pick up the car and dump the contents into a truck.

Fish Gallery Downwell Debris Skimmer

The configuration of the existing juvenile fish gallery downwell inside the erection bay of the powerhouse at Lower Granite presents a potential floating debris accumulation area. The cumulative effect of the floating debris being trapped in this area could result in restriction of the downwell area hydraulics and injury to fish as they pass through. Because the issue of primary interest is the floating material (the entrained material will be passed downstream to the juvenile facilities), a surface skimmer system has been developed which will rake the surface of the downwell area, depositing the material in a debris hopper for eventual removal by use of the small crane or boom truck previously mentioned (see Plate 1.1.4).

Due to the unique configurational constraints of the installation, it is anticipated that any commercially available rake systems would likely require extensive modifications. More realistically, a unique design would be developed. As configured, the proposed system would operate with a system of drive chains and rails and would likely be automated to a timed cleaning cycle. Because the debris encountered in this area would be “pre-screened” by the entrance racks and the majority of the debris accumulated on the dewatering screens would be lifted out of the conduit, the magnitude of the mechanical systems would be modest. Chain driven screen cleaner systems currently employed in many juvenile facility dewatering systems (e.g., Little Goose juvenile facilities primary dewatering screens) are similar in nature and these technologies could be adapted for the debris skimmer system.

It is possible that in the future redevelopment of the fish gallery at Lower Granite will eliminate the downwell resulting in an open channel system. In this case, the debris skimmer would not be required since the debris would simply flush down the system on the open water surface. This is similar to the existing gallery design at Little Goose and Lower Monumental. If this redevelopment were to occur, the debris skimmer system could be removed if it were not required, or it could be moved to a new location downstream at the fish handling facilities.

Hoist Systems

To facilitate the operation and maintenance of a number of components and systems on the SBC channel and the SES, hoisting systems must be provided. The major hoisting issues are:

- Installing and removing bulkhead panels on the SES at Spillbay 1
- Installing and removing screen panels for maintenance purposes at the SBC channel
- Installing and removing isolation bulkhead panels both upstream and downstream of the primary dewatering screens inside the fish conduits
- dumping of the debris hopper for the debris skimmer located at the erection bay
- dumping of the debris hopper on the muck car for the entrance debris rake system.

The hoisting strategies for each of these items ranges from independent, dedicated systems, to a general hoist for all lifting needs. A general approach to hoisting would be the use of a mobile crane which could access all the items. The appropriateness of this type of strategy involves an assessment of the distance from the crane to the load, the weight of the load, and the functionality of the application. At Lower Granite, the Corps currently has a 50-tonne (55-ton), 4-section hydraulic boom crane which is located at the project [11]. The crane is currently derated to 32 tonnes (35 tons) but conversion back to its rated capacity is possible. On its outriggers (manual sections extended), the crane has the following capacities in its 50-tonne (55-ton) configuration:

Load Radius	Boom Length	Capacity (Side)
12.2 m (40 ft)	32.0 m (105 ft)	7,394 kg (16,300 lb)
15.2 m (50 ft)	32.0 m (105 ft)	6,078 kg (13,400 lb)
18.3 m (60 ft)	32.0 m (105 ft)	4,536 kg (10,000 lb)
21.3 m (70 ft)	32.0 m (105 ft)	3,221 kg (7,100 lb)
24.4 m (80 ft)	32.0 m (105 ft)	2,268 kg (5,000 lb)

Thus, if this existing crane were utilized, the design of lifted items would be limited by this configuration. In the following discussion of hoisting equipment for Lower Granite, reference to the ‘existing’ crane assumes the above crane capacities. In lieu of using the existing crane, a new, larger capacity crane could be procured that would significantly increase the lifted load capacity, thereby gaining some design and operational flexibility (larger, heavier items could be lifted at one time). A 181-tonne (200-ton) mobile crane (Link-Belt Model HC-248H) would increase the lifted load capacity at the 24.4-meter (80-foot) distance to 18,688 kilograms (41,200 pounds) or roughly 8 times. At a distance of 18.3 meters (60 feet), this crane would have a lifting capacity of 27,352 kilograms (60,300 pounds) or roughly 6 times the capacity of the existing crane at that distance. A budgetary price for this crane would be around $2 million [12]. This represents a major cost item and the increased operational flexibility would have to justify this substantial cost. Each one of the lifting issues identified above will be discussed briefly as follows:

<u>SES Bulkhead Panels</u>

The bulkhead panels at the SES make up the upstream wall of the SES. They are removable to allow Spillbay 1 to pass its full design flood flow of 3,010 m^3/s (106.3 kcfs). The decision to pull these panels would be based on the predicted hydraulic capacity requirements of the project during a flood event. If the discharge capabilities of Spillbay 1 were not required to meet discharge requirements for the project, the panels would not be removed. Because the maximum discharge of record at the project was roughly half the total spillway design capacity, the frequency of the removal these panels would likely be very small. Nonetheless, a plan for removing them must be developed and must be in place as part of the emergency action plan for the project. Based on preliminary calculations for the bulkhead panels, the panels would weigh about 1,066 kilograms (2,350 pounds) per vertical foot of panel. The center of load is located approximately 18.3 meters (60 feet) from the crane location on the central non-overflow section. Placement of the crane on the spillway bridge deck is not recommended due to possible deck overload under the outriggers. Based on this load and distance, individual 1.07 meters (3.5 feet) tall by 19.5 meters (64 feet) long panels could be lifted with the existing crane. A specially designed lifting beam would be required to grab the panels underwater and is included in the lifted weight. About 25 panels would be required for the 26.8-meter (88-foot) tall opening. Using a 181-tonne (200-ton) crane, the individual panels could be about 7.3 meters (24 feet) tall reducing the number of panels dramatically. Alternatively, a dedicated bridge crane could be developed for the SES which would run along the top walls of the structure. The crane would lift short panels and store them on the tops of the wall straddling the well area of the SES. This seems rather an extravagant design and an unnecessary expense for the infrequent use anticipated. For the SES, the use of the existing crane is recommended, unless other project requirements would justify the purchase of a new larger crane which could then also be used for the SES.

<u>SBC Channel Screens and Emergency Isolation Bulkhead Panels</u>

The dewatering screens for the SBC channel are proposed as removable for the purpose of maintenance and inspection. The proposed screen system consists of a series of vertical brush bar cleaner frames each containing a stack of bar screen panels. Like the SES bulkhead panels, these panels can be sized to match the equipment available for lifting them. The screens are located at a maximum of 18.3 meters (60 feet) from the nearest lifting point on the powerhouse intake deck; therefore, the existing crane could be used but the screen panels would have to be sized appropriately. Based on an assumed screen panel width of 3.66 meters (12 feet) and a unit weight of 170 kg/m^2 (35 lb/ft^2), panels as tall as 6.1 meters (20 feet) could be lifted with the existing crane. As with the SES bulkhead panels, a special lifting beam would be designed to grab individual panels underwater. If a new, larger crane were specified, the entire screen panel stack could be lifted, eliminating the need for the special lifting beam and any complications associated with its use. Since there are a number of stacks of these screens, the savings in retrieval time could be substantial.

The emergency isolation panels would likewise be sized for the distance to the load (about the same). The number of panels would be governed by the crane capacity and the unit weight of the panels. A special lifting beam would be required if underwater picks are necessary.

Fish Gallery Debris Hopper and Entrance Rake Muck Car

Both of these loads are associated with debris removal. Thus, their frequency of use is anticipated to be much greater than for the other items described. For this reason, the appropriateness of the lifting system, the ease of use, and the flexibility of the system is much more critical. The debris hopper at the erection bay, as depicted on Plate 1.1.4, is close to the concrete deck of the erection bay. Thus, the lifting requirements for this load are much simplified and could be accomplished by a substantially smaller crane than the existing 50-tonne (55-ton) crane. However, procurement of a smaller crane, or development of a separate dedicated lifting system would be a matter of operational flexibility. Since the debris load anticipated may require daily (or more frequent) emptying of the hopper, a crane would be required for this task on a long-term basis. Depending on other competing crane needs, this might create an operational conflict at the project. Alternatives to the use of the existing crane include procurement of a smaller crane or development of a dedicated hoisting system. For the purposes of this study, it is assumed that a smaller 4.5- to 9.1-tonne (5- to 10-ton) boom truck or all terrain crane would be procured. This would optimize the operational flexibility at the project. The crane would have to pick the hopper load and carry it over the deck to allow dumping into an awaiting truck for disposal.

The issues associated with emptying the entrance rake muck car are much the same. It is assumed that the rail system for the car would carry the car to a point near the intake deck so that a crane could hoist the hopper to an awaiting truck for dumping. For this study, the same (new) smaller crane is proposed for this task.

Summary of Proposed Hoist Systems Type 1 Channel at Lower Granite:

For cost estimating and maintenance discussions below, it is assumed that the existing 50-tonne (55-ton) crane at Lower Granite will be the hoisting system for the infrequent hoisting requirements associated with the SES bulkhead panels, the channel dewatering screens, and the conduit isolation panels. This will require that these items be fabricated to sizes which can be lifted by this crane and that proper equipment be supplied to facilitate picking these items from under water. A new smaller boom truck with a capacity of 4.5 tonnes to 9.1 tonnes (5 tons to 10 tons) would be procured for the on-going debris maintenance activities at the debris skimmer and for the entrance rake muck car.

5.1.4 Electrical Requirements

Primary Power Considerations

Providing electrical power to the motors, lights and other electrical features of the SBC components involves an assessment of the electrical demands for the system components, identification of an appropriate power source for the required load (capacity of the circuit and its reliability), and the identification of a feasible method of routing the power to the point of consumption.

The major load demand for the Type 1 SBC components is found in the large number of relatively small motors used to operate the screen cleaners, gate actuators, etc. Larger loads can be found on the trash rake machine and muck car. Smaller miscellaneous loads (receptacles, walkway lighting, etc.) make up a relatively small portion of the total loads on the system.

Electrical power at Lower Granite Dam is available from a variety of sources. Spare 480-volt, 3-phase circuits are present at both the east and the west end of the navigation lock although the amperage at the breakers are rated lower than the anticipated loads for this system and thus are not useful for the purposes of the SBC components. Other power sources include tapping into existing feeders in the powerhouse area itself. Opportunities exist in the gate seal heater room at the central non-overflow section where an existing 4,160-volt feeder can be accessed, or in the valve room in the south non-overflow section where a similar tie-in to a 4,160-volt feeder can be accomplished. Since typical power requirements for most of the significant loads are 3-phase, 480-volt, a transformer would typically be required to step down the voltage. The valve room appears to have the greatest potential for development, being larger than the gate seal heater room [13]. The valve room is at elevation 225.5 meters (740.0 feet) and is thus relatively close to the deck elevation of elevation 228.9 meters (751.0 feet). Coring up to the deck to route power to the SBC appears to be feasible from this area.

Power reliability is an additional concern for these systems. Power at the dam is separated into critical and noncritical systems with electrical loads requiring the highest degree of reliability being assigned to noninterruptible power sources. During load shedding at the project, the noncritical busses are typically shut down while critical busses are operated on emergency power sources. It is anticipated that the SBC facilities will typically require a high level of reliability since endangered species issues are involved. Shutdown (even temporarily) of the SBC system due to electrical power outages (or any other reason) is not viewed as acceptable. Thus, in general, it is felt that the SBC components will require a tie-in to the critical system sources. The spare circuits at the east end of the navigation lock are on noncritical busses making them less attractive. Spare circuits at the west end of the lock are on critical busses and thus are candidates as power sources. The 4,160-volt feeders in the south and central non-overflow sections described above are on the station power system and are critical system sources. These make attractive, accessible sources of reliable power.

Extensive electrical cable galleries were designed originally for the routing of electrical power cabling through the entire length of the dam. For this reason, the routing of cabling, either from the non-overflow sections or from the navigation lock to the SBC channel area is not seen as a major issue for these designs. As noted earlier, coring of concrete to reach the intake deck from lower areas in the south and central non-overflow sections would be a relatively minor design and construction concern. Routing of the power to the floating channel from the fixed intake deck would require a flexible cable system involving festooning or similar support method.

<u>Type 1 SBC Electrical Requirements at Lower Granite</u>

For the Type 1 SBC described, the total electrical load is approximately 440 amperes at 480 volts alternating current. Calculations for estimated electrical loads are provided in Attachment A. This load is far in excess of the available spare circuits at the west end navigation lock switchgear. Because the spare circuits at the east end of the navigation lock are noncritical busses, these cannot be utilized for this purpose. Rather, it appears most feasible to tie into the existing 4,160-volt feeder in the valve room at the south non-overflow section, which has the capacity and is close to the demand location. This room is 4.0 meters by 5.8 meters (13 feet by 19 feet) and should be sufficiently sized to accommodate the transformer, primary fused switch and switchboard required to serve the Type 1 SBC electrical loads.

From the valve room, power feeders would be routed through the concrete deck via cored holes and from there to the floating SBC channel and electrical loads at the debris skimmer and tilting control weir. On the SBC channel, the feeders are routed to three separate motor control centers which serve the individual electrical demands associated with each of the three internal channel fish conduits as well as other miscellaneous loads. A one-line diagram illustrating the electrical loads, power sources and components for Type 1 SBC design at Lower Granite is provided on Plate 1.1.6.

Instrumentation and Controls

Despite the apparent complexity of the facilities associated with SBC channel design, the instrumentation and controls issues are seen as relatively straightforward. The primary issues revolve around the monitoring of liquid levels in the channel to control the settings of water control gates. Since the channel is floating, and the primary control gate for the entire system is the Tainter gate at Spillbay 1, the control system design would be relatively simple. Level sensors would monitor the water level inside and outside of the SES near Spillbay 1, with a sensor located in the forebay and one inside the SES well. A programmable logic controller (PLC) would control the Tainter gate based on input from the level sensor inside the SES well. A rating curve would be used to define the required opening to pass the design flow for any given head on the gate. The gate would be locked out at a maximum opening size to ensure that excessive pressures on the channel would be avoided. Additionally, if the difference between the level sensors inside and outside the SES reveal an excessive head differential the Tainter gate would close, either partially or completely, to protect the channel structure. With this control scenario, the design flow would be maintained at all times unless the head differential became excessive, generally indicating dirty screens or entrance racks. One concern with this flow control approach may be the existing Tainter gate motor and gear boxes. It is likely that this equipment is not rated for continuous modulating control. A review of this equipment would need to be made to determine if modifications or replacement would be necessary. However, modulation of the Tainter gate should, for the most part, be limited to adjustments required in response to variations in forebay level only. This would be facilitated by the PLC programming. Upon receiving an indication of increasing head differential, in the absence of a change in forebay level, the PLC would first begin a screen cleaning cycle since this would be the most likely cause of the problem. Only if this did not work and the head continued to rise would the flow rate be reduced by reducing the Tainter gate opening. Additionally, the cleaners could be set up on a regular cleaning cycle and/or operated manually. Likewise, the operation of the debris skimmer could be programmed into the PLC and/or operated manually.

Because the tilting weirs in the fish transport conduit discharges freely into the gallery at all design forebay elevations, this gate would be controlled based on level sensors or flow meters located in the conduit upstream of the weir.

5.1.5 Operation and Maintenance Issues

System Operations

Operation of the collector and its related components is intended to rely to a great degree on automated control systems to regulate flow through the channel, monitor screen cleaner requirements, and activate debris maintenance at the downwell debris skimmer, as described in Section 5.1.4. Despite the efficiencies offered by these features, operation of this relatively complex facility would likely require a moderately high degree of attention by operations personnel to respond to changing conditions, primarily in the area of screen cleaning and general debris maintenance. For the Type 1 SBC channel design, the equivalent of two full-time operators are anticipated to be required to handle the daily operations of the system. This number may increase during high debris loading periods and be reduced in low periods. Off-season maintenance and inspection duties will likely require more concentrated efforts on the parts of divers and other personnel performing structure inspections and maintenance.

Corrosion Protection

Components proposed for construction and installation in the SBC system must demonstrate a 50-year life span while in service. One of the primary issues related to longevity relates to the ability of the components to resist corrosion, and the ease and reliability of inspection for corrosion. The large steel structures proposed for the SBC channel are subjected to moderately corrosive environments (continual submergence in moving freshwater) and would be difficult to maintain since removal of these large submerged structures for periodic inspection and refinishing would not be economically feasible. Therefore, selection of an appropriate corrosion protection system is critical.

Two basic corrosion protection systems were reviewed for the steel structures. These include conventional organic coatings systems (painting) and cathodic protection systems. The latter includes use of galvanic anode systems, impressed current systems, and thermal spray metal coatings.

Organic systems include a wide range of painting systems that have historically provided (successfully and unsuccessfully) a large degree of the corrosion protection for steel structures. Typical in this category would be a primer coat (e.g., zinc-rich urethanes) with one or more urethane top coats. The Corps has successfully utilized a 6-coat vinyl paint system (Guide Specification CWGS-09940) for use on hydraulic structures and this system is currently the preferred coating system for many steel hydraulic structures. High volatile organic compound (VOC) concerns and complex application makes this system cumbersome to install yet it has proven very successful and durable in the proper applications [14]. Paint coatings electrically insulate the structure from the electrolytic environment thus interrupting the corrosion cell. Success of the system depends on the continued integrity of the coating. While this type of system can be applied at a reasonable cost during the fabrication of the structures, longevity of these systems is typically less than 20 years with refinishing accomplished periodically as required. While a life-cycle cost evaluation comparing paint systems to other systems would be appropriate, due to their lack of longevity, paint systems are seen as only appropriate for components in the SBC which can be readily removed for inspection and refinishing (e.g., the removable bulkhead panels, stop logs, screen panel framing, etc.)

The other class of corrosion protection systems reviewed are categorized as cathodic protection systems. These systems operate on the basis of transferring the corrosion from the protected structure to a sacrificial material or anode (typically zinc). Galvanic anode systems utilize a replaceable sacrificial anode on the protected structure and typically involve very low (naturally induced) driving voltages derived from the resulting electrochemical process. Periodic replacement of the anodes is required. Impressed current systems allow far greater driving voltages than the galvanic anodes. Voltage from an outside source is “impressed” on the circuit between the protected structures and the anodes. The most common source of power is the cathodic protection rectifier or D.C. power supply. Impressed current systems are inherently more complex than galvanic systems and typically require more maintenance. While relatively commonly applied by various districts (e.g., Mobile District), the need to ensure continued operation of the system is imperative. Experience with long-term application of impressed current has often resulted in failure of the impressed current system before failure of the associated paint system has occurred. Common for both the galvanic anode and impressed current systems is the need to assure that all protected structure parts are electrically connected. If a conventional paint system is utilized in conjunction with these systems (typical), each painted part must be electrically connected to assure protection. For a large complex steel structure with many fabricated parts (many bolted after fabrication), this is a daunting task. While technically feasible, these two cathodic protection systems are not viewed as reasonable alternatives for the large continually submerged (non-removable) steel structures forming the SBC channel system.

The final cathodic protection system reviewed is known as thermal spray metal coating (thermal spray) or historically as metalizing. Thermal spray metal coatings are depositions of metal which have been melted immediately prior to projection onto the substrate. The metals used and the application systems vary, but typical applications result in thin coatings of sacrificial metals being applied to surfaces requiring corrosion protection. While not as common as paint, sprayed metal coatings have been used for a number of years and exposure tests have proven them to be extremely durable and superior to conventional paint coatings. Uses have included protection of steel offshore drilling platforms, protection of ships in the U.S. Navy fleet, and by the Corps for protection of steel hydraulic structures where a wear-resistant, low maintenance system is required [15]. Typical metals applied in these systems are zinc and aluminum and commonly an 85/15 (zinc/aluminum) alloy is employed in freshwater applications. While similar to hot-dip galvanizing in protection theory, thermal spray systems attain a much higher level of purity due to the absence of contaminating elements typically found in the hot-dip process, and unlike hot-dip galvanizing which is limited by dipping tank sizes, thermal spray coatings are applied in much the same environment as conventional sprayed paint systems. Initial application cost has historically been an issue with these coatings, being as much as twice as expensive as conventional paint systems, and application of thermal spray metal coatings can take longer. However, these costs are being reduced dramatically through use of larger 4.8 millimeters (3/16 inch) wire systems and may soon approach the cost of painting. Minor damage to thermal spray coatings is most often not a concern since the cathodic action of the surrounding coating will dominate the electrolytic environment resulting in very little if any corrosion of small exposed bare metal areas. Where low maintenance requirements control, these systems are very attractive and present a very competitive system with practical protection possible (depending on the coating design) for as much a 50 years.

The use of zinc as a component of the thermal spray coating is an issue which may cause some concern, and should be addressed. Exposure to zinc in certain environmental conditions is documented to be toxic to many fish species, especially salmonids. This has been identified as a problem in confined environmental exposures, such as fish hatcheries and aquariums, where fish are confined for long periods with limited water turnover rates. Toxic levels for salmonids in these applications have been cited as 0.01milligram per liter [mg/l] [16], and 0.03 mg/l [17]. In the relatively high-velocity, high-flow conditions represented in the SBC channel design it is very unlikely that levels such as these could ever be created by the coating system. To establish even the more conservative concentration of 0.01 mg/l in a flow of 170 m^3/s (6,000 cfs) would require that the channel structure release approximately 4.5 tonnes (4.9 tons) of zinc into the water per month. If the thermal spray coating was being leached off the structure at even a tiny fraction of this rate it would not function as a protective coating for very long. Additionally, the fish which pass through this system are not confined, and in fact would spend less than a couple of minutes in the bypass system if they are moving at the design water velocity. In spite of these facts, given the sensitive nature of fish toxicity concerns, and the apparent advantages the thermal spray system could offer for long-term corrosion protection, it may be prudent to conduct a controlled test of fish exposure to these conditions before making a final decision to either use or not use a thermal spray coating system.

Based on the above discussions, the following corrosion protection measures are proposed for the components described for the SBC channel. For nonremovable, nonstainless steel structures and components with low or no maintenance opportunities (submerged), an 85/15 thermal sprayed system with a colored seal coat is proposed, assuming concerns about zinc concentrations are adequately addressed. These structures would include the proposed channel structure in the forebay, the debris and channel caisson at the south end, the SES, and the cutoff wall located below the channel. Periodic inspection by divers would monitor the integrity of these structures over the life of the system. Internal components and accessories which are removable could receive a conventional paint system or galvanizing in lieu of the thermal spray coating if cost savings justified this. The removable bulkhead panels in the SES for example, could be painted.

Debris Maintenance

Maintenance of water borne debris in and around the SBC channel is a relatively significant operational issue. The semi-circular debris racks and trash rake system described in Section 5.1.3 will exclude the larger debris, however, smaller floating and neutrally buoyant debris would inevitably be entrained in the channel flow. This debris will accumulate on the horizontal (or sloped) floor surfaces, become impinged on the screens, or be carried with the flow into the smaller channels and eventually to the juvenile collection facilities. The objective of debris maintenance activities would be to minimize the impacts of the debris on the operations of the facility by staying ahead of the debris rather than eliminating it completely. The vertical brush bar screen cleaning system should remove a relatively significant portion of small debris (aquatic weeds, thistles, etc.) from the flow path, but some of the debris would continue on and remain entrained in the flow.

Floating debris in the channel will likely accumulate at the downwell where the fish transport flow enters the powerhouse. The downwell debris rake, described in Section 5.1.3, would be periodically deployed to remove floating material in that area.

Accumulations of debris in the bottoms of the channel would likely occur in the lower velocity areas in the channel entrance and adjacent to the primary screen panels. It is assumed that divers would be required to dispense with this material at the end of the operational season. Inclusion of maintenance "trap" doors in the floors of these areas would assist in this removal activity allowing debris to be pushed through the openings and out of the channel. The alternative would be to have the material mucked out from above with nets and cranes. Even if trap doors are provided, a certain amount of mucking out may still be required due to the shear size of the channel.

Because a large portion of the channel is effectively screened from debris by the dewatering screens, these areas would likely not require a lot of attention. Similarly, the SES, which discharges the screened flow from the channel, would not likely accumulate a great deal of debris. Flushing of the SES would be possible by removing the upstream bulkhead panels of the SES and opening the Tainter gate.

Inspection

Inspection of the large submerged steel structures described for the SBC channel system is only reasonably accomplished by divers. These structures would include the SBC channel, the SES, the steel caisson at the erection bay, and the cutoff wall located under the channel. Remotely operated vehicles (ROVs) could be employed with video monitoring equipment to perform these inspections, but restricted visibility due to degraded water quality (turbidity) and the angular and irregular nature of much of these structures makes this equipment somewhat cumbersome to use from a practical standpoint. The proposed thermal spray coating system for the submerged steel structures should make inspection of these structures straightforward and less intensive than might be expected with a lesser coating system.

Some of the higher maintenance items are proposed as being completely removable for inspection, maintenance and cleaning. The screen cleaning system including the brush bars and the entire guide track frame structure, for example, would be completely removable.

If the fused attachment described in Section 5.1.2 is installed between the channel and the guides, the shear pins should be inspected by divers annually. Pins which appear to be damaged should be replaced in kind and mill certification provided for the high-strength steel material to document the actual shear capacity of the pin.

Routine inspection of the ESBS system is anticipated throughout the fish season. The magnitude and scope of these inspections is well documented and are expected to remain the same.

Mechanical Systems

Maintenance of the major mechanical systems will be greatly enhanced by the good access to the critical mechanisms. The drive mechanisms for the screen cleaning equipment are above the water surface and thus readily inspectable and serviceable. This is also the case for the debris rake equipment at the entrances and at the fish gallery downwell. Normal periodic maintenance for this equipment is assumed. Since machinery is available which is specifically designed for these types of applications, a high level of reliability is anticipated.

5.1.6 Construction Issues

Fabrication/Installation Strategies

Several fabrication/installation strategies could be adopted for the construction of the SBC channel and the SES. Because Lower Granite is barge-accessible, and since a strong fabrication presence exists in the Northwest region with good marine access, the use of barges for the conveyance of large pre-assembled components is attractive from a fabrication/installation viewpoint. A particular advantage lies in the ability to pre-assemble the channel components in a more controlled shop environment rather than at the job site. For example, proper fit-up and alignment of screens and internal panels is critical to the performance of cleaning equipment. The quality of the corrosion protection system would also be better if it were applied in a controlled environment before transport to the site, and if the field assembly were limited to bolting (i.e., no field welding). Pre-fabricated channel sections as long as 3.05 meters (10 feet) or more could conceivably be pre-assembled and transported by barge to the site for final installation. Barging equipment with capacities of 3,175 tonnes (3,500 tons) is available and would be ample for this work. Use of the area around the navigation locks could be used for staging and bolting of the channel sections prior to floating to the face of the powerhouse for final installation.

Alternatively, assembly of the SBC channel components could be undertaken at the job site. Trucking of panelized subassemblies is feasible for panels up to 5.0 meters (16.5 feet) wide without road closures, however, height restrictions would not allow for fully pre-fabricated channel sections to be trucked. Barging of these subassemblies would also obviously be feasible. A site-based final assembly shop (either on shore or on a barge) would be capable of bolting and a certain amount of welding. Cranes would be employed to allow placement of the smaller assemblies in the water for final assembly underwater by divers.

Installation of the concrete caissons for support of the cutoff wall (at the bottom of the forebay) will require a unit outage for Unit 6, and possibly Unit 5. If bedrock is encountered at the desired locations for the caissons, direct placement of tremie concrete inside a submerged steel shell would be performed. Otherwise, jetting and pumping of excavated material from inside the caissons may be feasible to sound material, with subsequent placement of tremie concrete. The concrete caisson would then be rock anchored to the underlying bedrock material. The lower panel of the cutoff wall, after shore (or barge) assembly, would be lowered into place and temporarily secured until arrival of the channel section outfitted with the braced upper wall section.

Similar issues are of consideration for the SES. The proposed large steel panels should be fabricated in sections as large as can be transported and handled efficiently at the site. Final assembly of the panels would occur at the site where they would be bolted to the face of the spillway piers utilizing rock bolts or large anchor bolts. Installation of the tremie concrete fill would follow.

At the erection bay monolith, routing of the fish transport conduit from the SBC channel to the existing fish collection gallery in the dam will require the removal of portions of the forebay wall (see Sections C and D on Plate 1.1.4). Since this area is normally submerged, removal of this concrete would either need to be accomplished underwater or in the dry behind a dewatering caisson. Removal of the concrete underwater would not be feasible since the downstream side of the wall would then be flooded to full forebay elevation which is not acceptable. Rather, it is proposed that the steel caisson designed for the final installation be installed prior to concrete removal and utilized during the concrete removal process. Some additional bulkheading would be required at the caisson penetration where the connection would ultimately be made to the floating structure. Diamond wire sawing of the concrete into manageable pieces would facilitate removal through the open top of the caisson.

Ultimately, the design of these structures should allow for flexibility in construction to accommodate a variety of fabrication/installation strategies to improve the bidding environment during the construction phase. Common to all of the construction activities would be the need for a relatively large amount of diver work. The goal would be to limit this work to assembly of bolted connections since recoating of painted or cathodically protected surfaces underwater is not seen as a reasonable undertaking.

Construction Sequencing

Major construction sequencing for the installation of the SBC channel components is constrained by the requirements of powerhouse and spillway operations including flood protection, downstream fish passage protection (mandated spill), and spill shaping to enhance upstream passage and navigation. In addition, construction activities in the river near the project are severely restricted from mid-April to mid-December to ensure that migrating fish are not disturbed by construction noise, degraded water quality due to construction, or blocked or otherwise compromised passage routes. The remainder of the year (mid-December to mid-March) is identified as the in-water work window for construction at the project. Unit outage and spillbay blockage opportunities, and less restrictive construction requirements in terms of water quality and noise are examples of construction impacts that are allowed during this period. Exceptions to this work window, however, are assumed to include construction activities that do not impact existing protection measures. This distinction might allow work to proceed on portions of the project that do not interfere with migrating fish.

Installation of the major portions of the SBC channel in the forebay is envisioned to take place during the work window identified above. Construction would progress along the face of the powerhouse requiring periodic unit outages to allow work to proceed in front of unit intakes. To optimize this effort, sections of the channel could be assembled remotely from the powerhouse (for example in the area of the navigation lock) and floated to the face of the powerhouse for attachment to the powerhouse and connection to the rest of the channel. Final finish work could proceed independently of powerhouse operations.

There may be an advantage from a fish passage protection standpoint to sequence the work starting at the spillway end of the channel and progressing toward the lower number powerhouse units. If it were not possible to complete construction of the channel during a single 3-month work window, which is likely, the channel could be operated in a nonscreening or emergency bypass mode during the fish passage season. The channel would need to be bulkheaded at the upstream end (where construction ended) and the completed entrance(s) opened to allow downstream migrants to enter the SBC and pass through to Spillbay 1. Because no screening would be involved, much of the internal mechanical and electrical features (screen cleaners, screen panels, control weirs, etc.) would not need to be installed at this point. It may in fact be possible to construct the channel shell and internal walls for the entire length of the SBC during the in-water work window so that all three entrances would be available in the nonscreening mode. Alternatively, the channel could be assumed to be non-operational during the fish passage months while internal construction work is completed so that the channel could be put into operation mid-season or the following April.

Work on the SES at Spillbay 1 could be conducted relatively independently of project operations except during periods of high spill or if spill shaping required use of Spillbay 1 during the fish migration season. Because Spillbay 1 is not specifically associated with current downstream juvenile fish passage (except as related to spill), it is assumed that work on this structure would be relatively unencumbered by the work window. However, because Spillbay 2 and perhaps Spillbay 3 would also need to be shutdown for safety during construction of portions of the SES, this would require a relatively close review of the project operational impacts discussed above. Assuming that operational issues can be resolved, it is conceivable that work could be started on the installation of the large steel panels (walls and floor) of the SES prior to December 15. Most of this work would be relatively benign from a fish disturbance standpoint. During the work window period, more sensitive construction activities could be conducted. This would include the tremie concrete installation. With use of anti-milking agents in the concrete mix, the water quality concerns can be minimized although not eliminated. Completion of the SES would be required during the first work window season if temporary full flow bypass (nonscreened) operation of the SBC channel were desired.

Construction Duration

Fabrication of the SBC channel and SES components shown for the Type 1 design at Lower Granite should take 3 to 5 months. Installation of the SES should take about 3 months. Installation of the channel to a fully operational condition should take 5 to 7 months.

5.1.7 Construction and O&M Costs

Total estimated cost of engineering design and construction for a Type 1 SBC system at Lower Granite is $61,449,000 in 1998 dollars. A cost breakdown is presented in spreadsheet format on the following page. Annual O&M costs are estimated as follows:

Maintenance	
Mechanical/electrical components	$236,700
Structural components	$133,900
Operations	
Labor requirements	$160,000
Total annual O&M	**$530,600**

These O&M costs do not include costs associated with O&M of the existing ESBS diversion system, juvenile fish facilities, or transportation costs. Biological study costs also are not included.

PROJECT: LOWER SNAKE RIVER S.B.C. SYSTEM COMBINATIONS - CONCEPT DESIGN REPORT
DESIGN STATUS: CONCEPTUAL

DATE: Nov-98
ESTIMATOR: PJC
CHECKED BY: RGW

Pre-decisional draft document. Not for distribution or release.

TYPE 1 SBC - FULL POWERHOUSE SBC (with Existing ESBS) - LOWER GRANITE LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**SBC CHANNEL**				
	Channel Structure (exterior floor and walls)	11,400	M^2	710	8,094,000
	Interior Conduit Structures (floors and walls minus screens)	4,810	M^2	710	3,415,100
	Miscellaneous Walkways, Roof Structures, Trash Racks, Bulkhead Panels (% of costs above)	11,509,100	$	10%	1,150,910
	Channel Flotation Cells	500	M	6,980	3,490,000
	Dewatering Screen Panels (removable panels stainless steel wedge-wire screen with spare panels	1,245	M^2	1,470	1,830,150
	Screen Cleaners (vertical brush cleaners)	40	EA	40,000	1,600,000
	Channel Entrance Debris Rake System	1	LS	659,000	659,000
	Emergency Bypass Doors and Tilting Control Weirs	120	M^2	1,640	196,800
	Cutoff Wall (includes foundation)	460	M^2	1,170	538,200
	Structural Support and Guide System	223	Tonne	5,000	1,115,000
	ITEM SUBTOTAL				22,089,160
2	**SPILLWAY EXTENSION STRUCTURE**				
	Structure Floor and Wall Panels	760	M^2	1,550	1,178,000
	Bulkhead Panels	670	M^2	540	361,800
	ITEM SUBTOTAL				1,539,800
3	**CHANNEL CONDUIT CONNECTION TO GALLERY (AT ERECTION BAY)**				
	Steel Caisson and Related Structures	160	M^2	1,530	244,800
	Concrete Removal	55	M^3	1,330	73,150
	Miscellaneous (Debris Skimmer, Hopper, Existing Caisson Removal, New Gate)	1	LS	170,000	170,000
	ITEM SUBTOTAL				487,950
4	**MISCELLANEOUS**				
	Trash Shear Boom Relocation	1	LS	75,000	75,000
	Existing Prototype SBC Channel and Prototype BGS Removal and Disposal	2,770	Tonne	900	2,493,000
	9.1-Tonne Boom Truck	1	EA	200,000	200,000
	Electrical Requirements	1	LS	530,100	530,100
	ITEM SUBTOTAL				3,298,100
	Subtotal Direct Construction Costs				27,415,010
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	27,415,010	$	5.0%	1,370,751
	General Contractors Overhead and Profit	28,785,761	$	26.5%	7,628,227
	CONSTRUCTION SUBTOTAL				36,413,987
	Construction Contingency	36,413,987	$	25.0%	9,103,497
	TOTAL CONSTRUCTION COSTS				***45,517,484***
	PLANNING AND ENGINEERING	45,517,484	$	22.5%	10,241,434
	CONSTRUCTION MANAGEMENT	45,517,484	$	12.5%	5,689,685
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				$61,448,603

App E/Annex B/cost spreadsheet.xls/Type 1 - Granite

5.2 Little Goose: Full Powerhouse SBC (with Existing ESBS) – SBC Type 1

The layout of the existing powerhouse and spillway at Little Goose is very similar to the layout at Lower Granite. Therefore, the general arrangement and operation of the Type 1 SBC channel at Little Goose is the same as was described for Lower Granite, with a few minor exceptions. Plans and details of this design are included on Plates 1.2.1 through 1.2.4, in Section 5.6. The exceptions are discussed below, and the effects they have on specific design details are discussed in the following sections.

One difference between Lower Granite and Little Goose is that the existing juvenile fish bypass gallery at Little Goose does not include a downwell. Rather, the entire gallery bypass system operates as an open-channel flow. Since the open-channel transport flow from the SBC conduit will be merged directly into this gallery flow, there is no one location where small floating debris would likely accumulate. Therefore, there is no need at Little Goose to include a debris skimmer at this location. The hydraulics associated with the merging of the SBC flow and the existing juvenile gallery flow is discussed in Section 5.2.1.

The location of the adult fish ladder exit at Little Goose is farther south of the powerhouse than is the case at Lower Granite. The ladder exit is incorporated into the navigation lock monolith, to the south of the south non-overflow section. As a result, the SBC channel does not extend in front of the fish ladder exit at Little Goose. The channel does, however, extend in front of the intake for the ladder attraction water turbine-pump, which is incorporated into the erection bay. This should not present a problem since the intake is located at a depth well below the channel flotation cell, and the wall of the channel would be far enough away from the intake so as not to cause a hydraulic problem. The erection bay at Little Goose extends upstream to an extent requiring that the SBC channel include a boxed-out portion to accommodate it. The reduced cross-sectional area of the channel at this location should not present a problem because the flow in this area is small.

An operational difference between Lower Granite and the other three projects (including Little Goose) is that only Lower Granite is operated as a flood control project. Therefore, the forebays at Little Goose, Lower Monumental, and Ice Harbor are never currently drawn down below the MOP elevation. This could reduce the length required for the channel attachment guides. However, for the purposes of this investigation it has been conservatively assumed that the guides at all four projects are the same length, allowing for a reservoir draw down to 9 feet below MOP. This would accommodate potential future changes in the operating procedures at these projects, and is reflected in the drawings and cost estimates.

One final difference between Lower Granite and the other three projects is that Lower Granite has a number of existing items in the forebay which need to be removed or relocated to facilitate installation of a new SBC. These items, which are not present at the other projects, include an SBC prototype with an SWI attached, a BGS prototype, and a forebay trash shear boom. Consequently, although none of these items effect the design of the SBC itself, the cost of installing any of the SBC designs described in this report at Lower Granite, for this reason alone, would be greater than installing an identical facility at the other three projects.

5.2.1 Hydraulics

Hydraulic characteristics of the Type 1 SBC installed at Little Goose are nearly identical to the Type 1 SBC installation at Lower Granite. The exception lies with the connection to the existing fish gallery. The SBC fish transport flow merges with the gallery flow on the outside and near the downstream end of a 90-degree bend in the gallery (see Plate 1.2.2). As a consequence, the gallery flow is converging on the zone that the SBC flow is emerging from. This could further aggravate mixing and yield a rough transition. It is proposed that a shroud or shell could be used to turn the SBC flow, aligning it with the gallery flow, and at the same time matching the SBC flow velocity to the gallery velocity. The two flows could then be merged with minimal mixing and shear. Considering the concentrations of juvenile fish in both flows, optimizing hydraulics appears to be desirable. A thin walled shroud should be used to minimize trailing separation zones. The shroud might be molded out of plastic or ABS material much like that used in kayak fabrication. The centerline radius of the included bend should be at least five conduit widths long. The shroud would converge on the gallery flow, however by using a gradual convergence and by rounding all corners on the shroud, adverse influences on the gallery flow should be minimized.

5.2.2 Structural Design

Structural design issues for the Type 1 SBC at Little Goose are the same as those described for Lower Granite in Section 5.1.2, with one exception. The straight-line fetch length of the river upstream of the dam at Little Goose is longer than at Lower Granite. At Little Goose, the fetch length is about 10.5 kilometers (6.5 miles), whereas at Lower Granite the fetch is only about 3.2 kilometers (2.0 miles). The result of the longer fetch is the potential for larger wind-driven waves and wave loading. The wave height and wave length associated with fully developed waves resulting from a 113-km/hr (70-mph) wind over a 10.5-kilometer (6.5-mile) fetch are 1.62 meters (5.3 feet) and 28 meters (93 feet), respectively. The resulting wave load on a vertical wall extending 21.3 meters (70 feet) deep is 74 kN/m (5,100 lb/ft), compared to 19 kN/m (1,300 lb/ft) at Lower Granite. This greater wind load is similar to the design ice loading at either project and should not effect the design considerations for the fused attachment. Additionally, the sustained wind required to mobilize the design wave described for Little Goose would be a much rarer event than that which would be required at Lower Granite. For a 113 km/hr (70 mph) wind to fully mobilize the fetch at Little Goose would require that it be sustained for 80 minutes, whereas mobilizing the shorter fetch at Lower Granite would require only 36 minutes of sustained design wind.

5.2.3 Mechanical Requirements

As with the other design issues, mechanical requirements for the Type 1 SBC design at Little Goose are the same as described for Lower Granite with the exception that Little Goose does not require a debris skimmer. Details concerning the mechanical requirements for this design can be found in Section 5.1.3.

Hoisting issues are the same as at Lower Granite except that since there is no debris skimmer, there is no debris hopper to be unloaded. Because Little Goose has the same 50-tonne (55-ton), 4-section hydraulic boom crane that Lower Granite has, use of this crane for the various loads associated with a Type 1 design would be appropriate. A boom truck was included for Lower Granite due to the relatively frequent light loads associated with unloading the debris hopper. Since there is no debris hopper to unload, no boom truck is specified for Little Goose. It is anticipated that the raking of the entrance trash racks will be a relatively infrequent process and would not justify the expense of dedicated hoist equipment for the muck car.

5.2.4 Electrical Requirements

Primary Power Considerations

Except for the lack of a debris skimmer in the juvenile gallery, the electrical loads for the Type 1 SBC at Little Goose are the same as for those for the Type 1 SBC at Lower Granite (see Section 5.1.4) and total approximately 430 amperes at 480 volts ac. Calculations for estimated electrical load are provided in Attachment A.

A reliable source of power is available at 4160 volts from the Station Service Switchgear Room located in the erection bay on Floor 3 [18]. A new cubicle and breaker would be added to existing switchgear in this room. From there, a 4,160-volt feeder would be routed to the XJ Breaker Gallery on the 7th floor where there would be sufficient room to add a load interrupter switch, transformer and secondary breaker. From this location, 480-volt power would be routed up through the concrete deck via cored holes and from there to the floating SBC channel. Distribution of power on the SBC channel would be similar to that described for the Type 1 SBC at Lower Granite. A one-line diagram illustrating the electrical loads, power sources and components is provided on Plate 1.2.4.

Instrumentation and Controls

Instrumentation and controls issues for the Type 1 SBC at Little Goose are the same as at Lower Granite except that the debris skimmer shown for Lower Granite is not required thereby reducing system complexity to a minor degree.

5.2.5 Operation and Maintenance Issues

O&M issues for the Type 1 SBC channel design at Little Goose are very similar to those at Lower Granite. Because there is no debris skimmer, it is estimated that there would be a reduction of approximately one-half equivalent worker for operation of the facility. Therefore, a total equivalent of one and one half full-time operators are anticipated to be required to handle the daily operations of the system.

5.2.6 Construction Issues

Construction issues for installation of the SBC channel and related components at Little Goose are expected to be similar to those at Lower Granite. The project layout and operation is similar with slightly better accessibility possibilities for barging since there are fewer lockage events required to reach this project from the lower river.

Construction sequencing and construction durations would likewise be similar to Lower Granite as in-water work windows are the same and since the scope of the construction work is similar.

5.2.7 Construction and O&M Costs

Total estimated cost of engineering design and construction for a Type 1 SBC system at Little Goose is $53,787,000 in 1998 dollars. A cost breakdown is presented in spreadsheet format on the following page. Annual O&M costs are estimated as follows:

Maintenance	
Mechanical/electrical components	$224,200
Structural components	$131,100
Operations	
Labor requirements	$120,000
Total annual O&M	**$475,300**

These O&M costs do not include costs associated with O&M of the existing ESBS diversion system, juvenile fish facilities, or transportation costs. Biological study costs are also not included.

5.3 Lower Monumental: Full Powerhouse SBC (with New ESBS) – SBC Type 1

The layout of the existing powerhouse and spillway at Lower Monumental is very similar to the layout at Lower Granite, but is reversed in the north-south direction. At Lower Monumental, the powerhouse is located to the north of the spillbays. Therefore, other than the layout being reversed, the general arrangement and operation of the Type 1 SBC channel at Lower Monumental is the same as was described for Lower Granite, with a few minor exceptions. Plans and details of this design are included on Plates 1.3.1 through 1.3.4, in Section 5.6. The exceptions are discussed below, and the effects they have on specific design details are discussed in the following sections.

As is the case at Little Goose, the existing juvenile fish bypass gallery at Lower Monumental does not include a downwell. Rather, the entire gallery bypass system operates as an open-channel flow. Since the open-channel transport flow from the SBC conduit will be merged directly into this gallery flow, there is no one location where small floating debris would likely accumulate. Therefore, there is no need to include a debris skimmer at this location. The hydraulics associated with the merging of the SBC flow and the existing juvenile gallery flow is discussed in Section 5.3.1.

Other aspects of the Type 1 SBC design at Lower Monumental which are similar to Little Goose, but different than Lower Granite, are the location of the adult fish ladder exit relative to the channel, and the lack of a flood drawdown forebay elevation. At Lower Granite, the ladder exit is located behind the channel, as noted earlier, whereas at Lower Monumental, it is located north of the channel resulting in clear passage upstream from the exit. With regards to forebay elevations, the operation of Lower Monumental does not call for flood drawdown of the reservoir, resulting in potential savings in the channel attachment requirements. Moreover, the operating range variation of the Lower Monumental forebay is only 0.914 meter (3.0 feet), as opposed to 1.52 meters (5.0 feet) for Lower Granite and Little Goose, which could result in even greater savings in the attachment requirements.

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DESIGN STATUS: CONCEPTUAL

DATE: Nov-98
ESTIMATOR: PJC
CHECKED BY: RGW

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TYPE 1 SBC - FULL POWERHOUSE SBC (with Existing ESBS) - LITTLE GOOSE LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**SBC CHANNEL**				
	Channel Structure (exterior floor and walls)	11,400	M^2	710	**8,094,000**
	Interior Conduit Structures (floors and walls minus screens)	4,660	M^2	710	**3,308,600**
	Miscellaneous Walkways, Roof Structures, Trash Racks, Bulkhead Panels (% of costs above)	11,402,600	$	10%	**1,140,260**
	Channel Flotation Cells	500	M	6,980	**3,490,000**
	Dewatering Screen Panels (removable panels stainless steel wedge-wire screen with spare panels	1,245	M^2	1,470	**1,830,150**
	Screen Cleaners (vertical brush cleaners)	40	EA	40,000	**1,600,000**
	Channel Entrance Debris Rake System	1	LS	659,000	**659,000**
	Emergency Bypass Doors and Tilting Control Weirs	120	M^2	1,640	**196,800**
	Cutoff Wall (includes foundation)	460	M^2	1,170	**538,200**
	Structural Support and Guide System	182	Tonne	5,000	**910,000**
	ITEM SUBTOTAL				**21,767,010**
2	**SPILLWAY EXTENSION STRUCTURE**				
	Structure Floor and Wall Panels	760	M^2	1,550	**1,178,000**
	Bulkhead Panels	670	M^2	540	**361,800**
	ITEM SUBTOTAL				**1,539,800**
3	**CHANNEL CONDUIT CONNECTION TO GALLERY (AT SOUTH NON-OVERFLOW SECTION)**				
	Steel Caisson and Related Structures	76	kg	1,530	**116,280**
	Concrete Removal	30	M^3	1,330	**39,900**
	ITEM SUBTOTAL				**156,180**
4	**MISCELLANEOUS**				
	Electrical Requirements	1	LS	533,860	**533,860**
	ITEM SUBTOTAL				**533,860**
	Subtotal Direct Construction Costs				**23,996,850**
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	23,996,850	$	5.0%	**1,199,843**
	General Contractors Overhead and Profit	25,196,693	$	26.5%	**6,677,124**
	CONSTRUCTION SUBTOTAL				**31,873,816**
	Construction Contingency	31,873,816	$	25.0%	**7,968,454**
	TOTAL CONSTRUCTION COSTS				***39,842,270***
	PLANNING AND ENGINEERING	39,842,270	$	22.5%	**8,964,511**
	CONSTRUCTION MANAGEMENT	39,842,270	$	12.5%	**4,980,284**
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				**$53,787,065**

5.3.1 Hydraulics

Hydraulic characteristics of the Type 1 SBC installed at Lower Monumental are nearly identical to the Type 1 SBC installations at Lower Granite and Little Goose. The exception again lies with the connection to the existing fish gallery. The SBC fish transport flow at this site is merged with the gallery flow in a gallery section that should have fairly well aligned flow, as shown on Plate 1.3.2. This location minimizes local flow concentrations and consequently offers potential for more stable merging hydraulics. Use of a shroud, as proposed for Little Goose, could again be used to further optimize flow merging. The shroud would align the SBC flow with the gallery flow and at the same time match flow velocities. The two flows could then be merged with minimal mixing and shear. The centerline radius of the included bend should again be at least five conduit widths long.

To optimize the ESBS design, the new ESBS should be evaluated in a single turbine intake model with an SBC-shaped box included since the SBC will modify the hydraulic field at the ESBS. The Lower Monumental turbine intake configuration is nearly identical to Little Goose and quite similar to Lower Granite. As a consequence, previous studies that developed the ESBS installations at those sites may give guidance to selection of design features (including screen porosity) for Lower Monumental. Knowledge gained from the experience of operating ESBS systems at these facilities (both positive or negative) should be used to further optimize the new design. Recognizing the importance of these hydraulic features and their influence on potential fish impingement and collection, care should be taken to optimize the ESBS design and the ESBS porosity. This may require additional hydraulic modeling. Modeling of the ESBS design should use a single turbine intake model of sufficient scale (approximately 1:12) to allow detailed evaluation of the velocity fields on the ESBS face and in the gate well entrance.

5.3.2 Structural Design

SBC Channel and SES

Structural design issues for the Type 1 SBC at Lower Monumental are the same as those discussed for Lower Granite in Section 5.1.2, with one exception. The straight-line fetch length of the river upstream of the dam at Lower Monumental is about 5.6 kilometers (3.5 miles). This is longer than the fetch at Lower Granite, but is considerably shorter than at Little Goose. The resulting wave loading would be less than was described in Section 5.2.2 for Little Goose, and considerably less than the design ice loading. Therefore, although the wave loading could potentially be somewhat greater than at Lower Granite, it would not affect the fuse pin attachment design previously described.

ESBS Intake Diversion System

The structural design of the ESBS systems is assumed to be the same as for previously constructed ESBS systems at other projects. No major structural modifications will be required to accommodate the screens. Modifications to add a gate to the handrails around the intake deck openings will be required since the gantry crane cannot lift the screens fully to clear the existing handrails. Also, handrail modifications to accommodate the dogging beams and devices will be required [19].

5.3.3 Mechanical Requirements

As with the other design issues, mechanical requirements for the Type 1 SBC design at Lower Monumental are the same as described for Lower Granite with the exception that like Little Goose, Lower Monumental does not require a debris skimmer. There are also additional mechanical issues related to the new ESBS system and hoisting as described below. Other details concerning the mechanical requirements for this design can be found in Section 5.1.3.

Hoist Systems

Hoisting issues are the same as at Lower Granite except that since there is no debris skimmer, there is no debris hopper to be unloaded. Lower Monumental has a 32-tonne (35-ton), hydraulic boom crane which is smaller than those at either Lower Granite or Little Goose. On its outriggers, the crane has the following capacities:

Load Radius	Boom Length	Capacity (Side)
12.2 m (40 ft)	34.1 m (112 ft)	5,625 kg (12,400 lb)
15.2 m (50 ft)	34.1 m (112 ft)	4,718 kg (10,400 lb)
18.3 m (60 ft)	34.1 m (112 ft)	3,629 kg (8,000 lb)
21.3 m (70 ft)	34.1 m (112 ft)	2,858 kg (6,300 lb)
24.4 m (80 ft)	34.1 m (112 ft)	1,996 kg (4,400 lb)

These load capacities are between 75 percent and 90 percent of those for the bigger cranes at Little Goose and Lower Granite. Thus, if this existing crane were utilized, it would be necessary to either reduce the magnitude of the loads for the removable channel components. Alternatively, a larger crane could be procured. This would be an issue for final design. This decision may be influenced by the fact that the 32-tonne (35-ton) crane is older and has been somewhat problematic to operate [20]. Since no debris skimmer is required at Lower Monumental, no boom truck is specified.

ESBS System

The typical ESBS designs at other projects include a screen cleaner made up of a vertically sweeping brush bar driven by a 5-horsepower motor. The bar sweeps debris across the length of the screens and into the intakes where it is carried away. It is assumed that this design will also be appropriate at Lower Monumental.

5.3.4 Electrical Requirements

Primary Power Considerations

The electrical loads for the Type 1 SBC at Lower Monumental are the same as those for the Type 1 SBC at Little Goose (i.e., as described for Lower Granite in Section 5.1.4, but without the debris skimmer) and total approximately 430 amperes at 480-volt alternating current. Calculations for estimated electrical load are provided in Attachment A.

A reliable source of power is available from the 4,160-volt switchgear located in the Station Service Switchgear Room located in the erection bay on Floor 3 at about elevation 135.3 meters (444 feet) [20]. A new cubicle and breaker would be added to existing switchgear in this room. From there, a 4,160-volt feeder would be routed to the service gallery near Spillbay 8 at about elevation 165.8 meters (544 feet) where there would be sufficient room to add a load interrupter switch, transformer, and secondary breaker. From this location, 480-volt power would be routed up through the concrete deck via cored holes and from there to the floating SBC channel. Distribution of power on the SBC channel would be similar to that described for the Type 1 SBC at Lower Granite. A one-line diagram illustrating the electrical loads, power sources and components is provided on Plate 1.3.4.

ESBS Intake Screens

Each of the 18 new ESBS installations specified to replace the existing submerged traveling screens systems has a 5-horsepower motor to drive the integrally designed brush bar screen cleaning system. This motor size is equal to the screen drive motor on the existing traveling screens and, based on experiences at Lower Granite and Little Goose, the electrical loads are similar [21]. Thus, no additional 480-volt electrical power requirements are anticipated for the new screens. The new screens do require limit switches and PLCs to control the operation of the brush bar; these loads, however, are minor.

Instrumentation and Controls

Instrumentation and controls issues for the Type 1 SBC at Lower Monumental are the same as at Little Goose except for the PLCs for the ESBS installations as discussed above.

5.3.5 Operation and Maintenance Issues

O&M issues for the Type 1 SBC channel at Lower Monumental are virtually identical to those at Little Goose. A total equivalent of one and one half full-time operators are anticipated to be required to handle the daily operations of the SBC system. O&M issues related to the new ESBS system would be similar to those currently experienced with ESBS systems at other projects, and are well documented by maintenance records. Additional O&M costs are considered insignificant since they would be similar to those currently associated with the existing STS system.

5.3.6 Construction Issues

Construction issues related to the installation of the Type 1 SBC channel components at Lower Monumental are similar to those at the other projects. With less lockage events, barge access is slightly better than at Lower Granite and Little Goose. Construction access and staging is expected to be similar.

The magnitude of construction activities at Lower Monumental associated with the installation of new ESBS intake screens will be quite limited compared to those associated with the SBC channel. Screen installation issues are expected to be similar to ones encountered at other projects where they have previously been installed. Because no major retrofit of existing facilities is anticipated to accommodate the screens, and because most of the construction activities involve fabrication off site, no major disruptions of project operations will likely occur, except to install and remove the screens. Some operational testing of the screens may be required to confirm screen porosities and other screen hydraulic performance characteristics. Testing and adjusting of the ESBS cleaner equipment may also be required. Consequently, some limited unit outages may occur. The installation of these screens would likely be accomplished during the in-water work window so as not to impact fish collection capabilities at the project.

5.3.7 Construction and O&M Costs

Total estimated cost of engineering design and construction for a Type 1 SBC system at Lower Monumental is $53,750,000 in 1998 dollars. The estimated cost for replacing the existing STS intake diversion system with a new ESBS system is an additional $16,058,000. A cost breakdown is presented in spreadsheet format on the following two pages. Annual O&M costs are estimated as follows:

Maintenance	
Mechanical/electrical components	$224,200
Structural components	$131,100
Operations	
Labor requirements	$120,000
Total annual O&M	**$475,300**

These O&M costs do not include costs associated with operation and maintenance of the ESBS diversion system, juvenile fish facilities or transportation costs. Biological study costs are also not included.

5.4 Ice Harbor: New ESBS Intake Screens

The turbine intakes at Ice Harbor are currently outfitted with a STS diversion system. System Combination 1 calls for these existing screens to be replaced by a new ESBS diversion system. The issues related to the change-out of the screening systems are addressed in Section 5.3 where a new ESBS system is added in conjunction with installation of a Type 1 SBC at Lower Monumental. Issues specific to Ice Harbor are described as follows.

5.4.1 Hydraulics

Intake screen performance is in part dependent on the specific turbine intake design with its associated hydraulics; and the length, porosity, and orientation of the screen. Either excessive or insufficient head differentials may be generated across the intake screen, which may generate excessive or insufficient flow into the gate well and through the VBS. This could result in excessive flow through the VBS with potential for fish impingement or ineffective fish guidance into the gate well. Addition of an ESBS diversion system to the Ice Harbor intakes constitutes use of a intake screen design in a turbine intake that is significantly different than the intakes at the other Snake River structures. To ensure proper operation, the proposed ESBS design should be evaluated in a single turbine intake model of sufficient scale (approximately 1:12) to allow detailed evaluation of the velocity fields on the ESBS face and in the gate well entrance.

5.4.2 Structural Design

Structural design issues related to the new ESBS system at Ice Harbor are as described in Section 5.3.2 for the new ESBS system at Lower Monumental.

5.4.3 Mechanical Requirements

Mechanical design issues related to the new ESBS system are as described in Section 5.3.3 for the new ESBS system at Lower Monumental. No new hoisting equipment is anticipated for Ice Harbor related to this new construction.

5.4.4 Electrical Requirements

Electrical requirements for the new ESBS are similar to those for the existing traveling screens and no additional electrical power considerations are anticipated. See Section 5.3.4 for a discussion on electrical requirements for the new screens as related to Lower Monumental.

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DESIGN STATUS: CONCEPTUAL

DATE: Nov-98
ESTIMATOR: PJC
CHECKED BY: RGW

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TYPE 1 SBC - FULL POWERHOUSE SBC - LOWER MONUMENTAL LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**SBC CHANNEL**				
	Channel Structure (exterior floor and walls)	11,400	M^2	710	**8,094,000**
	Interior Conduit Structures (floors and walls minus screens)	4,660	M^2	710	**3,308,600**
	Miscellaneous Walkways, Roof Structures, Trash Racks, Bulkhead Panels (% of costs above)	11,402,600	$	10%	**1,140,260**
	Channel Flotation Cells	500	M	6,980	**3,490,000**
	Dewatering Screen Panels (removable panels stainless steel wedge-wire screen with spare panels	1,245	M^2	1,470	**1,830,150**
	Screen Cleaners (vertical brush cleaners)	40	EA	40,000	**1,600,000**
	Channel Entrance Debris Rake System	1	LS	659,000	**659,000**
	Emergency Bypass Doors and Tilting Control Weirs	120	M^2	1,640	**196,800**
	Cutoff Wall (includes foundation)	450	M^2	1,170	**526,500**
	Structural Support and Guide System	185	Tonne	5,000	**925,000**
	ITEM SUBTOTAL				**21,770,310**
2	**SPILLWAY EXTENSION STRUCTURE**				
	Structure Floor and Wall Panels	760	M^2	1,550	**1,178,000**
	Bulkhead Panels	670	M^2	540	**361,800**
	ITEM SUBTOTAL				**1,539,800**
3	**CHANNEL CONDUIT CONNECTION TO GALLERY (AT NORTH NON-OVERFLOW SECTION)**				
	Steel Caisson and Related Structures	76	kg	1,530	**116,280**
	Concrete Removal	15	M^2	1,330	**19,950**
	ITEM SUBTOTAL				**136,230**
4	**MISCELLANEOUS**				
	Electrical Requirements	1	LS	533,860	**533,860**
	ITEM SUBTOTAL				**533,860**
	Subtotal Direct Construction Costs				**23,980,200**
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	23,980,200	$	5.0%	**1,199,010**
	General Contractors Overhead and Profit	25,179,210	$	26.5%	**6,672,491**
	CONSTRUCTION SUBTOTAL				**31,851,701**
	Construction Contingency	31,851,701	$	25.0%	**7,962,925**
	TOTAL CONSTRUCTION COSTS				***39,814,626***
	PLANNING AND ENGINEERING	39,814,626	$	22.5%	**8,958,291**
	CONSTRUCTION MANAGEMENT	39,814,626	$	12.5%	**4,976,828**
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				**$53,749,745**

5.4.5 Operation and Maintenance Issues

Based on previous experience with intake diversion screen systems, the O&M requirements associated with ESBS systems are similar to requirements associated with STS systems. Therefore, replacing the existing STS system with a new ESBS system should not result in a significant change in annual O&M requirements at Ice Harbor.

5.4.6 Construction Issues

Construction of the ESBS screens at Ice Harbor will be same as described for Lower Monumental in Section 5.3.6.

Construction Duration

Fabrication and installation of the ESBS system should take 7 to 8 months based on previous fabrications/installation experience [22].

5.4.7 Construction and O&M Costs

Total estimated cost of engineering design and construction for a new ESBS intake diversion system at Ice Harbor is $16,058,000 in 1998 dollars. A cost breakdown is presented in spreadsheet format on the following page. Annual O&M costs should be essentially unchanged from the existing costs associated with the STS intake diversion system.

5.5 Combination Summary

5.5.1 Combined Construction Issues

The construction aspects of the combined system of SBC channels and other components at the four projects appear to have little impact on each other. A few issues, however, are worth considering. One is in the development of experience in design, construction, and fabrication practices. Since so many of the components are similar from dam to dam, there may be a benefit to stage construction and design so as to draw from the experiences at previous project installations. A single contractor engaged for all the construction work would likely be able to resolve issues at subsequent projects more efficiently based on previous experience. Should scheduling pressures dictate a more accelerated construction and design schedule, these benefits would be reduced. There may also be cost benefit from a contracting viewpoint. For example, a single supplier of 36 ESBS screen systems (18 each for Lower Monumental and Ice Harbor) may provide a better price than 2 contractors supplying 18 screens each.

5.5.2 Summary Construction and O&M Costs

The total combined estimated engineering design and construction cost for the System Combination 1 design is $202,102,000 in 1998 dollars. Additional costs will likely be incurred if prototyping and/or major hydraulic modeling efforts of system components are deemed to be required, as is discussed in Section 4.2. Some savings in cost may be experienced due to efficiency of repetitive design and construction, as discussed in Section 5.5.1. However, this potential savings has not been estimated as part of this report.

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ESTIMATOR: PJC
CHECKED BY: RGW

NEW EXTENDED LENGTH SUBMERGED BAR SCREENS - ICE HARBOR LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**ESBS INTAKE DIVERSION SCREENS**				
	Installation of ESBS Diversion Screens	18	EA	398,000	7,164,000
	ITEM SUBTOTAL				7,164,000
	Subtotal Direct Construction Costs				7,164,000
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	7,164,000	$	5.0%	358,200
	General Contractors Overhead and Profit	7,522,200	$	26.5%	1,993,383
	CONSTRUCTION SUBTOTAL				9,515,583
	Construction Contingency	9,515,583	$	25.0%	2,378,896
	TOTAL CONSTRUCTION COSTS				***11,894,479***
	PLANNING AND ENGINEERING	11,894,479	$	22.5%	2,676,258
	CONSTRUCTION MANAGEMENT	11,894,479	$	12.5%	1,486,810
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				$16,057,546

A summary of the estimated costs by project is shown below.

Estimated Engineering Design and Construction Cost – System Combination 1

Project	Description	Estimated Construction Cost
Lower Granite	Type 1 SBC (with existing ESBS)	$61,449,000
Little Goose	Type 1 SBC (with existing ESBS)	$53,787,000
Lower Monumental	Type 1 SBC	$53,750,000
Lower Monumental	New ESBS	$16,058,000
Ice Harbor	New ESBS	$16,058,000
	System Combination Subtotal	$201,102,000
	Feasibility Studies	$1,000,000
	Total Estimated Construction Cost	**$202,102,000**

The total annual O&M costs for System Combination 1 are estimated to be $1,481,200 in 1998 dollars. These O&M costs represent estimated increases in annual requirements and do not include existing costs associated with O&M of the intake diversion screen systems, existing juvenile fish facilities, or transportation costs. Biological study costs are also not included. A summary of the SBC O&M costs by project is shown below.

Estimated SBC Operation and Maintenance Cost – System Combination 1

Project	Description	Estimated O&M Cost
Lower Granite	Type 1 SBC (with existing ESBS)	$530,600
Little Goose	Type 1 SBC (with existing ESBS)	$475,300
Lower Monumental	Type 1 SBC (with new ESBS)	$475,300
Ice Harbor	New ESBS	$0
	Total Estimated Annual O&M Cost	**$1,481,200**

5.5.3 Implementation Schedule

An implementation schedule is included below. The assumptions and rationale used for development of the implementation schedule is provided. The implementation schedule includes time for hydraulic model testing as appropriate, preliminary design, preparation of construction contract documents, and construction. The implementation schedule assumes no funding or manpower restraints. Such restraints would likely impact the schedule included herein.

Lower Granite Dam

The implementation schedule assumes that hydraulic model testing would occur in the year 2000. The model testing would include testing of dewatering features of a surface collector used for fish transportation. A prototype surface collector construction contract may then be prepared in the year 2001. The prototype would be used for testing various dewatering schemes to determine biological impacts on fish due to dewatering. Also, the prototype may be used to investigate various screen-cleaning strategies. Construction of the prototype would be scheduled for year 2002. Data would then be collected in the year 2003. The implementation schedule assumes that dewatering and screen cleaning will both be found feasible from an engineering and biological perspective. Preliminary and final designs leading to development of a construction contract for a final SBC at Lower Granite would then be prepared in the years 2003 and 2004. Construction of the SBC would occur in the years 2005 and 2006. The surface collector would be operational in the year 2006.

Little Goose Dam

It is assumed that final design of an SBC structure at Little Goose Dam would not proceed until one year of testing at Lower Granite Dam is complete. The operation of the Lower Granite SBC would provide data useful for development of an improved SBC at Little Goose Dam. Also, the need for additional SBC structures downstream of Lower Granite could be reconsidered. Preliminary and final design leading to development of a construction contract would be scheduled for years 2007 and 2008. Construction would be scheduled for years 2009 and 2010. The surface collector would then be operational in the year 2010.

Lower Monumental Dam

It is assumed the lessons learned during the first year following completion of the Lower Granite SBC could also be applied at Lower Monumental. Therefore, the implementation schedule for the SBC structure would be the same as for Little Goose. The implementation schedule for the new ESBSs would be identical to that described for Lower Monumental under Combination 1A.

Ice Harbor Dam

The new ESBSs would be installed under the same schedule as described for Combination 1A.

5.6 System Combination 1 Drawings

Drawings depicting the SBC designs which form System Combination 1 are included on the following pages. These drawings include:

SBC Type 1 – Lower Granite

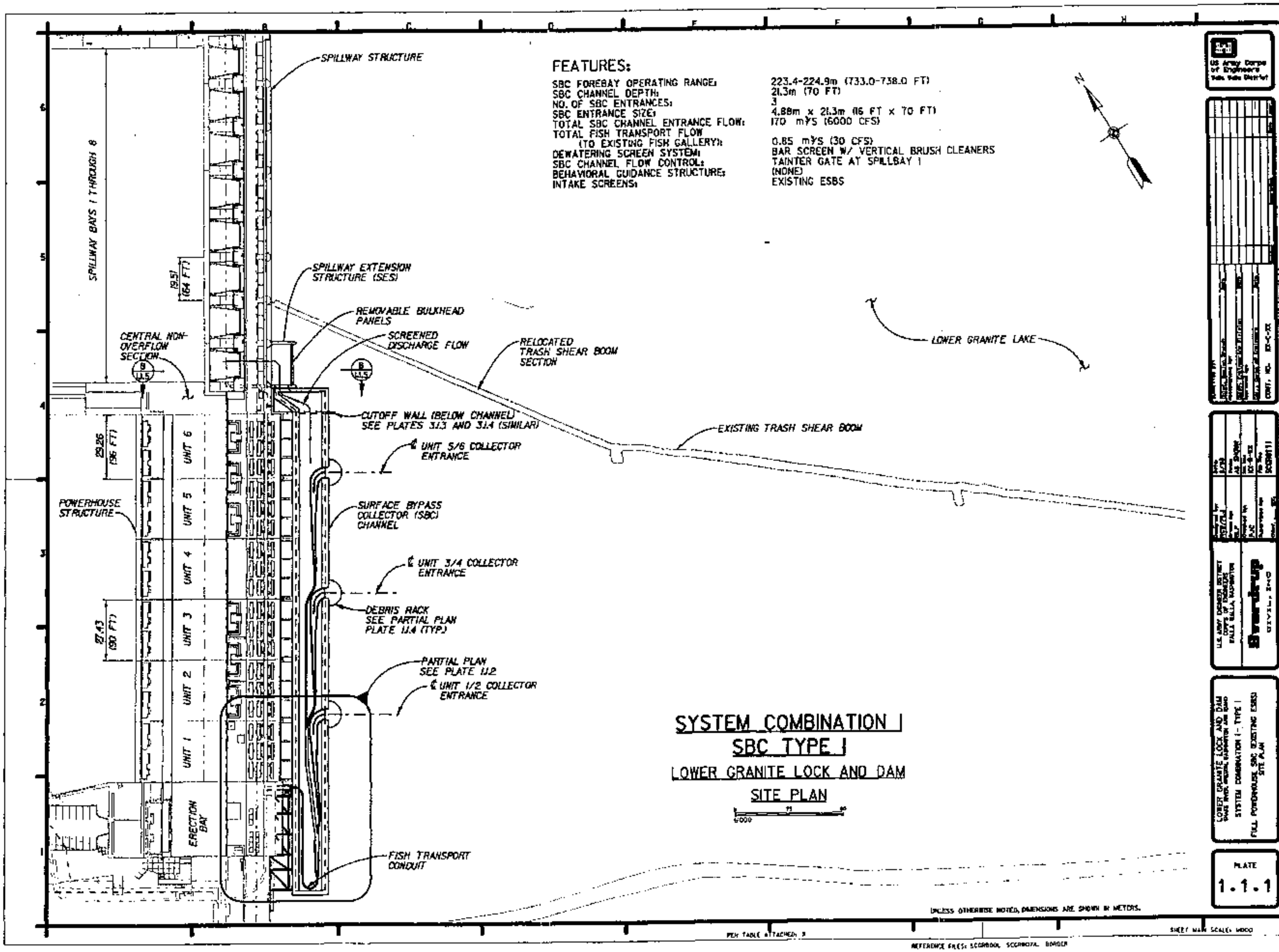
Plate 1.1.1 – SBC Type 1 – Full Powerhouse SBC (Existing ESBS) - Site Plan
Plate 1.1.2 – SBC Type 1 – Unit 1/2 Entrance - Plan and Sectional Elevation
Plate 1.1.3 – SBC Type 1 – Sections
Plate 1.1.4 – SBC Type 1 – Sections and Details
Plate 1.1.5 – SBC Type 1 – Spillbay 1 - Section
Plate 1.1.6 – SBC Type 1 – Electrical One-Line Diagram

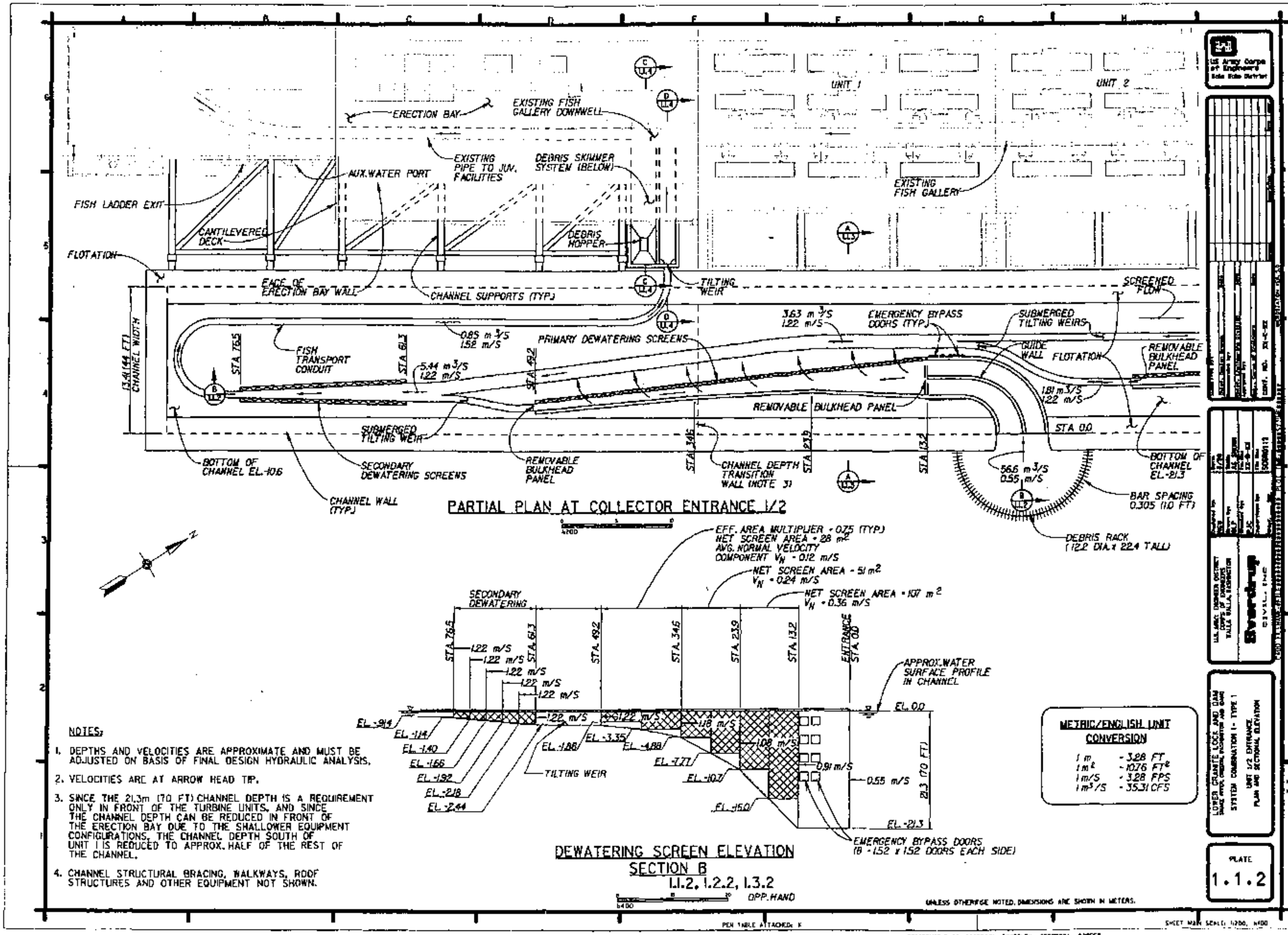
SBC Type 1 – Little Goose

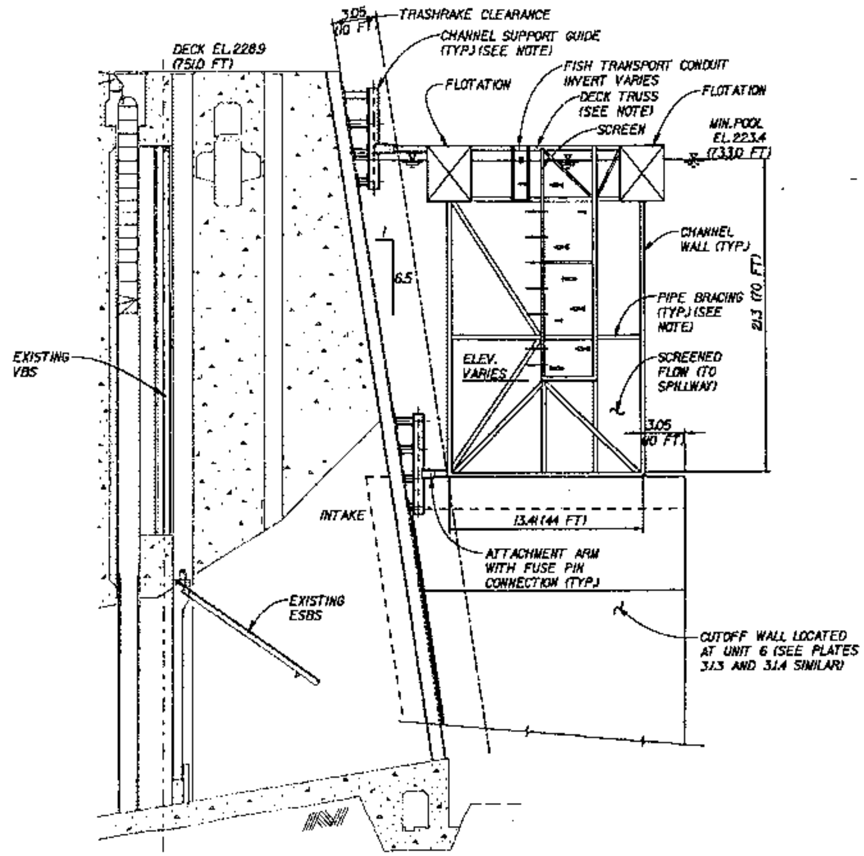
Plate 1.2.1 – SBC Type 1 – Full Powerhouse SBC (Existing ESBS) - Site Plan
Plate 1.2.2 – SBC Type 1 – Unit 1/2 Entrance - Plan
Plate 1.2.3 – SBC Type 1 – Sections
Plate 1.2.4 – SBC Type 1 – Electrical One-Line Diagram

SBC Type 1 – Lower Monumental

Plate 1.3.1 – SBC Type 1 – Full Powerhouse SBC (New ESBS) - Site Plan
Plate 1.3.2 – SBC Type 1 – Unit 1/2 Entrance - Plan
Plate 1.3.3 – SBC Type 1 – Sections
Plate 1.3.4 – SBC Type 1 – Electrical One-Line Diagram


FEATURES:
SBC FOREBAY OPERATING RANGE: 223.4-224.9m (733.0-738.0 FT)
SBC CHANNEL DEPTH: 21.3m (70 FT)
NO. OF SBC ENTRANCES: 3
SBC ENTRANCE SIZE: 4.88m x 21.3m (16 FT x 70 FT)
TOTAL SBC CHANNEL ENTRANCE FLOW: 170 m³/S (6000 CFS)
TOTAL FISH TRANSPORT FLOW (TO EXISTING FISH GALLERY): 0.85 m³/S (30 CFS)
DEWATERING SCREEN SYSTEM: BAR SCREEN W/ VERTICAL BRUSH CLEANERS
SBC CHANNEL FLOW CONTROL: TAINTER GATE AT SPILLBAY 1
BEHAVIORAL GUIDANCE STRUCTURE: (NONE)
INTAKE SCREENS: EXISTING ESBS
SPILLWAY STRUCTURE
SPILLWAY BAYS 1 THROUGH 8
19.51 (64 FT)
SPILLWAY EXTENSION STRUCTURE (SES)
REMOVABLE BULKHEAD PANELS
SCREENED DISCHARGE FLOW
CENTRAL NON-OVERFLOW SECTION
RELOCATED TRASH SHEAR BOOM SECTION
LOWER GRANITE LAKE
CUTOFF WALL (BELOW CHANNEL) SEE PLATES 3.1.3 AND 3.1.4 (SIMILAR)
EXISTING TRASH SHEAR BOOM
29.26 (96 FT)
UNIT 6
UNIT 5
UNIT 4
UNIT 3
UNIT 2
UNIT 1
℄ UNIT 5/6 COLLECTOR ENTRANCE
POWERHOUSE STRUCTURE
SURFACE BYPASS COLLECTOR (SBC) CHANNEL
℄ UNIT 3/4 COLLECTOR ENTRANCE
27.43 (90 FT)
DEBRIS RACK SEE PARTIAL PLAN PLATE 1.1.4 (TYP.)
PARTIAL PLAN SEE PLATE 1.1.2
℄ UNIT 1/2 COLLECTOR ENTRANCE
ERECTION BAY
FISH TRANSPORT CONDUIT
SYSTEM COMBINATION I
SBC TYPE I
LOWER GRANITE LOCK AND DAM
SITE PLAN
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers
PLATE
1.1.1


PARTIAL PLAN AT COLLECTOR ENTRANCE 1/2
ERECTION BAY
EXISTING FISH GALLERY DOWNWELL
UNIT 1
UNIT 2
EXISTING PIPE TO JUV. FACILITIES
DEBRIS SKIMMER SYSTEM (BELOW)
AUX.WATER PORT
FISH LADDER EXIT
EXISTING FISH GALLERY
CANTILEVERED DECK
DEBRIS HOPPER
FLOTATION
FACE OF ERECTION BAY WALL
CHANNEL SUPPORTS (TYP.)
TILTING WEIR
SCREENED FLOW
3.63 m³/S 1.22 m/S
EMERGENCY BYPASS DOORS (TYP.)
SUBMERGED TILTING WEIRS
0.85 m³/S 1.52 m/S
PRIMARY DEWATERING SCREENS
GUIDE WALL
REMOVABLE BULKHEAD PANEL
13.4(44 FT) CHANNEL WIDTH
FISH TRANSPORT CONDUIT
STA 76.5
STA 61.3
5.44 m³/S 1.22 m/S
STA 49.2
1.81 m³/S 1.22 m/S
STA 0.0
SUBMERGED TILTING WEIR
BOTTOM OF CHANNEL EL.-10.6
SECONDARY DEWATERING SCREENS
REMOVABLE BULKHEAD PANEL
STA 34.6
CHANNEL DEPTH TRANSITION WALL (NOTE 3)
STA 23.9
STA 13.2
56.6 m³/S 0.55 m/S
BOTTOM OF CHANNEL EL.-21.3
BAR SPACING 0.305 (1.0 FT)
CHANNEL WALL (TYP.)
DEBRIS RACK (12.2 DIA.x 22.4 TALL)
EFF. AREA MULTIPLIER = 0.75 (TYP.)
NET SCREEN AREA = 28 m²
AVG. NORMAL VELOCITY COMPONENT V_N = 0.12 m/S
NET SCREEN AREA = 51 m²
V_N = 0.24 m/S
NET SCREEN AREA = 107 m²
V_N = 0.36 m/S
SECONDARY DEWATERING
1.22 m/S
APPROX.WATER SURFACE PROFILE IN CHANNEL
ENTRANCE STA 0.0
EL. 0.0
EL.-9.14
EL.-1.14
EL.-1.40
EL.-1.66
EL.-1.92
EL.-2.18
EL.-2.44
EL.-1.88
EL.-3.35
EL.-4.88
EL.-7.77
EL.-10.7
EL.-15.0
EL.-21.3
1.18 m/S
1.08 m/S
0.91 m/S
0.55 m/S
21.3 (70 FT)
TILTING WEIR
EMERGENCY BYPASS DOORS (8 - 1.52 x 1.52 DOORS EACH SIDE)
DEWATERING SCREEN ELEVATION
SECTION B
1.1.2, 1.2.2, 1.3.2
OPP. HAND
METRIC/ENGLISH UNIT CONVERSION
1 m = 3.28 FT
1 m² = 10.76 FT²
1 m/S = 3.28 FPS
1 m³/S = 35.31 CFS
NOTES:
1. DEPTHS AND VELOCITIES ARE APPROXIMATE AND MUST BE ADJUSTED ON BASIS OF FINAL DESIGN HYDRAULIC ANALYSIS.
2. VELOCITIES ARE AT ARROW HEAD TIP.
3. SINCE THE 21.3m (70 FT) CHANNEL DEPTH IS A REQUIREMENT ONLY IN FRONT OF THE TURBINE UNITS, AND SINCE THE CHANNEL DEPTH CAN BE REDUCED IN FRONT OF THE ERECTION BAY DUE TO THE SHALLOWER EQUIPMENT CONFIGURATIONS, THE CHANNEL DEPTH SOUTH OF UNIT 1 IS REDUCED TO APPROX. HALF OF THE REST OF THE CHANNEL.
4. CHANNEL STRUCTURAL BRACING, WALKWAYS, ROOF STRUCTURES AND OTHER EQUIPMENT NOT SHOWN.
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
LOWER GRANITE LOCK AND DAM
SYSTEM COMBINATION 1 - TYPE 1
UNIT 1/2 ENTRANCE PLAN AND SECTIONAL ELEVATION
PLATE
1.1.2



SECTION A
1.1.2

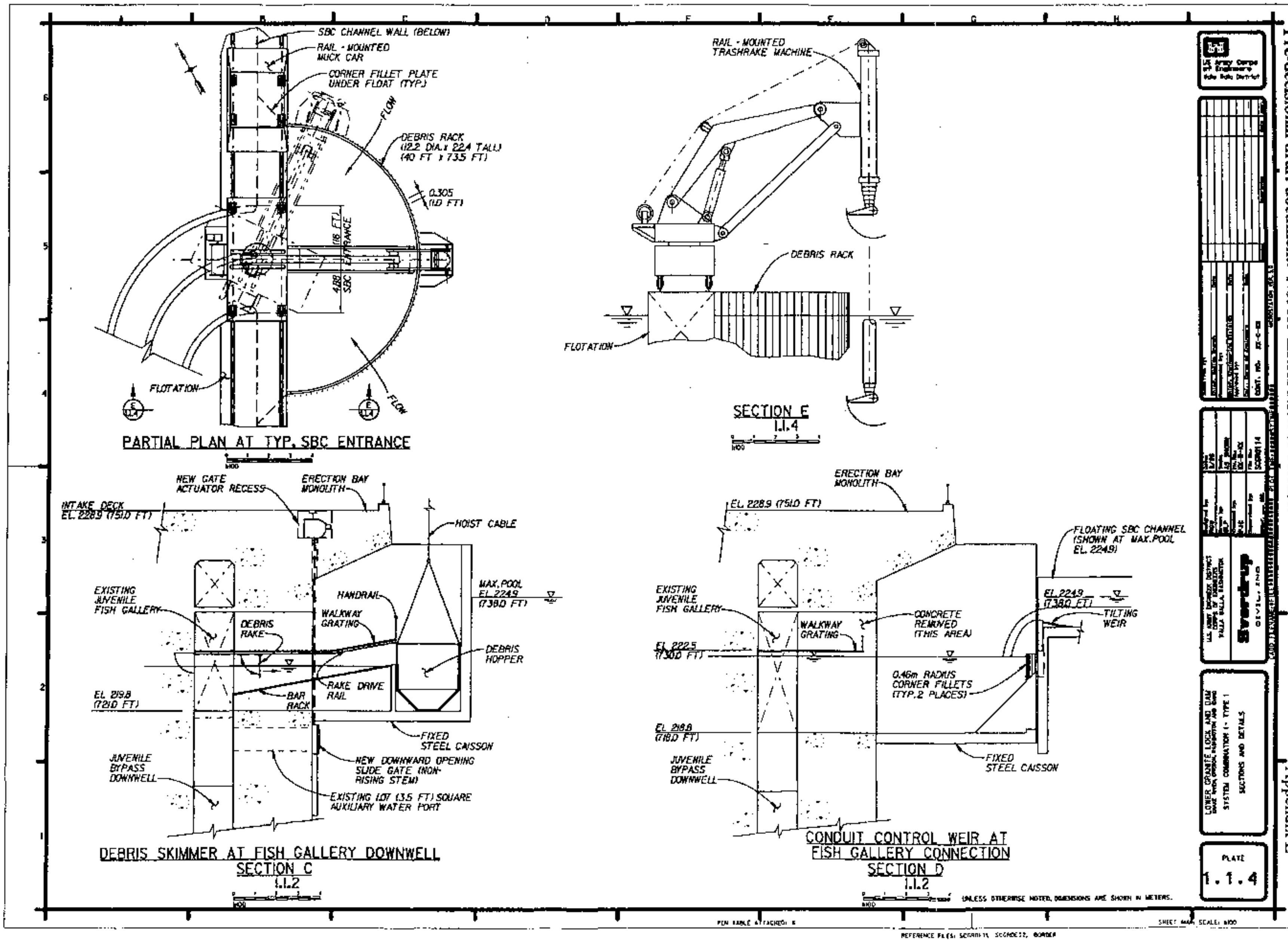
NOTE
STRUCTURAL BRACING AND OTHER MEMBERS ARE SHOWN FOR CONCEPT ONLY. INTERNAL BRACING AND DECK TRUSS OCCUR AT PIER SUPPORT LOCATIONS (APPROX. 9.1m (30 FT) INTERVALS ALONG THE CHANNEL). ROOF STRUCTURES, WALKWAYS AND EQUIPMENT NOT SHOWN.

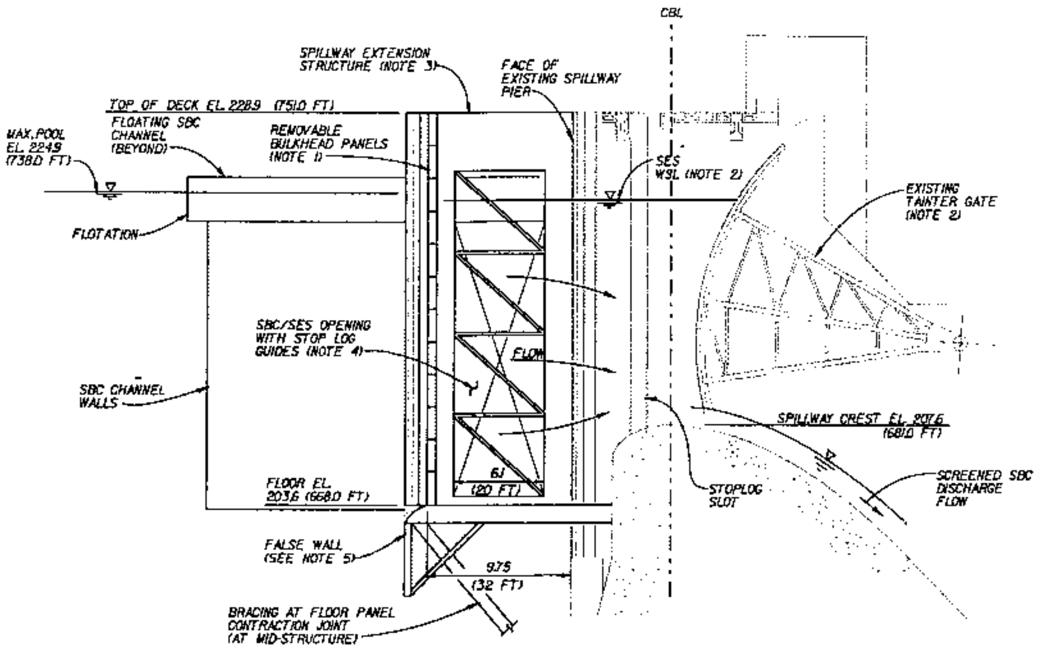
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

US Army Corps of Engineers Walla Walla District

LOWER GRANITE LOCK AND DAM
SYSTEM CONFIGURATION 1 - TYPE 1
SECTION

PLATE
1.1.3


SBC CHANNEL WALL (BELOW)
RAIL - MOUNTED MUCK CAR
CORNER FILLET PLATE UNDER FLOAT (TYP.)
FLOW
DEBRIS RACK (12.2 DIA. x 22.4 TALL) (40 FT x 73.5 FT)
0.305 (1.0 FT)
4.88 SBC ENTRANCE (16 FT)
FLOTATION
PARTIAL PLAN AT TYP. SBC ENTRANCE
RAIL - MOUNTED TRASHRAKE MACHINE
DEBRIS RACK
FLOTATION
SECTION E
1.1.4
NEW GATE ACTUATOR RECESS
ERECTION BAY MONOLITH
INTAKE DECK EL. 228.9 (751.0 FT)
HOIST CABLE
EXISTING JUVENILE FISH GALLERY
HANDRAIL
WALKWAY GRATING
MAX. POOL EL. 224.9 (738.0 FT)
DEBRIS RAKE
DEBRIS HOPPER
RAKE DRIVE RAIL
EL. 219.8 (721.0 FT)
BAR RACK
FIXED STEEL CAISSON
JUVENILE BYPASS DOWNWELL
NEW DOWNWARD OPENING SLIDE GATE (NON-RISING STEM)
EXISTING 1.07 (3.5 FT) SQUARE AUXILIARY WATER PORT
DEBRIS SKIMMER AT FISH GALLERY DOWNWELL
SECTION C
1.1.2
ERECTION BAY MONOLITH
EL. 228.9 (751.0 FT)
FLOATING SBC CHANNEL (SHOWN AT MAX. POOL EL. 224.9)
EXISTING JUVENILE FISH GALLERY
WALKWAY GRATING
CONCRETE REMOVED (THIS AREA)
EL. 224.9 (738.0 FT)
TILTING WEIR
EL. 222.5 (730.0 FT)
0.46m RADIUS CORNER FILLETS (TYP. 2 PLACES)
EL. 218.8 (718.0 FT)
FIXED STEEL CAISSON
JUVENILE BYPASS DOWNWELL
CONDUIT CONTROL WEIR AT FISH GALLERY CONNECTION
SECTION D
1.1.2
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
Sverdrup
LOWER GRANITE LOCK AND DAM
SYSTEM CONFIGURATION 1 - TYPE 1
SECTIONS AND DETAILS
PLATE
1.1.4



SPILLWAY EXTENSION STRUCTURE (SES)
AT SPILLBAY 1

SECTION B

NOTES:

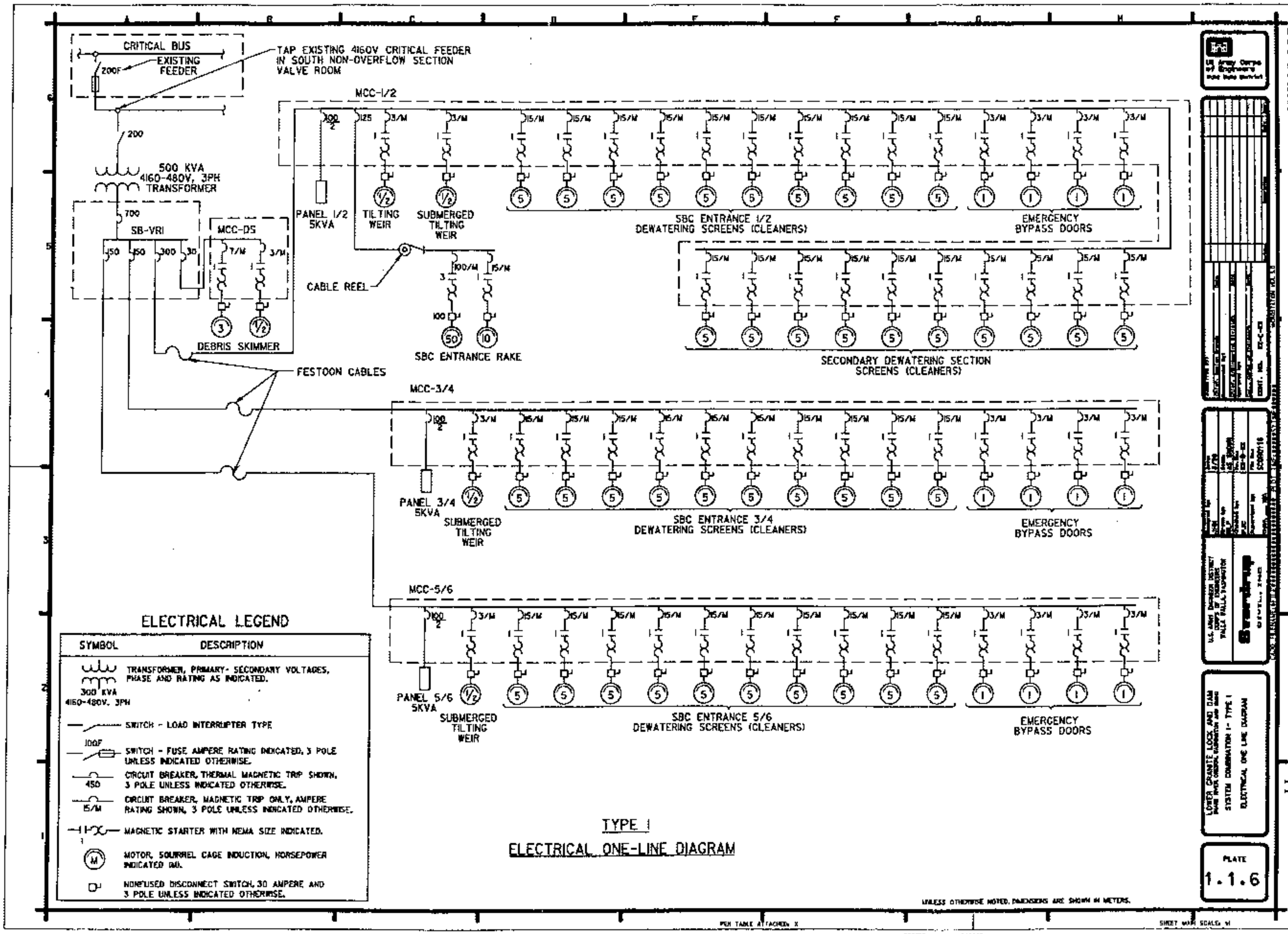
1. BULKHEAD PANELS CAN BE REMOVED TO ALLOW SPILLBAY TO DISCHARGE FULL DESIGN FLOW OF 3,008 m3/S (106,250 CFS).
2. THE WATER SURFACE LEVEL (WSL) INSIDE THE SES IS CONTROLLED BY VARYING THE TAINTER GATE OPENING TO PROVIDE THE REQUIRED HEAD DIFFERENTIAL FOR THE SBC CHANNEL DEWATERING SYSTEM.
3. STRUCTURAL BRACING AT TOP OF SES NOT SHOWN FOR CLARITY.
4. STOP LOGS WOULD BE INSERTED TO CLOSE OFF THIS OPENING WHEN THE SPILLWAY IS BEING USED FOR SPILL FLOW. THIS IS REQUIRED TO PREVENT EXCESSIVE HEAD DIFFERENTIAL IN THE CHANNEL.
5. A FALSE WALL COULD BE ATTACHED UNDER THE SES TO REDUCE OR ELIMINATE ANY RE-ENTRANT EFFECTS DURING FULL SPILL OPERATION. IF THIS WALL IS FOUND TO BE BENEFICIAL, FINAL DIMENSIONS WOULD BE DETERMINED THROUGH HYDRAULIC MODELING.

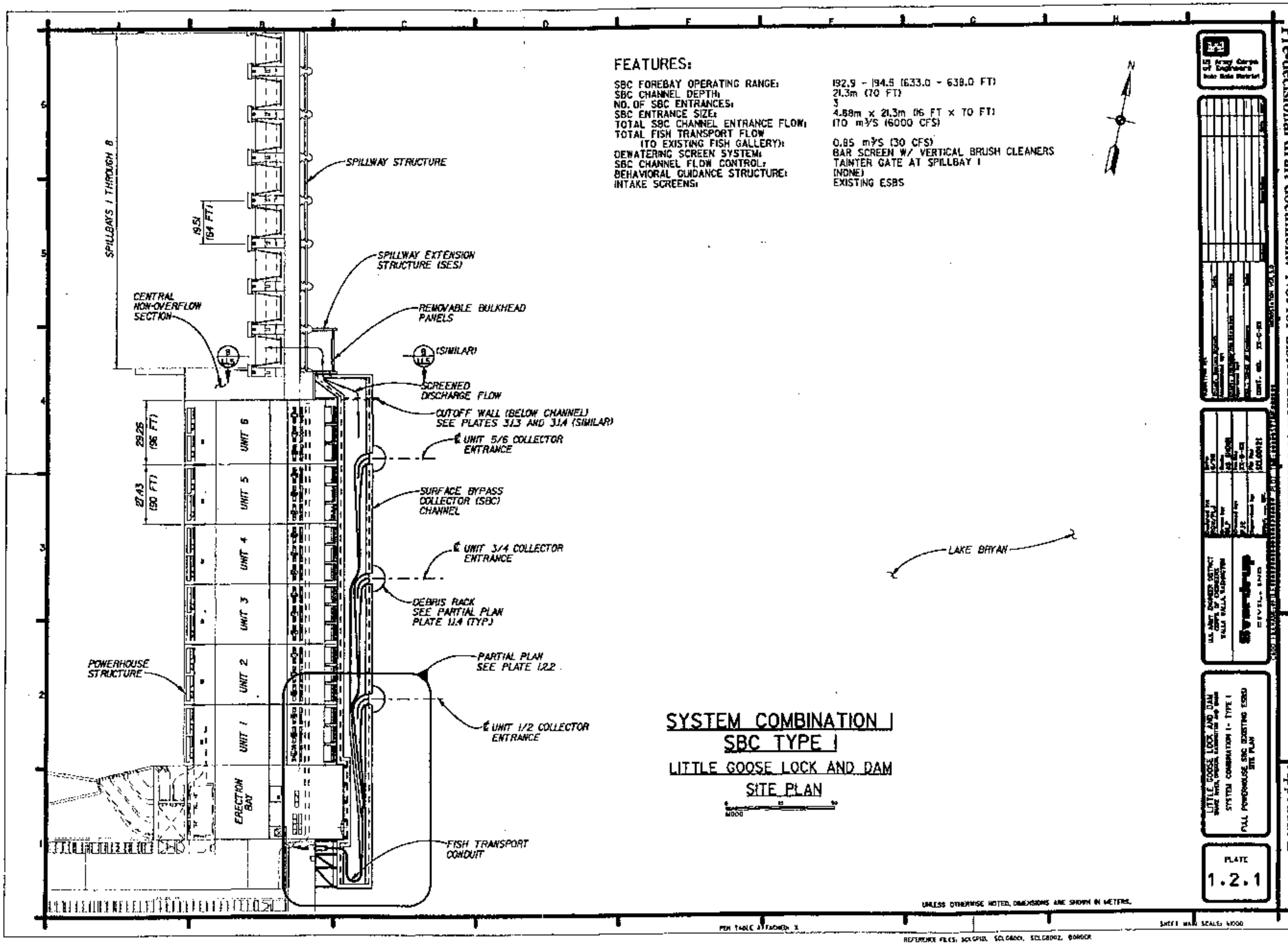
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

US Army Corps of Engineers
Walla Walla District

LOWER GRANITE LOCK AND DAM
SYSTEM CONFIGURATION - TYPE 1
SPILLBAY 1
SECTION

PLATE
1.1.5

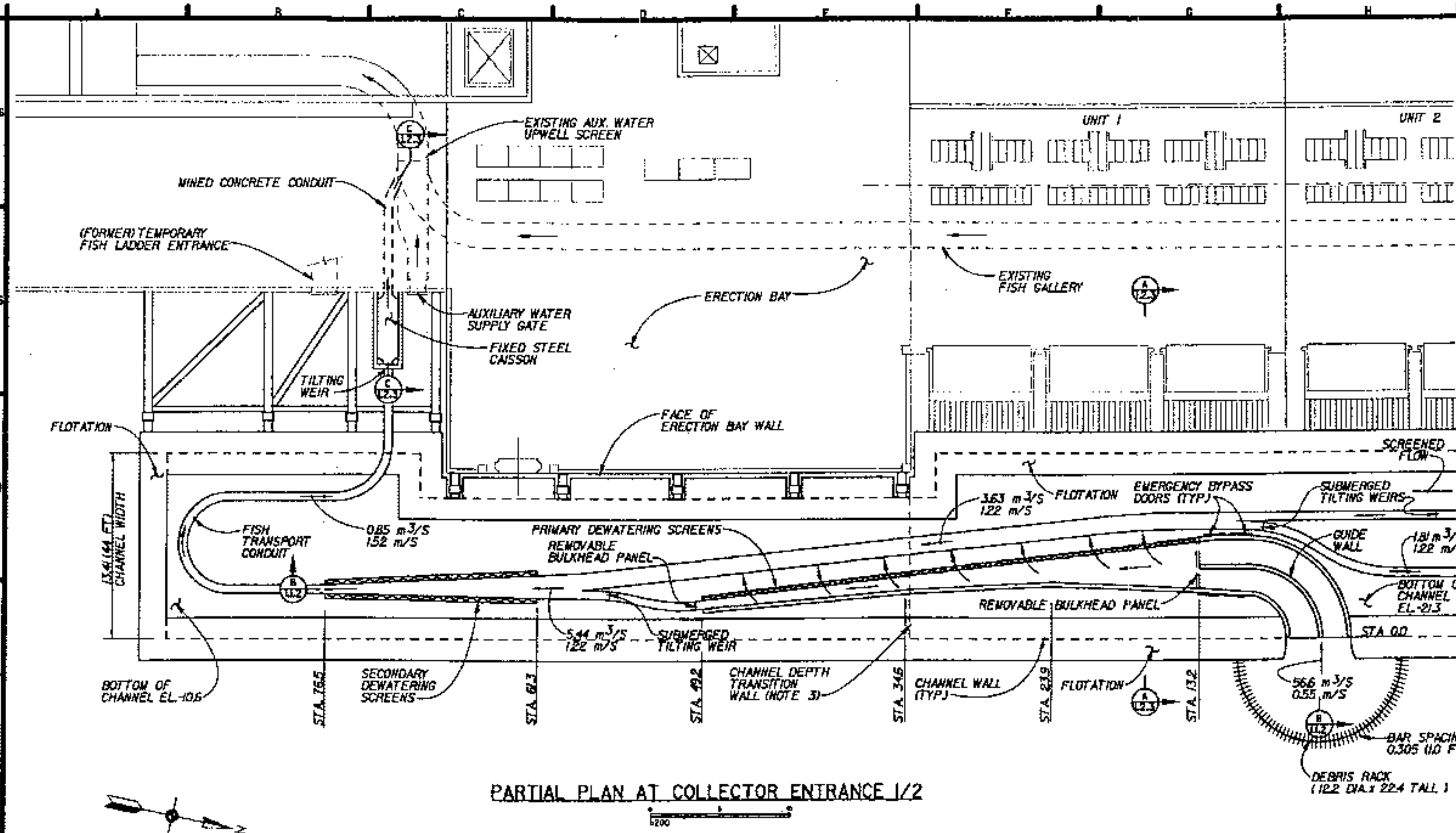

CRITICAL BUS
EXISTING FEEDER
200F
TAP EXISTING 4160V CRITICAL FEEDER IN SOUTH NON-OVERFLOW SECTION VALVE ROOM
200
500 KVA 4160-480V, 3PH TRANSFORMER
700
SB-VRI
MCC-DS
DEBRIS SKIMMER
FESTOON CABLES
CABLE REEL
MCC-1/2
PANEL 1/2 5KVA
TILTING WEIR
SUBMERGED TILTING WEIR
SBC ENTRANCE 1/2 DEWATERING SCREENS (CLEANERS)
EMERGENCY BYPASS DOORS
SBC ENTRANCE RAKE
SECONDARY DEWATERING SECTION SCREENS (CLEANERS)
MCC-3/4
PANEL 3/4 5KVA
SUBMERGED TILTING WEIR
SBC ENTRANCE 3/4 DEWATERING SCREENS (CLEANERS)
EMERGENCY BYPASS DOORS
MCC-5/6
PANEL 5/6 5KVA
SUBMERGED TILTING WEIR
SBC ENTRANCE 5/6 DEWATERING SCREENS (CLEANERS)
EMERGENCY BYPASS DOORS
ELECTRICAL LEGEND
SYMBOL
DESCRIPTION
TRANSFORMER, PRIMARY- SECONDARY VOLTAGES, PHASE AND RATING AS INDICATED.
300 KVA 4160-480V, 3PH
SWITCH - LOAD INTERRUPTER TYPE
100F
SWITCH - FUSE AMPERE RATING INDICATED, 3 POLE UNLESS INDICATED OTHERWISE.
450
CIRCUIT BREAKER, THERMAL MAGNETIC TRIP SHOWN, 3 POLE UNLESS INDICATED OTHERWISE.
15/M
CIRCUIT BREAKER, MAGNETIC TRIP ONLY, AMPERE RATING SHOWN, 3 POLE UNLESS INDICATED OTHERWISE.
MAGNETIC STARTER WITH NEMA SIZE INDICATED.
MOTOR, SQUIRREL CAGE INDUCTION, HORSEPOWER INDICATED (M).
NONFUSED DISCONNECT SWITCH, 30 AMPERE AND 3 POLE UNLESS INDICATED OTHERWISE.
TYPE I
ELECTRICAL ONE-LINE DIAGRAM
US Army Corps of Engineers
LOWER GRANITE LOCK AND DAM
SYSTEM COMBINATION 1 - TYPE 1
ELECTRICAL ONE LINE DIAGRAM
PLATE
1.1.6
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.



Pre-decisional draft document. Not for distribution or release.

Appendix E

Pre-decisional draft document. Not for distribution or release.



PARTIAL PLAN AT COLLECTOR ENTRANCE 1/2

1:200

METRIC/ENGLISH UNIT CONVERSION

1 m	= 3.28 FT
1 m²	= 10.76 FT²
1 m/S	= 3.28 FPS
1 m³/S	= 35.31 CFS

NOTES:

1. DEPTHS AND VELOCITIES ARE APPROXIMATE AND MUST BE ADJUSTED ON BASIS OF FINAL DESIGN HYDRAULIC ANALYSIS.
2. VELOCITIES ARE AT ARROW HEAD TIP.
3. SINCE THE 21.3m (70 FT) CHANNEL DEPTH IS A REQUIREMENT ONLY IN FRONT OF THE TURBINE UNITS, AND SINCE THE CHANNEL DEPTH CAN BE REDUCED IN FRONT OF THE ERECTION BAY DUE TO THE SHALLOWER EQUIPMENT CONFIGURATIONS, THE CHANNEL DEPTH SOUTH OF UNIT 1 IS REDUCED TO APPROX. HALF OF THE REST OF THE CHANNEL.
4. CHANNEL STRUCTURAL BRACING, WALKWAYS, ROOF STRUCTURES AND OTHER EQUIPMENT NOT SHOWN.

UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

US Army Corps of Engineers Walla Walla District

Sverdrup

LITTLE GOOSE LOCK AND DAM
SYSTEM COMBINATION 1 - TYPE 1
UNIT 1/2 ENTRANCE PLAN

PLATE 1.2.2

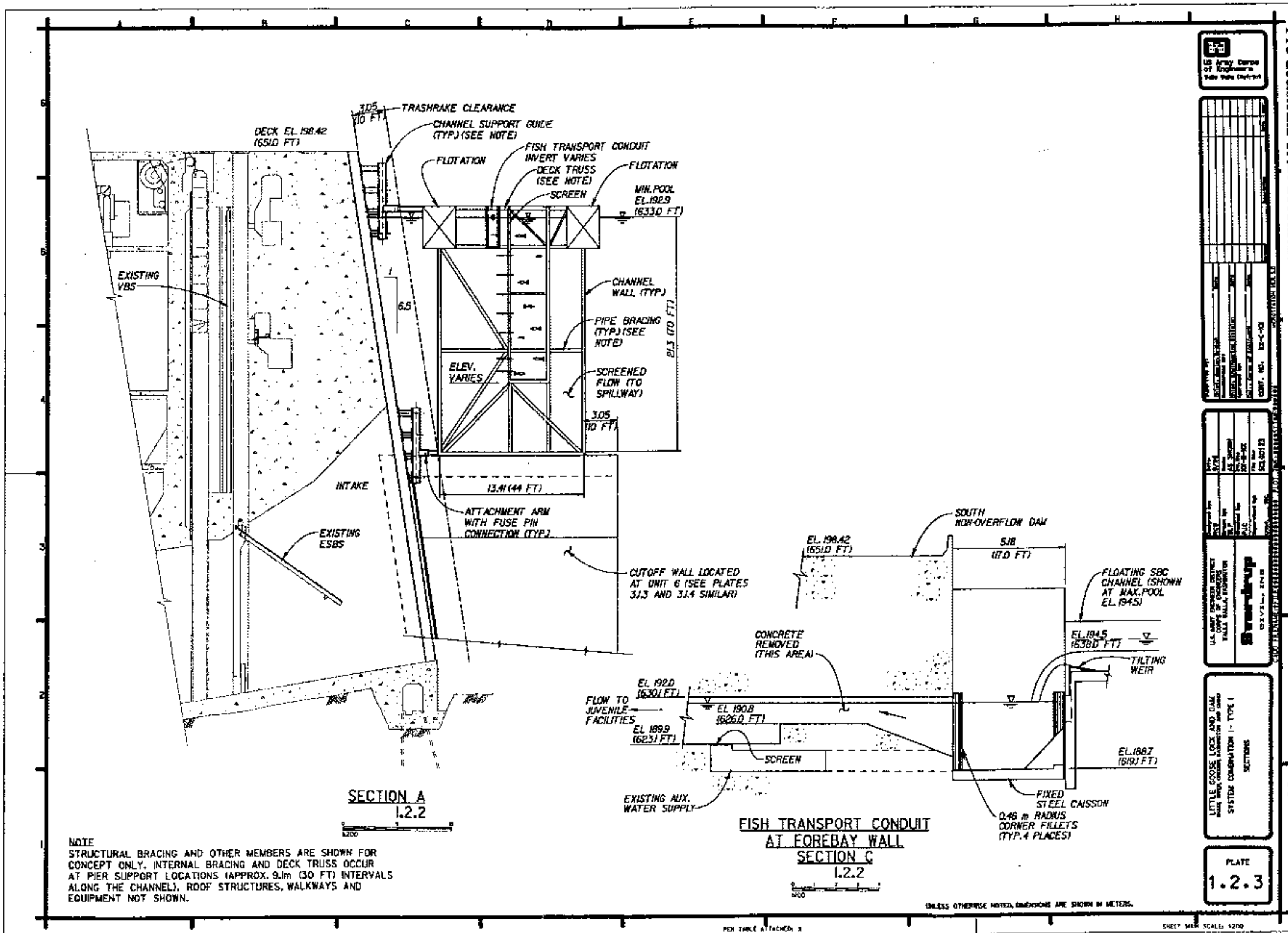
PEN TABLE ATTACHED: X

SHEET MAIN SCALE: 1:200

REFERENCE FILES: SCLG00C2, SCLGP01, BORDER

Appendix E

Pre-decisional draft document. Not for distribution or release.



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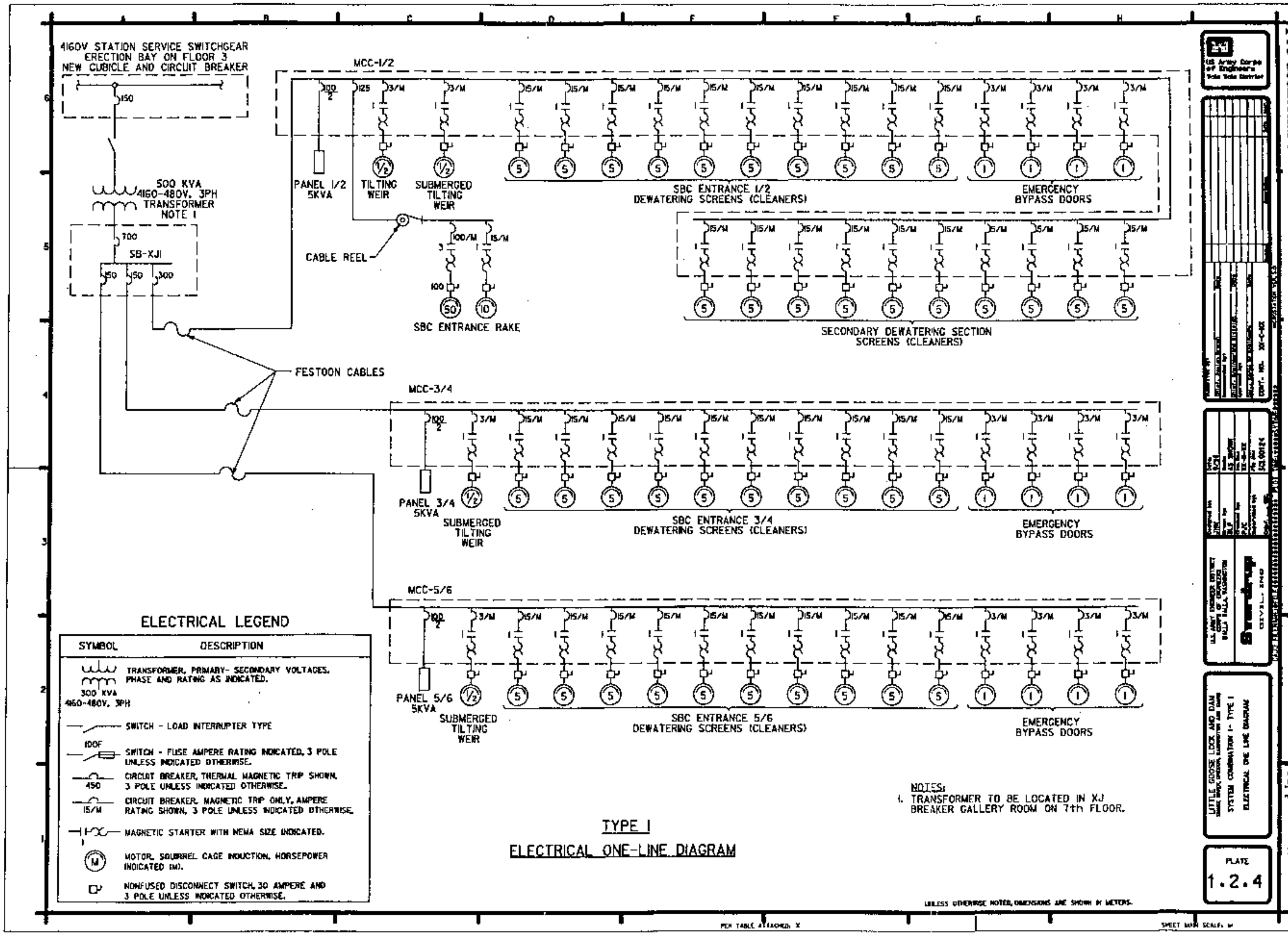
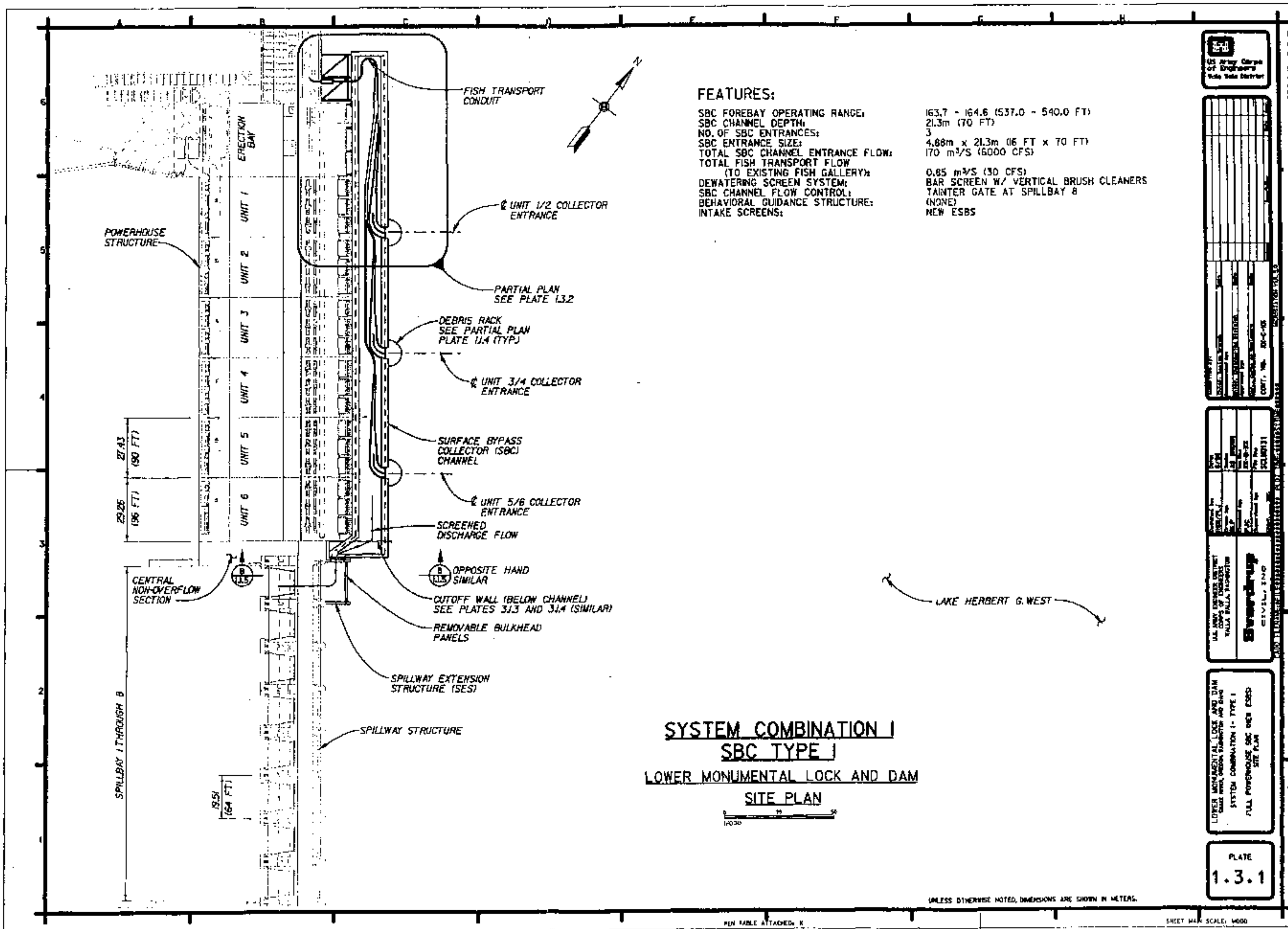
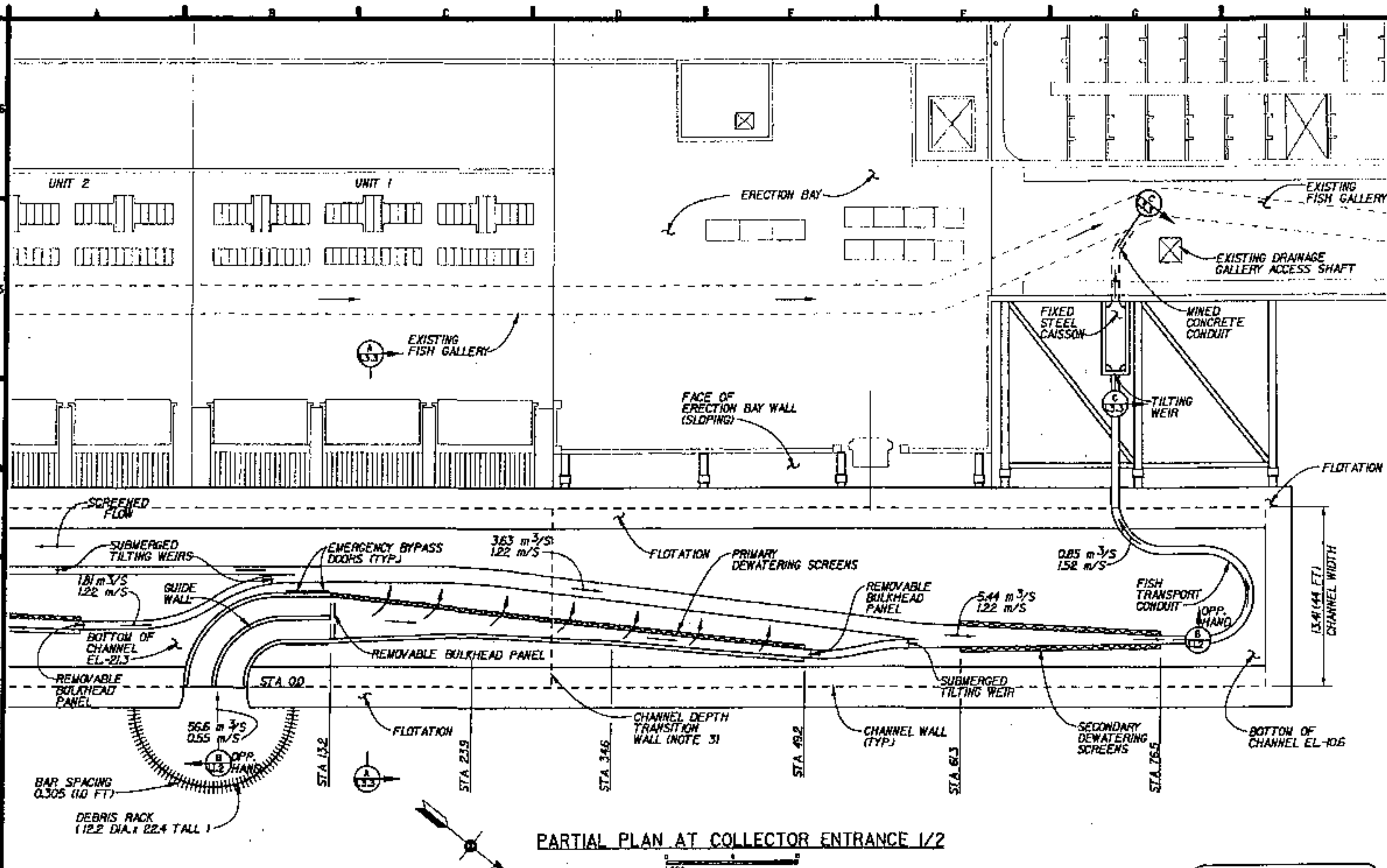


Appendix E


FEATURES:
SBC FOREBAY OPERATING RANGE: 163.7 - 164.6 (537.0 - 540.0 FT)
SBC CHANNEL DEPTH: 21.3m (70 FT)
NO. OF SBC ENTRANCES: 3
SBC ENTRANCE SIZE: 4.88m x 21.3m (16 FT x 70 FT)
TOTAL SBC CHANNEL ENTRANCE FLOW: 170 m³/S (6000 CFS)
TOTAL FISH TRANSPORT FLOW (TO EXISTING FISH GALLERY): 0.85 m³/S (30 CFS)
DEWATERING SCREEN SYSTEM: BAR SCREEN W/ VERTICAL BRUSH CLEANERS
SBC CHANNEL FLOW CONTROL: TAINTER GATE AT SPILLBAY 8
BEHAVIORAL GUIDANCE STRUCTURE: (NONE)
INTAKE SCREENS: NEW ESBS
FISH TRANSPORT CONDUIT
℄ UNIT 1/2 COLLECTOR ENTRANCE
POWERHOUSE STRUCTURE
PARTIAL PLAN SEE PLATE 1.3.2
DEBRIS RACK SEE PARTIAL PLAN PLATE 1.1.4 (TYP.)
℄ UNIT 3/4 COLLECTOR ENTRANCE
SURFACE BYPASS COLLECTOR (SBC) CHANNEL
℄ UNIT 5/6 COLLECTOR ENTRANCE
SCREENED DISCHARGE FLOW
OPPOSITE HAND SIMILAR
CENTRAL NON-OVERFLOW SECTION
CUTOFF WALL (BELOW CHANNEL) SEE PLATES 3.1.3 AND 3.1.4 (SIMILAR)
REMOVABLE BULKHEAD PANELS
SPILLWAY EXTENSION STRUCTURE (SES)
SPILLWAY STRUCTURE
LAKE HERBERT G. WEST
ERECTION BAY
UNIT 1
UNIT 2
UNIT 3
UNIT 4
UNIT 5
UNIT 6
27.43 (90 FT)
29.26 (96 FT)
19.51 (64 FT)
SPILLBAY 1 THROUGH 8
SYSTEM COMBINATION I
SBC TYPE I
LOWER MONUMENTAL LOCK AND DAM
SITE PLAN
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
PLATE 1.3.1



PARTIAL PLAN AT COLLECTOR ENTRANCE 1/2

NOTES:

1. DEPTHS AND VELOCITIES ARE APPROXIMATE AND MUST BE ADJUSTED ON BASIS OF FINAL DESIGN HYDRAULIC ANALYSIS.
2. VELOCITIES ARE AT ARROW HEAD TIP.
3. SINCE THE 21.3m (70 FT) CHANNEL DEPTH IS A REQUIREMENT ONLY IN FRONT OF THE TURBINE UNITS, AND SINCE THE CHANNEL DEPTH CAN BE REDUCED IN FRONT OF THE ERECTION BAY DUE TO THE SHALLOWER EQUIPMENT CONFIGURATIONS, THE CHANNEL DEPTH NORTH OF UNIT 1 IS REDUCED TO APPROX. HALF OF THE REST OF THE CHANNEL.
4. CHANNEL STRUCTURAL BRACING, WALKWAYS, ROOF STRUCTURES AND OTHER EQUIPMENT NOT SHOWN.

METRIC/ENGLISH UNIT CONVERSION

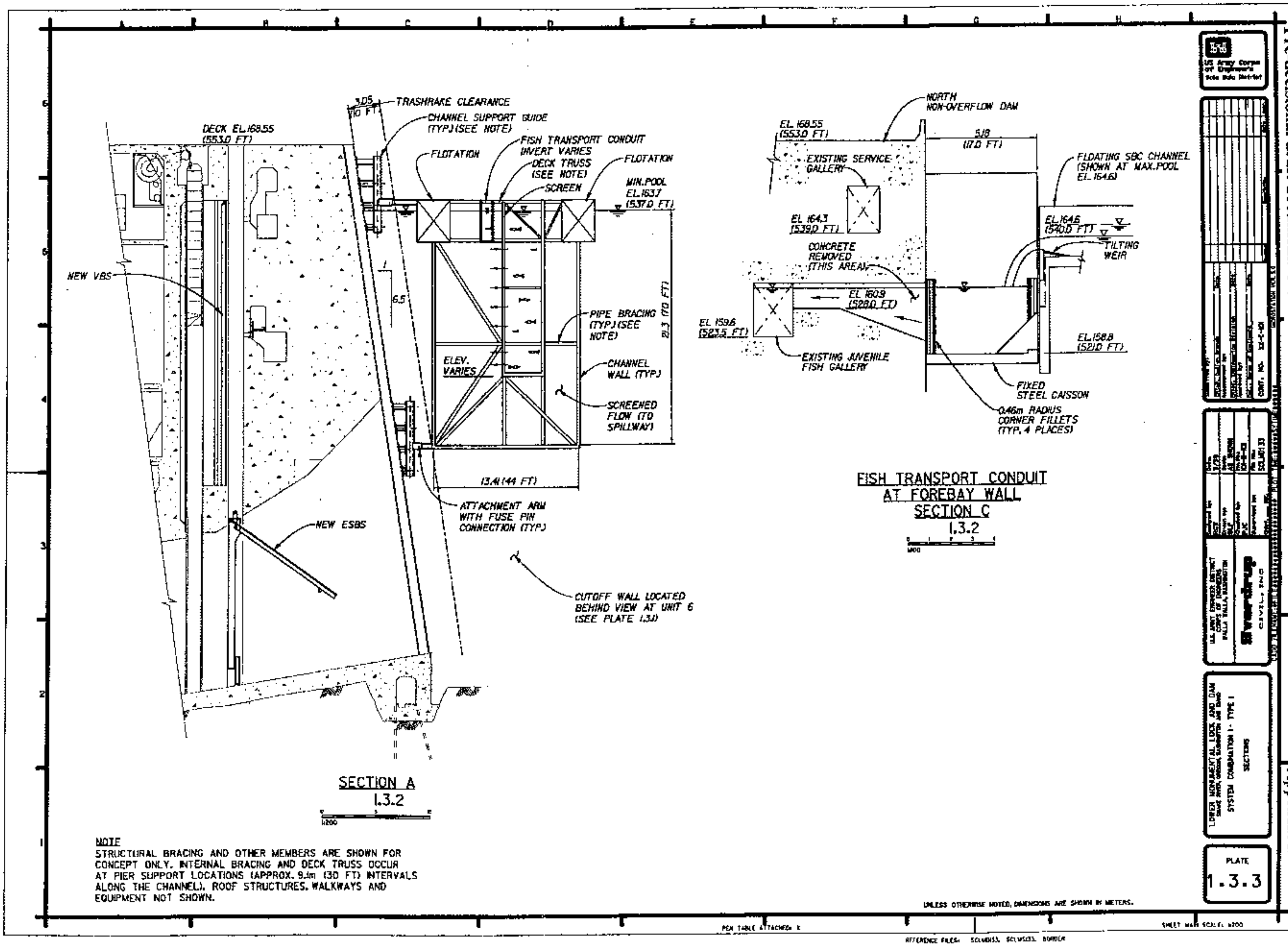
1 m	= 3.28 FT
1 m²	= 10.76 FT²
1 m/S	= 3.28 FPS
1 m³/S	= 35.31 CFS

US Army Corps of Engineers Walla Walla District

LOWER MONUMENTAL LOCK AND DAM
SYSTEM CONFIGURATION 1 - TYPE 1
UNIT 1/2 ENTRANCE PLAN

PLATE 1.3.2

UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.


TRASHRAKE CLEARANCE
3.05 (10 FT)
CHANNEL SUPPORT GUIDE (TYP.) (SEE NOTE)
FISH TRANSPORT CONDUIT INVERT VARIES
DECK TRUSS (SEE NOTE)
SCREEN
FLOTATION
FLOTATION
MIN. POOL EL.163.7 (537.0 FT)
DECK EL.168.55 (553.0 FT)
NEW VBS
6.5
PIPE BRACING (TYP.) (SEE NOTE)
21.3 (70 FT)
ELEV. VARIES
CHANNEL WALL (TYP.)
SCREENED FLOW (TO SPILLWAY)
13.41 (44 FT)
ATTACHMENT ARM WITH FUSE PIN CONNECTION (TYP.)
NEW ESBS
CUTOFF WALL LOCATED BEHIND VIEW AT UNIT 6 (SEE PLATE 1.3.1)
SECTION A
1.3.2
NOTE
STRUCTURAL BRACING AND OTHER MEMBERS ARE SHOWN FOR CONCEPT ONLY. INTERNAL BRACING AND DECK TRUSS OCCUR AT PIER SUPPORT LOCATIONS (APPROX. 9.1m (30 FT) INTERVALS ALONG THE CHANNEL). ROOF STRUCTURES, WALKWAYS AND EQUIPMENT NOT SHOWN.
NORTH NON-OVERFLOW DAM
EL.168.55 (553.0 FT)
5.18 (17.0 FT)
EXISTING SERVICE GALLERY
FLOATING SBC CHANNEL (SHOWN AT MAX. POOL EL.164.6)
EL.164.3 (539.0 FT)
EL.164.6 (540.0 FT)
TILTING WEIR
CONCRETE REMOVED (THIS AREA)
EL.160.9 (528.0 FT)
EL.159.6 (523.5 FT)
EL.158.8 (521.0 FT)
EXISTING JUVENILE FISH GALLERY
FIXED STEEL CAISSON
0.46m RADIUS CORNER FILLETS (TYP. 4 PLACES)
FISH TRANSPORT CONDUIT AT FOREBAY WALL
SECTION C
1.3.2
US Army Corps of Engineers Walla Walla District
LOWER MONUMENTAL LOCK AND DAM
SYSTEM CONFIGURATION 1 - TYPE 1
SECTIONS
PLATE
1.3.3
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

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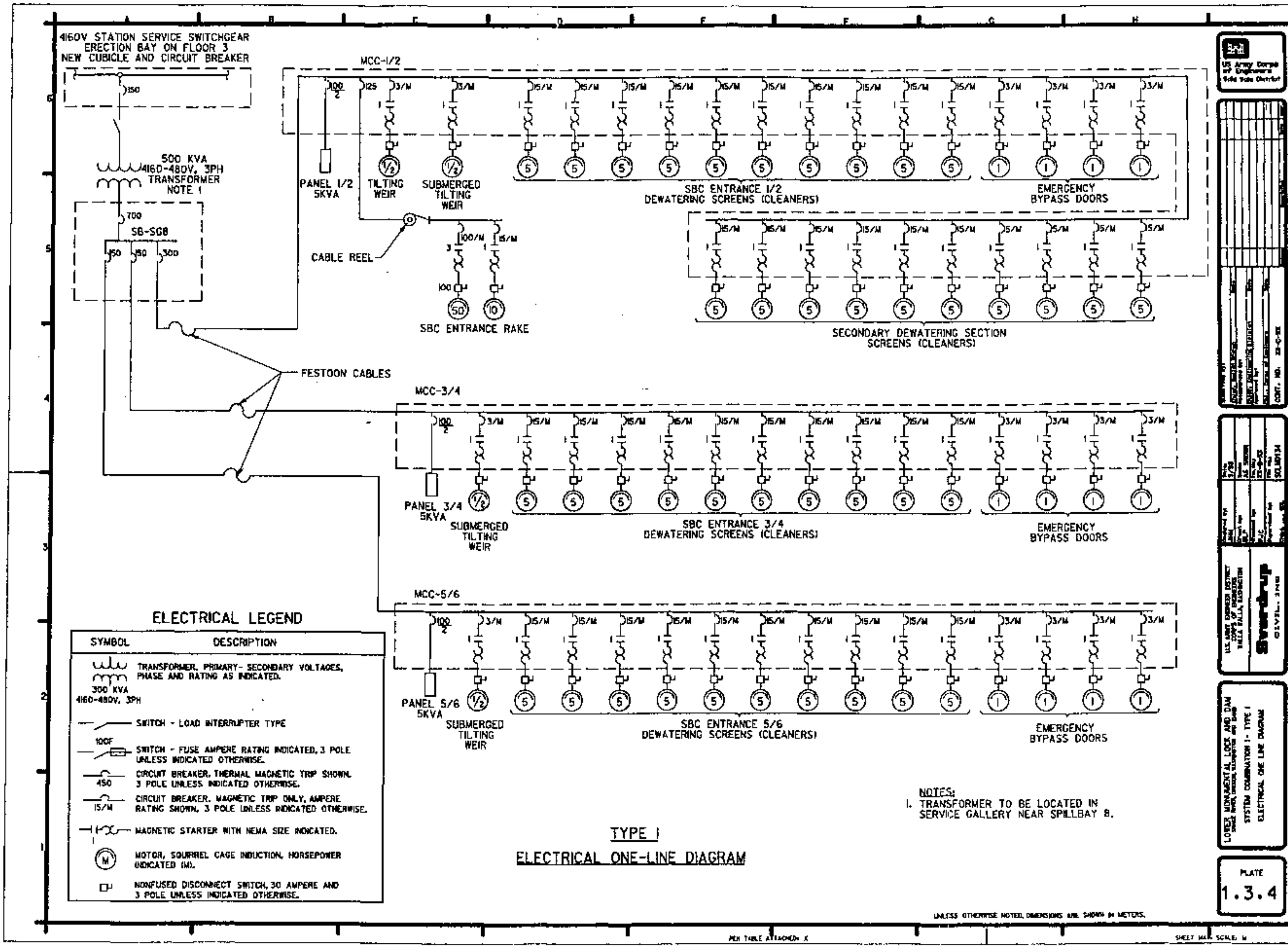

Appendix E

6. System Combination 1A—Fish Transportation at a Reduced Cost

System Combination 1A is a reduced scale version of System Combination 1 requiring significantly reduced initial and operational costs. More significantly, it represents the most likely approach to an initial installation and testing phase for System Combination 1. This combination also emphasizes the continued and enhanced use of the fish transportation facilities. To facilitate this approach, the same collection facilities as described for System Combination 1 at Lower Granite would be constructed (SBC Type 1). This would include the construction of a full length powerhouse SBC channel to be used in conjunction with the existing ESBS system. At the lower three projects (Little Goose, Lower Monumental, and Ice Harbor) only ESBS intake diversion systems would be used. Since ESBS already exist at Little Goose there would be no required modifications at this project, and the existing diversion/bypass facilities would continue to be used. At Lower Monumental and Ice Harbor the existing STS intake diversion systems would be removed and replaced with ESBS systems, but no additional SBC channels would be constructed to augment these systems.

Detailed descriptions of the specific bypass and collection facilities at each project which make up System Combination 1A are presented in the following text, or referenced to earlier text where applicable.

6.1 Lower Granite: Full Powerhouse SBC (with Existing ESBS) – SBC Type 1

For System Combination 1A, a Type 1 SBC channel would be constructed at Lower Granite. The SBC Type 1 design is described in Section 5.1 of this report and is not repeated here. As described, the SBC channel would be used in conjunction with the existing ESBS intake diversion system with the goal of collecting a maximum number of migrating fish from the Lower Granite reservoir and delivering them to the existing juvenile facilities at the project.

6.2 Little Goose: Existing ESBS Intake Screens

The turbine intakes at Little Goose are currently outfitted with an ESBS diversion system. System Combination 1A calls for the continued use of this system with no modification. Therefore, no new construction or O&M requirements need to be addressed. Since no new construction is required, and all hydraulic, structural, and mechanical issues associated with the diversion screen system were presumably addressed during its original design, these issues are also not addressed as part of this report.

6.3 Lower Monumental: New ESBS Intake Screens

As noted earlier, the turbine intakes at Lower Monumental are currently outfitted with a STS diversion system. System Combination 1A calls for these existing screens to be replaced by a new ESBS diversion system. The issues related to the change-out of the screening systems are addressed in Section 5.3 where a new ESBS system is added in conjunction with installation of a Type 1 SBC at this project. Issues specific to Lower Monumental (without the addition of an SBC channel) are described as follows.

6.3.1 Hydraulics

Discussion related to the hydraulic performance of the new ESBS system at Lower Monumental in Section 5.3.1 are applicable for this design also, except that in this case, the SBC channel is not present and would not need to be considered in the hydraulic model.

6.3.2 Structural Design

Structural design issues related to the new ESBS system at Lower Monumental are as described in Section 5.3.2.

6.3.3 Mechanical Requirements

Mechanical design issues related to the new ESBS system at Lower Monumental are as described in Section 5.3.3.

6.3.4 Electrical Requirements

Electrical requirements for new ESBS installations at Lower Monumental are described in Section 5.3.4. No additional 480-volt electrical power requirements are anticipated.

6.3.5 Operation and Maintenance Issues

O&M of the ESBS at Lower Monumental will be same as described for Lower Granite in Section 5.1.5.

6.3.6 Construction Issues

Construction issues related to the installation of the ESBS at Lower Monumental will be same as described in Section 5.3.6.

6.3.7 Construction and O&M Costs

Total estimated cost of engineering design and construction for a new ESBS intake diversion system at Lower Monumental is $16,058,000 in 1998 dollars. A cost breakdown is presented in spreadsheet format on the following page. Annual O&M costs should be essentially unchanged from the existing costs associated with the STS intake diversion system.

6.4 Ice Harbor: New ESBS Intake Screens

For System Combination 1A, a new ESBS diversion system would be constructed at Ice Harbor. A discussion of this installation at Ice Harbor is described in Section 5.4 of this report and is not repeated here.

PROJECT: LOWER SNAKE RIVER S.B.C. SYSTEM COMBINATIONS - CONCEPT DESIGN REPORT
DESIGN STATUS: CONCEPTUAL

DATE: Nov-98
ESTIMATOR: PJC
CHECKED BY: RGW

NEW EXTENDED LENGTH SUBMERGED BAR SCREENS - ICE HARBOR LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	ESBS INTAKE DIVERSION SCREENS				
	Installation of ESBS Diversion Screens	18	EA	398,000	7,164,000
	ITEM SUBTOTAL				7,164,000
	Subtotal Direct Construction Costs				7,164,000
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	7,164,000	$	5.0%	358,200
	General Contractors Overhead and Profit	7,522,200	$	26.5%	1,993,383
	CONSTRUCTION SUBTOTAL				9,515,583
	Construction Contingency	9,515,583	$	25.0%	2,378,896
	TOTAL CONSTRUCTION COSTS				*11,894,479*
	PLANNING AND ENGINEERING	11,894,479	$	22.5%	2,676,258
	CONSTRUCTION MANAGEMENT	11,894,479	$	12.5%	1,486,810
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				$16,057,546

DEIS/E - Major Sys Imp/CanRdy/Annexes/Annex B/cost spreadsheet.xls/ESBS - Ice Harbor

6.5 Combination Summary

6.5.1 Combined Construction Issues

The principle construction effort associated with System Combination 1A is associated with the installation of the Type 1 SBC channel at Lower Granite. The installation of ESBS screens at Lower Monumental and Ice Harbor are seen as predictable construction activities since they have been accomplished at other projects which are similarly configured. Besides the cost efficiency that might be obtained by awarding all 36 screens to a single contractor, as suggested in Section 5.5.1, there are no other combined construction issues anticipated.

6.5.2 Summary Construction and O&M Costs

The total combined estimated engineering design and construction cost for the System Combination 1A design is $94,565,000 in 1998 dollars. This represents a significant savings over the cost of System Combination 1. As previously discussed, if the ultimate goal of surface collection on the lower Snake River is to maximize the effectiveness of fish transportation, then System Combination 1A would represent a prudent first-build design. Additional costs associated with hydraulic modeling efforts may also be reduced over those associated with System Combination 1, since issues surrounding the use of the spillways at Little Goose and Lower Monumental are eliminated. A summary of the estimated costs by project is shown below.

Estimated Engineering Design and Construction Cost – System Combination 1A

Project	Description	Estimated Construction Cost
Lower Granite	Type 1 SBC (with existing ESBS)	$61,449,000
Little Goose	Existing ESBS	$0
Lower Monumental	New ESBS	$16,058,000
Ice Harbor	New ESBS	$16,058,000
	System Combination Subtotal	$93,565,000
	Feasibility Studies	$1,000,000
	Total Estimated Construction Cost	**$94,565,000**

The total annual O&M costs for System Combination 1A are estimated to be $530,600 in 1998 dollars. These O&M costs are associated entirely with the new SBC installation at Lower Granite, as documented in Section 5.1.7, and do not include existing O&M costs associated with O&M of the intake diversion screen systems, existing juvenile fish facilities, or transportation costs. Biological study costs are also not included.

6.5.3 Implementation Schedule

An implementation schedule is included below. The assumptions and rationale used for development of the implementation schedule is provided. The implementation schedule includes time for hydraulic model testing as appropriate, preliminary design, preparation of construction contract documents, and construction. The implementation schedule assumes no funding or manpower restraints. Such restraints would likely impact the schedule included herein.

Lower Granite Dam

The implementation schedule assumes that hydraulic model testing would occur in the year 2000. The model testing would include testing of dewatering features of a surface collector used for fish transportation. A prototype surface collector construction contract may then be prepared in the year 2001. The prototype would be used for testing various dewatering schemes to determine biological impacts on fish due to dewatering. Also, the prototype may be used to investigate various screen-cleaning strategies. Construction of the prototype would be scheduled for year 2002. Data would then be collected in the year 2003. The implementation schedule assumes that dewatering and screen cleaning will both be found feasible from an engineering and biological perspective. Preliminary and final designs leading to development of a construction contract for a final SBC at Lower Granite would then be prepared in the years 2003 and 2004. Construction of the SBC would occur in the years 2005 and 2006. The surface collector would be operational in the year 2006.

Another option is to design a prototype surface collector that would ultimately be used as a portion of the final surface collector. The prototype surface collector would likely consist of an SBC spanning the width of generator bays 5 and 6. Also, the SES structure would be constructed. Assuming the prototype surface collector proves to be successful, the remaining two thirds of the SBC structure could then be designed and constructed. This approach would save money since the prototype would be used as a portion of the final structure instead of being salvaged. However, the final layout of the SBC may be different than described previously in this report. The layout included in this report assumes juvenile fish enter the collection channel at the erection bay. However, the prototype SBC would likely be located near the spillway to pass the water exiting through the dewatering screens. Therefore, a more appropriate entrance to the fish channel would be near the central non-overflow, similar to that described for the Adaptive Migration Strategy option for Lower Granite. It is likely the layout of the SBC components could be reconfigured without any significant conceptual changes to the design.

Little Goose Dam

No new work is scheduled for this dam.

Lower Monumental and Ice Harbor Dams

Both of these projects have the same implementation schedule. The work involves installation of ESBSs to replace existing submerged travelling screens. The new ESBSs would likely be similar to those installed at Lower Granite and Little Goose Dams. However, there would likely be some differences. Therefore, hydraulic model testing is assumed for the year 2001 to help determine the best design for Lower Monumental and Ice Harbor Dams. The results of the model testing would be used for development of a construction contract for just three screens at each project. It is felt that three screens should be tested at each project before investing a large amount of money in all the screens. Design, construction, and installation of the three screens at each project would be scheduled for the year 2002. The screens would be tested at each project in the year 2003. The schedule assumes that the screens will be effective with a minimum of design modifications required for the remaining screens. Development of a contract for construction and installation of the remaining screens would then be scheduled for year 2004 with construction and installation scheduled for completion in year 2005.

7. System Combination 2—Emphasis on Inriver Passage

The migration strategy for System Combination 2 is to focus on effective diversion of the fish away from the turbines while emphasizing inriver migration, and de-emphasizing transportation. For this combination, all four projects would be outfitted with a full-length powerhouse SBC channel. However, these channels would not include dewatering screens and the fish would be passed directly downstream to the tailrace through modified spill flow (SBC Type 2). To maximize effective diversion away from the turbines, ESBS intake diversion systems would be used in conjunction with the channels at all four projects to divert fish which might pass under the channels and into the turbine intakes. Fish diverted by the ESBS systems would continue to be directed to the juvenile transportation facilities where a reduced transportation program could still be operated, or these fish could be delivered directly into the tailrace at that location.

As previously described, Lower Granite and Little Goose already have ESBS systems, and these would continue to be used in conjunction with the new SBC channels. The STS systems at Lower Monumental and Ice Harbor would be removed and replaced with new ESBS systems.

Detailed descriptions of the SBC facilities at each project which make up System Combination 2 are presented in the following text, or referenced to earlier text where applicable.

7.1 Lower Granite: Full Powerhouse Bypass SBC (with Existing ESBS) – SBC Type 2

Like the SBC Type 1 design, the goals of the Type 2 SBC channel include providing a collector channel at the powerhouse designed to attract fish away from the turbine intakes. However, unlike the Type 1 SBC, the operational goal of this channel is to deliver the fish with the full flow directly to the tailrace, with no dewatering of the flow taking place (i.e., no dewatering screens). An additional goal of this design is to provide a discharge for the channel that is a surface withdrawal (rather than a pressurized release) which also minimizes the impact on the ability of the project to pass flood flows. Plans and details of the SBC Type 2 design, as installed at Lower Granite, are shown on Plates 2.1.1 through 2.1.5, in Section 7.6.

This full flow bypass design (SBC Type 2) at Lower Granite includes a floating SBC channel that spans across the entire upstream face of the powerhouse intake structure. The channel is 21.3 meters (70 feet) deep by 14.0 meters (46 feet) wide with three collector entrances along the upstream wall, similar to the Type 1 design. As with all the designs evaluated in this report, ESBS intake diversion screens would be used in conjunction with the SBC. Because the screens are existing at Lower Granite, no modifications are required to add them. The channel extends from the south end of powerhouse Unit 1 to the middle of Spillbay 1. The floating structure connects to a fixed spillway extension structure (SES) extending 15.2 meters (50 feet) east from the face of the southern half of Spillbay 1. Spillbay 1 is modified to form a 4.88-meter (16-foot)-wide overflow ogee with crest elevation 216.7 meters (710.8 feet) for surface withdrawal from the SBC channel. The northern half of the spillbay is preserved at its full depth and will function in the same manner as the other seven spillbays, except at about half the discharge. Modifications of the spillbay include construction of a new 2.74-meter (9.0-foot)-wide pier and trunnion block at approximately the middle of the spillbay to define the southern extent of the full depth spillbay leaving a 7.6-meter (25-foot)-wide spillway. The southern half of the spillway will be filled with concrete to define the new higher ogee crest.

A new underflow vertical leaf gate is provided at the elevated ogee for on/off control of the SBC channel discharge. During normal operation of the channel, the leaf gates are hoisted out of the flow path allowing free overflow at the weir within the normal SBC operating range of 223.4 meters to 224.9 meters (733.0 feet to 738.0 feet). At forebay elevations above 224.9 meters (738.0 feet) the leaf gates would either close completely or could throttle flow. Presumably, forebay elevations higher than 224.9 meters (738.0 feet) would be outside the operating window of the SBC fish passage requirements and passage of flow through the SBC during these periods would be strictly for the purpose of adding spill capacity during flood discharge.

To accommodate the narrower spillway at the northern half of Spillbay 1, the existing 15.2-meter (50-foot)-wide Tainter gate at Spillbay 1 would be removed and replaced with a new, narrower Tainter gate sized to fit the reduced spillbay width of 7.6 meters (25 feet). At project flood forebay elevation of 227.5 meters (746.5 feet), it is anticipated that Spillbay 1 in its modified condition, in combination with the SBC capacity, would be able to pass over 1,840 m^3/s (65 kcfs) or about 60 percent of its premodified capacity. As shown on Figure 7.1, the modifications to Spillbay 1 would result in a total project discharge capacity of about 22,900 m^3/s (810 kcfs), or over 95 percent of the unmodified project capacity of 24,100 m^3/s (850 kcfs). The portion of this total project capacity which would be released through the SBC would be approximately 340 m^3/s (12 kcfs).

There are three approaches that might be taken to fully restore the project spill capacity to existing level while maintaining the SBC discharge location at Spillbay 1, if this should be required. These include:

- lowering the crest of the north half of Spillbay 1 by up to 9.75 meters (32 feet)
- lowering the crest of the north half of Spillbay 1 and the other 7 bays by 0.76 meter (2.5 feet)
- construction of a new overflow spillway in the area of the existing embankment.

Given the extensive work required to accomplish any of these solutions, it may be possible that none of these approaches is feasible from an economic standpoint. In the case of the spillway modifications, this level of modification to the spillbay crests not only involves lowering and reshaping of the spillway ogees, but will also require significant modification to the Tainter gates or possibly full replacement. The cost for construction of a new overflow spillway would likely be prohibitive, approaching by some estimates to be nearly $300 million dollars [23].

As an alternative, should maintaining the existing spill capacity be required and the above described modifications are determined to be unfeasible, the location of the SBC discharge may be transferred to an alternate location, eliminating the obstruction at Spillbay 1 altogether. A conceptual layout of a design at Lower Granite for providing the SBC discharge at the central non-overflow section was investigated in the SBC Conceptual Design Report. In that report, the investigation was related to a full flow bypass SBC referred to as Option 7, which is virtually identical to the Type 2 SBC. In this report, the conceptual layout is presented in Attachment A where the alternative is shown in sketches as applied to the Type 2 and Type 3 designs. Construction cost estimates for each of these designs with the alternative discharge location, as well as hydraulic profiles in the discharge chute, are also included. Issues related to structural

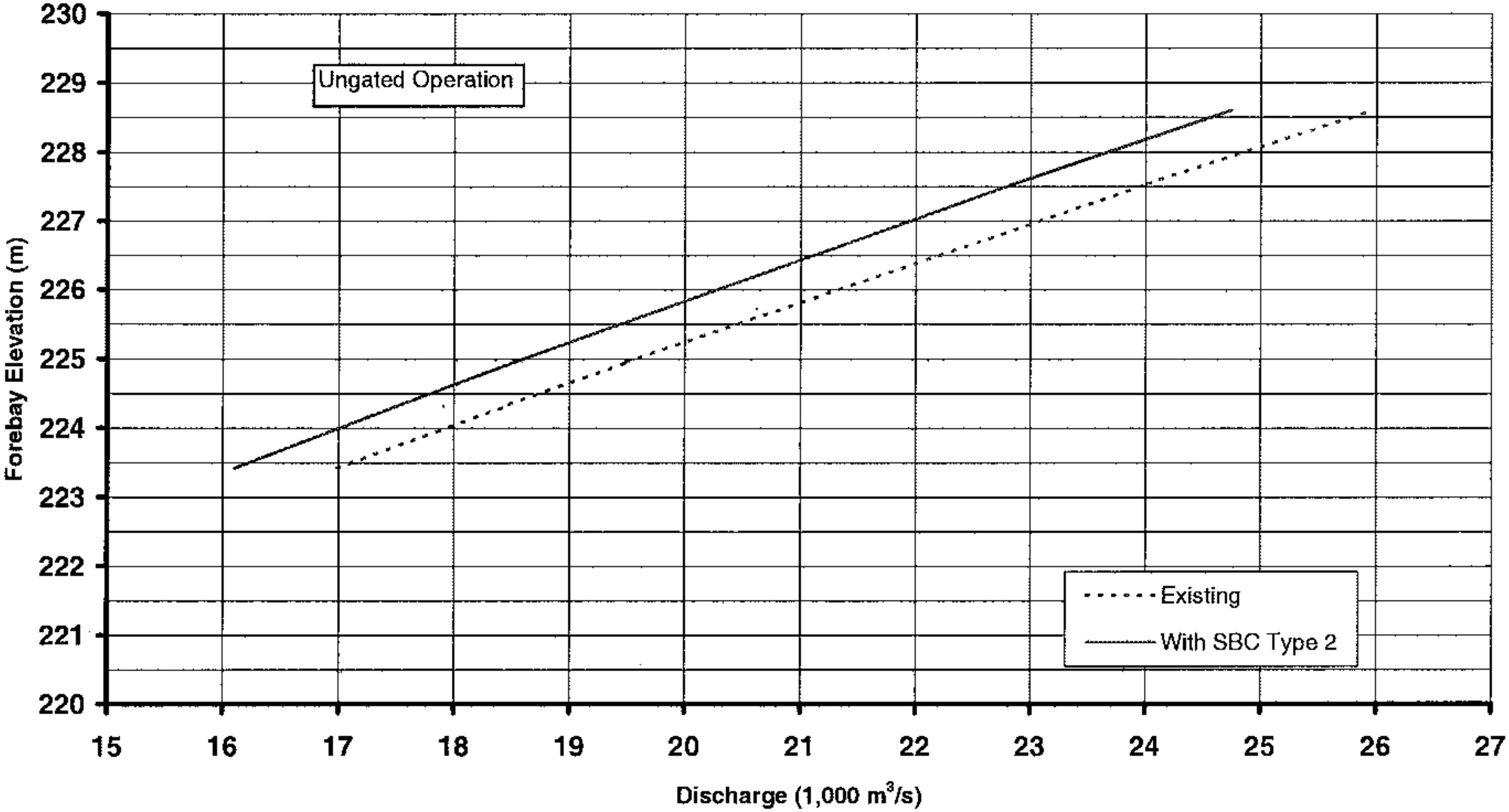

Figure 7.1 - Lower Granite Lock and Dam - Spill Capacity with SBC Type 2

stability and hydraulics were reviewed in the context of Option 7 from the SBC Conceptual Design Report. In this design, a 4.88-meter (16-foot)-wide concrete channel is excavated through the central non-overflow section and a concrete discharge chute is constructed on the tailrace side of the section discharging near the position of the south training wall. Although feasible, this design also raises a number of issues. These include:

- Excavation of the channel through the central non-overflow section would interrupt the service gallery and the juvenile fish gallery in that part of the structure. Also, the elevator machinery room would be impacted requiring relocation of that equipment. The drainage gallery access shaft would also be interrupted. Provisions for restoring the functionality of these items would have to be made.

- The discharge chute located on the downstream side of the central non-overflow section will have a number of impacts on the fish facilities located underneath the tailrace deck.

- The discharge chute structure will obstruct access to the fishway transverse bulkhead. This bulkhead will need to be relocated to the south to maintain its function.

- A number of other fishway gates will also be impacted depending on the amount of overhead space required for access and maintenance.

- The crane rails at the north end will no longer be accessible because the structure will block access.

- The flip lip elevation at the bottom of the chute, as shown in the sketches, is assumed to be at the same elevation as the existing spillway flip lips. Investigation would be required to determine if this is appropriate.

- The tailrace at the proposed discharge point is approximately 19.2 meters (63 feet) deep at normal tailwater of 194.5 meters (638 feet) and erosional issues are assumed to be minimal due to the considerable depth at this location. This would have to be investigated further to confirm this assumption.

- The discharge chute was routed straight through the non-overflow section and not turned either left or right. This position allows for the spillway and/or powerhouse flow to be used as training flow if desired, but may affect adult fish attraction conditions at the ladder entrances.

While these issues would have to be resolved, the feasibility of the central non-overflow discharge alternative, from an engineering and cost perspective, is considered to be better than the spillway modification alternatives if the existing spill capacity needs to be maintained. Compared to the cost of the Type 2 SBC discharging at Spillbay 1, it is estimated that locating the discharge at the central non-overflow section would decrease the cost of the Type 2 SBC design at Lower Granite by about $3 million or roughly 6.3 percent. However, this review of the cost only addresses the construction of the SBC components, and did not include estimates of costs associated with resolution of the interferences or problems listed above. Final design, including resolution of these issues, may result in a cost closer to that of the spillway discharge design proposed for Lower Granite.

Application of a discharge location at the central non-overflow section appears to be feasible at the other dams as well. Little Goose and Lower Monumental, which are almost identical to Lower Granite, share similar concerns with similar interferences. Therefore, it can be assumed that construction costs would be similar at these projects. While configured somewhat differently than the other projects, Ice Harbor also has a similar central non-overflow section through which routing of an excavated channel appears feasible. The deck at the tailrace side of the monolith at Ice Harbor has fewer apparent conflicts than at the other projects and may present fewer operational concerns. The existing layout of the powerhouse and spillway at Ice Harbor, and the shallower SBC channel, result in an estimated savings of approximately half of that estimated for Lower Granite (about $1.7 million). Once again, these costs do not reflect resolution of potential interferences identified in final design which may offset any cost savings.

Prior to undertaking any modifications to restore the full design discharge capacity of the project, a review of the design flood flow should be performed in light of the fact that the flood of record is 11,600 m^3/s (409 kcfs) and considerable flood storage capacity exists at the projects upstream.

The SBC channel has three vertical entrances through the upstream wall. The entrances are located near the unit joints between Units 1 and 2, 3 and 4, and 5 and 6. Flow through each entrance is approximately 56.6 m^3/s (2,000 cfs), for a combined SBC collection flow of 170 m^3/s (6,000 cfs), when the forebay is at the MOP of 223.4 meters (733.0 feet). For this design the entrances do not have full height debris racks since most debris entrained in the flow would simply pass though the system to the tailrace. This reduces the equipment and operational requirements associated with keeping the racks clean. If the entrances are left completely open to the surface, there is a possibility that very large floating debris could enter the channel and get hung up in the conduits. To minimize the potential for this, a debris skirt is placed in front of the entrance. Similar to the Type 1 trash rack, this is a semi-circular shape with a 6.1-meter (20-foot)-radius, but rather than being the full entrance height, it extends only about 1.5 meters (5 feet) deep. Also, the bar spacing would be increased from 0.31 meter (1 foot) to as much as 0.91 meter (3 feet). This is shown on the drawings for all four projects, but in a final analysis the benefit of including this debris skirt should be assessed on a project-by-project basis. No provision for mechanical raking of this skirt is provided. Maintenance is assumed to be performed from above the skirt utilizing a handheld rake, or the project crane for large items. There may be a biological benefit, however, in allowing a debris mat to form in front of the entrance providing a safe area for migrating juveniles.

The fish enter the channel through the entrances, which are 4.87 meters (16 feet) wide and 21.3 meters (70 feet) high. The floor of the channel coincides with the bottom of the entrances located 21.3 meters (70 feet) below the forebay water surface. After entering the channel the fish are diverted 90-degrees to the north. Each entrance is associated with an individual transport conduit. As shown in the channel cross section on Plate 2.1.3, the conduit from Entrance 1/2 can be conveniently located under the flotation cell on the downstream side of the channel. In this way the overall channel width can be minimized. Although the natural lighting in this section of conduit will be diminished, the flow velocity is high enough that it is unlikely fish will avoid continuing down the conduit. However, if this is viewed as a concern, the overall channel could be widened to provide room for a fully open conduit or the downstream flotation cell could be moved to the outboard side of the channel wall. The width of each individual conduit narrows down to 1.83 meters (6 feet) and is maintained at this constant width up to the northern part of powerhouse at Unit 6 where all three conduits combine together to form a single conduit of 6.1-meter (20-foot)-width. The floor of the conduits slopes up through the section where the conduits come together. The combined conduit then gradually converges to a width of 4.88 meters (16 feet) in front of the central non-overflow section of the dam where the conduit makes a 90-degree turn toward the west and joins the fixed SES attached to the upstream face of the southern half of Spillbay 1. All the flow that enters through the collector entrances travels through the transport conduits, into the SES and ultimately over the overflow ogee to the tailrace. Therefore, the portion of the channel outside the conduits but internal to the channel structure is not exposed to the normal channel flow. The outer wall of the channel is required to lead the fish toward the entrances as well as perform structural functions for the channel. This requires that some means of allowing for exchange of the water in this area is provided to keep the water from becoming overly stagnant or filling due to rain fall. It is suggested that the floor of the channel in these areas, and possibly the lower portions of the walls, could be perforated to allow for water exchange.

Like the Type 1 SBC channel, a cutoff wall has been included below the channel at the northern end of the Unit 6 intake to preclude fish movement beneath the north end of the channel into the Unit 6 intake. The wall design would be similar to that described in Section 5.1 for the Type 1 SBC channel.

7.1.1 Hydraulics

Floating Structure Issues

The hydraulic advantages of the floating structure previously described for the Type 1 SBC in Section 5.1.1 also apply in this case. The only hydraulic disadvantage of the floating structure is the complexity of the connection between the floating channel and the fixed dam structure. This will occur at the north end of the floating channel, where the SBC channel connects to the fixed SES attached to the southern half of Spillbay 1 (see Plate 2.1.4).

The invert of the SES at the connection is at elevation 210.3 meters (690.0 feet). The invert of the floating SBC structure will vary between elevations 206.8 meters (678.5 feet) and 213.7 meters (701 feet) for corresponding forebay elevations of 220.7 meters (724 feet) when the forebay is drafted and 227.6 meters (746.5 feet) during a flood surcharge, respectively. The connection should allow an extreme differential vertical movement of the floating structure of 6.89 meters (22.5 feet). During normal operation of the SBC channel, there will either be a step up of 0.75 meter (2.5 feet) at minimum normal operating pool or a step down of 0.75 meter (2.5 feet) at maximum normal operating pool. Minor flow separations can be expected immediately downstream of the step (near the bottom of the conduit) in the step down condition. However, the upward sloping SES floor will be helpful in minimizing the zone of separation to some extent. Moreover, the velocity from the SBC channel to the SES will be about 3.2 m/s (10.5 ft/s) under the maximum operating pool condition, which is higher than the trapping velocity and it is unlikely any fish will get a chance to enter the separation zone. At a surcharged pool elevation of 227.6 meters (746.5 feet), there will be a step drop of 3.35 meters (11 feet) in the conduit invert from the SBC channel to the SES. Since this forebay elevation is not within the normal operating range of the SBC channel, hydraulic and fish behavior anomalies associated with this drop are not deemed to be significant. Alternatively, the elevation of the SES invert could be 211.1 meters (692.5 feet) resulting in a smooth invert transition at high normal operating pool and a step up of 1.52 meters (5 feet) at low normal operating pool. This would be a decision to be made during final design based on hydraulic analysis and biological considerations.

Collector Entrances and Transport Conduits

Each of the three SBC entrances is 21.3 meters (70 feet) deep by 4.88 meters (16 feet) wide. A combined flow of 170 m^3/s (6,000 cfs) enters the channel when the forebay is at MOP elevation 223.4 meters (733 feet). Since the flow through the channel is dictated by the available energy head upstream of the ogee crest at the surface discharge, and since the energy head is a function of the forebay elevation, the entrance flow will be higher at higher forebay levels. At the MOP of 224.9 meters (738 feet), the total flow will be 235 m^3/s (8,300 cfs), while at the flood pool elevation of 227.5 meters (746.5 feet) the total flow through all the entrances will be approximately 340 m^3/s (12,000 cfs). This should be compared to the 1,504 m^3/s (53,125 cfs) spill capacity for half of an unmodified spillbay to represent the total lost spillway capacity.

Distribution of flow through each of the three entrances should be relatively uniform with the proposed channel design. At elevation 223.4 meters (733 feet), the headloss due to friction through the longest conduit would be approximately 46 millimeters (1.8 inches) resulting in a difference in the entrance flow rates of approximately 2.5 m^3/s (88 cfs) between Entrance 1/2 and Entrance 5/6. This difference would increase somewhat for the forebay at elevation 224.9 meters (738 feet).

The approximately 56.6 m^3/s (2,000 cfs) attraction flow enters each entrance at a velocity of 0.55 m/s (1.8 ft/s) when the forebay elevation is 223.4 meters (733 feet). For the purpose of discussion of hydraulics, the minimum normal pool at elevation 223.4 meters (733.0 feet) is assumed and the subsequent hydraulic analysis corresponds to this design condition.

Immediately downstream of each entrance, the entrance conduit makes a 90-degree turn to north. The width of the conduit remains constant at 4.88 meters (16 feet) through the bend. There is a guide wall along the centerline of the bend to achieve the desired width to radius ratios to minimize flow separation. Flow velocity in each conduit remains constant from its entrance to the end of the bend where the conduit starts a gradual contraction from 4.88 meters (16 feet) wide to 1.83 meters (6 feet) wide within an approximate conduit length of 21.3 meters (70 feet). The average velocity is increased to 1.45 m/s (4.76 ft/s) through the contraction. After the contraction, each conduit remains at constant depth and width up to the location where the three conduits join (Plate 2.1.2).

There is a gradually sloping floor just prior to where the three conduits combine into one. The conduit floor rises at this section from 21.3 meters (70 feet) to 13.9 meters (45.5 feet) deep. After the floor rises to this depth the three conduits combine into a single conduit which is 6.1 meters (20 feet) wide. The width of the combined conduit then narrows from 6.1 meters (20 feet) to 4.88 meters (16 feet) within a conduit length of 9.14 meters (30 feet) before turning west to connect to the SES.

After the sloped rise, the conduit invert remains constant up to the SES. The transport velocity accelerates from 2.01 m/s (6.59 ft/s) to 2.51 m/s (8.24 ft/s) along the contracting section. Velocity then remains essentially constant to the SES. The flow in the Unit 5/6 transport conduit enters the converging section at an angle. The convergence and bend areas represent a relatively active hydraulic area and a model study of this portion of the channel would likely be required to ensure smooth flow transitions.

Spillway Extension Structure

The primary objective of the fixed SES is to provide connection between the floating and the fixed structure beyond the zone of influence of an open adjacent spillbay at flood. The zone of influence is defined as the distance from the gate within which there will be a noticeable drawdown of the water surface. It was felt that placement of a floating structure in close proximity to a highly variable water surface, as would be the case near a spillway discharging at flood levels, would place unnecessary burdens on the design of the floating structure. It was concluded from an approximate analysis that the zone of influence will be about 15.2 meters (50 feet) upstream from the crest of the spillway. Consequently, the length of the SES has been established at approximately 12.8 meters (42 feet) upstream of the spillway piers or about 19.8 meters (65 feet) upstream of the centerline of the full depth spillway ogee crest. The conduit invert in the SES rises linearly from elevation 210.3 meters (690 feet) at the connection with the channel up to approximately the crest of the ogee at elevation 216.7 meters (710.8 feet). Along the SES the transport velocity varies from approximately 2.66 m/s (8.72 ft/s) to critical velocity of 6.98 m/s (22.9 ft/s) at the crest of the ogee. The final design of the SES for the Type 2 SBC will need to take into consideration the hydraulics of the half-width spillbay which will be created immediately to the north. Hydraulic analysis or modeling should be done to determine if special consideration needs to be made concerning the design of the north wall of the SES.

Overflow Ogee

As mentioned earlier, flow through the SBC system depends on the available energy head upstream of the crest of the ogee. To calculate the elevation of the new ogee crest, the energy losses through the system up to the SES were estimated and a weir coefficient based on the approach conditions was established from available literature. The crest elevation was set at elevation 216.7 meters (710.8 feet) to pass 170 m^3/s (6,000 cfs) discharge over the uncontrolled ogee, with the forebay at the MOP. The value of the weir coefficient will increase with higher approach flow velocity and increasing head and approach depth as the forebay level increases. Based on a re-evaluation of the coefficient and losses at the maximum operating pool, discharge at these conditions was estimated to be 235 m^3/s (8,300 cfs). Details of this calculation are included in Attachment A. For proper estimation of the weir coefficient, and to optimize the approach flow shaping in the SES, a model study should be performed. Additionally, the adequacy of the existing spillway deflector design considering this new ogee shape at a variety of tailwater conditions should be investigated. The shape of the proposed ogee is presented on Plate 2.1.4

ESBS Performance

As with the Type 1 SBC, the presence of the Type 2 SBC will modify velocity magnitudes and distribution in the turbine intake. This will result in modification of the velocity field intercepted by the ESBS. Changes in the velocity field across the ESBS and flow balance across the VBS will likely be modified. Influence of the SBC on ESBS performance should be evaluated in a single turbine intake model. Changes in ESBS porosity may be required.

Cutoff Wall

The cutoff wall is positioned with flow on one side accelerating into the turbine intake and with relatively static flow conditions on the other side. This will generate differential loading on the wall. This loading should be evaluated through use of a power house sectional hydraulic model.

7.1.2 Structural Design

Floating Channel Issues

Cross sections of the Type 2 SBC channel at Lower Granite are shown on Plate 2.1.3. The structural discussion in Section 5.1.2 for the Type 1 channel is applicable to this design as well, with a few notable exceptions. Because there are no screens or other mechanical equipment in the collection channel, the structural aspects are more simplified than with the Type 1 design. Some structural members are anticipated in the flow path, but these will be minimized to the extent possible and will be hydrodynamically shaped. This will be done for both fish protection and to minimize debris build up.

The horizontal restraint and dam stability issues for the channel attachment to the dam are likewise applicable to this design and a fused attachment utilizing shear pins is proposed for attachment of the channel to the dam as well.

Since the Type 2 channel has no dewatering screens, the total headloss through the channel system is substantially reduced. Therefore, the design of the channel walls and floors would be for a reduced pressure. To account for discharge at maximum flood pool where discharge (and headloss) in the channel would be greatest, a design pressure of 0.91 meter (3 feet) of water would be appropriate. This compares with a proposed design pressure of 1.52 meters (5 feet) of water for the screened Type 1 channel. This will result in a more economical design.

Spillway 1 Modifications

The selected design for the channel discharge requires modification to Spillbay 1. A new 2.7-meter (9.0-foot)-wide pier wall will be constructed at roughly the middle of the spillbay leaving a 7.6-meter (25-foot)-wide spillway ogee on the northern half, which would remain at its original shape and elevation, and a new 4.9-meter (16-foot)-wide elevated ogee crest would be constructed on the southern half. The elevated ogee will require the addition of approximately 500 m^3 (650 cubic yards [yd^3]) of concrete to achieve the required crest shape while the new pier will require approximately 1,800 m^3 (2,350 yd^3) of new concrete. Loads to the new (narrower) pier will be about half of those experienced by the existing 4.3-meter (14-foot)-wide piers and would include reactions from the relocated trunnion block for the new narrower Tainter gate. The concrete added to the spillway section at Spillbay 1 will result in an overall increase in the stability of the central non-overflow/half spillbay monolith.

To accommodate the new narrower full-depth northern half of the spillbay, a Tainter gate with a width of 7.62 meters (25 feet) would be required. It may be possible to modify the existing Tainter gate rather than to construct a new one. However, modification would involve cutting the gate (which is a fully welded structure) into smaller pieces, removing 7.6 meters (25 feet) of the middle portion of the gate, rewelding, and reinstalling the gate. The need to cut the gate into smaller pieces would be required to allow for handling with cranes. This becomes an issue of feasibility and overall cost. A decision to modify the gate or design a new one would be an issue for final design, however, it appears that design and installation of a new gate would have the greatest overall value to the project. The new gate would be designed as a bolted structure to facilitate installation and would be designed for reduced loads due to the narrower width. For the purposes of estimating cost, it is assumed that a new gate would be installed.

Spillway Extension Structure

The SES depicted is proposed as a steel structure possibly filled with concrete to increase its overall mass and consequently its dynamic performance in light of its proximity to potentially high velocity flows in the area of the spillway Tainter gate. The structure would be bolted to the face of the spillway piers to secure it against uplift and transverse loads due to hydraulic forces and seismic loads. By comparison to the SES proposed for the Type 1 design, this structure is much smaller and is confined to the south half of the spillbay, which is monolithic with the central non-overflow section and will have significant concrete weight added to it in the form of the raised ogee and the new center pier. Therefore, stability of the spillway structure and the central non-overflow section due to the presence of the Type 2 SES, even if it is not a concrete filled structure, is not compromised.

Channel Cutoff Wall

The structural design issues described in Section 5.1.2 for the cutoff wall below the Type 1 SBC channel would be the same for this design. The only minor difference is that the Type 2 channel is 0.61 meter (2.0 feet) wider than the Type 1 channel and the cutoff wall would, therefore, be slightly longer.

7.1.3 Mechanical Requirements

Compared to the Type 1 SBC channel design, the Type 2 bypass design has significantly less mechanical issues to deal with. The Type 2 design does not include dewatering screens, so screen cleaners are not required. There are also no tilting weirs for controlling the conduits flow. Because the fish are delivered directly to the tailrace instead of into the existing juvenile gallery, there are no issues associated with debris accumulation in the gallery. However, a few mechanical requirements unique to the Type 2 design are addressed below.

Vertical Leaf Gate

A leaf gate is provided at the crest of the new elevated ogee spillway, as depicted on Plate 2.1.4. As discussed above, the gate is an on/off gate during normal operational ranges of the channel. In this way the gate is never present in the flow path when fish are passing over the crest. During flood discharge conditions, when the forebay is surcharged, the gate could be fully open, closed, or could throttle flow in an underflow configuration. A double hoist is shown for the gate since both leaves would need to be lifted to fully clear the water surface at the maximum normal operating pool elevation. Design of the gate would be similar to the spill gates at Wells Dam with both an upper and a lower leaf arrangement, and would be designed to open or close under full head conditions. Hoisting equipment requirements would be determined at the final design stage.

Tainter Gate Hoisting Equipment

To accommodate the new narrow width of the Tainter gate at Spillbay 1, the existing hoisting equipment would need to be modified. Because the total hoisted load for the new gate would be reduced (narrower gate), the existing equipment should be capable of being adapted to the new configuration. The crossover shaft would need to be shortened as the equipment on the south side of the gate would be relocated to the new pier in the center of the original spillbay.

7.1.4 Electrical Requirements

The electrical power requirements for the Type 2 full bypass channel at Lower Granite are quite limited. There are no screen cleaners, trash rakes, weir actuators, or other loads from the channel itself except for convenience lighting and receptacles. The single large power demand for the improvements shown on Plates 2.1.1 through 2.1.4 comes from the hoist motors for the new vertical leaf gates on the elevated ogee at Spillbay 1. Since electrical loads are relatively small, power for the installation at Lower Granite is proposed to be routed from an existing spare 480-volt breaker at LSQ1 (a critical bus) at the west end of the navigation lock [13]. Routing is through existing cable galleries to the leaf-gate-motor loads at Spillbay 1. There are no control issues for this design except for the leaf gates which should be tied into the main project control room to indicate gate position and status. A manual override at the gates should be included.

For the Type 2 SBC at Lower Granite, the total electrical load is estimated to be approximately 42 amperes at 480 volts ac. Calculations for estimated electrical loads are provided in Attachment A. A one-line diagram illustrating the electrical loads, power sources, and components is provided on Plate 2.1.5.

7.1.5 Operation and Maintenance Issues

System Operations

Operation of the full-flow bypass channel is the least complex of all the three SBC channel designs reviewed in this report. Operational issues include opening the vertical leaf gate, periodic monitoring of the transport conduits for large debris, occasional raking of the debris skirt, and operation of the existing ESBS system. The frequency of maintaining the debris skirt is seen in some ways as a biological decision since the formation of a debris mat is considered by some as a fishery enhancement feature. Thus, this could involve varying degrees of attention. If no debris skirt were added, the debris should simply flush through the system.

Corrosion Protection

Corrosion protection measures for the channel would be similar to those discussed and proposed for the Type 1 design in Section 5.1.5, where access for maintenance of steel surfaces is limited or nonexistent. This would include thermal spray metal coating for the collection channel, the SES, and the cutoff wall below the channel. Since inspection and maintenance access would be easier for the new leaf gate and Tainter gate, these items could be painted if this proved to be more cost effective than a thermal spray metal coating.

Debris Maintenance

Debris should be less of a problem with this design than with channel designs which include dewatering screens and delivery of flow into the existing juvenile gallery. Since the channel is capable of conveying the majority of the debris that may be present directly to the tailrace, only a surface debris skirt (which extends about 1.5 meters [5 feet] into the flow) has been added to each channel entrance to keep large floating objects out of the channel. Maintenance of this rack would vary depending on perceived benefits for a debris mat in front of the channel entrance. Apart from periodic maintenance of the debris skirt, some maintenance and review of the floating collection channel will be needed to ensure that materials have not become lodged against structural supports in the channel. Once dislodged, the materials can be removed from the channel or passed downstream with the rest of the flow.

Inspection Issues

Inspection of the channel will occur periodically with divers for the portions that are below water and by other maintenance personnel for the above water portions. The sliding mechanism at the interface between the floating channel and the SES will require some routine inspection, as would the sliding mechanisms associated with the cutoff wall.

Vertical Leaf Gate

The vertical leaf gate is lifted completely free of the water during normal operation of the SBC system. Routine maintenance of the gate can be performed when the gate is in this position. Alternatively, the gate could be temporarily removed for major maintenance activities while the SBC remains in operation.

Due to the ease of inspection of the gate during normal operation, no dewatering/maintenance bulkheads have been included in the design.

7.1.6 Construction Issues

Fabrication/Installation Strategies

Fabrication and installation issues for the Type 2 channel components and the SES are similar to those described in Section 5.1.6 for the Type 1 channel. However, due to the lack of screens, the complexity of the channel construction will be reduced substantially and should result in a shorter construction duration.

Construction of the spillway modifications will need to be accomplished in a dewatered spillbay. Except for the downstream-most portion of the new center pier, which extends down to approximately elevation 192.0 meters (630.0 feet), or about 2.4 meters (8 feet) below normal tailwater, dewatering of the construction area can be accomplished with a single dewatering bulkhead located on the upstream face of the spillway piers. For application at Lower Granite, this bulkhead will need to be designed for approximately 22.4 meters (73.4 feet) of head or down to elevation 205.2 meters (673.1 feet). Below this elevation, which represents the beginning of the ogee crest shape on the existing spillway, the only feature that would remain underwater would be the lower portion of the new pier nose which could be constructed using underwater concrete placement techniques.

Installation of the ogee crest and the new pier would employ conventional cast-in-place concrete techniques. Access would be from a barge located in the tailrace for major construction materials; however, concrete placement could take place from the spillway bridge or the central non-overflow deck in lieu of pumping from a barge. Removal of the existing Tainter gate would be by crane and barge. The new gate would be installed in pieces and bolted together in place.

Construction Sequencing

Construction sequencing issues for the floating channel components and the SES are also similar to those previously described. These include considerations for in-water work windows and other project operation constraints such as spill and unit outages. Because the channel operation is dependent on the completion of the discharge structure, it would be prudent to phase sequence the construction so that completion of the channel and spillway modification coincide. In actuality, because the spillbay construction area is relatively unencumbered by work windows and project operations, work on this part of the project could be accomplished ahead to reduce congestion and competition for sparse construction staging areas on the dam itself.

Construction Duration

Fabrication of the SBC channel and SES components shown for the Type 2 design should take 3 to 5 months. Installation of the SES should take about 2 months. Installation of the channel to a fully operational condition should take 3 to 5 months. Spillway modifications should take 5 to 7 months.

7.1.7 Construction and O&M Costs

Total estimated cost of engineering design and construction for the Type 2 SBC bypass at Lower Granite is $49,553,000 in 1998 dollars. A cost breakdown is presented in spreadsheet format on the following page.

PROJECT: LOWER SNAKE RIVER S.B.C. SYSTEM COMBINATIONS - CONCEPT DESIGN REPORT
DESIGN STATUS: CONCEPTUAL

DATE: Nov-98
ESTIMATOR: PJC
CHECKED BY: RGW

TYPE 2 SBC - FULL POWERHOUSE BYPASS SBC (with Existing ESBS) - LOWER GRANITE LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**SBC CHANNEL**				
	Channel Structure (exterior floor and walls)	9,850	M^2	568	5,594,800
	Interior Conduit Structures (floors and walls minus screens)	8,650	M^2	568	4,913,200
	Miscellaneous Walkways, Roof Structures, Entrance Debris Skirt (% of costs above)	10,508,000	$	4%	420,320
	Channel Flotation Cells	400	M	6,520	2,608,000
	Cutoff Wall (includes foundation)	480	M^2	1,170	561,600
	Structural Support and Guide System	123	Tonne	5,000	615,000
	ITEM SUBTOTAL				14,712,920
2	**SPILLWAY EXTENSION STRUCTURE**				
	Structure Floor and Wall Panels	570	M^2	1,530	872,100
	ITEM SUBTOTAL				872,100
3	**SPILLBAY 1 MODIFICATIONS**				
	Elevated Ogee Concrete	530	M^3	466	246,980
	Mid-Spillbay Pier Wall Concrete	1,800	M^3	598	1,076,400
	Removal of Existing 15.24-M Wide Tainter Gate	1	LS	342,000	342,000
	New 7.62-M Wide Tainter Gate including Gate Hoist Modifications	1	LS	613,000	613,000
	Vertical Leaf Gate and Hoists	1	LS	285,000	285,000
	Stoplogs for 7.62-M Wide Spillbay	150	M^2	636	95,400
	Upstream Dewatering Bulkhead (for use during construction of spillbay modifications)	1	LS	1,220,000	1,220,000
	ITEM SUBTOTAL				3,878,780
4	**MISCELLANEOUS**				
	Trash Shear Boom Relocation	1	LS	75,000	75,000
	Existing Prototype SBC Channel and Prototype BGS Removal and Disposal	2,770	Tonne	900	2,493,000
	Electrical Requirements	1	LS	75,990	75,990
	ITEM SUBTOTAL				2,643,990
	Subtotal Direct Construction Costs				22,107,790
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	22,107,790	$	5.0%	1,105,390
	General Contractors Overhead and Profit	23,213,180	$	26.5%	6,151,493
	CONSTRUCTION SUBTOTAL				29,364,672
	Construction Contingency	29,364,672	$	25.0%	7,341,168
	TOTAL CONSTRUCTION COSTS				***36,705,840***
	PLANNING AND ENGINEERING	36,705,840	$	22.5%	8,258,814
	CONSTRUCTION MANAGEMENT	36,705,840	$	12.5%	4,588,230
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				$49,552,884

App E/Annex B/cost spreadsheet.xls/Type 2 - Granite

Annual O&M costs are estimated as follows:

Maintenance	
Mechanical/electrical components	$27,100
Structural components	$110,100
Operations	
Labor requirements	$20,000
Total annual O&M	**$157,200**

These O&M costs do not include costs associated with O&M of the ESBS diversion system, juvenile fish facilities, or transportation costs, as these are considered existing documented costs. Biological study costs are also not included. If transportation is utilized, the associated O&M costs would be significantly less than those for the Type 1 SBC at Lower Granite, since only the fish diverted by the ESBS would be available for transportation.

7.2 Little Goose: Full Powerhouse Bypass SBC (with Existing ESBS) – SBC Type 2

The design of the Type 2 SBC channel at Little Goose is virtually the same as described for the Type 2 SBC for Lower Granite described in Section 7.1. Plans and details of the SBC Type 2 design, as installed at Little Goose, are shown on Plates 2.2.1 through 2.2.5, in Section 7.6.

7.2.1 Hydraulics

The hydraulics associated with the Type 2 SBC installation at Little Goose are the same as described for Lower Granite in Section 7.1.1, except for the conditions downstream on the spillway. At Little Goose the release from the elevated ogee will discharge into a roller bucket stilling basin instead of passing over a deflector which skims the release flow across a hydraulic jump basin (as at Lower Granite). Although energy levels and corresponding shear intensities in the plunging flow at the tailrace are comparable for the two projects, the lack of a spillway deflector at Little Goose results in the fish being exposed to substantially higher tailrace pressures. Velocity fields generated in the stilling basin should be documented in the sectional spillway models and analyzed to determine if they will be acceptable for fish passage. It may prove desirable to add a deflector to Spillbay 1 at Little Goose.

Reductions in spill capacity are likewise identical to those described for Lower Granite. A spillway rating curve for Little Goose is presented in Figure 7.2

7.2.2 Structural Design

Structural design issues and criteria for the Type 2 SBC at Little Goose are the same as presented for Lower Granite in Section 7.1.2. As discussed in Section 5.2.2 for the Type 1 SBC design at Little Goose, there is a potential for greater wave loading at Little Goose than at Lower Granite. However, the magnitude of this greater load would not necessitate a change in the fuse pin attachment design.

7.2.3 Mechanical Requirements

Mechanical design issues for the Type 2 SBC at Little Goose are also the same as presented for Lower Granite in Section 7.1.3. This would include the hoisting equipment for the new leaf gate at the raised spillbay and modifications to the existing Tainter gate equipment.

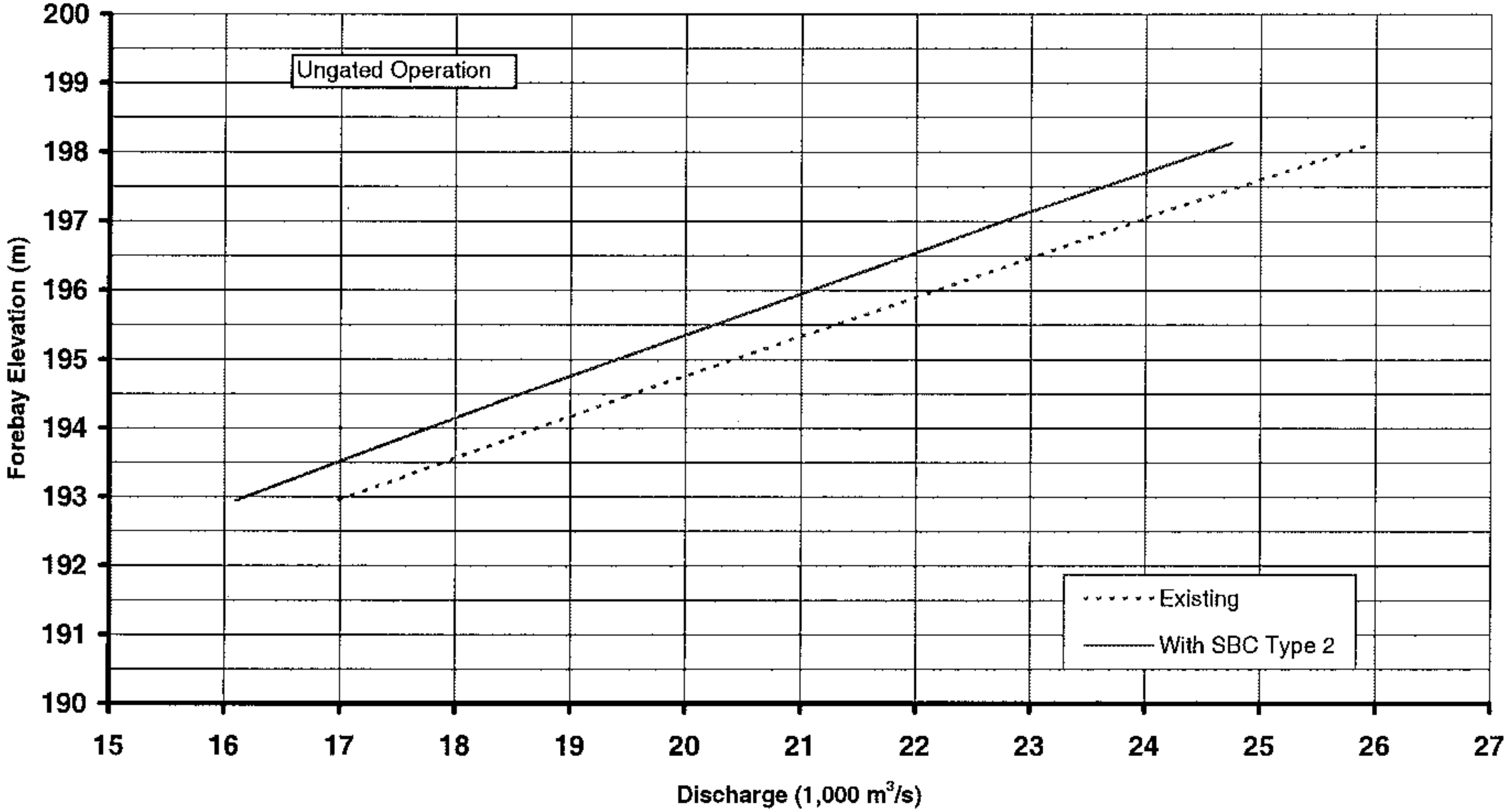

Figure 7.2 - Little Goose Lock and Dam - Spill Capacity with SBC Type 2

7.2.4 Electrical Requirements

Primary Power Considerations

The electrical loads for the Type 2 SBC at Little Goose are the same as for those for the Type 2 SBC at Lower Granite (see Section 7.1.4) and total approximately 42 amperes at 480 volts ac. Calculations for estimated electrical load are provided in Attachment A.

A reliable source of power is available at 480 volts from load center SQO2 located in the Upstream Gallery at Bay 5 on Floor 3 [18]. A new breaker will be required. From Floor 3, a 480-volt feeder would be routed up to the intake deck through existing electrical chases and in existing trays before penetrating the concrete intake deck in the area of Spillbay 1. A one-line diagram illustrating the electrical loads, power sources, and components is provided on Plate 2.2.5.

Instrumentation and Controls

Control issues are the same as at Lower Granite (see Section 7.1.4.) and relate to gate position information for the vertical leaf gates.

7.2.5 Operation and Maintenance Issues

O&M issues are the same as at Lower Granite (see Section 7.1.5) and are limited to operation of the vertical leaf gate, periodic monitoring of the transport conduits, occasional raking of the entrance debris skirt, and operation of the ESBS system.

7.2.6 Construction Issues

Construction issues are the same as at Lower Granite (see Section 7.1.6). As for all the Little Goose designs, barging access from the lower river during construction is slightly better with one less lockage event required than at Lower Granite.

7.2.7 Construction and O&M Costs

Total estimated cost of engineering design and construction for the Type 2 SBC bypass at Little Goose is $43,796,000 in 1998 dollars. A cost breakdown is presented in spreadsheet format on the following page. Annual O&M costs are estimated as follows:

Maintenance	
Mechanical/electrical components	$25,900
Structural components	$110,100
Operations	
Labor requirements	$20,000
Total annual O&M	**$156,000**

These O&M costs do not include costs associated with O&M of the ESBS diversion system, juvenile fish facilities, or transportation costs, as these are considered existing documented costs. Biological study costs are also not included.

PROJECT: LOWER SNAKE RIVER S.B.C. SYSTEM COMBINATIONS - CONCEPT DESIGN REPORT
DESIGN STATUS: CONCEPTUAL

DATE: Nov-98
ESTIMATOR: PJC
CHECKED BY: RGW

TYPE 2 SBC - FULL POWERHOUSE BYPASS SBC (with Existing ESBS) - LITTLE GOOSE LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**SBC CHANNEL**				
	Channel Structure (exterior floor and walls)	9,850	M^2	568	**5,594,800**
	Interior Conduit Structures (floors and walls minus screens)	8,650	M^2	568	**4,913,200**
	Miscellaneous Walkways, Roof Structures, Entrance Debris Skirt (% of costs above)	10,508,000	$	4%	**420,320**
	Channel Flotation Cells	400	M	6,520	**2,608,000**
	Cutoff Wall (includes foundation)	480	M^2	1,170	**561,600**
	Structural Support and Guide System	123	Tonne	5,000	**615,000**
	ITEM SUBTOTAL				**14,712,920**
2	**SPILLWAY EXTENSION STRUCTURE**				
	Structure Floor and Wall Panels	570	M^2	1,530	**872,100**
	ITEM SUBTOTAL				**872,100**
3	**SPILLBAY 1 MODIFICATIONS**				
	Elevated Ogee Concrete	530	M^3	466	**246,980**
	Mid-Spillbay Pier Wall Concrete	1,800	M^3	598	**1,076,400**
	Removal of Existing 15.24-M Wide Tainter Gate	1	LS	342,000	**342,000**
	New 7.62-M Wide Tainter Gate including Gate Hoist Modifications	1	LS	613,000	**613,000**
	Vertical Leaf Gate and Hoists	1	LS	285,000	**285,000**
	Stoplogs for 7.62-M Wide Spillbay	150	M^2	636	**95,400**
	Upstream Dewatering Bulkhead (for use during construction of spillbay modifications)	1	LS	1,220,000	**1,220,000**
	ITEM SUBTOTAL				**3,878,780**
4	**MISCELLANEOUS**				
	Electrical Requirements	1	LS	75,440	**75,440**
	ITEM SUBTOTAL				**75,440**
	Subtotal Direct Construction Costs				**19,539,240**
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	19,539,240	$	5.0%	**976,962**
	General Contractors Overhead and Profit	20,516,202	$	26.5%	**5,436,794**
	CONSTRUCTION SUBTOTAL				**25,952,996**
	Construction Contingency	25,952,996	$	25.0%	**6,488,249**
	TOTAL CONSTRUCTION COSTS				***32,441,244***
	PLANNING AND ENGINEERING	32,441,244	$	22.5%	**7,299,280**
	CONSTRUCTION MANAGEMENT	32,441,244	$	12.5%	**4,055,156**
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				**$43,795,680**

7.3 Lower Monumental: Full Powerhouse Bypass SBC (with New ESBS) – SBC Type 2

The design of the Type 2 SBC channel at Lower Monumental is similar to that described for Lower Granite in Section 7.1, with some exceptions. Plans and details of the SBC Type 2 design, as installed at Lower Monumental, are shown on Plates 2.3.1 through 2.3.5, in Section 7.6. One notable exception is that the project layout is reversed at Lower Monumental, with the powerhouse located to the north of the spillway. Therefore, the reader should note that references to north and south in the discussions for Lower Granite are reversed in their application to Lower Monumental. Additionally, this reversed orientation results in the SBC flow being discharged at Spillbay 8, instead of Spillbay 1, as described for Lower Granite. Since Lower Monumental currently uses STSs, these would be removed and replaced with new ESBS systems.

The forebay elevations at Lower Monumental vary from a maximum operating pool of 164.6 meters (540 feet) to a MOP of 163.7 meters (537 feet). This results in a total forebay level fluctuation of 0.91 meter (3.0 feet), within the normal operating range. This range is less than the 1.52-meter (5.0-foot) range of forebay levels at Lower Granite and Little Goose. With the system designed to pass the design flow of 170 m^3/s (6,000 cfs) at MOP, the increase in flow resulting from operation at the maximum operating pool is not as great as at Lower Granite and Little Goose. This is discussed in Section 7.3.1.

7.3.1 Hydraulics

The Type 2 SBC installation at Lower Monumental is nearly identical to the Type 2 installations at Lower Granite and Little Goose. As a consequence of the smaller variation in operating pool range, discharges through the SBC at Lower Monumental will vary over a smaller range. As with Lower Granite and Little Goose, the crest elevation of the elevated ogee is set to generate a total SBC release of 170 m^3/s (6,000 cfs) at MOP. The 0.91-meter (3.0-foot) increase in forebay elevation at Lower Monumental would increase the SBC release to approximately 210 m^3/s (7,400 cfs). The uncontrolled discharge through the SBC at the maximum flood pool elevation of 167.1 meters (548.3 feet) is estimated to be 289 m^3/s (10,200 cfs).

Because the increases in discharge and velocity that occur over the normal operating forebay range are smaller, corresponding increases in head losses in each of the SBC channels are reduced below the increases that occur at Lower Granite and Little Goose. This in turn limits unbalanced flow distributions between the SBC entrances. The flow distribution between the entrances should be fairly uniform over the full operating forebay range.

To optimize the ESBS design, the new ESBS should be evaluated in a single turbine intake model with an SBC-shaped box included since the SBC will modify the hydraulic field at the ESBS.

Reductions in spill capacity associated with the installation of the Type 2 SBC at Lower Monumental are identical to those described for Lower Granite and Little Goose. A spillway rating curve is presented in Figure 7.3.

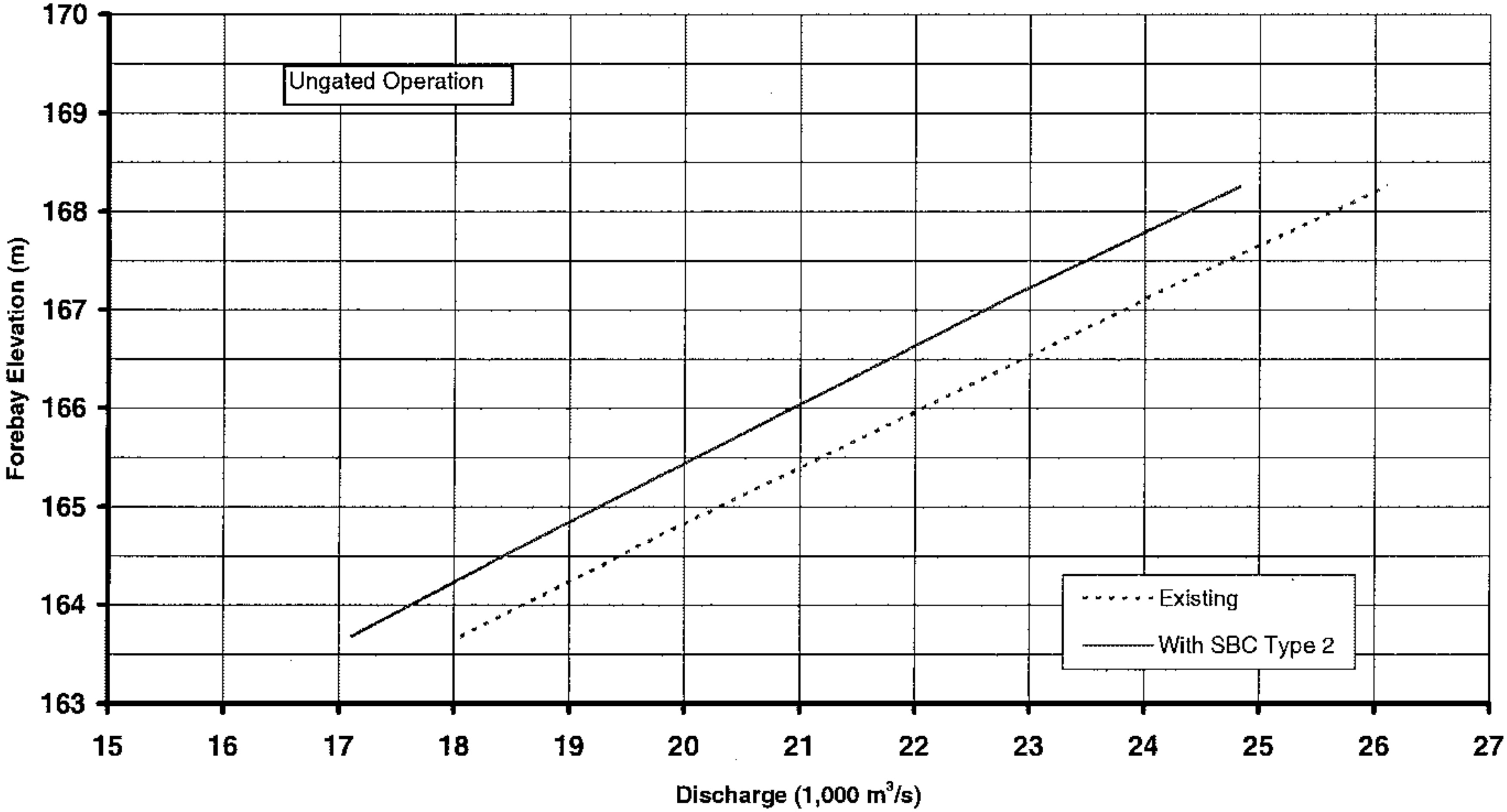

Figure 7.3 - Lower Monumental Lock and Dam - Spill Capacity with SBC Type 2

7.3.2 Structural Design

Structural design issues and criteria for the Type 2 SBC at Lower Monumental are the same as presented for Lower Granite in Sections 7.1.2 and 5.1.2 as applicable to the Type 2 design. Although potential wind-driven wave loading is slightly greater than for Lower Granite, it is significantly less than at Little Goose and should not present a problem. Structural issues associated with the new ESBS intake diversion system are as described in Section 5.3.2.

7.3.3 Mechanical Requirements

Mechanical design issues for the Type 2 SBC at Lower Monumental are also the same as presented for Lower Granite in Section 7.1.3. This would include the hoisting equipment for the new leaf gate at the raised spillbay and modifications to the existing Tainter gate equipment. Mechanical requirements associated with the new ESBS intake diversion system are as described in Section 5.3.3.

7.3.4 Electrical Requirements

Primary Power Considerations

The electrical loads for the Type 2 SBC at Lower Monumental are the same as for those for the Type 2 SBC at Lower Granite (see Section 7.1.4) and total approximately 42 amperes at 480 volts ac. Calculations for estimated electrical load are provided in Attachment A.

A reliable source of power is available from existing motor control center (MCC) DCQ2 located in the spillway service gallery about mid-way down the gallery [20]. This MCC currently feeds spillway equipment (gate hoists, etc.). A spare 125-amp breaker is available in DCQ2 and would more than adequately handle these loads. From this location, a 480-volt feeder would be routed to the spillway deck in the area of Spillbay 8 to supply the leaf gate hoist motors. A one-line diagram illustrating the electrical loads, power sources, and components is provided on Plate 2.3.5.

Instrumentation and Controls

Control issues are the same as at Lower Granite (see Section 7.1.4.) and relate to gate position information for the vertical leaf gates.

7.3.5 Operation and Maintenance Issues

O&M issues are the same as at Lower Granite (see Section 7.1.5) and are limited to operation of the vertical leaf gate, periodic monitoring of the transport conduits, occasional raking of the entrance debris skirt, and operation of the ESBS system. O&M requirements for the new ESBS system are assumed to be similar in magnitude and cost to the existing requirements associated with the STS system.

7.3.6 Construction Issues

Construction issues are the same as at Lower Granite (see Section 7.1.6) except that new ESBS systems are being added. Construction issues related to the ESBS are as described in Section 5.3.6.

7.3.7 Construction and O&M Costs

Total estimated cost of engineering design and construction for the Type 2 SBC bypass at Lower Monumental is $43,767,000 in 1998 dollars. The estimated cost for replacing the existing STS intake diversion system with a new ESBS system is an additional $16,058,000. A cost breakdown is presented in spreadsheet format on the following four pages. Annual O&M costs are estimated as follows:

Maintenance	
Mechanical/electrical components	$27,400
Structural components	$110,000
Operations	
Labor requirements	$20,000
Total annual O&M	**$157,400**

These O&M costs do not include costs associated with O&M of the ESBS diversion system, juvenile fish facilities, or transportation costs, as these are considered existing documented costs. Biological study costs are also not included.

7.4 Ice Harbor: Full Powerhouse Bypass SBC (with New ESBS) – SBC Type 2

Application of a Type 2 SBC at Ice Harbor involves many of the same design issues found at the other projects. One aspect of the Ice Harbor design which is significantly different, and which significantly affects the shape of the channel, is the depth of the forebay and, consequently, the geometry of the intake. The forebay depth at the face of the Ice Harbor powerhouse is approximately 6.1 meters (20 feet) shallower than at the other 3 projects. However, the height of the turbine intake roof above the bottom of the forebay in only about one meter less. The remainder of the difference in depth is due to the intake roof being located at a shallower position. As a result, the Type 2 SBC design at Ice Harbor utilizes a floating channel with a flow depth of 16.8 meters (55 feet), as opposed to 21.3 meters (70 feet) at the other 3 projects. At this depth, the channel will create a hydraulic presence in front of the intakes approximately equal to the condition at the other three projects. The channel is also slightly shorter, due to the shorter turbine unit spacing at Ice Harbor. Plans and details of this design are shown on Plates 2.4.1 through 2.4.5, in Section 7.6.

Other than the difference in channel depth, the design of the Type 2 SBC at Ice Harbor is essentially the same as described for the Type 2 design at Lower Granite in Section 7.1. As with the other Type 2 designs, the raised concrete ogee crest is sized to pass the design flow of 170 m^3/s (6,000 cfs) at the MOP. Because the design discharge is the same as with the other Type 2 SBC designs, the SES and the north end of the channel (north of Unit 6) are the same as previously described. Due to the free discharge at the spillway, the system flow will be somewhat higher at the maximum operating pool. This is discussed in Section 7.4.1.

The turbine intakes at Ice Harbor are currently outfitted with an STS intake diversion system. These screens will be removed and replaced with a new ESBS diversion system. As described for the other projects and SBC designs, the ESBS will be used in conjunction with the SBC.

7.4.1 Hydraulics

The turbine intake submergence at Ice Harbor is approximately 4.6 meters (15 feet) less than at the other 3 sites. As a consequence, if a full 21.3-meter (70-foot)-SBC depth were used at Ice Harbor, excessive blockage of the turbine intake could result. This could potentially yield negative influences on the ESBS

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TYPE 2 SBC - FULL POWERHOUSE BYPASS SBC - LOWER MONUMENTAL LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**SBC CHANNEL**				
	Channel Structure (exterior floor and walls)	9,850	M^2	568	**5,594,800**
	Interior Conduit Structures (floors and walls minus screens)	8,650	M^2	568	**4,913,200**
	Miscellaneous Walkways, Roof Structures, Entrance Debris Skirt (% of costs above)	10,508,000	$	4%	**420,320**
	Channel Flotation Cells	400	M	6,520	**2,608,000**
	Cutoff Wall (includes foundation)	465	M^2	1,170	**544,050**
	Structural Support and Guide System	123	Tonne	5,000	**615,000**
	ITEM SUBTOTAL				**14,695,370**
2	**SPILLWAY EXTENSION STRUCTURE**				
	Structure Floor and Wall Panels	570	M^2	1,530	**872,100**
	ITEM SUBTOTAL				872,100
3	**SPILLBAY 1 MODIFICATIONS**				
	Elevated Ogee Concrete	530	M^3	466	**246,980**
	Mid-Spillbay Pier Wall Concrete	1,800	M^3	598	**1,076,400**
	Removal of Existing 15.24-M Wide Tainter Gate	1	LS	342,000	**342,000**
	New 7.62-M Wide Tainter Gate including Gate Hoist Modifications	1	LS	613,000	**613,000**
	Vertical Leaf Gate and Hoists	1	LS	285,000	**285,000**
	Stoplogs for 7.62-M Wide Spillbay	150	M^2	636	**95,400**
	Upstream Dewatering Bulkhead (for use during construction of spillbay modifications)	1	LS	1,220,000	**1,220,000**
	ITEM SUBTOTAL				3,878,780
4	**MISCELLANEOUS**				
	Electrical Requirements	1	LS	80,160	80,160
	ITEM SUBTOTAL				80,160
	Subtotal Direct Construction Costs				19,526,410
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	19,526,410	$	5.0%	**976,321**
	General Contractors Overhead and Profit	20,502,731	$	26.5%	**5,433,224**
	CONSTRUCTION SUBTOTAL				**25,935,954**
	Construction Contingency	25,935,954	$	25.0%	**6,483,989**
	TOTAL CONSTRUCTION COSTS				***32,419,943***
	PLANNING AND ENGINEERING	32,419,943	$	22.5%	**7,294,487**
	CONSTRUCTION MANAGEMENT	32,419,943	$	12.5%	**4,052,493**
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				$43,766,923

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NEW EXTENDED LENGTH SUBMERGED BAR SCREENS - LOWER MONUMENTAL LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**ESBS INTAKE DIVERSION SCREENS**				
	Installation of ESBS Diversion Screens	18	EA	398,000	7,164,000
	ITEM SUBTOTAL				7,164,000
	Subtotal Direct Construction Costs				7,164,000
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	7,164,000	$	5.0%	358,200
	General Contractors Overhead and Profit	7,522,200	$	26.5%	1,993,383
	CONSTRUCTION SUBTOTAL				9,515,583
	Construction Contingency	9,515,583	$	25.0%	2,378,896
	TOTAL CONSTRUCTION COSTS				***11,894,479***
	PLANNING AND ENGINEERING	11,894,479	$	22.5%	2,676,258
	CONSTRUCTION MANAGEMENT	11,894,479	$	12.5%	1,486,810
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				$16,057,546

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TYPE 3 SBC - 2-UNIT BYPASS/COLLECTION SBC - LOWER MONUMENTAL LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**SBC CHANNEL**				
	Channel Structure (exterior floor and walls)	4,060	M^2	710	**2,882,600**
	Interior Conduit Structures (floors and walls minus screens)	3,950	M^2	710	**2,804,500**
	Miscellaneous Walkways, Roof Structures, Entrance Debris Skirt (% of costs above)	5,687,100	$	10%	**568,710**
	Channel Flotation Cells	180	M	7,660	**1,378,800**
	Dewatering Screen Panels (removable panels stainless steel wedge-wire screen with spare panels	390	M^2	1,470	**573,300**
	Screen Cleaners (vertical brush cleaners)	12	EA	35,000	**420,000**
	Channel Entrance Debris Rake System	1	LS	482,000	**482,000**
	Entrance Sliding Doors, Hinged Gate, Control Gates, and Tilting Weir	215	M^2	1,640	**352,600**
	Cutoff Wall (includes foundation)	475	M^2	1,170	**555,750**
	Structural Support and Guide System	50	Tonne	5,000	**250,000**
	ITEM SUBTOTAL				**10,268,260**
2	**SPILLWAY EXTENSION STRUCTURE**				
	Structure Floor and Wall Panels	520	M^2	1,530	**795,600**
	ITEM SUBTOTAL				**795,600**
3	**CHANNEL CONDUIT CONNECTION TO GALLERY (AT CENTRAL NON-OVERFLOW)**				
	Steel Caissons and Related Structures	139	M^2	1,530	**212,670**
	Concrete Removal	60	M^3	1,330	**79,800**
	ITEM SUBTOTAL				**292,470**
4	**SPILLBAY 1 MODIFICATIONS**				
	Elevated Ogee Concrete	200	M^3	466	**93,200**
	Mid-Spillbay Pier Wall Concrete	1,800	M^3	598	**1,076,400**
	Removal of Existing 15.24-M Wide Tainter Gate	1	LS	342,000	**342,000**
	New 10.67-M Wide Tainter Gate including Gate Hoist Modifications	1	LS	835,000	**835,000**
	Vertical Leaf Gate and Hoists	1	LS	107,000	**107,000**
	Stoplogs for 10.67-M Wide Spillbay	203	M^2	880	**178,640**
	Upstream Dewatering Bulkhead (for use during construction of spillbay modifications)	1	LS	1,220,000	**1,220,000**
	ITEM SUBTOTAL				**3,852,240**
5	**BEHAVIORAL GUIDANCE STRUCTURE (BGS)**				
	BGS	518	M	18,200	**9,427,600**
	FLE	214	M	8,070	**1,726,980**
	Mechanical Requirements	1	LS	175,000	**175,000**
	ITEM SUBTOTAL				**11,329,580**

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TYPE 3 SBC - 2-UNIT BYPASS/COLLECTION SBC - LOWER MONUMENTAL LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
6	**MISCELLANEOUS**				
	Electrical Requirements	1	LS	267,790	267,790
	ITEM SUBTOTAL				**267,790**
	Subtotal Direct Construction Costs				**26,805,940**
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	26,805,940	$	5.0%	**1,340,297**
	General Contractors Overhead and Profit	28,146,237	$	26.5%	**7,458,753**
	CONSTRUCTION SUBTOTAL				**35,604,990**
	Construction Contingency	35,604,990	$	25.0%	**8,901,247**
	TOTAL CONSTRUCTION COSTS				***44,506,237***
	PLANNING AND ENGINEERING	44,506,237	$	22.5%	**10,013,903**
	CONSTRUCTION MANAGEMENT	44,506,237	$	12.5%	**5,563,280**
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				**$60,083,420**

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system and possibly on turbine operation. To limit intrusion on the intake to a level comparable to the other sites, the vertical depth of the SBC was reduced to 16.8 meters (55 feet). For the purposes of this study, it is assumed that the reduction in entrance and channel depth will be biologically acceptable from a fish collection viewpoint.

Collector Entrances and SBC Channel

As with the Type 2 designs at the other three projects, the flow through the channel will vary with the available head on the raised ogee, resulting in increased flow at higher forebay levels. The elevated ogee crest was set at elevation 126.4 meters (414.7 feet), as shown on Plate 2.4.4. to develop a flow of 170 m^3/s (6,000 cfs) at the MOP level of 133.2 meters (437 feet). At the MOP level, the 56.6 m^3/s (2,000 cfs) entrance flow will enter each 16.8 meters (55 feet) deep by 4.88 meters (16 feet) wide SBC entrance at a velocity of 0.69 m/s (2.27 ft/s). This is a higher velocity than is generated in the Type 2 channel design at the other three projects, due to the shallower entrances. From the entrance, the flow will pass through approximately a 90-degree bend which contains a centerline guide wall which helps maintain a uniform flow distribution. Use of the guide wall yields centerline radius to conduit width ratios of about 2.0 and 3.0 for each half of the conduit through the bend. As with the deeper Type 2 channel design, the conduit remains constant depth through the bend and through a subsequent contraction section in which the width is reduced to 1.83 meters (6.0 feet). This contraction accelerates the velocity to 1.85 m/s (6.1 ft/s). The flow from the three entrances is then routed north and merged through use of parallel channel sections with sloping floors that further accelerate the flow to approximately a velocity of 2.51 m/s (8.2 ft/s). From the merged section through the ogee, flow conditions are identical to the previously discussed Type 2 designs.

The higher entrance and initial conduit velocities increase total head losses by approximately 150 millimeters (0.5 foot) over the normal operating forebay range. The increased velocities will likewise increase imbalances in flow distribution between the collector entrances. Flow distributions will be more comparable to those predicted at maximum operating pool at Lower Granite and Little Goose.

At the maximum operating pool elevation of 134.1 meters (440.0 feet), the combined discharge through the SBC would be approximately 198 m^3/s (7,000 cfs). At the maximum flood pool elevation of 136.1 meters (446.4 feet), the combined unregulated discharge through the SBC would be approximately 266 m^3/s (9,400 cfs).

ESBS Performance

As with the other SBC designs, the presence of the SBC will modify velocity magnitudes and distribution in the turbine intake. This will result in modification of the velocity field intercepted by the new ESBS, which will influence the velocity field across the ESBS and flow balance across the VBS. Uncertainty with the Ice Harbor design is more pronounced in that the intake is substantially different than those at the other three sites. Influence of the SBC on ESBS performance should be evaluated in a single turbine intake model.

Cutoff Wall

As at the other sites and other SBC designs, the cutoff wall is positioned with flow on one side accelerating into the turbine intake and with relatively static flow conditions on the other side. This will impose differential loading on the wall. Because of the unique features of the Ice Harbor design, differences in the loading from those generated at the other sites may occur at Ice Harbor. This loading should be evaluated through use of a powerhouse sectional hydraulic model.

Influence on Spillway Capacity

Ice Harbor has ten spillbays verses the eight that are present at the other sites. As a consequence, the loss of half of one spillbay capacity yields less relative loss. The current spill capacity of 24,100 m^3/s (850 kcfs) would be reduced to 22,890 m^3/s (808.4 kcfs) with no SBC release, or 23,156 m^3/s (817.8 kcfs) with supplemental SBC release. This corresponds to approximately a 3.8 percent reduction in total spill capacity. A spillway rating curve for Ice Harbor with the SBC installed is presented in Figure 7.4.

7.4.2 Structural Design

Although the SBC channel at Ice Harbor is shallower, the channel structure design approach would be virtually the same since the design differential head in the channel would be the same. A design criteria which is unique to Ice Harbor is the greater design seismic acceleration of 0.38 g. This issue was addressed with respect to the fused channel attachment and the stability of the spillway with the proposed modifications. These analyses are discussed below and details included in Attachment A.

Channel Attachment

The proposed fuse pin channel attachment at the other three projects was designed for a seismic acceleration of 0.1 g. The greater seismic acceleration at Ice Harbor results in a greater differential between the design ice loading (which is the same as the other projects) and the design seismic load placed on the powerhouse by the forebay. Because it is this differential which is the basis for the factor of safety in the fuse pin design, there is an opportunity to use a larger fuse pin at Ice Harbor, which would result in a greater factor of safety. However, whether or not to take advantage of this (or simply use pins of the same size as at the other projects) would be an issue for final design.

Spillway Modifications and SES

Based on a preliminary review of the spillway with the SES modifications, the addition of the raised concrete ogee and the new spillway pier at Spillbay 1, in conjunction with the SES, will increase the stability of the central non-overflow monolith in both sliding and overturning. This is the result of the added weight of the new structures. Although this increase in overall stability is significant for the normal operating and flood level conditions, it is somewhat less substantial for the earthquake loading, due to the relatively large 0.38 g earthquake acceleration. Based on the information provided for this analysis, it is not possible to fully document the overall sliding stability of the existing central non-overflow or spillway monoliths under an earthquake loading of 0.38 g. It is recommended that this issue be addressed more thoroughly during final design. Additionally, a dynamic analysis of the spillway and central non-overflow monoliths should be performed to determine the effect of the SES on the internal concrete stresses.

7.4.3 Mechanical Requirements

Mechanical design issues for the Type 2 SBC at Ice Harbor are also the same as presented for Lower Granite in Section 7.1.3. This would include the hoisting equipment for the new leaf gate at the raised spillbay and modifications to the existing Tainter gate equipment. It should be noted that the vertical leaf gates (and the leaf gate hoisting equipment) have been moved to on top of the SES because there is

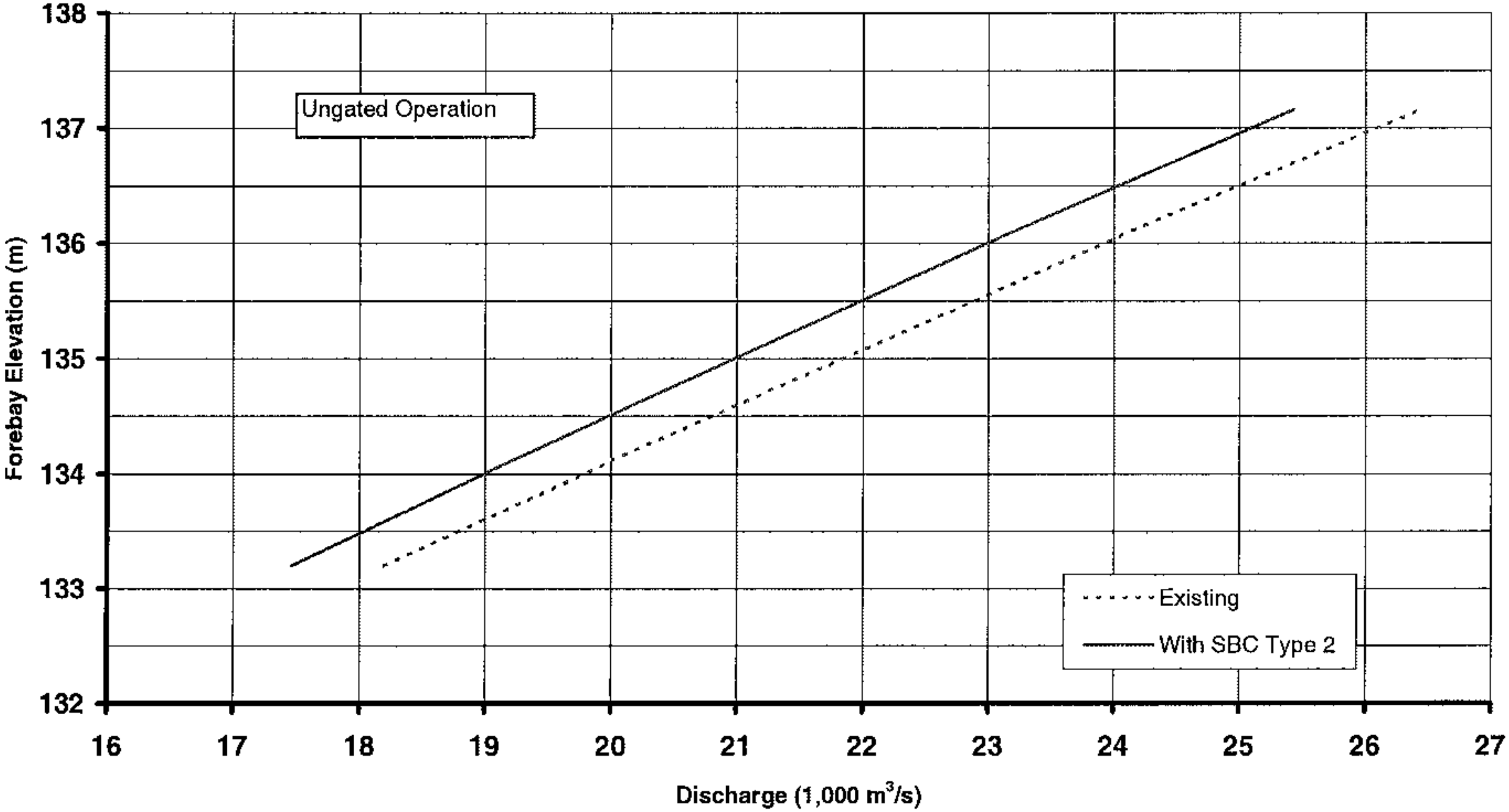

Figure 7.4 - Ice Harbor Lock and Dam - Spill Capacity with SBC Type 2

App E/Annex B/Figures 7.1 - 8.3.xls

insufficient space on the pier noses to located the gate without making significant modifications to the spillway deck which would impact the driveable width and the crane rails. Mechanical requirements associated with the new ESBS intake diversion system are as described in Section 5.3.3.

7.4.4 Electrical Requirements

Primary Power Considerations

The electrical loads for the Type 2 SBC at Ice Harbor are the same as for those for the Type 2 SBC at Lower Granite (see Section 7.1.4) and total approximately 42 amperes at 480 volts ac. Calculations for estimated electrical load are provided in Attachment A.

A reliable source of power is available at 480 volts from a spare 175-amp breaker in MCC CQO8 located in the erection bay intake gallery between Floors 7 and 8 [24]. A feeder would be routed from there in existing cable trays to the central non-overflow area and then up to the area of the leaf gates. A one-line diagram illustrating the electrical loads, power sources, and components is provided on Plate 2.4.5.

Instrumentation and Controls

Control issues are the same as at Lower Granite (see Section 7.1.4.) and relate to gate position information for the vertical leaf gates.

7.4.5 Operation and Maintenance Issues

O&M issues are the same as at Lower Granite (see Section 7.1.5) and are limited to operation of the vertical leaf gate, periodic monitoring of the transport conduits, occasional raking of the entrance debris skirt, and operation of the ESBS system. O&M requirements for the new ESBS system are assumed to be similar in magnitude and cost to the existing requirements associated with the STS system.

7.4.6 Construction Issues

Construction issues are the same as at Lower Granite (see Section 7.1.6).

7.4.7 Construction and O&M Costs

Total estimated cost of engineering design and construction for the Type 2 SBC bypass at Ice Harbor, including a new ESBS intake diversion system, is $37,825,000 in 1998 dollars. The estimated cost for replacing the existing STS intake diversion system with a new ESBS system is $16,058,000. A cost breakdown is presented in spreadsheet format on the following two pages. Annual O&M costs are estimated as follows:

Maintenance	
Mechanical/electrical components	$27,600
Structural components	$93,700
Operations	
Labor requirements	$20,000
Total annual O&M	**$141,300**

These O&M costs do not include costs associated with O&M of the ESBS diversion system, juvenile fish facilities, or transportation costs, as these are considered existing documented costs. Biological study costs are also not included.

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TYPE 2 SBC - FULL POWERHOUSE BYPASS SBC - ICE HARBOR LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**SBC CHANNEL**				
	Channel Structure (exterior floor and walls)	7,980	M^2	568	4,532,640
	Interior Conduit Structures (floors and walls minus screens)	7,230	M^2	568	4,106,640
	Miscellaneous Walkways, Roof Structures, Entrance Debris Skirt (% of costs above)	8,639,280	$	4%	345,571
	Channel Flotation Cells	380	M	6,080	2,310,400
	Cutoff Wall (includes foundation)	430	M^2	1,170	503,100
	Structural Support and Guide System	123	Tonne	5,000	615,000
	ITEM SUBTOTAL				12,413,351
2	**SPILLWAY EXTENSION STRUCTURE**				
	Structure Floor and Wall Panels	570	M^2	1,530	872,100
	ITEM SUBTOTAL				872,100
3	**SPILLBAY 1 MODIFICATIONS**				
	Elevated Ogee Concrete	460	M^3	466	214,360
	Mid-Spillbay Pier Wall Concrete	1,470	M^3	598	879,060
	Removal of Existing 15.24-M Wide Tainter Gate	1	LS	296,000	296,000
	New 7.62-M Wide Tainter Gate including Gate Hoist Modifications	1	LS	530,000	530,000
	Vertical Leaf Gate and Hoists	1	LS	285,000	285,000
	Stoplogs for 7.62-M Wide Spillbay	130	M^2	636	82,680
	Upstream Dewatering Bulkhead (for use during construction of spillbay modifications)	1	LS	1,220,000	1,220,000
	ITEM SUBTOTAL				3,507,100
4	**MISCELLANEOUS**				
	Electrical Requirements	1	LS	82,920	82,920
	ITEM SUBTOTAL				82,920
	Subtotal Direct Construction Costs				16,875,471
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	16,875,471	$	5.0%	843,774
	General Contractors Overhead and Profit	17,719,245	$	26.5%	4,695,600
	CONSTRUCTION SUBTOTAL				22,414,845
	Construction Contingency	22,414,845	$	25.0%	5,603,711
	TOTAL CONSTRUCTION COSTS				***28,018,556***
	PLANNING AND ENGINEERING	28,018,556	$	22.5%	6,304,175
	CONSTRUCTION MANAGEMENT	28,018,556	$	12.5%	3,502,319
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				$37,825,050

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NEW EXTENDED LENGTH SUBMERGED BAR SCREENS - ICE HARBOR LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**ESBS INTAKE DIVERSION SCREENS**				
	Installation of ESBS Diversion Screens	18	EA	398,000	7,164,000
	ITEM SUBTOTAL				7,164,000
	Subtotal Direct Construction Costs				7,164,000
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	7,164,000	$	5.0%	358,200
	General Contractors Overhead and Profit	7,522,200	$	26.5%	1,993,383
	CONSTRUCTION SUBTOTAL				9,515,583
	Construction Contingency	9,515,583	$	25.0%	2,378,896
	TOTAL CONSTRUCTION COSTS				***11,894,479***
	PLANNING AND ENGINEERING	11,894,479	$	22.5%	2,676,258
	CONSTRUCTION MANAGEMENT	11,894,479	$	12.5%	1,486,810
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				$16,057,546

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7.5 Combination Summary

7.5.1 Combined Construction Issues

With multiple installations of the same design at all four projects, the projected efficiencies from progressive installation sequencing (stage construction at one project to follow behind the other), as described in Section 5.5.1, would apply here also. Engagement of a single contractor for the work may increase this efficiency as enhancements and skills developed at one project could be applied at subsequent ones.

7.5.2 Summary Construction and O&M Costs

The total combined estimated engineering design and construction cost for the System Combination 2 design is $208,057,000 in 1998 dollars. Additional costs associated with prototyping and/or major hydraulic modeling efforts would likely be reduced over those associated with System Combination 1, due to the absence of dewatering screen systems in the Type 2 designs. A summary of the estimated costs by project is shown below.

Estimated Engineering Design and Construction Cost – System Combination 2

Project	Description	Estimated Construction Cost
Lower Granite	Type 2 SBC (with existing ESBS)	$49,553,000
Little Goose	Type 2 SBC (with existing ESBS)	$43,796,000
Lower Monumental	Type 2 SBC	$43,767,000
Lower Monumental	New ESBS	$16,058,000
Ice Harbor	Type 2 SBC	$37,825,000
Ice Harbor	New ESBS	$16,058,000
	System Combination Subtotal	**$207,057,000**
	Feasibility Studies	$1,000,000
	Total Estimated Construction Cost	**$208,057,000**

The total annual O&M costs for System Combination 2 are estimated to be $611,900 in 1998 dollars. These O&M costs do not include costs associated with operation and maintenance of the intake diversion screen systems, existing juvenile fish facilities, or transportation costs, as these are existing documented costs. Experience may show that the O&M costs associated with transportation are less than those currently experienced due to the bypass nature of the SBC systems. Biological study costs are also not included. A summary of the O&M costs by project is shown below.

Estimated SBC Operation and Maintenance Cost – System Combination 2

Project	Description	Estimated O&M Cost
Lower Granite	Type 2 SBC (with existing ESBS)	$157,200
Little Goose	Type 2 SBC (with existing ESBS)	$156,000
Lower Monumental	Type 2 SBC (with new ESBS)	$157,400
Ice Harbor	Type 2 SBC (with new ESBS)	$141,300
	Total Estimated Annual O&M Cost	**$611,900**

7.5.3 Implementation Schedule

An implementation schedule is included below. The assumptions and rationale used for development of the implementation schedule is provided. The implementation schedule includes time for hydraulic model testing as appropriate, preliminary design, preparation of construction contract documents, and construction. The implementation schedule assumes no funding or manpower restraints. Such restraints would likely impact the schedule included herein.

Lower Granite Dam

Improvements at Lower Granite include a raised spillbay that would require hydraulic model testing to determine the optimum weir shape. Model testing would be scheduled for year 2000. Preliminary and final design leading to preparation of construction contract documents would be scheduled for years 2001 and 2002 with construction in years 2003 and 2004. The SBC improvements would be operational in year 2004.

Little Goose, Lower Monumental, and Ice Harbor Dams

It is assumed the SBC improvements at Little Goose, Lower Monumental, and Ice Harbor may be done simultaneously. Model testing of the proposed modified spillbays would be required. The model testing would be scheduled for year 2001. Evaluation of the performance of the Lower Granite SBC would be scheduled for completion in year 2005. Information gained from this evaluation would be used for the final design of the SBC at Little Goose, Lower Monumental, and Ice Harbor. Preliminary and final design leading to preparation of construction contract documents would be scheduled for years 2005 and 2006. Construction would be scheduled for years 2007 and 2008. The SBC improvements would be operational in the year 2008.

7.6 System Combination 2 Drawings

Drawings depicting the SBC designs which form System Combination 2 are included on the following pages. These drawings include:

SBC Type 2 – Lower Granite

Plate 2.1.1 – SBC Type 2 – Full Powerhouse Bypass SBC (Existing ESBS) – Site Plan
Plate 2.1.2 – SBC Type 2 – Unit 5/6 Entrance and Spillbay 1 - Plan
Plate 2.1.3 – SBC Type 2 – Sections
Plate 2.1.4 – SBC Type 2 – Spillbay 1 – Section
Plate 2.1.5 – SBC Type 2 – Electrical One-Line Diagram

SBC Type 2 – Little Goose

Plate 2.2.1 – SBC Type 2 – Full Powerhouse Bypass SBC (Existing ESBS) - Site Plan
Plate 2.2.2 – SBC Type 2 – Unit 5/6 Entrance and Spillbay 1 – Plan
Plate 2.2.3 – SBC Type 2 – Sections
Plate 2.2.4 – SBC Type 2 – Spillbay 1 – Section
Plate 2.2.5 – SBC Type 2 – Electrical One-Line Diagram

SBC Type 2 – Lower Monumental

Plate 2.3.1 – SBC Type 2 – Full Powerhouse Bypass SBC (New ESBS) - Site Plan

Plate 2.3.2 – SBC Type 2 – Unit 5/6 Entrance and Spillbay 8 - Plan

Plate 2.3.3 – SBC Type 2 – Sections and Details

Plate 2.3.4 – SBC Type 2 – Spillbay 8 – Section

Plate 2.3.5 – SBC Type 2 – Electrical One-Line Diagram

SBC Type 2 – Ice Harbor

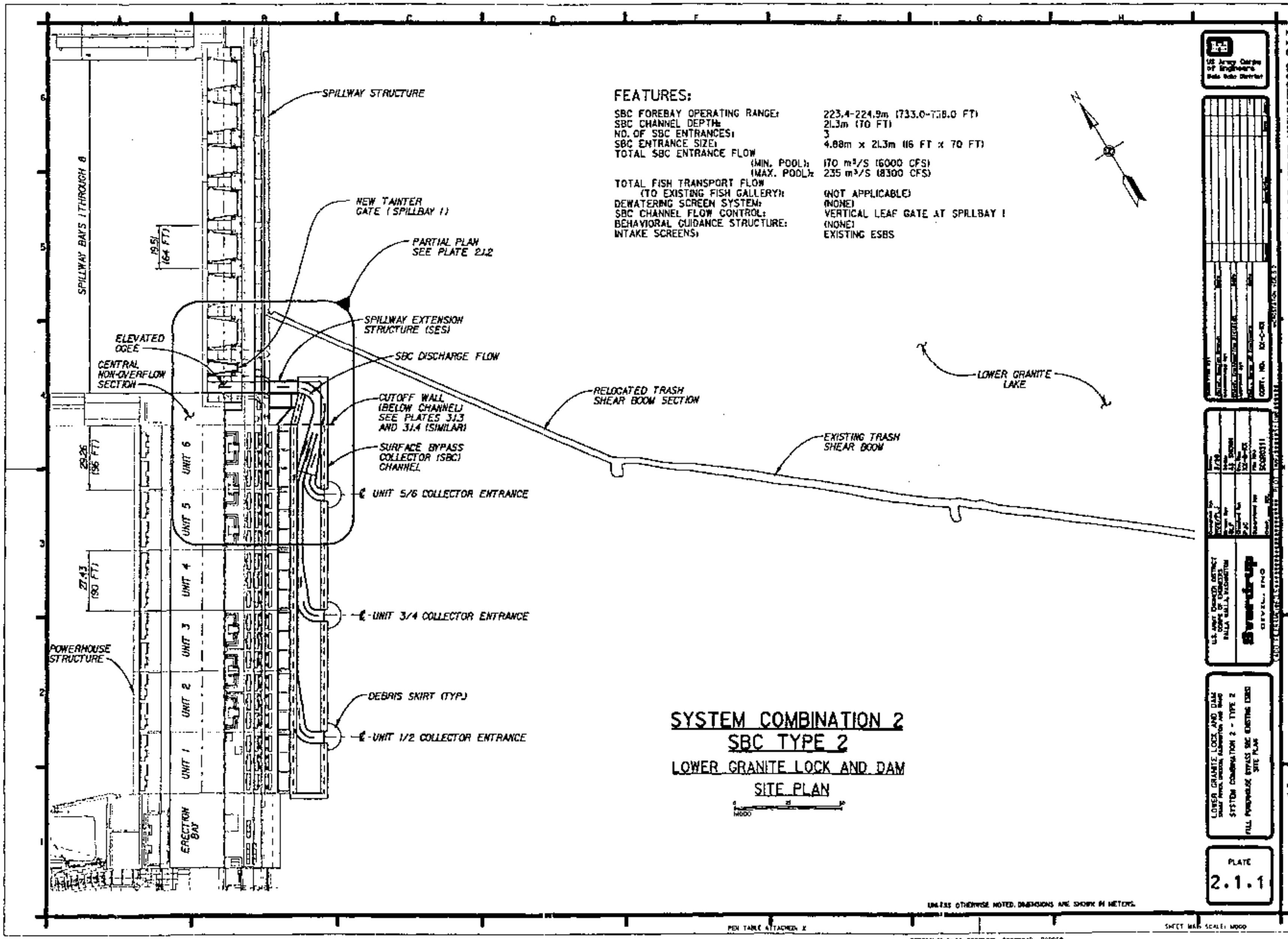
Plate 2.4.1 – SBC Type 2 – Full Powerhouse Bypass SBC (New ESBS) – Site Plan

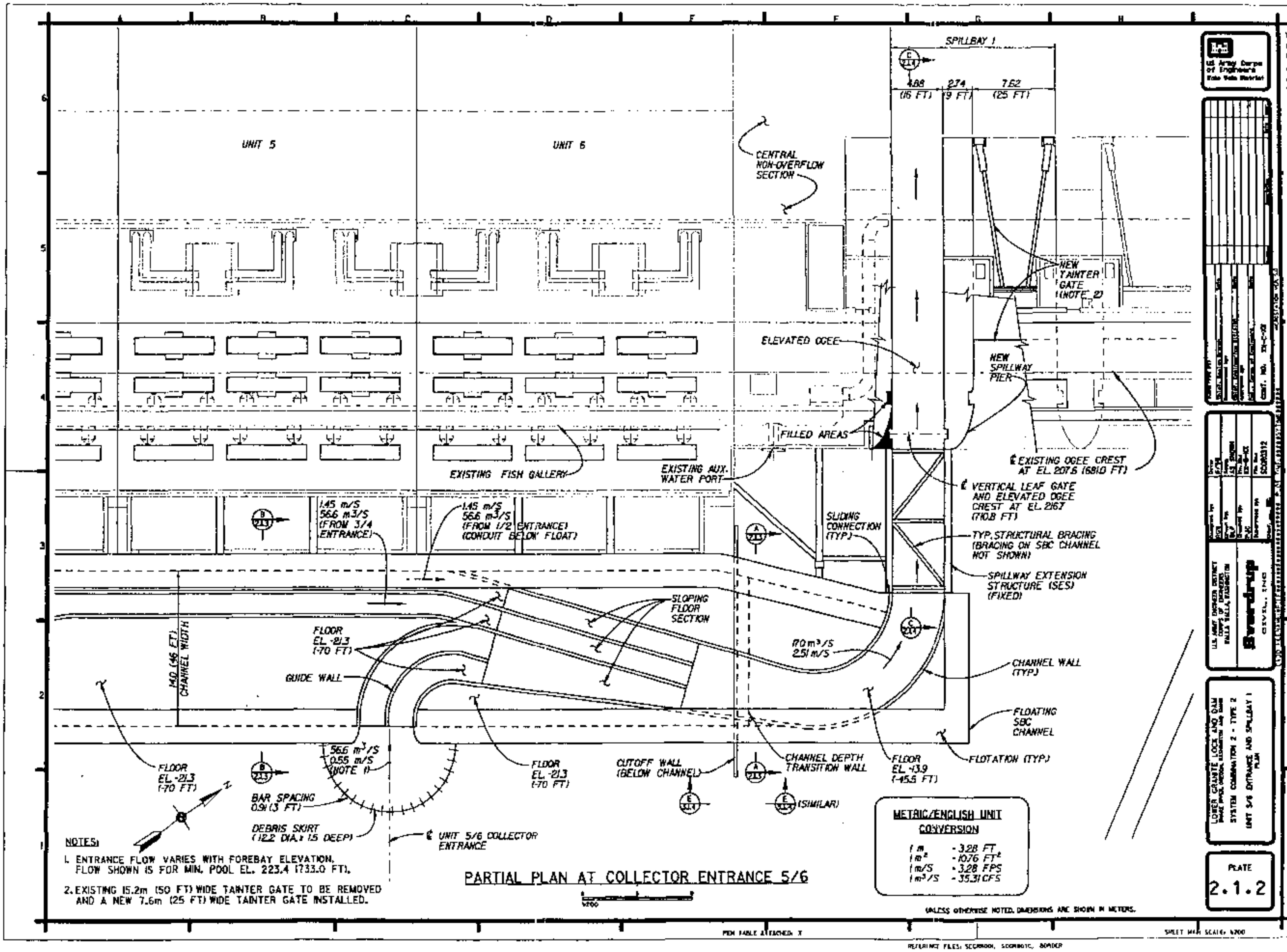
Plate 2.4.2 – SBC Type 2 – Unit 5/6 Entrance and Spillbay 1 - Plan

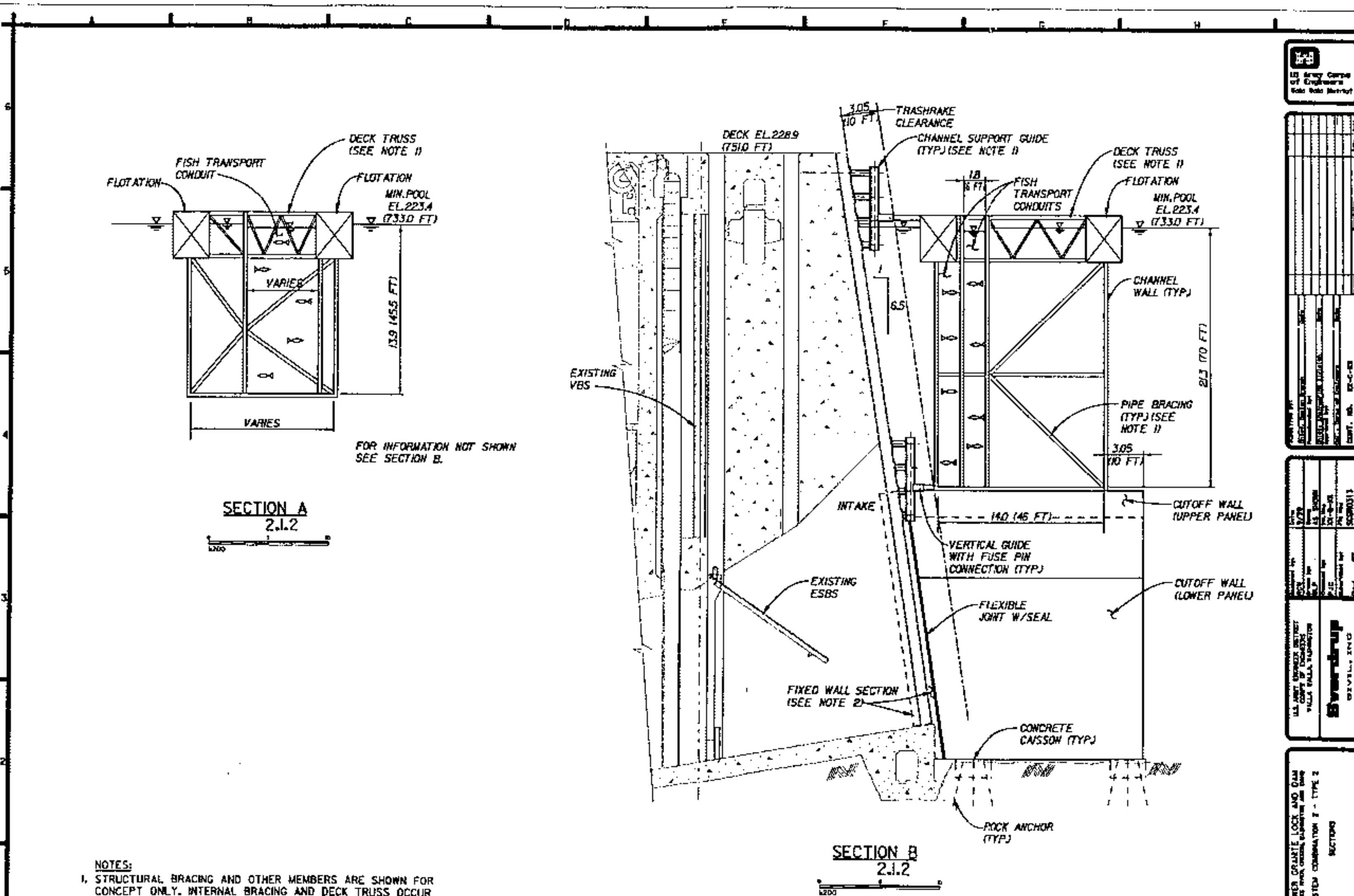
Plate 2.4.3 – SBC Type 2 – Sections

Plate 2.4.4 – SBC Type 2 – Spillbay 1 – Section

Plate 2.4.5 – SBC Type 2 – Electrical One-Line Diagram


FEATURES:
SBC FOREBAY OPERATING RANGE: 223.4-224.9m (733.0-738.0 FT)
SBC CHANNEL DEPTH: 21.3m (70 FT)
NO. OF SBC ENTRANCES: 3
SBC ENTRANCE SIZE: 4.88m x 21.3m (16 FT x 70 FT)
TOTAL SBC ENTRANCE FLOW (MIN. POOL): 170 m³/S (6000 CFS)
(MAX. POOL): 235 m³/S (8300 CFS)
TOTAL FISH TRANSPORT FLOW (TO EXISTING FISH GALLERY): (NOT APPLICABLE)
DEWATERING SCREEN SYSTEM: (NONE)
SBC CHANNEL FLOW CONTROL: VERTICAL LEAF GATE AT SPILLBAY 1
BEHAVIORAL GUIDANCE STRUCTURE: (NONE)
INTAKE SCREENS: EXISTING ESBS
SPILLWAY STRUCTURE
SPILLWAY BAYS 1 THROUGH 8
19.51 (64 FT)
NEW TAINTER GATE (SPILLBAY 1)
PARTIAL PLAN SEE PLATE 2.1.2
SPILLWAY EXTENSION STRUCTURE (SES)
ELEVATED OGEE
CENTRAL NON-OVERFLOW SECTION
SBC DISCHARGE FLOW
CUTOFF WALL (BELOW CHANNEL) SEE PLATES 3.1.3 AND 3.1.4 (SIMILAR)
SURFACE BYPASS COLLECTOR (SBC) CHANNEL
RELOCATED TRASH SHEAR BOOM SECTION
EXISTING TRASH SHEAR BOOM
LOWER GRANITE LAKE
29.26 (96 FT)
27.43 (90 FT)
UNIT 6
UNIT 5
UNIT 4
UNIT 3
UNIT 2
UNIT 1
ERECTION BAY
POWERHOUSE STRUCTURE
℄ UNIT 5/6 COLLECTOR ENTRANCE
℄-UNIT 3/4 COLLECTOR ENTRANCE
℄-UNIT 1/2 COLLECTOR ENTRANCE
DEBRIS SKIRT (TYP)
SYSTEM COMBINATION 2
SBC TYPE 2
LOWER GRANITE LOCK AND DAM
SITE PLAN
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
PLATE
2.1.1

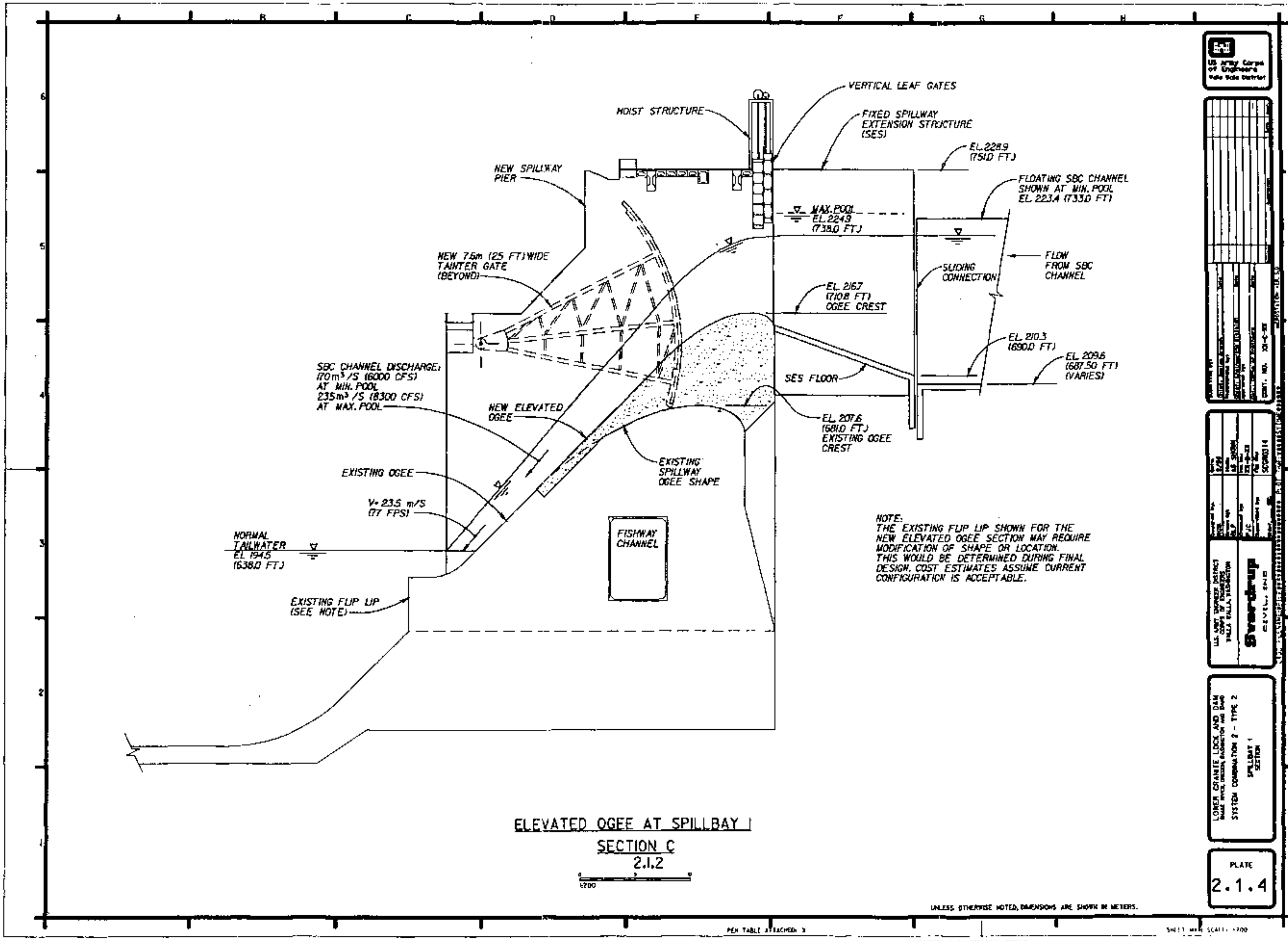

SPILLBAY 1
4.88 (16 FT)
2.74 (9 FT)
7.62 (25 FT)
UNIT 5
UNIT 6
CENTRAL NON-OVERFLOW SECTION
NEW TAINTER GATE (NOTE 2)
ELEVATED OGEE
NEW SPILLWAY PIER
FILLED AREAS
EXISTING FISH GALLERY
EXISTING AUX. WATER PORT
℄ EXISTING OGEE CREST AT EL. 207.6 (681.0 FT)
℄ VERTICAL LEAF GATE AND ELEVATED OGEE CREST AT EL. 216.7 (710.8 FT)
TYP. STRUCTURAL BRACING (BRACING ON SBC CHANNEL NOT SHOWN)
SPILLWAY EXTENSION STRUCTURE (SES) (FIXED)
1.45 m/S 56.6 m3/S (FROM 3/4 ENTRANCE)
1.45 m/S 56.6 m3/S (FROM 1/2 ENTRANCE) (CONDUIT BELOW FLOAT)
SLIDING CONNECTION (TYP.)
SLOPING FLOOR SECTION
FLOOR EL. -21.3 (-70 FT)
14.0 (46 FT) CHANNEL WIDTH
GUIDE WALL
170 m3/S 2.51 m/S
CHANNEL WALL (TYP.)
FLOATING SBC CHANNEL
FLOTATION (TYP.)
FLOOR EL. -21.3 (-70 FT)
56.6 m3/S 0.55 m/S (NOTE 1)
BAR SPACING 0.91 (3 FT)
DEBRIS SKIRT (12.2 DIA. x 1.5 DEEP)
℄ UNIT 5/6 COLLECTOR ENTRANCE
FLOOR EL. -21.3 (-70 FT)
CUTOFF WALL (BELOW CHANNEL)
CHANNEL DEPTH TRANSITION WALL
FLOOR EL. -13.9 (-45.5 FT)
(SIMILAR)
METRIC/ENGLISH UNIT CONVERSION
1 m = 3.28 FT
1 m² = 10.76 FT²
1 m/S = 3.28 FPS
1 m³/S = 35.31 CFS
NOTES:
1. ENTRANCE FLOW VARIES WITH FOREBAY ELEVATION. FLOW SHOWN IS FOR MIN. POOL EL. 223.4 (733.0 FT).
2. EXISTING 15.2m (50 FT) WIDE TAINTER GATE TO BE REMOVED AND A NEW 7.6m (25 FT) WIDE TAINTER GATE INSTALLED.
PARTIAL PLAN AT COLLECTOR ENTRANCE 5/6
1:200
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
LOWER GRANITE LOCK AND DAM
SYSTEM COMBINATION 2 - TYPE 2
UNIT 5/6 ENTRANCE AND SPILLBAY 1 PLAN
PLATE
2.1.2

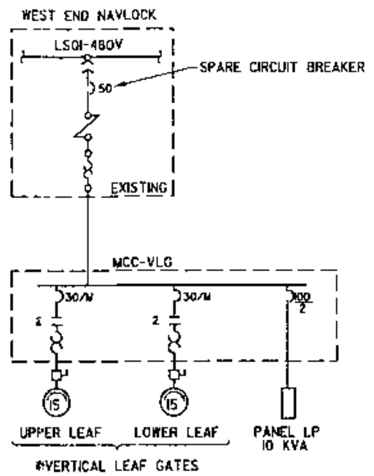


NOTES:

1. STRUCTURAL BRACING AND OTHER MEMBERS ARE SHOWN FOR CONCEPT ONLY. INTERNAL BRACING AND DECK TRUSS OCCUR AT PIER SUPPORT LOCATIONS (APPROX. 9.1m (30 FT) INTERVALS ALONG THE CHANNEL). ROOF STRUCTURES, WALKWAYS AND EQUIPMENT NOT SHOWN.
2. FIXED SECTION OF CUTOFF WALL TO BE BOLTED TO NORTH SIDE OF UNIT 6 INTAKE.

UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.


VERTICAL LEAF GATES
HOIST STRUCTURE
FIXED SPILLWAY EXTENSION STRUCTURE (SES)
EL 228.9 (751.0 FT)
NEW SPILLWAY PIER
FLOATING SBC CHANNEL SHOWN AT MIN. POOL EL 223.4 (733.0 FT)
MAX. POOL EL 224.9 (738.0 FT)
NEW 7.6m (25 FT) WIDE TAINTER GATE (BEYOND)
SLIDING CONNECTION
FLOW FROM SBC CHANNEL
EL 216.7 (710.8 FT) OGEE CREST
EL 210.3 (690.0 FT)
EL 209.6 (687.50 FT) (VARIES)
SBC CHANNEL DISCHARGE: 170 m³/S (6000 CFS) AT MIN. POOL 235 m³/S (8300 CFS) AT MAX. POOL
SES FLOOR
NEW ELEVATED OGEE
EL 207.6 (681.0 FT) EXISTING OGEE CREST
EXISTING OGEE
EXISTING SPILLWAY OGEE SHAPE
V= 23.5 m/S (77 FPS)
NORMAL TAILWATER EL 194.5 (638.0 FT)
FISHWAY CHANNEL
NOTE: THE EXISTING FLIP LIP SHOWN FOR THE NEW ELEVATED OGEE SECTION MAY REQUIRE MODIFICATION OF SHAPE OR LOCATION. THIS WOULD BE DETERMINED DURING FINAL DESIGN. COST ESTIMATES ASSUME CURRENT CONFIGURATION IS ACCEPTABLE.
EXISTING FLIP LIP (SEE NOTE)
ELEVATED OGEE AT SPILLBAY 1
SECTION C
2.1.2
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
LOWER GRANITE LOCK AND DAM
SYSTEM CONFIGURATION 2 - TYPE 2
PLATE
2.1.4



* INTERLOCKED SO THAT ONLY ONE MOTOR CAN RUN AT A TIME.

ELECTRICAL LEGEND

SYMBOL	DESCRIPTION
300 KVA 4160-480V, 3PH	TRANSFORMER, PRIMARY- SECONDARY VOLTAGES. PHASE AND RATING AS INDICATED.
100F	SWITCH - FUSE AMPERE RATING INDICATED, 3 POLE UNLESS INDICATED OTHERWISE.
450	CIRCUIT BREAKER, THERMAL MAGNETIC TRIP SHOWN, 3 POLE UNLESS INDICATED OTHERWISE.
15/M	CIRCUIT BREAKER, MAGNETIC TRIP ONLY, AMPERE RATING SHOWN, 3 POLE UNLESS INDICATED OTHERWISE.
1	MAGNETIC STARTER WITH NEMA SIZE INDICATED.
M	MOTOR, SQUIRREL CAGE INDUCTION, HORSEPOWER INDICATED (M).
	NONFUSED DISCONNECT SWITCH, 30 AMPERE AND 3 POLE UNLESS INDICATED OTHERWISE.

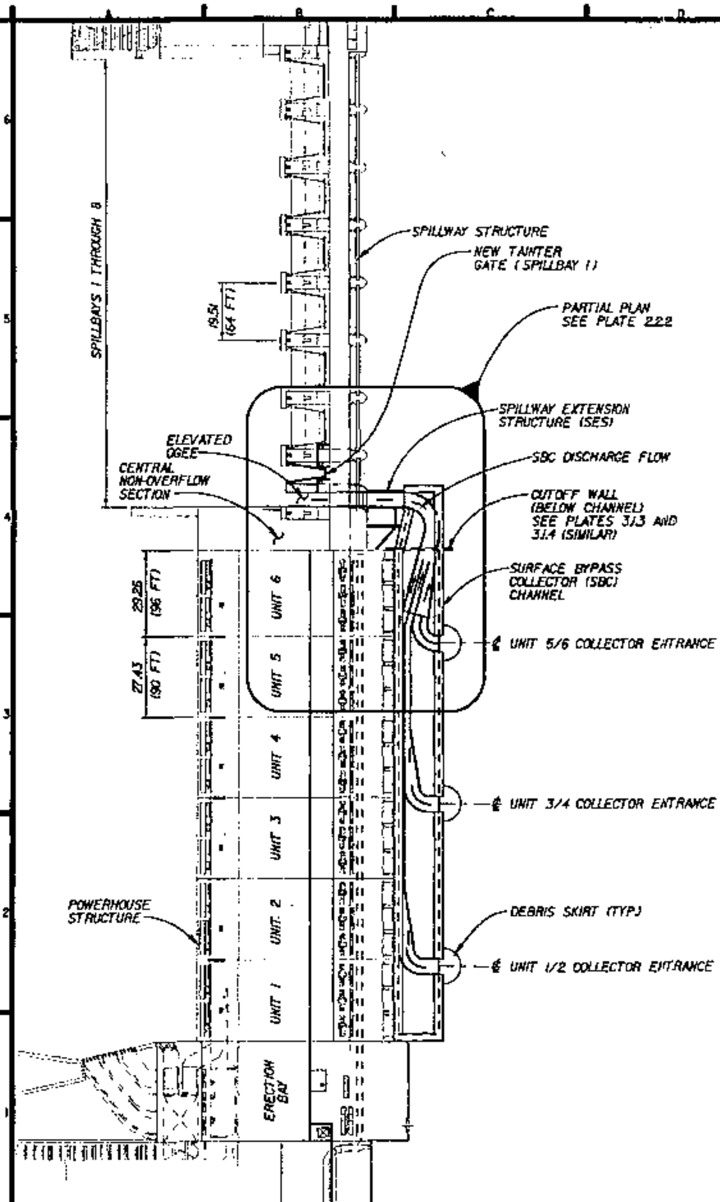
TYPE 2
ELECTRICAL ONE-LINE DIAGRAM

US Army Corps of Engineers Walla Walla District

LOWER GRANITE LOCK AND DAM
SYSTEM COMBINATION 2 - TYPE 2
ELECTRICAL ONE-LINE DIAGRAM

PLATE
2.1.5

UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.



FEATURES:

SBC FOREBAY OPERATING RANGE:	192.9 - 194.5m (633.0 - 638.0 FT)
SBC CHANNEL DEPTH:	21.3m (70 FT)
NO. OF SBC ENTRANCES:	3
SBC ENTRANCE SIZE:	4.88m x 21.3m (16 FT x 70 FT)
TOTAL SBC ENTRANCE FLOW (MIN. POOL):	170 m^3/S (6000 CFS)
(MAX. POOL):	235 m^3/S (8300 CFS)
TOTAL FISH TRANSPORT FLOW (TO EXISTING FISH GALLERY):	(NOT APPLICABLE)
DEWATERING SCREEN SYSTEM:	(NONE)
SBC CHANNEL FLOW CONTROL:	VERTICAL LEAF GATE AT SPILLBAY 1
BEHAVIORAL GUIDANCE STRUCTURE:	(NONE)
INTAKE SCREENS:	EXISTING ESBS

LAKE BRYAN

SYSTEM COMBINATION 2
SBC TYPE 2
LITTLE GOOSE LOCK AND DAM
SITE PLAN

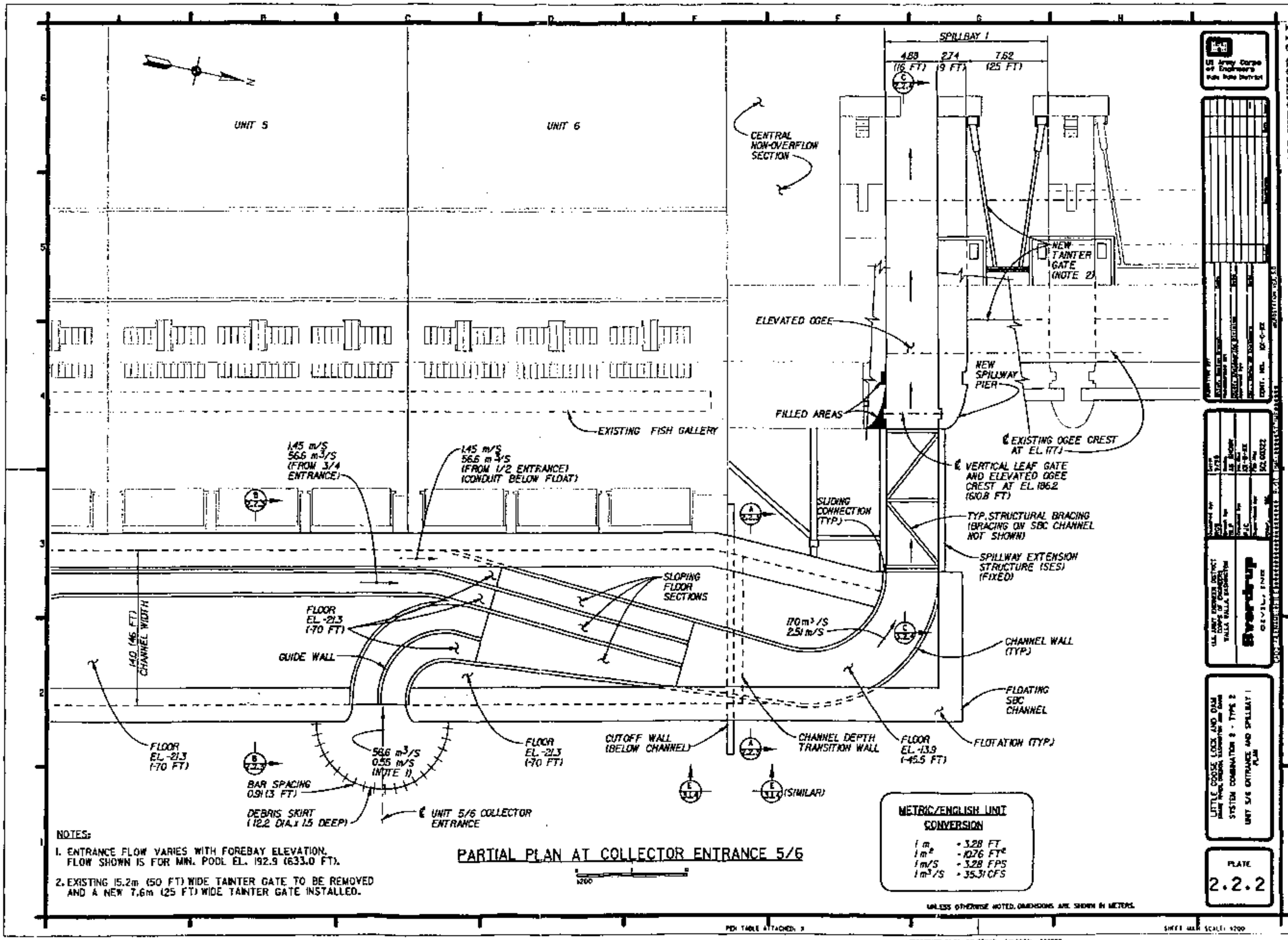
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

US Army Corps of Engineers Walla Walla District

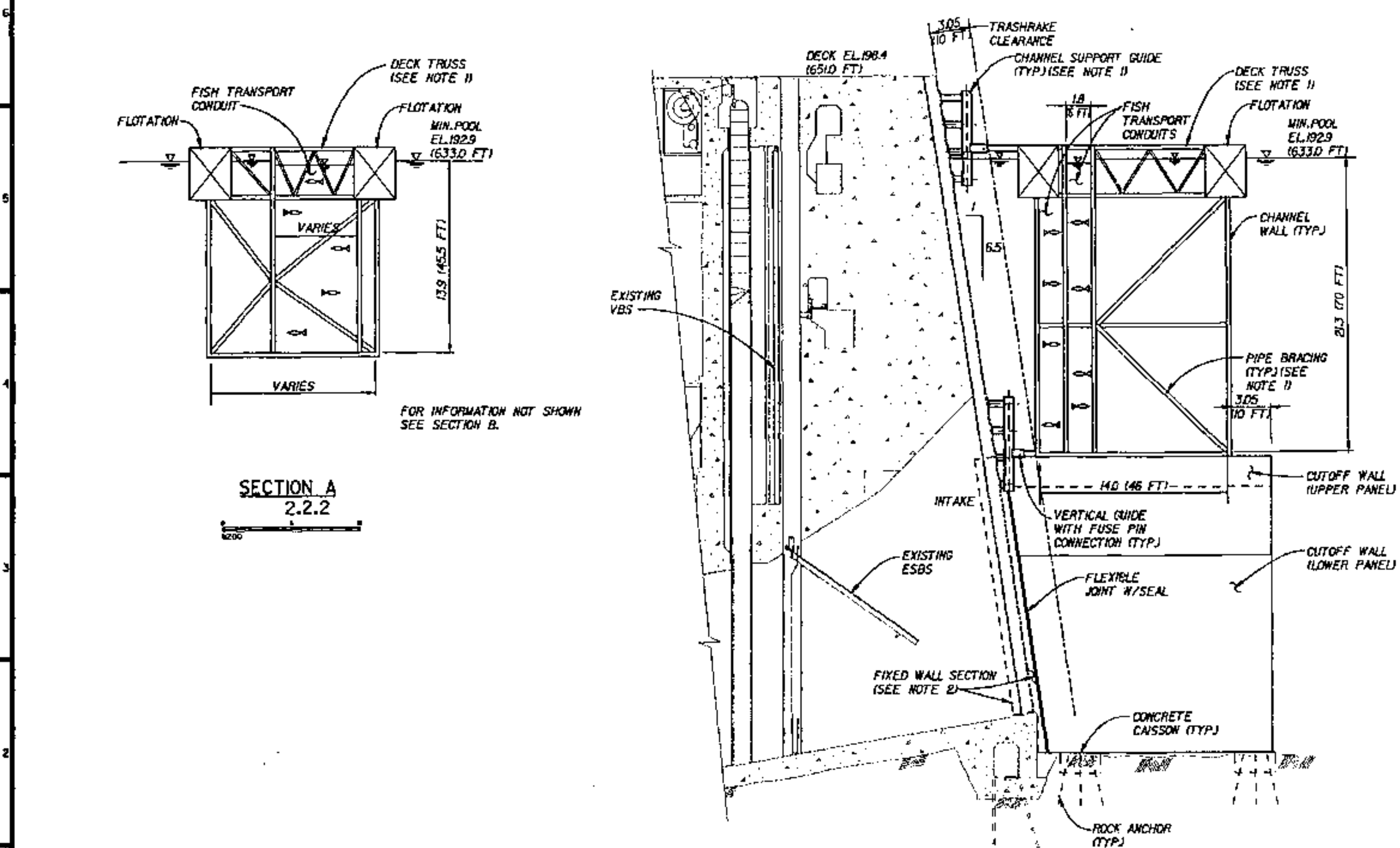
Sverdrup

LITTLE GOOSE LOCK AND DAM
SYSTEM COMBINATION 2 - TYPE 2
SITE PLAN

PLATE 2.2.1

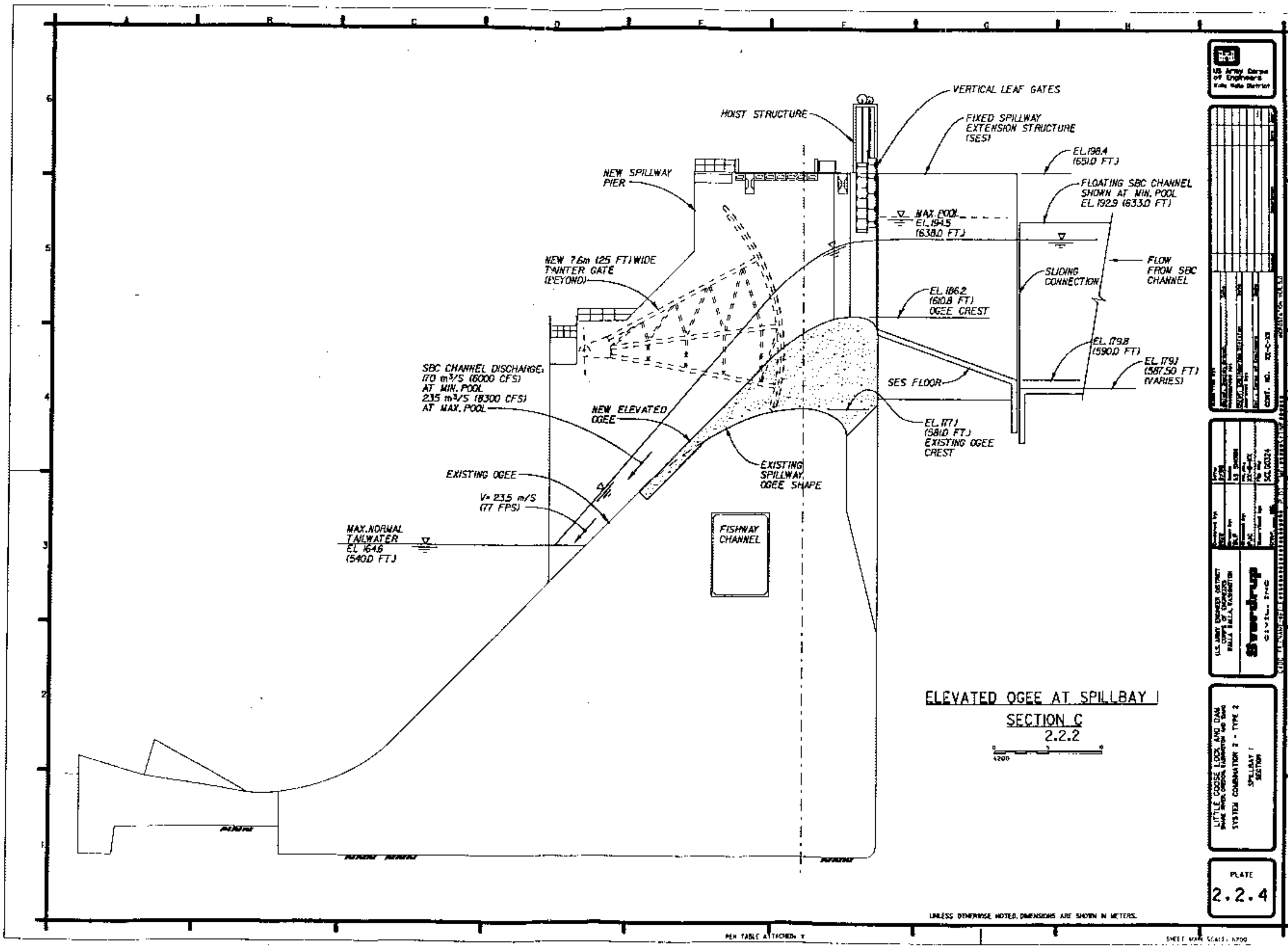


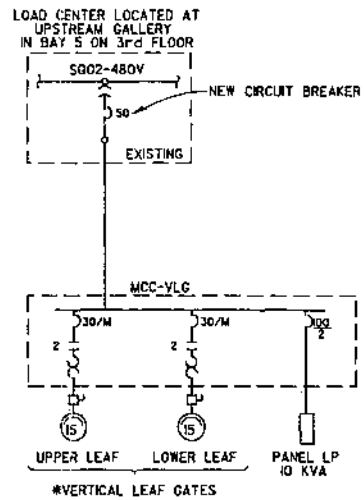
SPILLBAY 1
4.88 (16 FT)
2.74 (9 FT)
7.62 (25 FT)
UNIT 5
UNIT 6
CENTRAL NON-OVERFLOW SECTION
NEW TAINTER GATE (NOTE 2)
ELEVATED OGEE
NEW SPILLWAY PIER
FILLED AREAS
EXISTING FISH GALLERY
℄ EXISTING OGEE CREST AT EL. (FT)
℄ VERTICAL LEAF GATE AND ELEVATED OGEE CREST AT EL. 186.2 (610.8 FT)
1.45 m/S 56.6 m³/S (FROM 3/4 ENTRANCE)
1.45 m/S 56.6 m³/S (FROM 1/2 ENTRANCE) (CONDUIT BELOW FLOAT)
SLIDING CONNECTION (TYP.)
TYP. STRUCTURAL BRACING (BRACING ON SBC CHANNEL NOT SHOWN)
SPILLWAY EXTENSION STRUCTURE (SES) (FIXED)
SLOPING FLOOR SECTIONS
14.0 (46 FT) CHANNEL WIDTH
FLOOR EL. -21.3 (-70 FT)
GUIDE WALL
170 m³/S 2.51 m/S
CHANNEL WALL (TYP.)
FLOATING SBC CHANNEL
FLOTATION (TYP.)
FLOOR EL. -21.3 (-70 FT)
56.6 m³/S 0.55 m/S (NOTE 1)
BAR SPACING 0.91 (3 FT)
DEBRIS SKIRT (12.2 DIA. x 1.5 DEEP)
℄ UNIT 5/6 COLLECTOR ENTRANCE
FLOOR EL. -21.3 (-70 FT)
CUTOFF WALL (BELOW CHANNEL)
CHANNEL DEPTH TRANSITION WALL
FLOOR EL. -13.9 (-45.5 FT)
(SIMILAR)
NOTES:
1. ENTRANCE FLOW VARIES WITH FOREBAY ELEVATION. FLOW SHOWN IS FOR MIN. POOL EL. 192.9 (633.0 FT).
2. EXISTING 15.2m (50 FT) WIDE TAINTER GATE TO BE REMOVED AND A NEW 7.6m (25 FT) WIDE TAINTER GATE INSTALLED.
PARTIAL PLAN AT COLLECTOR ENTRANCE 5/6
METRIC/ENGLISH UNIT CONVERSION
1 m = 3.28 FT
1 m² = 10.76 FT²
1 m/S = 3.28 FPS
1 m³/S = 35.31 CFS
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
LITTLE GOOSE LOCK AND DAM
UNIT 5/6 ENTRANCE AND SPILLBAY 1
PLATE
2.2.2



NOTES:

1. STRUCTURAL BRACING AND OTHER MEMBERS ARE SHOWN FOR CONCEPT ONLY. INTERNAL BRACING AND DECK TRUSS OCCUR AT PIER SUPPORT LOCATIONS (APPROX. 9.1m (30 FT) INTERVALS ALONG THE CHANNEL). ROOF STRUCTURES, WALKWAYS AND EQUIPMENT NOT SHOWN.
2. FIXED SECTION OF CUTOFF WALL TO BE BOLTED TO NORTH SIDE OF UNIT 6 INTAKE.


VERTICAL LEAF GATES
HOIST STRUCTURE
FIXED SPILLWAY EXTENSION STRUCTURE (SES)
EL 198.4 (651.0 FT)
NEW SPILLWAY PIER
FLOATING SBC CHANNEL SHOWN AT MIN. POOL EL 192.9 (633.0 FT)
MAX. POOL EL 194.5 (638.0 FT)
NEW 7.6m (25 FT) WIDE TAINTER GATE (BEYOND)
SLIDING CONNECTION
FLOW FROM SBC CHANNEL
EL 186.2 (610.8 FT) OGEE CREST
EL 179.8 (590.0 FT)
EL 179.1 (587.50 FT) (VARIES)
SBC CHANNEL DISCHARGE: 170 m³/S (6000 CFS) AT MIN. POOL 235 m³/S (8300 CFS) AT MAX. POOL
SES FLOOR
NEW ELEVATED OGEE
EL 177.1 (581.0 FT) EXISTING OGEE CREST
EXISTING OGEE
EXISTING SPILLWAY OGEE SHAPE
V= 23.5 m/S (77 FPS)
MAX. NORMAL TAILWATER EL 164.6 (540.0 FT)
FISHWAY CHANNEL
ELEVATED OGEE AT SPILLBAY 1
SECTION C
2.2.2
US Army Corps of Engineers Walla Walla District
U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS WALLA WALLA, WASHINGTON
Sverdrup
LITTLE GOOSE LOCK AND DAM
SYSTEM COMBINATION 2 - TYPE 2
SPILLBAY 1 SECTION
PLATE
2.2.4
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.



* INTERLOCKED SO THAT ONLY ONE MOTOR CAN RUN AT A TIME.

ELECTRICAL LEGEND

SYMBOL	DESCRIPTION
300 KVA 4160-480V, 3PH	TRANSFORMER, PRIMARY- SECONDARY VOLTAGES, PHASE AND RATING AS INDICATED.
100F	SWITCH - FUSE AMPERE RATING INDICATED, 3 POLE UNLESS INDICATED OTHERWISE.
450	CIRCUIT BREAKER, THERMAL MAGNETIC TRIP SHOWN, 3 POLE UNLESS INDICATED OTHERWISE.
15/M	CIRCUIT BREAKER, MAGNETIC TRIP ONLY, AMPERE RATING SHOWN, 3 POLE UNLESS INDICATED OTHERWISE.
1	MAGNETIC STARTER WITH NEMA SIZE INDICATED.
M	MOTOR, SQUIRREL CAGE INDUCTION, HORSEPOWER INDICATED ON.
	NONFUSED DISCONNECT SWITCH, 30 AMPERE AND 3 POLE UNLESS INDICATED OTHERWISE.

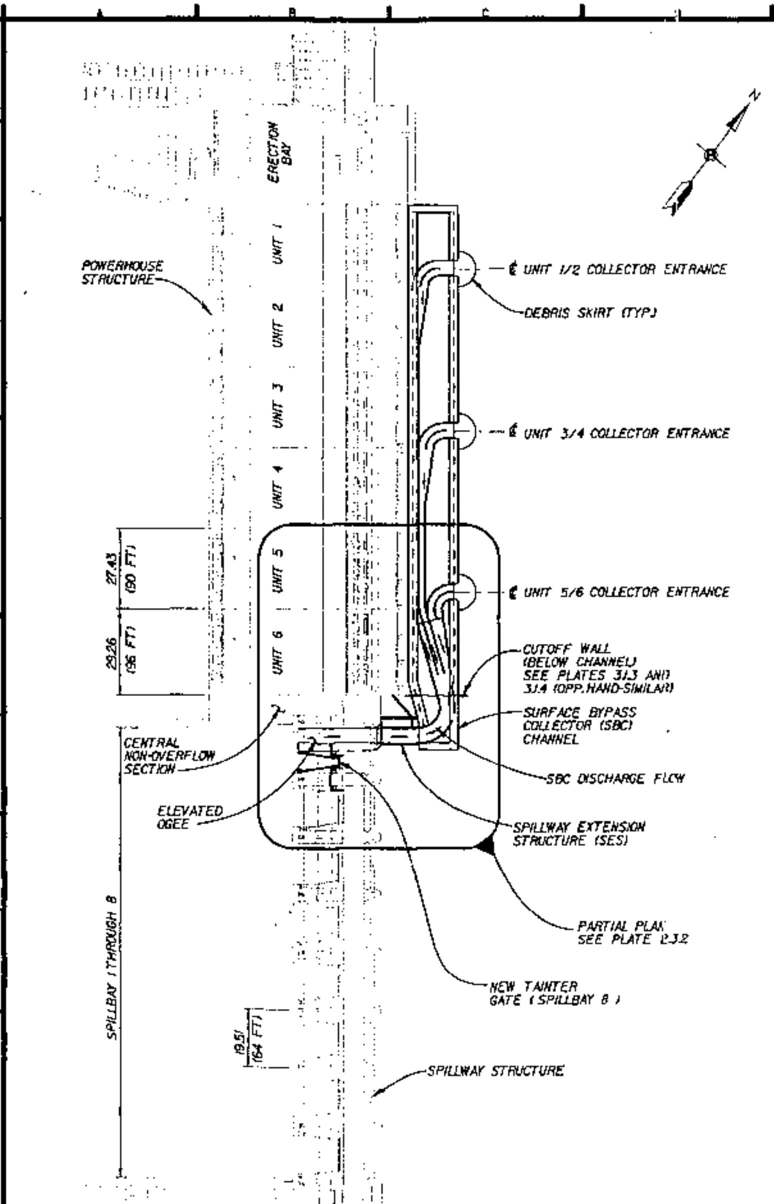
TYPE 2
ELECTRICAL ONE-LINE DIAGRAM

US Army Corps of Engineers Walla Walla District

LITTLE GOOSE LOCK AND DAM
SYSTEM COMBINATION 2 - TYPE 2
ELECTRICAL ONE-LINE DIAGRAM

PLATE
2.2.5

UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.



FEATURES:

SBC FOREBAY OPERATING RANGE:	163.7 - 164.6 (537.0-540.0 FT)
SBC CHANNEL DEPTH:	21.3m (70 FT)
NO. OF SBC ENTRANCES:	3
SBC ENTRANCE SIZE:	4.88m x 21.3m (16 FT x 70 FT)
TOTAL SBC ENTRANCE FLOW (MIN. POOL):	170 m³/S (6000 CFS)
(MAX. POOL):	210 m³/S (7400 CFS)
TOTAL FISH TRANSPORT FLOW (TO EXISTING FISH GALLERY):	(NOT APPLICABLE)
DEWATERING SCREEN SYSTEM:	(NONE)
SBC CHANNEL FLOW CONTROL:	VERTICAL LEAF GATE AT SPILLBAY 8
BEHAVIORAL GUIDANCE STRUCTURE:	(NONE)
INTAKE SCREENS:	NEW ESBS

LAKE HERBERT G. WEST

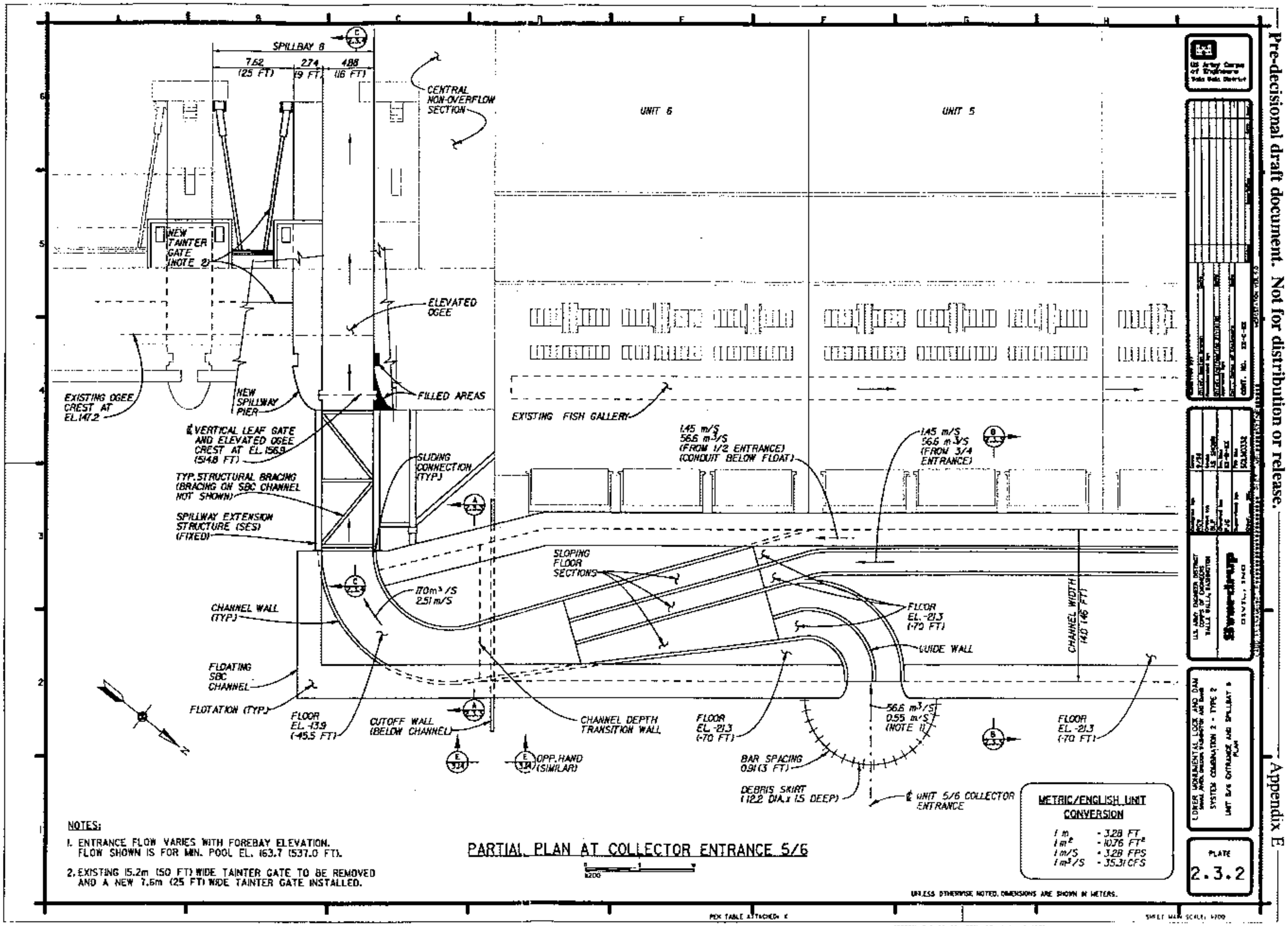
SYSTEM COMBINATION 2
SBC TYPE 2
LOWER MONUMENTAL LOCK AND DAM
SITE PLAN

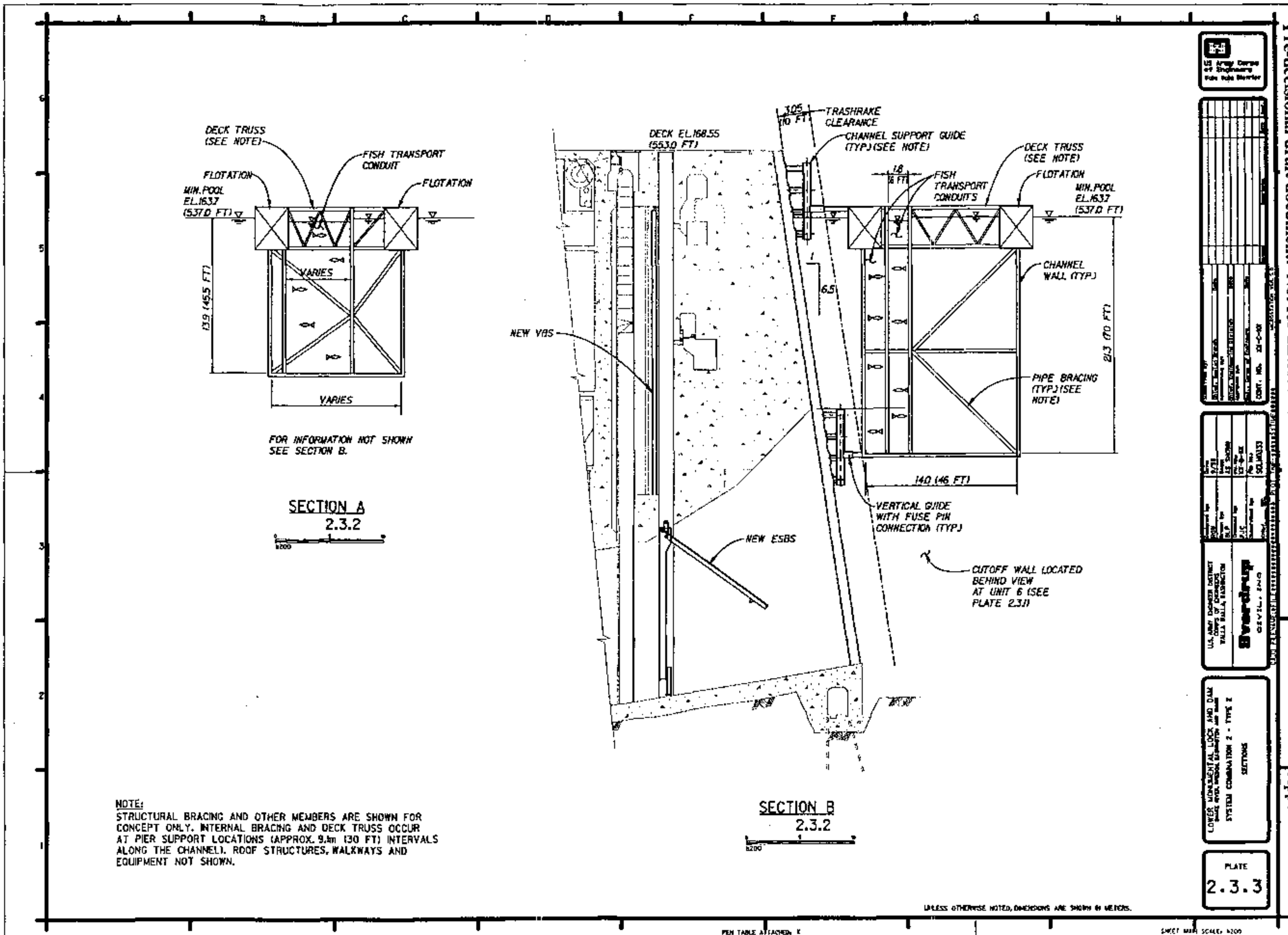
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

US Army Corps of Engineers Walla Walla District

LOWER MONUMENTAL LOCK AND DAM
SYSTEM COMBINATION 2 - TYPE 2
FULL POWERHOUSE BYPASS SBC W/ ESBS
SITE PLAN

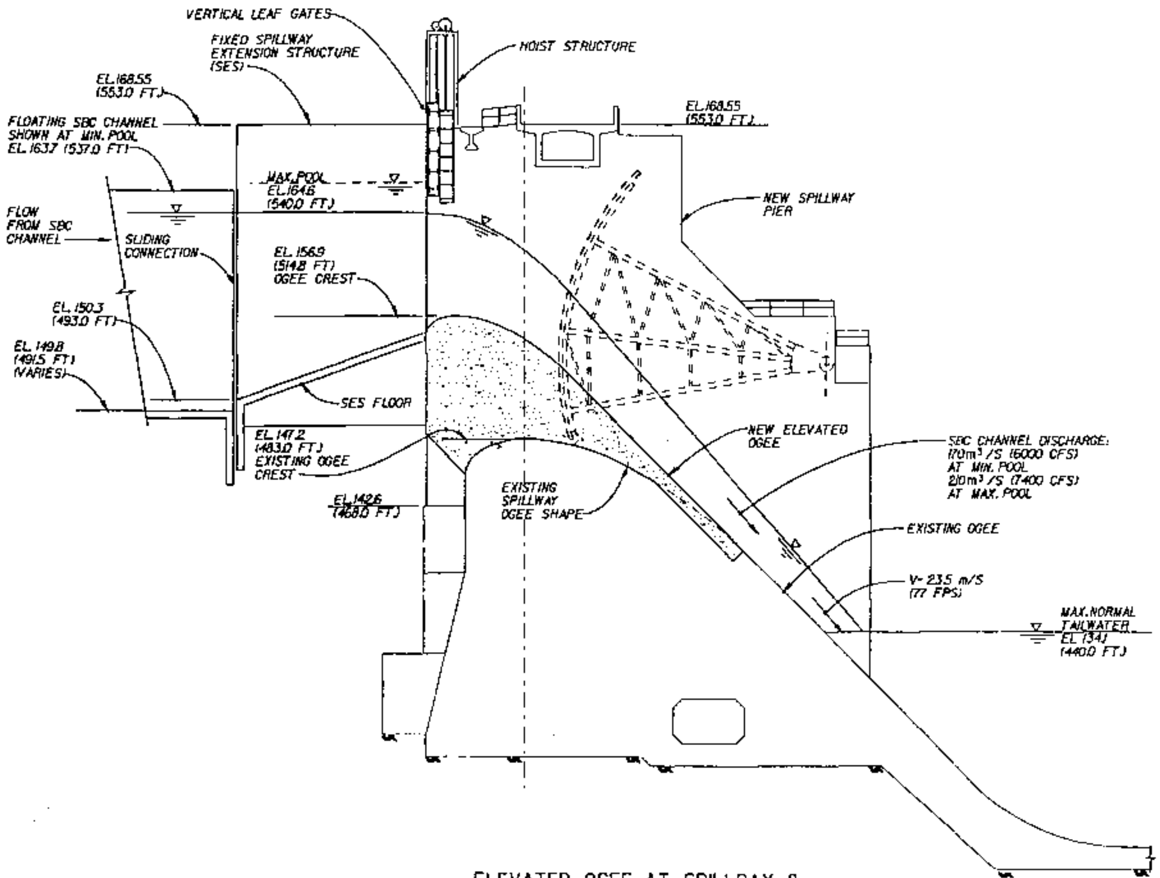
PLATE 2.3.1


SPILLBAY 8
7.62 (25 FT)
2.74 (9 FT)
4.88 (16 FT)
CENTRAL NON-OVERFLOW SECTION
UNIT 6
UNIT 5
NEW TAINTER GATE (NOTE 2)
ELEVATED OGEE
NEW SPILLWAY PIER
FILLED AREAS
EXISTING OGEE CREST AT EL.147.2
℄ VERTICAL LEAF GATE AND ELEVATED OGEE CREST AT EL.156.9 (514.8 FT)
EXISTING FISH GALLERY
1.45 m/S 56.6 m³/S (FROM 1/2 ENTRANCE) (CONDUIT BELOW FLOAT)
1.45 m/S 56.6 m³/S (FROM 3/4 ENTRANCE)
SLIDING CONNECTION (TYP)
TYP. STRUCTURAL BRACING (BRACING ON SBC CHANNEL NOT SHOWN)
SPILLWAY EXTENSION STRUCTURE (SES) (FIXED)
SLOPING FLOOR SECTIONS
170m³/S 2.51 m/S
CHANNEL WALL (TYP)
FLOOR EL. -21.3 (-70 FT)
GUIDE WALL
CHANNEL WIDTH 14.0 (46 FT)
FLOATING SBC CHANNEL
FLOTATION (TYP)
FLOOR EL. -13.9 (-45.5 FT)
CUTOFF WALL (BELOW CHANNEL)
CHANNEL DEPTH TRANSITION WALL
FLOOR EL. -21.3 (-70 FT)
56.6 m³/S 0.55 m/S (NOTE 1)
FLOOR EL. -21.3 (-70 FT)
OPP. HAND (SIMILAR)
BAR SPACING 0.91 (3 FT)
DEBRIS SKIRT (12.2 DIA. x 1.5 DEEP)
℄ UNIT 5/6 COLLECTOR ENTRANCE
NOTES:
1. ENTRANCE FLOW VARIES WITH FOREBAY ELEVATION. FLOW SHOWN IS FOR MIN. POOL EL. 163.7 (537.0 FT).
2. EXISTING 15.2m (50 FT) WIDE TAINTER GATE TO BE REMOVED AND A NEW 7.6m (25 FT) WIDE TAINTER GATE INSTALLED.
PARTIAL PLAN AT COLLECTOR ENTRANCE 5/6
METRIC/ENGLISH UNIT CONVERSION
1 m - 3.28 FT
1 m² - 10.76 FT²
1 m/S - 3.28 FPS
1 m³/S - 35.31 CFS
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
LOWER MONUMENTAL LOCK AND DAM
SYSTEM CONFIGURATION 2 - TYPE 2
UNIT 5/6 ENTRANCE AND SPILLBAY 8 PLAN
PLATE
2.3.2



Pre-decisional draft document. Not for distribution or release.

Appendix E



ELEVATED OGEE AT SPILLBAY 8
SECTION C
2.3.2

1:200

UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

US Army Corps of Engineers Walla Walla District

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS WALLA WALLA, WASHINGTON

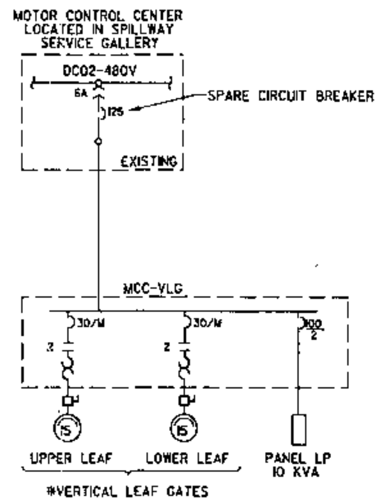
Sverdrup CIVIL, INC.

LOWER MONUMENTAL LOCK AND DAM
SYSTEM COMBINATION 2 - TYPE 2
SPILLBAY 8 SECTION

PLATE
2.3.4

PEN TABLE ATTACHED: X

REFERENCE FILES: SCLM000L BORDER



* INTERLOCKED SO THAT ONLY ONE MOTOR CAN RUN AT A TIME.

ELECTRICAL LEGEND

SYMBOL	DESCRIPTION
300 KVA 4160-480V, 3PH	TRANSFORMER, PRIMARY- SECONDARY VOLTAGES. PHASE AND RATING AS INDICATED.
100F	SWITCH - FUSE AMPERE RATING INDICATED, 3 POLE UNLESS INDICATED OTHERWISE.
450	CIRCUIT BREAKER, THERMAL MAGNETIC TRIP SHOWN, 3 POLE UNLESS INDICATED OTHERWISE.
15/M	CIRCUIT BREAKER, MAGNETIC TRIP ONLY, AMPERE RATING SHOWN, 3 POLE UNLESS INDICATED OTHERWISE.
	MAGNETIC STARTER WITH NEMA SIZE INDICATED.
M	MOTOR, SQUIRREL CAGE INDUCTION, HORSEPOWER INDICATED (M).
	NONFUSED DISCONNECT SWITCH, 30 AMPERE AND 3 POLE UNLESS INDICATED OTHERWISE.

TYPE 2
ELECTRICAL ONE-LINE DIAGRAM

UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

US Army Corps of Engineers Walla Walla District

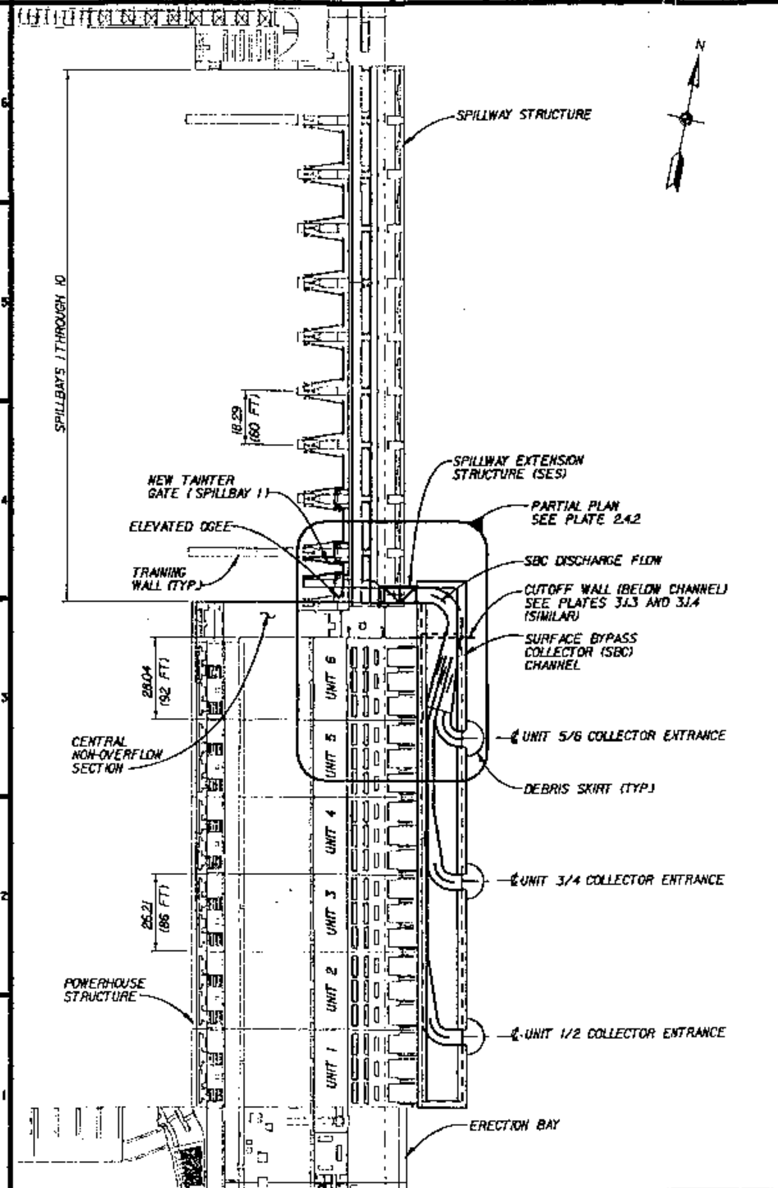
U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS WALLA WALLA, WASHINGTON

LOWER MONUMENTAL LOCK AND DAM
SYSTEM COMBINATION 2 - TYPE 2
ELECTRICAL ONE-LINE DIAGRAM

PLATE
2.3.5

PEN TABLE ATTACHED: X

REFERENCE FILES: BORDER



FEATURES:

SBC FOREBAY OPERATING RANGE:	133.2 - 134.1m (437.0 - 440.0 FT)
SBC CHANNEL DEPTH:	16.8m (55 FT)
NO. OF SBC ENTRANCES:	3
SBC ENTRANCE SIZE:	4.88m x 16.8m (16 FT x 55 FT)
TOTAL SBC ENTRANCE FLOW	
(MIN. POOL):	170 m^3/S (6000 CFS)
(MAX. POOL):	198 m^3/S (7000 CFS)
TOTAL FISH TRANSPORT FLOW (TO EXISTING FISH GALLERY):	(NOT APPLICABLE)
DEWATERING SCREEN SYSTEM:	(NONE)
SBC CHANNEL FLOW CONTROL:	VERTICAL LEAF GATE AT SPILLBAY 1
BEHAVIORAL GUIDANCE STRUCTURE:	(NONE)
INTAKE SCREENS:	NEW ESBS

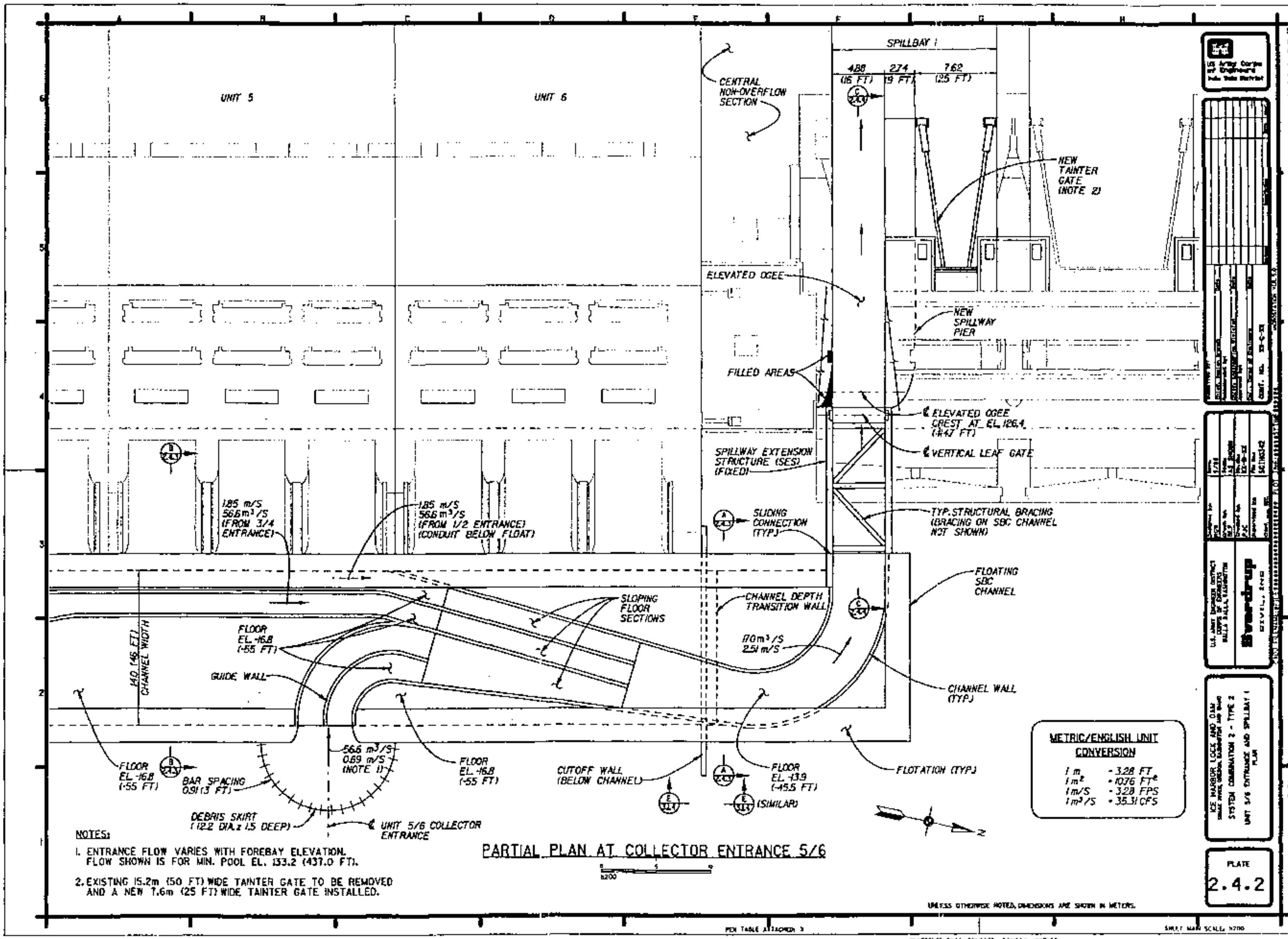
LAKE SACAJAWEA

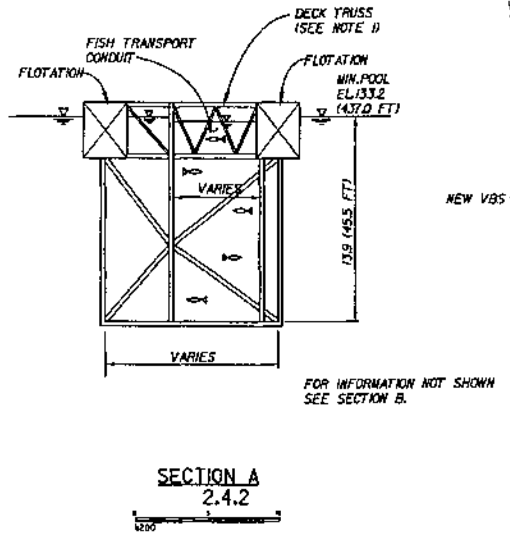
SYSTEM COMBINATION 2
SBC TYPE 2
ICE HARBOR LOCK AND DAM
SITE PLAN

UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

US Army Corps of Engineers Walla Walla District

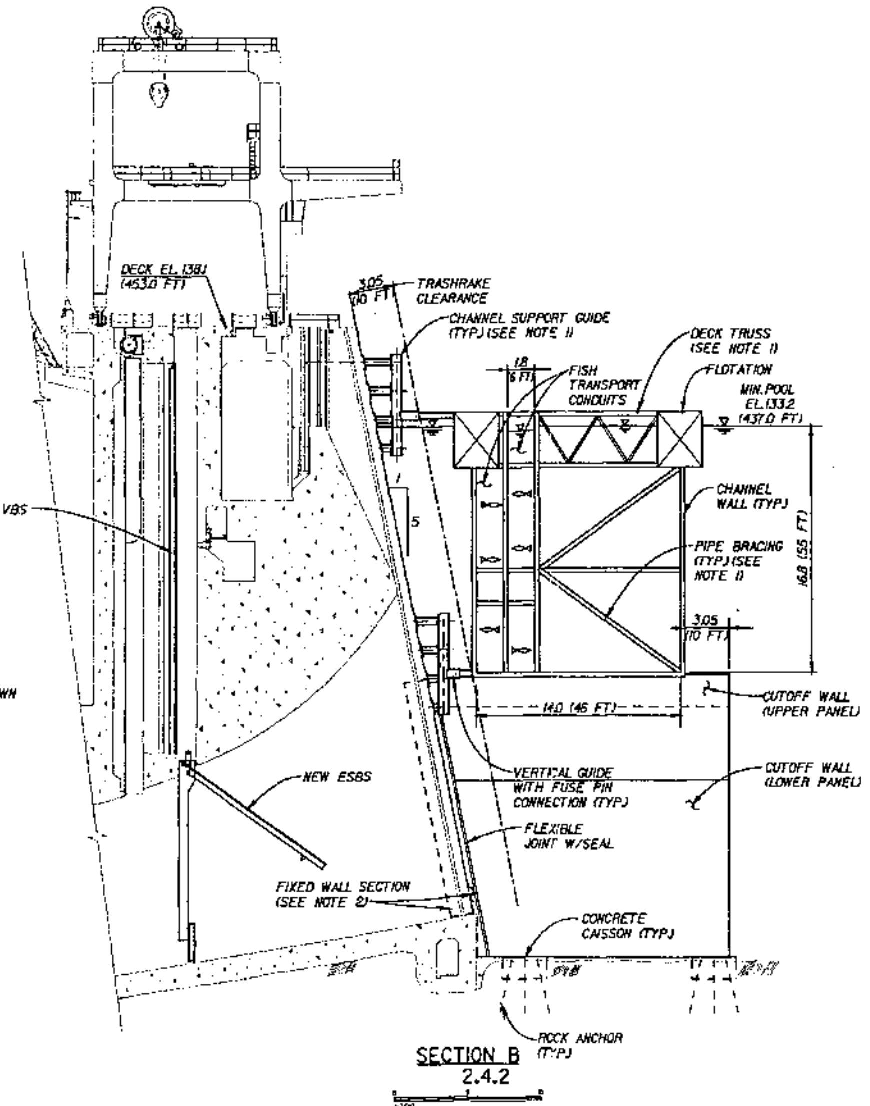
PLATE 2.4.1


UNIT 5
UNIT 6
SPILLBAY 1
4.88 (16 FT)
2.74 (9 FT)
7.62 (25 FT)
CENTRAL NON-OVERFLOW SECTION
NEW TAINTER GATE (NOTE 2)
ELEVATED OGEE
NEW SPILLWAY PIER
FILLED AREAS
℄ ELEVATED OGEE CREST AT EL. 126.4 (417 FT)
℄ VERTICAL LEAF GATE
SPILLWAY EXTENSION STRUCTURE (SES) (FIXED)
SLIDING CONNECTION (TYP)
TYP. STRUCTURAL BRACING (BRACING ON SBC CHANNEL NOT SHOWN)
1.85 m/S 56.6 m³/S (FROM 3/4 ENTRANCE)
1.85 m/S 56.6 m³/S (FROM 1/2 ENTRANCE) (CONDUIT BELOW FLOAT)
FLOATING SBC CHANNEL
CHANNEL DEPTH TRANSITION WALL
SLOPING FLOOR SECTIONS
FLOOR EL. -16.8 (-55 FT)
170 m³/S 2.51 m/S
14.0 (46 FT) CHANNEL WIDTH
GUIDE WALL
CHANNEL WALL (TYP)
FLOOR EL. -16.8 (-55 FT)
BAR SPACING 0.91 (3 FT)
56.6 m³/S 0.69 m/S (NOTE 1)
FLOOR EL. -16.8 (-55 FT)
CUTOFF WALL (BELOW CHANNEL)
FLOOR EL. -13.9 (-45.5 FT)
(SIMILAR)
FLOTATION (TYP)
DEBRIS SKIRT (12.2 DIA. x 1.5 DEEP)
℄ UNIT 5/6 COLLECTOR ENTRANCE
METRIC/ENGLISH UNIT CONVERSION
1 m = 3.28 FT
1 m² = 10.76 FT²
1 m/S = 3.28 FPS
1 m³/S = 35.31 CFS
NOTES:
1. ENTRANCE FLOW VARIES WITH FOREBAY ELEVATION. FLOW SHOWN IS FOR MIN. POOL EL. 133.2 (437.0 FT).
2. EXISTING 15.2m (50 FT) WIDE TAINTER GATE TO BE REMOVED AND A NEW 7.6m (25 FT) WIDE TAINTER GATE INSTALLED.
PARTIAL PLAN AT COLLECTOR ENTRANCE 5/6
1:200
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
Sverdrup
ICE HARBOR LOCK AND DAM
SYSTEM COMBINATION 2 - TYPE 2
UNIT 5/6 ENTRANCE AND SPILLBAY 1 PLAN
PLATE 2.4.2



FOR INFORMATION NOT SHOWN
SEE SECTION B.

SECTION A
2.4.2



SECTION B
2.4.2

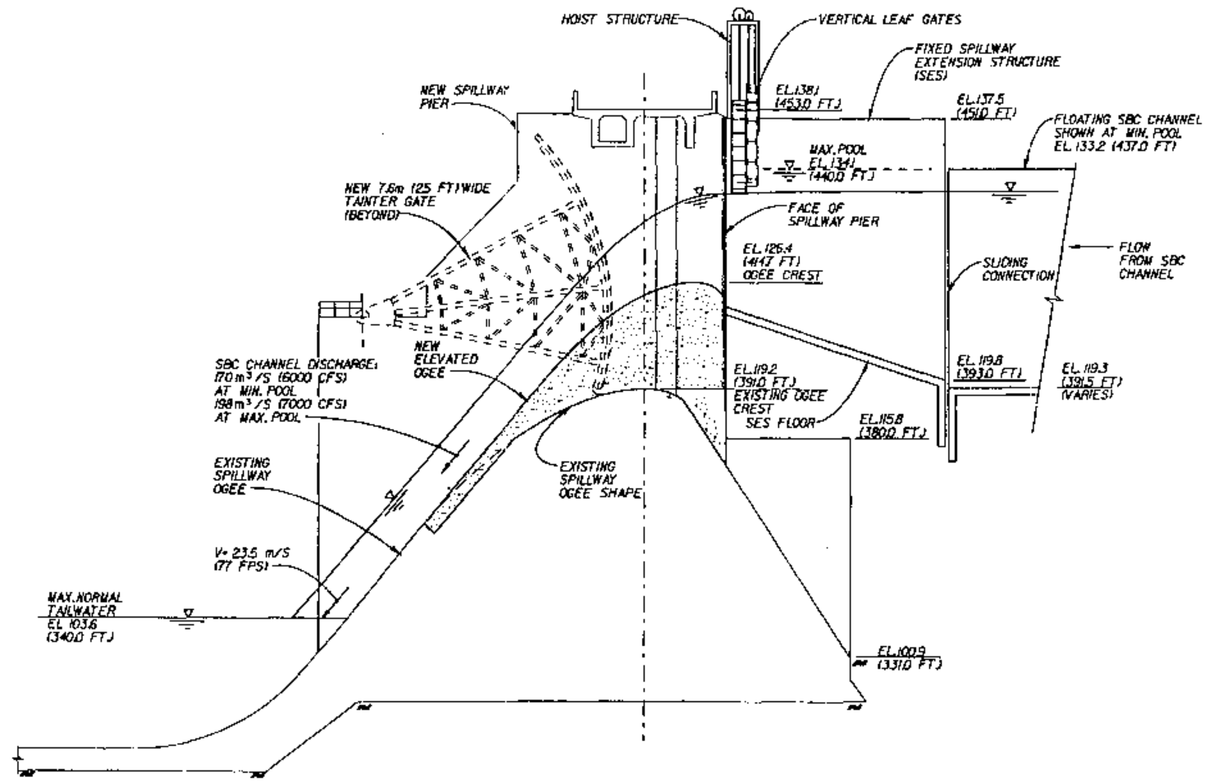
NOTES:
1. STRUCTURAL BRACING AND OTHER MEMBERS ARE SHOWN FOR CONCEPT ONLY. INTERNAL BRACING AND DECK TRUSS OCCUR AT PIER SUPPORT LOCATIONS (APPROX. 8.8m (29 FT) INTERVALS ALONG THE CHANNEL). ROOF STRUCTURES, WALKWAYS AND EQUIPMENT NOT SHOWN.
2. FIXED SECTION OF CUTOFF WALL TO BE BOLTED TO NORTH SIDE OF UNIT 6 INTAKE.

UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

US Army Corps of Engineers
Walla Walla District

ICE HARBOR LOCK AND DAM
SNAKE RIVER, OREGON, WASHINGTON AND IDAHO
SYSTEM COMBINATION 2 - TYPE 2
SECTIONS

PLATE
2.4.3



ELEVATED OGEE AT SPILLBAY 1
SECTION C
2.4.2

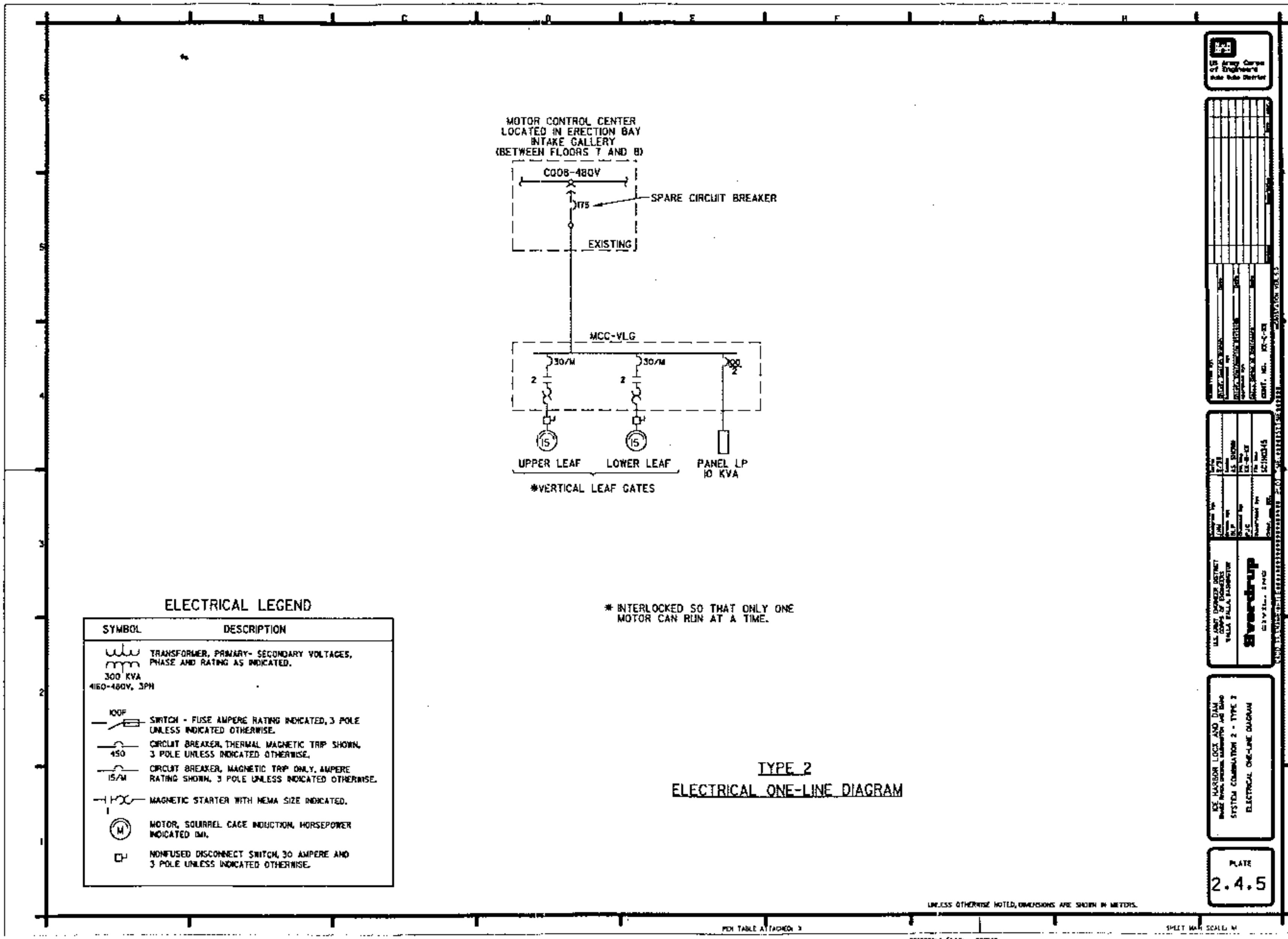
1. UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

US Army Corps of Engineers Walla Walla District

ICE HARBOR LOCK AND DAM
SYSTEM COMBINATION 2 - TYPE 2
SPILLBAY 1 SECTION

PLATE 2.4.4

Pre-decisional draft document. Not for distribution or release.



Appendix E

8. System Combination 3—Adaptive Migration Strategy for Transportation and Bypass

System Combination 3 applies a migration strategy which allows for adaptive flexibility between transportation and inriver migration. At Lower Granite and Lower Monumental, partial powerhouse length SBC channels would be constructed at Turbine Units 5 and 6 (SBC Type 3). The Type 3 SBC design allows for flexibility in operation, allowing for either collection of juveniles for transportation or direct passage to the tailrace. In this way it represents a combination of the Type 1 and Type 2 SBC channel designs. To guide fish toward the partial length channel, and away from Units 1 through 4, a BGS would be constructed in the forebay.

As with the other system combinations, ESBS intake diversion screen systems would be used in conjunction with the Type 3 SBC channels to collect fish which might pass under or around the components of the SBC system and into the turbine intakes. At Lower Granite the existing ESBS would be used, whereas at Lower Monumental there would need to be new ESBS to replace the existing STS diversion screen system. The ESBS would be located in turbine intakes at all six units to offer a bypass alternative to turbine passage for those fish which may pass under the BGS.

At Little Goose, a full-length powerhouse SBC channel without dewatering would collect and pass fish directly to the tailrace (SBC Type 2). This is the same system as described for Little Goose in System Combination 2, and would utilize the existing ESBS intake diversion systems in all unit intakes.

At Ice Harbor, a spillway SBC would be constructed at Spillbay 1 (SBC Type 4), the spillbay closest to the powerhouse. The spillway SBC would consist of a removable raised ogee crest to be placed between the upstream portions of the spillbay piers, spanning the entire spillbay width, with the downstream remainder of the spillbay to remain at its existing elevation. A BGS would be included in the forebay to direct fish away from the powerhouse intakes. Fish collected by the spillway SBC would be passed directly to the tailrace via the modified spillbay. New ESBS intake diversion screens would replace the existing STS diversion screens in the turbine intakes to offer improved bypass efficiency for any fish which do pass under the BGS.

Detailed descriptions of the specific bypass and collection facilities at each project which make up System Combination 3 are presented in the following text or referenced to earlier text where applicable.

8.1 Lower Granite: 2-Unit Bypass/Collection SBC (with Existing ESBS) – SBC Type 3

The goal of the Type 3 SBC channel design is to provide a surface collection channel which combines the operational objectives of both the Type 1 and Type 2 SBC designs. That is, the floating channel allows for either a screened-flow operation which passes the fish into the existing juvenile gallery, or a full-flow bypass operation which passes the fish directly to the tailrace. To maximize the effectiveness of either operating scenario, two separate conduits are provided within the channel to accommodate the two modes of operation. Unlike the Type 1 and 2 channels, the Type 3 SBC channel extends over only two units at the spillway end of the powerhouse. Application of this design at Lower Granite entails a channel located at the north end of the powerhouse over Units 5 and 6, as shown on Plates 3.1.1 through 3.1.6, in Section 8.6. The channel includes two side-by-side vertical entrances, one for each conduit, although only one would be open at time. To guide fish away from Units 1 through 4, a BGS is located in the forebay with the channel entrances at the downstream end.

Each of the two entrances is 4.88 meters (16 feet) wide by 21.3 meters (70 feet) deep, with the bottom of the channel coinciding with the invert of the entrances. A vertical array of sliding or rolling gate panels would close off either one or the other entrance at any given time. The discharge control would be a new elevated concrete ogee spillway to be located at the south end of Spillbay 1. This design would be similar to the design described for the elevated spillway for the Type 2 design in Section 7. However, this new section of spillway would be narrower than described for Type 2 because the flow rate is less. This discharge could be open-surface discharge, or controlled by lowering the vertical leaf gate into the flow to maintain a constant flow rate for different operating conditions. As described for the Type 2 design, the overall flow rate is controlled by the head available to the elevated spillway. The system is designed to pass a relatively constant entrance flow of 56.6 m^3/s (2,000 cfs) while in screening mode. When operating in the screening mode with the forebay above MOP, the leaf gate would be used to control the flow so the hydraulic conditions on the screens remain constant. Because no fish would be in the spilled portion of the flow (the fish are bypassed in the existing fish gallery in the dam), this is presumed to be acceptable. Operating in the bypass mode with no gate control would result in an entrance flow of approximately 67.8 m^3/s (2,392 cfs) at MOP and 90.9 m^3/s (3,209 cfs) at maximum operating pool. A more detailed discussion of the hydraulic controls and flow rates is provided in Section 8.1.1. A final decision concerning operation of the bypass mode in either the uncontrolled mode, as described above, or in a constant flow mode with the leaf gate partially deployed would be a biological decision beyond the scope of this report.

The BGS is shown on Plates 3.1.1 and 3.1.5. The downstream end of the BGS is located at the south end of the channel, near the unit joint between Units 4 and 5. The structure extends from this location 489.5 meters (1,606 feet) upstream to reach the shore. The upstream end of the BGS is closed off to preclude juveniles from entering the excluded area behind the BGS. A fish ladder extension (FLE) structure has been added to the existing south-bank fish ladder exit to a point approximately one quarter of the distance along the BGS. This ladder extension effectively relocates the ladder exit from the face of the dam to a location on the upstream side of the BGS and gives adult fish a direct path from behind the BGS to points upriver. The FLE was originally developed in 1995 for Ice Harbor (though not constructed) and the design has been adapted for Lower Granite. The location and orientation of the BGS was considered when deciding to locate the SBC entrances near the south end of the channel. Should fish moving downstream be guiding along the north face of the BGS, the optimal location for the entrance would appear to be at the south end of the channel, near the downstream end of the BGS. The hydraulic and structural design of the BGS is discussed in Sections 8.1.1 and 8.1.2.

Other features of this design are similar to those previously described for the Type 1 or Type 2 designs at Lower Granite, these include a floating channel with internal fish conduits, a cutoff wall below the channel at the north end of Unit 6, use of the existing ESBS system in conjunction with the channel, and channel attachment to a stationary SES located at Spillbay 1. A unique feature of this design is in how the attachment is made to the existing juvenile gallery. Although a stationary caisson would be attached to the upstream face of the dam to form an open channel entrance into the gallery (as in the Type 1 design), this caisson would be located near the north auxiliary water port at the upstream end of the gallery. A debris skimmer would be included, to facilitate debris management at the downwell in the Lower Granite juvenile bypass system, however, it would be in a second dedicated caisson located at the downstream end of the gallery directly over the downwell.

Like the Type 2 SBC, because Spillbay 1 is modified to provide discharge of the Type 3 SBC channel flow, the overall spillway capacity at the project will be reduced. For the Type 3 design presented, this reduction is less significant than with the Type 2 design, because a smaller section of Spillbay 1 would be impacted by the modifications (see Section 8.1.1). As described in Section 7.1 for the Type 2 SBC design, there are alternatives for restoring the hydraulic capacity of the project if this capacity reduction is not acceptable. These alternatives include lowering the spillway crest elevations (either selected bays or all the bays), construction of a new spillway at the embankment section, or using the central non-overflow section of the dam for discharging the SBC flow, rather than Spillbay 1. As was discussed earlier, there are cost and engineering advantages to discharging at the central non-overflow section over the other alternatives. In the case of the Type 3 design, although the channel width required is only 1.83 meters (6 feet), which is smaller than the 4.88 meters (16 feet) required for the Type 2 SBC, many of the same issues are encountered (see sketches in Attachment A). For example, the fish and service gallery would be interrupted; however, the drainage gallery access shaft might be spared. Depending on priorities, the elevator machinery room could be spared by a circuitous routing scheme. Operational effects on the deck at tailrace elevation would be similar but, with a narrower channel, may be less severe. Compared to the cost of the Type 3 SBC discharging at Spillbay 1, it is estimated that locating the discharge at the central non-overflow section would decrease the cost by approximately $4 million, or roughly 6.1 percent. This represents a reduction in construction cost for the SBC components only, and does not include estimated costs for resolution of potential interferences or operational problems created by the location of the chute.

Application of a discharge location for the Type 3 SBC at the central non-overflow section appears to be feasible at Lower Monumental as well. A similar cost reduction would be anticipated at Lower Monumental.

8.1.1 Hydraulics

<u>Channel Entrances</u>

To simplify the entrance roller gate design and to minimize structure, the two entrances and channels were placed side-by-side with a common wall between. A semi-circular trash rack that contains both entrances is provided to preclude large entrained debris from entering the channels. The trash rack has a radius of 6.1 meters (20 feet) and has features similar to those described for the Type 1 concept.

As with collector entrances in the Type 1 design, a velocity of 0.55 m/s (1.8 ft/s) is developed with the channel operating in the screened flow mode with an attraction flow of 56.6 m^3/s (2,000 cfs). Immediately downstream of the screened channel entrance, the flow passes through approximately a 90-degree bend that includes a centerline guide wall which helps to maintain a uniform flow distribution. Use of the guide wall yields centerline radius to conduit width ratios of approximately 4.0 and 5.0 for each half of the conduit through the bend. The conduit will remain at constant depth, but walls of the conduit will converge to a 2.89-meter (9.5-foot) width to accelerate the flow to 0.92 m/s (3.0 ft/s). The acceleration combined with the low Froude Number (0.10) will prevent flow separations (potential fish holding areas) from forming at the inside walls of the conduit bends.

Emergency bypass gates were not included with the screened channel because the adjacent parallel full-flow bypass conduit can provide this function if required.

As noted, with an uncontrolled ogee regulating the full-flow bypass channel, discharges through the bypass will vary with forebay levels when operating in the bypass mode. Therefore, entrance velocity will also vary with forebay level. With the MOP of 223.4 meters (733.0 feet), the discharge through the full-flow bypass would be approximately 67.8 m^3/s (2,393 cfs). With the forebay at the maximum normal pool of 224.9 meters (738.0 feet), the discharge through the full flow bypass would be approximately 90.9 m^3/s (3,209 cfs). The corresponding entrance velocities would be 0.66 m/s and 0.88 m/s (2.15 ft/s and 2.89 ft/s). Immediately downstream of the bypass channel entrance, the flow passes through approximately a 90-degree bend that includes a centerline guide wall which helps to maintain a uniform flow distribution. Use of the guide wall yields centerline radius to conduit width ratios of approximately 2.0 and 3.0 for each half of the conduit through the bend. The conduit will remain at constant depth, but walls of the conduit will converge to a 2.89-meter (9.5-foot)-width to accelerate the flow to velocities ranging from 1.10 m/s to 1.60 m/s (3.6 ft/s to 4.8 ft/s) for minimum and maximum operating pool levels, respectively. The acceleration combined with the low Froude Number (0.10) will prevent flow separations from forming at the inside walls of the conduit bends.

Dewatering Screens

To facilitate the simultaneous operation of the SBC in a screened flow mode and the ESBS intake diversion system, which both pass fish into the existing juvenile gallery, the fish transport flow in the screened flow conduit must be reduced from 56.6 m^3/s (2,000 cfs) to 0.85 m^3/s (30 cfs) before it is released to the gallery. The dewatering screens designed for this purpose were designed using the screening criteria defined in Section 3.3.1. These include screen approach velocity components which vary from 0.36 m/s (1.2 ft/s) in the upstream third of the screen length, to 0.24 m/s (0.8 ft/s) in the middle third, to the conventional fry criterion of 0.12 m/s (0.4 ft/s) in the downstream third. The screen areas were sized assuming that 75 percent of the gross area would be effective.

The developed screen section (see Plate 3.1.3) consists of 12 stacks of 3.05-meter (10.0-foot)-wide screen panels, two each with depths of 15.3 meters, 9.72 meters, 6.61 meters, 3.84 meters, 2.65 meters, and 1.52 meters (50.1 feet, 31.9 feet, 21.7 feet, 12.6 feet, 8.7 feet, and 5.0 feet). This is a conceptual arrangement and represents one of many possible layouts. Transport velocities were held at 3.0 ft/s through the entire dewatering reach. This reduced velocity in addition to that used in the Type 1 design allows for a maximized cross-section and screen depth at the exit from the screen section, yielding an exiting transport conduit that is 1.5 meters deep (5.0 feet) and 0.61 meter (2.0 feet) wide. To sustain a constant transport velocity while dewatering rates vary, the conduit width and depth were reduced non-linearly. The conduit width varies from 2.89 meters to 1.67 meters (9.5 feet to 5.5 feet) over the first third, from 1.67 meters to 0.91 meter (5.5 feet to 3.0 feet) over the middle third, and from 0.91 meter to 0.61 meter (3.0 feet to 2.0 feet) over the final third of the screen. A linear screen alignment was sustained with the width reduction made with the opposite wall. With the 36.6 meters (120 feet) total screen length, transport time past the screen is about 40 seconds for fish moving at the transport velocity.

The limited available gallery capacity requires dewatering to 0.85 m^3/s (30 cfs) or 1.5 percent of the initial flow. Although a control weir is included at the transport channel attachment to the dam, this finish discharge is so small that variation in dewatering performance could yield enough variation in water stage that undesirable transport velocity variations could occur approaching the transport conduit entrance. As a consequence, independent control was added to the last two screen stacks. The adjustable control is achieved by adding a compartmentalized, gated box to the back of the screens. The box would extend the full 6.1-meter (20-foot) length and the full 1.5-meter (5.0-foot) height of the screen stacks. It would include three motorized 0.76-meter (2.5-foot) square, low head, vertical slide gates. Headloss across these gates under normal operation would be approximately 0.03 meter (0.1 foot). Velocities approaching the transport conduit could be monitored and used to direct gate control.

Although dewatering flow adjustment capability provided by this gated box is limited to approximately one percent of total dewatering capacity, it represents approximately two-thirds of the bypass discharge. Consequently, if the dewatering system is functioning close to design, the independently controlled screen panel does offer good capability to optimize bypass operation. The actual configuration of an independent control structure, and an estimate of the operational benefits to be gained, would be determined in a hydraulic model of the screening system.

Bypass Conduit

The floor of the bypass conduit, in the 36.6-meter (120-foot)-long reach parallel to the screen section, ramps up from an elevation 21.3 meters (70.0 feet) below the forebay water surface to an elevation 15.2 meters (50.0 feet) below the forebay water surface. Likewise, through this reach the width of the channel reduces from 2.89 meters (9.5 feet) to 1.83 meters (6.0 feet). As a consequence, at MOP velocities will accelerate from approximately 1.10 m/s (3.6 ft/s) to approximately 2.5 m/s (8.2 ft/s) through this reach. At maximum operating pool, corresponding velocities will accelerate from 1.60 m/s (4.8 ft/s) to 3.35 m/s (11.0 ft/s). The bypass flow exits this converging section and then passes through a conduit section leading to the SES. This section of conduit is 1.82 meters (6.0 feet) wide by 14.6 meters to 15.2 meters (48 feet to 50 feet) deep (depending on velocity and head losses) and turns through a 90-degree bend. The bend has a 9.1-meter (30.0-foot) centerline radius which yields a radius to channel width ratio of 5.0.

Switch Gate

A 15.2-meter (50.0-foot)-deep by 6.10-meter (20.0-foot)-long switch gate is included in the wall of the 1.82-meter (6.0-foot)-wide conduit section described above. With the switch gate set in the wall, an obstruction-free path is created for the full-flow bypass. With the switch gate open, the screened flow would be directed to the raised ogee. The switch gate generates both a fairly well aligned boundary for guidance of the screened flow into the channel and a wall that prevents backflow into the full-flow bypass channel. Depending on transition treatments and the resulting gate coefficient, the headlosses in the screened flow passing the switch gate may be substantial. Based on a coefficient of 0.6, head loss across the switch gate when passing a screened flow discharge of 56.6 m^3/s (2,000 cfs) would be approximately 0.4 meter (1.3 feet). It may be desirable to explore options for reducing losses across this gate if the concept is pursued. Refining the design would lead to raising the ogee crest elevation which in turn would reduce full-flow bypass discharges and differential loading on the structure.

Elevated Spillway Flow Control

A single raised ogee is used to control flow through both the screened and full-flow bypass channels. The 56.6 m^3/s (2,000 cfs) flow rate for the screened mode of operation is held approximately constant, independent of forebay stage, to optimize control of flow conditions through the screens and to minimize screen size. Near constant flow during screen operation is achieved through use of the leaf gate positioned at the ogee crest. Because larger head losses occur through the system during screened operation than when in the bypass mode, the critical design head for the ogee occurs on the screened path. Head losses through the SBC system during screened operation are approximately 0.85 meter (2.8 feet). Considering the available head at the ogee, and estimating an ogee coefficient as discussed for the Type 2 design in Section 7.1.1, the ogee crest was set at elevation 216.5 meters (710.3 feet). With this design, at the MOP, the 56.6 m^3/s (2,000 cfs) discharge would be passed through the screened system and over an uncontrolled ogee. As the forebay elevation rises and the resulting head on the ogee increases, the 56.6 m^3/s (2,000 cfs) discharge would be maintained through use of leaf gate control.

With the above ogee, flows through the full-flow bypass and over the uncontrolled ogee will range from 67.8 m^3/s (2,392 cfs) at the MOP to 90.9 m^3/s (3,209 cfs) at the maximum operating pool.

Influence on Spillway Capacity

The elevated ogee yields approximately a 30 percent loss of spill capacity in one of the eight spillbays. As a consequence, the current spill capacity of 24,100 m^3/s (850 kcfs) would be reduced to 23,210 m^3/s (819.6 kcfs) with no SBC release, or 23,320 m^3/s (823.6 kcfs) with supplemental SBC release. This corresponds to approximately a 3.1 percent reduction in total release capacity. A spillway rating curve with the SBC installed is presented in Figure 8.1.

Behavioral Guidance System

The collector configuration and BGS presented on Plates 3.1.1 and 3.1.5 have not been specifically model studied. However, sufficient hydraulic modeling has been conducted to project what conditions may be effective at generating guidance velocities along the BGS toward the proposed collector entrance. Additionally, testing of the prototype BGS at Lower Granite was performed in 1998, and the results are discussed in Section 2.2.2 of this report. However, this prototype is a BGS extending 335 meters (1,100 feet) upstream and covering only three powerhouse units, as opposed to four units proposed for this design. It is suggested that prior to final design of a four-unit BGS extending 489.5 meters (1,606 feet) upstream modeling should be performed to determine the design details most likely to achieve biological success. The following performance features and design considerations were applied in developing the conceptual design presented in this report:

- Results from modeling at the WES [25] and data obtained from Glen Davis at WES, show the BGS does not generate velocity concentrations on its face, but does supply a deep barrier that crosses the approach velocity field to the turbine intakes. Velocities along the BGS face reduce with distance from the turbine intakes. By placing the BGS at a small angle relative to the general approach flow direction, it is likely that fish will guide along the barrier and not be attracted or entrained under it.

- The flow entering the turbine intakes behind the BGS must pass under the BGS. To assure that velocities under the BGS are less than the 0.61 m/s (2.0 ft/s) criterion, an underflow area greater than or equal to the turbine discharge divided by the velocity criterion should be supplied at the minimum normal pool of 223.4 meters (733.0 feet).

- The distribution of velocities along and under the BGS will depend on power release and spill discharge magnitudes and distributions. Operations required to sustain the desired flow conditions should be thoroughly reviewed through physical modeling prior to commitment to a design.

- The modeling conducted at WES shows that the distribution of velocities under the BGS is not strongly dependent on proximity to the powerhouse face (i.e., velocities under the BGS are not substantially higher near the powerhouse). As a consequence, it is not necessary to make the BGS much deeper near the powerhouse.

- The BGS should be fairly deep throughout its length to optimize fish interception and guidance.

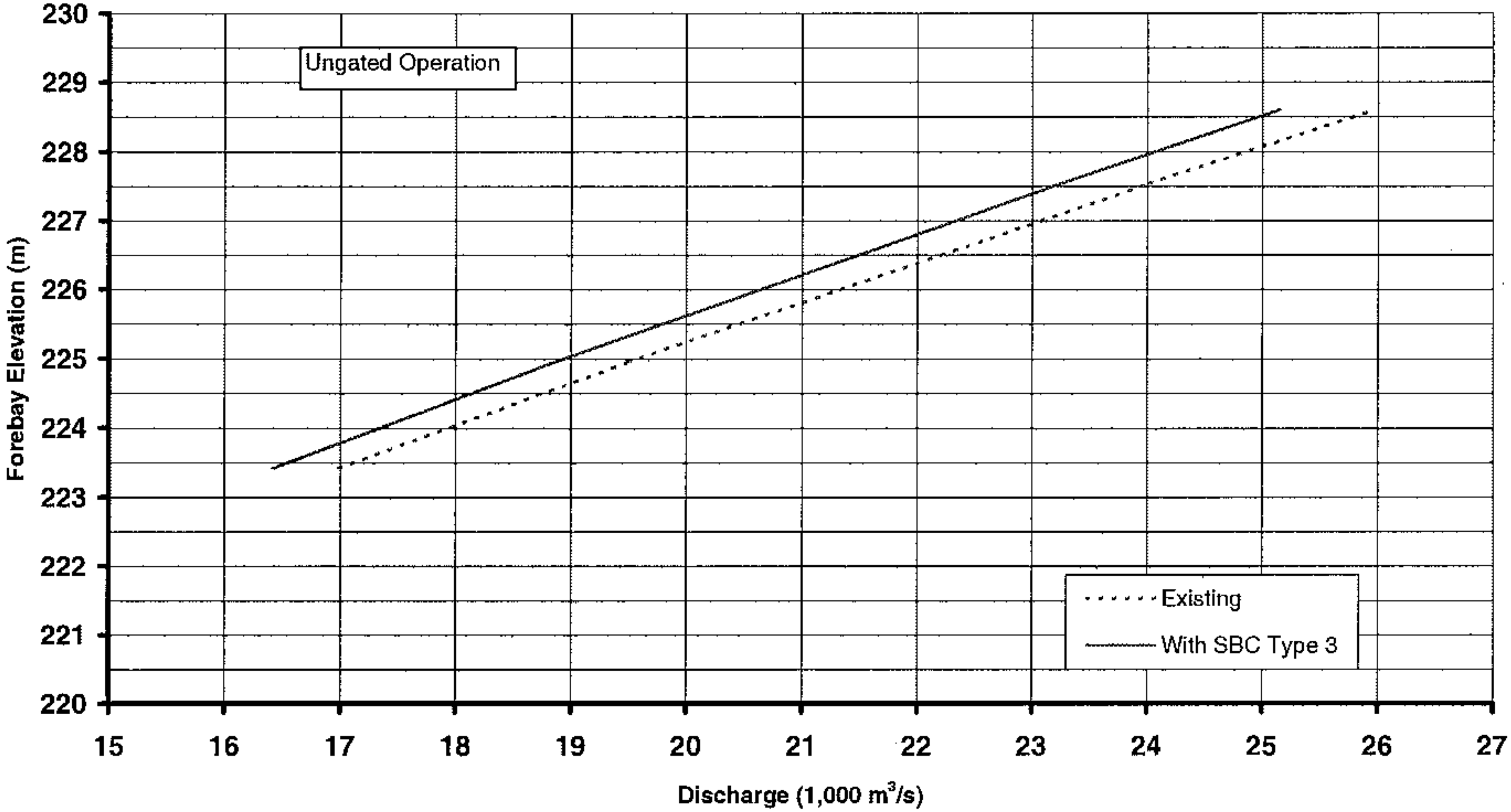


Figure 8.1 - Lower Granite Lock and Dam - Spill Capacity with SBC Type 3

- The BGS should extend to the bank, thus allowing interception of juvenile fish in this preferred near shore habitat zone.
- Extending the BGS far below the bottom of the SBC channel may expose the BGS (near the powerhouse) to higher velocities, which might cause stability problems. As a consequence, the maximum depth of the BGS should probably be approximately 24 meters (80 feet).
- The minimum BGS to reservoir bottom clearance should be 4.9 meters (16 feet), at a minimum normal reservoir pool elevation of 223.4 meters (733.0 feet). This should prevent the BGS from impinging on the bottom, even if the BGS is left in place through operation at the minimum flood control pool, elevation 220.0 meters (724.0 feet).

With this design, Units 1 through 4 would draw their flow under the BGS. Assuming a discharge of 617 m^3/s (21,800 cfs) per unit, the area under the BGS was sized for a discharge of 2,470 m^3/s (87,200 cfs). The recommended BGS is presented on Plate 3.1.5. The depth of the BGS ranges from 24.4 meters (80 feet) to 3.0 meters (10 feet) over a 489.5-meter (1,606-foot) length. The final 32 meters (106 feet) of this length consists of a surface to bottom flexible curtain section attached to a new earthfill embankment with a concrete headwall. This section is added to extend the BGS barrier to the bank. The curtain supplies a vertically adjustable barrier that would vary with forebay stage in the shallow zone. Use of the embankment prevents extending the curtain across bare ground and should also reduce the potential for vandalism of the curtain. The proposed BGS has an underflow area of 4,127 m^2 (44,426 ft^2) at MOP elevation of 223.4 meters (733.0 feet), which yields an average underflow velocity of 0.59 m/s (1.95 ft/s). At the minimum flood control pool elevation of 220.7 meters (724 feet) the underflow area would be approximately 2,873 m^2 (30,926 ft^2) resulting in an average underflow velocity of 0.86 m/s (2.82 ft/s) with all four units operating. Although this is outside the design range for normal operation with fish present in the forebay, the BGS would structurally need to be designed for this potential underflow velocity.

<u>Fish Ladder Extension</u>

The BGS extends to the bank and may pose a barrier to adult fish passage. To improve adult passage, FLE structures were proposed and developed in previous studies, that would extend the south fish ladder across the forebay and through the BGS. It was proposed that supplemental flow and flow generating head be added to this floating channel through use of a pump placed at the dam (i.e., pump from the FLE near the current ladder exit and discharge back to the reservoir). Use of the pump would compensate for head losses and flow reduction influences of the 168-meter (551-foot) long FLE channel. The target velocity range for flows in the FLE channel designed originally for Ice Harbor, from which this is design based, was approximately 0.46 m/s to 0.69 m/s (1.5 ft/s to 2.25 ft/s) [26]. Evaluation of the hydraulic conditions in the FLE for Lower Granite would need to be confirmed.

8.1.2 Structural Design

<u>SBC Channel and Spillway Extension Structure</u>

The two-unit Type 3 SBC channel is a floating structure similar to those described for the previous two designs. As with the Type 2 SBC channel, the bulk of the flow would be discharged to the tailrace over a new elevated concrete spillway section incorporated into the existing Spillbay 1. A new vertical leaf gate and a new Tainter gate for the remaining unmodified portion of Spillbay 1 would be required; however, the dimensions of these gates would be different than those described for the Type 2 design (see Plate 3.1.2). Structural issues and design criteria for the channel and SES as applied to Lower Granite are similar to those addressed for the Type 1 and Type 2 designs, with the following notable exceptions.

Because the fish transport flow is directed to the north, a penetration in the forebay wall of the central non-overflow section of the dam is made. The proposed design is to cut an opening through the concrete to the north of the existing auxiliary water port and add a steel caisson to receive the conduit flow. This is depicted on Plates 3.1.2 and 3.1.3. The new opening leads directly to the existing fish gallery in the dam. The caisson would be similar in design to that described at the south end of the powerhouse for the Type 1 design, except that it would not contain the debris skimmer. The caisson consists of stiffened steel panels designed for a fully dewatered condition at the forebay maximum flood elevation of 227.5 meters (746.5 feet). As in the Type 1 design at Lower Granite, a debris skimmer system would still be required at the gallery downwell in the erection bay where the floating debris would accumulate. The size of the caisson and the opening at the debris skimmer would be smaller than previously described since the fish transport conduit is located at the north end of the powerhouse.

The SES, the caisson at the gallery penetration, and the section of transport conduit outside the channel are all relatively slender structural components. Bracing will be required to laterally support these systems. A majority of this bracing could be outside the structures themselves to avoid interference with fish transport and to minimize debris accumulation.

A structural concern exists with the dual-channel layout of the Type 3 channel. If the sliding doors at the entrance and the hinged switch gate within the conduit (depicted on Plate 3.1.2) are set in opposite modes, and the spillway leaf gate is opened, rapid evacuation of one of the conduits and possible collapse of channel components might result. This would occur, for example, if the sliding doors were set to close off the bypass conduit while the hinged switch gate were set in its retracted position in line with the conduit wall. Therefore, interlocks should be incorporated into the controls design to prevent this scenario from occurring accidentally.

Channel Cutoff Wall

The structural design issues for the cutoff wall located below the channel at the northern end of the powerhouse are the same as previously described for the Type 1 SBC channel design.

Behavioral Guidance Structure

The BGS is effectively an articulated rigid-panel steel curtain suspended in the forebay by pontoons with the desired goal of precluding fish from passing behind it. The proposed BGS for the Type 3 SBC is essentially a direct incorporation of the design of the prototype BGS tested at Lower Granite in 1998. One major difference assumed in this report is that the BGS would be a permanently moored structure, while the prototype is one that can be towed into a storage position for testing purposes. Consequently, many of the operational issues associated with the prototype will not be present. Foremost of these is a testing protocol which requires a rather complex system of winches and cables and multiple shore-based anchorage systems that allows the prototype to be moved in the forebay. Rather, a permanent anchorage system is proposed. The structure will accommodate all credible design loads and forebay elevation fluctuations. The other major difference with the BGS design depicted is that the opening between the upstream end of the BGS and the shore has been closed to preclude juvenile fish from entering the excluded area via a near-shore path. To accomplish this, the rigid panels have been extended closer to the shore and a flexible curtain has been added between the rigid panels sections and the shore. The flexible curtain section is proposed due to the need to account for very shallow near-shore depths and the significant fluctuations possible in the forebay elevation. A rigid panel system would “bottom out” during low forebay events so near to shore. In addition, because of the need to accommodate these forebay fluctuations and out of concern of damaging the flexible curtain in the wave zone, an earth fill embankment structure with a concrete headwall is depicted protruding from the shore. The curtain is attached to the concrete headwall with a sliding attachment that would allow the end of the curtain to rise and fall with the forebay.

In response to a potential debris maintenance problem associated with the multiple buoy/cable attachments on the upstream face of the prototype, an enhancement of the cable attachment system to the pontoons on the BGS is proposed as shown on Plate 3.1.5. The vertical guide buoys (which enable the pontoons to tilt freely under hydraulic load) have been incorporated into the pontoon system itself, rather than being located just upstream of the face of the BGS and attached by near-surface cables. This should result in a substantial reduction in the chance that debris will accumulate and become entangled in the anchor cable and buoys. It would also allow small boats performing debris maintenance to pass alongside the upstream face with a reduced chance of fouling their propellers.

A system of transverse anchor cables and back anchor cables keeps the BGS in the desired position in the forebay while a longitudinal cable secures the articulated structure along its length. The longitudinal cable would be secured to the shore with a deadman anchor incorporated into the new embankment and concrete headwall on the shore.

It is anticipated that during periods of high spill or during load rejection the BGS could float in an outward manner (away from the powerhouse). The back anchor cables preclude excess movement in the upstream transverse direction. It is not anticipated, however, that a direct attachment to the powerhouse or SBC channel would be required to stabilize the movement of the BGS. Confirmation of this would be required in model studies of the forebay under different project hydraulic conditions. Rather, a flexible closure seal with the SBC channel would be required to preclude fish from escaping around the end of the BGS. This seal should be flexible enough, and the gap large enough between solid structures, to allow the BGS to travel slightly downstream (or upstream) during fluctuations in the forebay water level or periods of fluctuating powerhouse hydraulic loads.

Fish Ladder Extension

As noted above, the FLE is a structure that has been included in this design to allow upstream migrating adult fish a direct path from behind the BGS to a location on the upstream side. This is required because the upstream end of the BGS closes off the forebay at the shore, precluding unimpeded travel upriver. The FLE is a 1.8-meter (6-foot)-wide by 168-meter (551-foot)-long floating steel channel that attaches at its downstream end to a fixed structure located at the existing fish ladder exit. At its upstream end, it penetrates the pontoons of the BGS to allow for a direct path from the existing ladder exit to the rest of the forebay upstream of the BGS. The FLE shown was adapted from a design originally developed for Ice Harbor. It is assumed that the design is appropriate for Lower Granite although no extensive review of this has been performed. One problem unique to Lower Granite which must be addressed in the final design is that Lower Granite can be operated as a flood storage reservoir. This results in a greater potential fluctuation of the forebay water surface at Lower Granite than at Ice Harbor. Since the forebay can be drawn down up to 2.74 meters (9 feet) below MOP, the design of the structure would have to be adjusted somewhat, especially at the downstream end where it attaches to the dam. To account for this, the cost of the FLE at Lower Granite has been increased by approximately 10 percent in the cost estimates.

The FLE is attached to the dam at the existing fish ladder exit with a pinned or sliding connection to accommodate the forebay fluctuations. It is also anchored in the forebay with both an anchoring system and a guy wire system back to the dam. A pump is incorporated into the FLE design to add flow capacity to the channel to optimize flow conditions for the adult fish. Hydraulically actuated control gates make isolation of the FLE possible so that adult fish can be shunted directly to the forebay, if that were desired.

8.1.3 Mechanical Requirements

Many of the mechanical components and issues discussed for the Type 1 design at Lower Granite (Section 5.1.3) also apply to this design. These include the use of vertical brush bar screen cleaners, a pivoting trash rake with muck car at the channel entrance, a tilting weir to control the flow rate into the juvenile gallery, and a debris skimmer located at the gallery downwell. One item not required is the set of emergency bypass doors prescribed for the Type 1 designs because this design has a bypass operating mode built into it. As previously described, the dewatering screen panels and cleaner frames would be designed to be lifted with the existing project mobile crane, and a new smaller boom truck would be procured to lift the muck car and debris skimmer hopper. Mechanical requirements associated with the channel discharge are as described for the Type 2 design in Section 7.1.3, including a hoist for the new leaf gate and modifications to the existing Tainter gate hoist. However, in each of these cases a few minor differences exist with this design, as noted below.

- The dewatering screen wall length is 36.6 meters (120 feet). For the purposes of estimating equipment requirements it is assumed that screen cleaning would be accomplished with 10 vertical brush bar frames, each 3.66 meters (12 feet) wide. This represents 25 percent of the number of cleaners required for the Type 1 design.

- The pivoting trash rake at the channel entrance is dedicated to a single entrance reducing the mechanical requirement that it be mobile. This reduces the estimated cost of this machine from $659,000 to $482,000.

- No submerged weirs are required within the conduit system to control flows; therefore, only on weir is required at the end of the conduit.

- New hoisting machinery requirements for the vertical leaf gate at the elevated spillway section would be smaller than with the Type 2 design because the gate is smaller.

A number of mechanical components unique to the Type 3 design will also be required. These are discussed in detail below:

<u>Entrance Doors and Hinged Switch Gate</u>

The Type 3 SBC channel design includes two side-by-side entrances, each associated with a separate internal conduit. Although the operational mode of each of these internal systems is different (screened or bypass flow), the design flow rates for each conduit are about the same. Additionally, the design intent is that these two systems would never operate simultaneously; therefore, it would appear redundant and unnecessarily expensive to provide individual controls and discharge facilities for each system. As a result, a single discharge facility is provided at Spillbay 1 with a means of hydraulically switching between the two systems. This is accomplished with the sliding doors at the entrances and a hinged switch gate inside the channel.

The sliding doors are designed to move horizontally in tracks closing off either one or the other entrance. Because the entrances are 4.88 meters (16 feet) wide, the doors are also approximately 4.88 meters (16 feet) wide. Four, approximately square, door panels, each 5.33 meters (17.5 feet) tall, would be stacked vertically to cover the total entrance height of 21.3 meters (70 feet). The full stroke of the doors would be about 4.88 meters (16 feet). This would preclude both entrances from being open simultaneously. The actuation of the door panels would be accomplished with submerged pistons mounted to the outside face of the channel wall. The pistons could be either pneumatically or hydraulically controlled. If hydraulic cylinders are to be used, the fluid should be environmentally approved for inriver usage.

The hinged switch gate is located along the internal conduit wall just upstream of the 90-degree conduit bend leading to the SES. The gate is 6.10 meters (20 feet) wide by 15.8 meters (52 feet) high and is mounted on hinge pins at its upstream end. It could consist of a single panel or multiple panels stacked vertically. This gate would be set in either one of two positions. When the gate is in the position lined up with the conduit wall, the flow leading to the SES would come through the unscreened bypass conduit. When the gate is rotated such that its downstream end is sealed against the far conduit wall, the flow would be drawn from the downstream side of the dewatering screens. Similar to the sliding doors, this gate would also be controlled by a series of pneumatic or hydraulic pistons. The pistons and cylinders would be located inside the channel but outside the conduit and would actuate the gate from its west face. In this way the pistons would pull the gate back to allow for fish bypass flow leaving no obstructions in the flow path when operating in this position. To operate in the screened mode the pistons would push the gate to the opposite position. This would leave the pistons in the flow path, however, the flow would be from the downstream side of the dewatering screens and would not contain fish or debris.

Gated Porosity Control

The gated porosity control box located behind the downstream end of the dewatering screen section includes three low-head slide gates to better control the final dewatering flow rate. These gates will each require motorized operators. The control of these operators would be tied to a PLC monitoring various flow rates throughout the system.

Fish Ladder Extension Pumps and Gates

A 0.66 m^3/s (23.4 cfs) water pump is included as part of the design of the FLE, based on the Corps' previously prepared design for Ice Harbor. The size of this pump may be adjusted for Lower Granite but this would be a matter for final design. In addition to the water pump, there is a hydraulic pump for the hydraulic cylinders on the two water control gates at the FLE. Control of these pumps and operators would be by a PLC, with manual backup.

8.1.4 Electrical Requirements

Primary Power Considerations

Except for the slightly reduced electrical loading for the Type 3 SBC (as compared to the Type 1 design), the electrical requirements are similar to the requirements for the Type 1 screened collection channel and the Type 2 bypass collection channel. For the Type 3 SBC design, typical loads include screen cleaner motors, the entrance rake machinery, motors for the tilting weir and the gated porosity control section at the end of the dewatering section, a motor for the compressed air system which supplies air to the pneumatic actuators for the switch gate and sliding doors at the channel entrance, and the hoist for the leaf gate at the new raised ogee spillway crest. Additionally, like the Type 1 SBC at Lower Granite, electrical power is required in the area of the erection bay for the drive motors for the debris skimmer. The Type 3 SBC also includes an FLE, adding electrical loads for the attraction water pump motor and the hydraulic system pump motor (for the FLE control gates) near the fish ladder exit at the south non-overflow section.

Because of the similarities with the Type 1 SBC at Lower Granite (including the magnitude of total load), the same power source and feeder routing are employed (see Section 5.1.4). For the Type 3 at Lower Granite, the total electrical load is approximately 350 amperes at 480 volts ac. Calculations for estimated electrical loads are provided in Attachment A. A one-line diagram illustrating the electrical loads, power sources and components is provided on Plate 3.1.6.

Instrumentation and Controls

Controls issues for the Type 3 SBC are similar to those for the full powerhouse screened channel of Type 1. However, rather than the Tainter gate providing control of flow in the channel during screening mode, the vertical leaf gates will provide this control. Unlike the Type 1 channel, the additional bypass route through the channel (the nonscreened route) introduces a greater level of complexity and additional safety issues related to the channel operation. These stem from the need to ensure that the gates that close one or the other channel entrance (the sliding gates) are never deployed without regard for the position of the switch gate located downstream in the channel. Failure to properly sequence the manipulation of these gates in conjunction with the leaf gate at the spillway could result in excessive dewatering of a portion of the channel, leading to damage of the channel and channel components. Proper programming of the PLC through data collected with water level indicators and gate position indicators will prevent this problem. As an additional safety measure, fused blow-out panels located in the walls of the conduits could guard against collapse of the conduit walls if the gates are improperly moved and the channel is inadvertently overloaded.

Separate control issues are introduced with the FLE to regulate the FLE water pump and control gates. These typically do not interrelate with the control issues for the channel and could be handled by the same or a separate PLC.

8.1.5 Operation and Maintenance Issues

Except for the presence of the BGS and the FLE, the system operations, corrosion protection, debris maintenance, and mechanical system maintenance issues for the Type 3 SBC are similar to those discussed for the Type 1 design, although reduced in magnitude. With the fixed entrance debris rake (rather than a rail-mounted one) the complexity of that system will be reduced from an O&M standpoint. Also, since the total magnitude of the system is reduced (only one entrance and dewatering area), it is anticipated that one full-time operator will be required to handle the daily operations of the channel. This would represent an average requirement over the operating season. Off-season maintenance requirements would be reduced over the previously described designs due to the reduction in overall magnitude of the system.

Because the BGS directs fish (and debris) to the SBC entrance, it is likely that the entrance debris rake will operate more frequently to keep the entrance rack clear of debris. Debris management at the BGS is anticipated to be similar to that of the existing trash shear boom, except that the total volume of material should be reduced due to the presence of the trash shear boom upstream of the BGS. Good, unfettered access by boat to both faces of the BGS is possible with the integration of the vertical guide buoy into the pontoon system as shown on Plate 3.1.5. This anchorage attachment design also results in relatively little opportunity for debris to hang up on the BGS pontoon or anchor system.

Routine O&M of the ESBS system will be required. These requirements are well documented and should be the same as currently experienced at Lower Granite. O&M costs associated with the ESBS system are not included in the SBC O&M estimates as these are viewed as existing costs which are not changed by the presence of the SBC channel.

8.1.6 Construction Issues

Fabrication/Installation Strategies

Construction issues for the Type 3 SBC design are similar to those discussed for the Type 1 design (as concerning the channel) and the Type 2 design (as concerning the spillway modifications) with the exception of the addition of the BGS and FLE. Thus, installation strategies for the components would be the same utilizing barged or trucked sub-assemblies erected remotely from the powerhouse for final installation by floating them into position. Final fit-out would be accomplished with the channel in place.

The BGS, being a separate floating structure, could be constructed anywhere that sufficient draft is available for the rigid curtain to be assembled, installed, and floated into place. Installation of the anchorage system for the BGS would require the use of barges, cranes, and divers. Assembly and installation of the FLE would be performed in a similar manner and would be most efficiently done in conjunction with the BGS installation. Since the FLE components have considerably less draft than the BGS components, the depth requirements for locations in the river where the construction and initial assembly could take place are less restrictive.

Construction Sequencing

Sequencing of construction is constrained by the same issues identified for the Type 1 SBC. The narrow 3-month in-water work window substantially affects scheduling and performance of work that would be disruptive to fish passage (upstream and downstream) and makes it questionable whether the entire SBC system could be made operational prior to start of the following year's fish migration season. With the shorter channel proposed for the Type 3 SBC, it is more likely that all the internal systems could be made operational in less time than for the Type 1 or 2 designs. As a compromise position, for the first season, the channel could be operated as a nonscreened channel bypassing all the flow through the spillbay with internal components installed during the next in-water work window.

Construction Duration

Fabrication of the SBC channel, SES, BGS, and FLE components should take 3 to 5 months. Installation of the SES, BGS, and FLE should take about 3 months. Installation of the channel to a fully operational condition should take 3 to 5 months.

8.1.7 Construction and O&M Costs

Total estimated cost of engineering design and construction for the Type 3 SBC bypass at Lower Granite is $65,698,000 in 1998 dollars. A cost breakdown is presented in spreadsheet format on the following two pages.

Annual O&M costs are estimated as follows:

Maintenance	
Mechanical/electrical components	$125,000
Structural components	$145,300
Operations	
Labor requirements	$80,000
Total annual O&M	**$350,300**

These O&M costs do not include costs associated with O&M of the ESBS diversion system, juvenile fish facilities, or transportation costs, as these are considered existing documented costs. Biological study costs are also not included.

8.2 Little Goose: Full Powerhouse Bypass SBC (with Existing ESBS) – SBC Type 2

For System Combination 3, a Type 2 Bypass SBC would be constructed at Little Goose. The Type 2 SBC is fully described in Section 7.1, and application of the Type 2 Bypass SBC at Little Goose in particular is described in Section 7.2 and is not repeated here. The goal of incorporating this design into System Combination 3 is to safely pass the fish through Little Goose Dam which were not collected at Lower Granite. These fish would then approach Lower Monumental, along with fish from the Lyons Ferry Hatchery, where a Type 3 Bypass/Collection SBC would be installed.

8.3 Lower Monumental: 2-Unit Bypass/Collection SBC (with New ESBS) – SBC Type 3

The design of the Type 3 SBC channel at Lower Monumental is similar to that described for Lower Granite in Section 8.1, with some exceptions. Plans and details of the SBC Type 3 design, as installed at Lower Monumental, are shown on Plates 3.2.1 through 3.2.6, in Section 8.6. One notable exception is that the project layout is reversed at Lower Monumental, with the powerhouse located to the north of the spillway. Therefore, the reader should note that references to north and south in the discussions for Lower Granite are reversed in their application to Lower Monumental. Additionally, this reversed orientation results in the SBC flow being discharged at Spillbay 8 instead of Spillbay 1, as described for Lower Granite.

As previously discussed, other differences at Lower Monumental include the 0.91-meter (3.0-foot) normal operating range fluctuation of the forebay and the need to replace the existing STS intake diversion system with a new ESBS diversion system. Details concerning the effects of these differences are discussed in the following sections.

8.3.1 Hydraulics

The Type 3 SBC installation at Lower Monumental is nearly identical to the Type 3 SBC installation at Lower Granite. As at Lower Granite the elevated ogee crest was placed at an elevation to provide a flow of 56.6 m^3/s (2,000 cfs) through the dewatering conduit at MOP during screening mode. At Lower Monumental the resulting ogee crest elevation is 156.8 meters (514.3 feet). When in screening mode, gate control would be used to maintain constant discharges through the dewatering conduit, independent of forebay elevation. When in bypass mode, discharges through the full-flow bypass conduit would vary with

PROJECT: LOWER SNAKE RIVER S.B.C. SYSTEM COMBINATIONS - CONCEPT DESIGN REPORT
DESIGN STATUS: CONCEPTUAL

DATE: Nov-98
ESTIMATOR: PJC
CHECKED BY: RGW

TYPE 3 SBC - 2-UNIT BYPASS/COLLECTION SBC (with Existing ESBS) - LOWER GRANITE LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**SBC CHANNEL**				
	Channel Structure (exterior floor and walls)	4,060	M^2	710	**2,882,600**
	Interior Conduit Structures (floors and walls minus screens)	3,950	M^2	710	**2,804,500**
	Miscellaneous Walkways, Roof Structures, Entrance Debris Skirt (% of costs above)	5,687,100	$	10%	**568,710**
	Channel Flotation Cells	180	M	7,660	**1,378,800**
	Dewatering Screen Panels (removable panels stainless steel wedge-wire screen with spare panels	390	M^2	1,470	**573,300**
	Screen Cleaners (vertical brush cleaners)	12	EA	35,000	**420,000**
	Channel Entrance Debris Rake System	1	LS	482,000	**482,000**
	Entrance Sliding Doors, Hinged Gate, Control Gates and Tilting Weir	215	M^2	1,640	**352,600**
	Cutoff Wall (includes foundation)	490	M^2	1,170	**573,300**
	Structural Support and Guide System	50	Tonne	5,000	**250,000**
	ITEM SUBTOTAL				**10,285,810**
2	**SPILLWAY EXTENSION STRUCTURE**				
	Structure Floor and Wall Panels	520	M^2	1,530	**795,600**
	ITEM SUBTOTAL				**795,600**
3	**CHANNEL CONDUIT CONNECTION TO GALLERY (AT CENTRAL NON-OVERFLOW & ERECTION BAY)**				
	Steel Caissons and Related Structures	280	M^2	1,530	**428,400**
	Concrete Removal	45	M^3	1,330	**59,850**
	Miscellaneous (Debris Skimmer, Hopper, Existing Caisson Removal, New Gate)	1	LS	170,000	**170,000**
	ITEM SUBTOTAL				**658,250**
4	**SPILLBAY 1 MODIFICATIONS**				
	Elevated Ogee Concrete	200	M^3	466	**93,200**
	Mid-Spillbay Pier Wall Concrete	1,800	M^3	598	**1,076,400**
	Removal of Existing 15.24-M Wide Tainter Gate	1	LS	342,000	**342,000**
	New 10.67-M Wide Tainter Gate including Gate Hoist Modifications	1	LS	835,000	**835,000**
	Vertical Leaf Gate and Hoists	1	LS	107,000	**107,000**
	Stoplogs for 10.67-M Wide Spillbay	203	M^2	880	**178,640**
	Upstream Dewatering Bulkhead (for use during construction of spillbay modifications)	1	LS	1,220,000	**1,220,000**
	ITEM SUBTOTAL				**3,852,240**
5	**BEHAVIORAL GUIDANCE STRUCTURE (BGS)**				
	Behavioral Guidance Structure (BGS)	457	M	19,700	**9,002,900**
	Fish Ladder Extension (FLE) (13m cost added to provide flood adjustability)	181	M	8,070	**1,460,670**
	Mechanical Requirements	1	LS	175,000	**175,000**
	ITEM SUBTOTAL				**10,638,570**

PROJECT: LOWER SNAKE RIVER S.B.C. SYSTEM COMBINATIONS - CONCEPT DESIGN REPORT
DESIGN STATUS: CONCEPTUAL

DATE: Nov-98
ESTIMATOR: PJC
CHECKED BY: RGW

TYPE 3 SBC - 2-UNIT BYPASS/COLLECTION SBC (with Existing ESBS) - LOWER GRANITE LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
6	**MISCELLANEOUS**				
	Trash Shear Boom Relocation	1	LS	75,000	**75,000**
	Existing Prototype SBC Channel and Prototype BGS Removal and Disposal	2,770	Tonne	900	**2,493,000**
	9.1-Tonne Boom Truck	1	EA	200,000	**200,000**
	Electrical Requirements	1	LS	312,270	**312,270**
	ITEM SUBTOTAL				**3,080,270**
	Subtotal Direct Construction Costs				**29,310,740**
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	29,310,740	$	5.0%	**1,465,537**
	General Contractors Overhead and Profit	30,776,277	$	26.5%	**8,155,713**
	CONSTRUCTION SUBTOTAL				**38,931,990**
	Construction Contingency	38,931,990	$	25.0%	**9,732,998**
	TOTAL CONSTRUCTION COSTS				***48,664,988***
	PLANNING AND ENGINEERING	48,664,988	$	22.5%	**10,949,622**
	CONSTRUCTION MANAGEMENT	48,664,988	$	12.5%	**6,083,124**
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				**$65,697,734**

Pre-decisional draft document. Not for distribution or release.

App E/Annex B/cost spreadsheet.xls/Type 3 - Granite

forebay stage, ranging from 67.7 m^3/s (2,393 cfs) at MOP to 81.1 m^3/s (2,863 cfs) at maximum operating pool. In this mode, the gate would be lifted completely out of the flow providing no control of the flow.

Influences on spill capacity at Lower Monumental are basically identical to those at Lower Granite. A spillway rating curve with the SBC installed is shown in Figure 8.2.

Likewise issues and features associated with the BGS design are similar. As a result of the forebay shoreline features at Lower Monumental, the BGS is 556 meters (1,824 feet) long, or over 13 percent longer than the BGS described for Lower Granite. The final 38 meters (124 feet) consists of a surface to bottom flexible curtain section. The longer BGS proposed for Lower Monumental yields a larger underflow area. At MOP, the presented BGS has an approximate underflow area of 4,550 m^2 (49,000 ft^2) which yields an underflow velocity of 0.54 m/s (1.77 ft/s). On the other hand, the lack of a flood drawdown scenario at Lower Monumental will allow the final design of the BGS panels to come closer to the bottom of the forebay should this prove advantageous.

The hydraulic features of the FLE are as described in Section 8.1.1, including supplemental pumping. A final design analysis may reveal the need for slightly greater pumping capabilities because the FLE at Lower Monumental would be about 46 meters (150 feet) longer.

8.3.2 Structural Design

Structural design issues and criteria for the Type 3 SBC at Lower Monumental are the same as presented for Lower Granite in Section 8.1.2, and Section 5.1.2 as applicable to the Type 3 design. Although potential wind-driven wave loading is slightly greater than for Lower Granite, it is significantly less than at Little Goose and should not present a problem. Structural issues associated with the new ESBS intake diversion system are as described in Section 5.3.2.

8.3.3 Mechanical Requirements

Mechanical requirements for the Type 3 SBC at Lower Monumental are similar to those at Lower Granite except that the debris skimmer is not required, which reduces the system complexity somewhat. Mechanical requirements for the new ESBS systems are as described in Section 5.3.3.

8.3.4 Electrical Requirements

Except for the lack of a debris skimmer in the juvenile gallery, the electrical loads for the Type 3 SBC at Lower Monumental are the same as for those for the Type 3 SBC at Lower Granite (see Section 8.1.4) and total approximately 350 amperes at 480 volts ac. Calculations for estimated electrical load are provided in Attachment A. Power source and routing issues are the same as for the Type 1 SBC at Lower Monumental for a load of this magnitude (see Section 5.3.4). A one-line diagram illustrating the electrical loads, power sources, and components are provided on Plate 3.2.6.

8.3.5 Operation and Maintenance Issues

O&M issues are similar to those for the Type 3 at Lower Granite and are described in Section 8.1.5, except that there is no debris skimmer to maintain. O&M issues and costs associated with the new ESBS system are assumed to be similar to the existing STS system and do not represent a significant change in requirements.

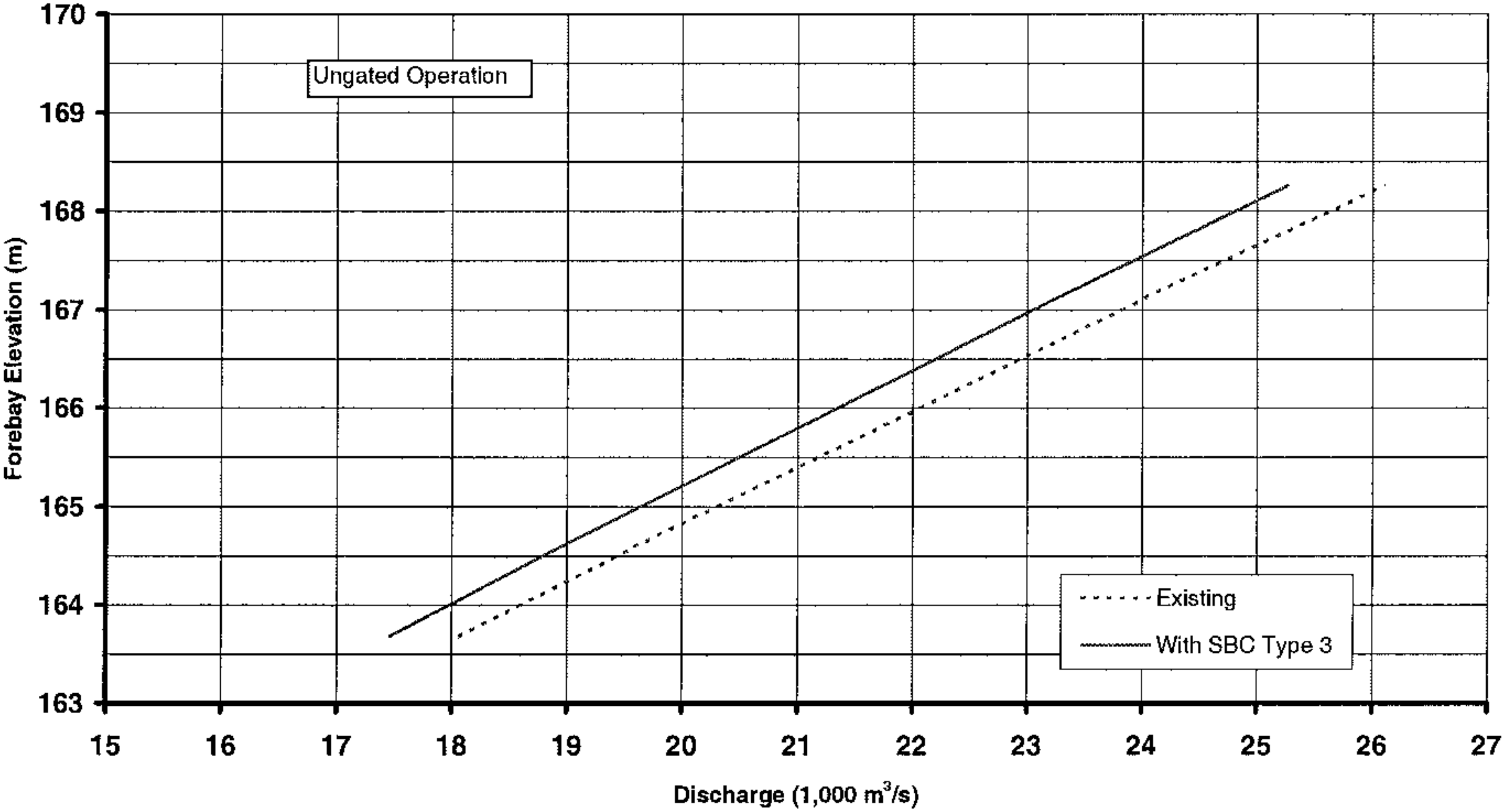


Figure 8.2 - Lower Monumental Lock and Dam - Spill Capacity with SBC Type 3

App E/Annex B/Figures 7.1 - 8.3.xls

Construction Issues

Construction issues are similar to those for the Type 3 at Lower Granite and are described in Section 8.1.6. Access is slightly improved due to fewer lockage events to reach Lower Monumental.

8.3.6 Construction and O&M Costs

Total estimated cost of engineering design and construction for the Type 3 SBC bypass at Lower Monumental, including a new ESBS intake diversion system, is $60,083,000 in 1998 dollars. The estimated cost for replacing the existing STS intake diversion system with a new ESBS system is an additional $16,058,000. A cost breakdown is presented in spreadsheet format on the following three pages. Annual O&M costs are estimated as follows:

Maintenance	
Mechanical/electrical components	$108,900
Structural components	$148,200
Operations	
Labor requirements	$80,000
Total annual O&M	**$337,100**

These O&M costs do not include costs associated with O&M of the ESBS diversion system, juvenile fish facilities, or transportation costs, as these are considered existing documented costs. Biological study costs are also not included.

8.4 Ice Harbor: Spillway SBC (with New ESBS) – SBC Type 4

The goal of the Type 4 SBC design is to provide an SBC facility at the spillway to divert fish away from the powerhouse and toward the spillway. One (or possibly more) spillbays would be modified to (each) provide an overflow spill of approximately 170 m^3/s (6,000 cfs) at the surface of the forebay to attract and safely pass the fish directly to the tailrace. An RSW is proposed to serve this function at Ice Harbor, as depicted on Plates 3.3.1 through 3.3.4 in Section 8.6.

The RSW is a removable steel ogee-shaped structure which is inserted into the existing spillbay creating a raised overflow weir above and upstream of the existing concrete ogee crest. No modifications, except addition of support brackets, would be required to the existing spillway to accommodate the RSW. The elevation of the new crest is designed to pass approximately 170 m^3/s (6,000 cfs) in an uncontrolled open-channel flow condition at the average operating pool elevation of 133.7 meters (438.5 feet). The flow would be either on or off, dictated by whether the Tainter gate is in a fully open or fully closed position, as shown on Plate 3.3.2. Since the flow is essentially uncontrolled, the flow rate would vary depending on the forebay water surface elevation. Discharge would be greater when the forebay is at maximum operating pool and smaller when at the MOP. The details of the hydraulic characteristics of the structure are discussed in Section 8.4.1.

A BGS is included in the forebay to guide fish away from the powerhouse and toward the spillway where they can experience the hydraulic effects of the modified spillway flow. The basic design and function of the BGS is the same as was described for the Type 3 design in Section 8.1. However, for the Type 4 design the downstream end of the BGS would be located between the powerhouse and the spillway.

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TYPE 3 SBC - 2-UNIT BYPASS/COLLECTION SBC - LOWER MONUMENTAL LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**SBC CHANNEL**				
	Channel Structure (exterior floor and walls)	4,060	M^2	710	**2,882,600**
	Interior Conduit Structures (floors and walls minus screens)	3,950	M^2	710	**2,804,500**
	Miscellaneous Walkways, Roof Structures, Entrance Debris Skirt (% of costs above)	5,687,100	$	10%	**568,710**
	Channel Flotation Cells	180	M	7,660	**1,378,800**
	Dewatering Screen Panels (removable panels stainless steel wedge-wire screen with spare panels	390	M^2	1,470	**573,300**
	Screen Cleaners (vertical brush cleaners)	12	EA	35,000	**420,000**
	Channel Entrance Debris Rake System	1	LS	482,000	**482,000**
	Entrance Sliding Doors, Hinged Gate, Control Gates, and Tilting Weir	215	M^2	1,640	**352,600**
	Cutoff Wall (includes foundation)	475	M^2	1,170	**555,750**
	Structural Support and Guide System	50	Tonne	5,000	**250,000**
	ITEM SUBTOTAL				**10,268,260**
2	**SPILLWAY EXTENSION STRUCTURE**				
	Structure Floor and Wall Panels	520	M^2	1,530	**795,600**
	ITEM SUBTOTAL				**795,600**
3	**CHANNEL CONDUIT CONNECTION TO GALLERY (AT CENTRAL NON-OVERFLOW**				
	Steel Caissons and Related Structures	139	M^2	1,530	**212,670**
	Concrete Removal	60	M^3	1,330	**79,800**
	ITEM SUBTOTAL				**292,470**
4	**SPILLBAY 1 MODIFICATIONS**				
	Elevated Ogee Concrete	200	M^3	466	**93,200**
	Mid-Spillbay Pier Wall Concrete	1,800	M^3	598	**1,076,400**
	Removal of Existing 15.24-M Wide Tainter Gate	1	LS	342,000	**342,000**
	New 10.67-M Wide Tainter Gate including Gate Hoist Modifications	1	LS	835,000	**835,000**
	Vertical Leaf Gate and Hoists	1	LS	107,000	**107,000**
	Stoplogs for 10.67-M Wide Spillbay	203	M^2	880	**178,640**
	Upstream Dewatering Bulkhead (for use during construction of spillbay modifications)	1	LS	1,220,000	**1,220,000**
	ITEM SUBTOTAL				**3,852,240**
5	**BEHAVIORAL GUIDANCE STRUCTURE (BGS)**				
	BGS	518	M	18,200	**9,427,600**
	FLE	214	M	8,070	**1,726,980**
	Mechanical Requirements	1	LS	175,000	**175,000**
	ITEM SUBTOTAL				**11,329,580**

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TYPE 3 SBC - 2-UNIT BYPASS/COLLECTION SBC - LOWER MONUMENTAL LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
6	**MISCELLANEOUS**				
	Electrical Requirements	1	LS	267,790	267,790
	ITEM SUBTOTAL				267,790
	Subtotal Direct Construction Costs				26,805,940
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	26,805,940	$	5.0%	1,340,297
	General Contractors Overhead and Profit	28,146,237	$	26.5%	7,458,753
	CONSTRUCTION SUBTOTAL				35,604,990
	Construction Contingency	35,604,990	$	25.0%	8,901,247
	TOTAL CONSTRUCTION COSTS				***44,506,237***
	PLANNING AND ENGINEERING	44,506,237	$	22.5%	10,013,903
	CONSTRUCTION MANAGEMENT	44,506,237	$	12.5%	5,563,280
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				$60,083,420

Because the entire powerhouse flow for all six turbines must pass below the BGS in this case, it needs to be considerably longer than the Type 3 BGS design. Therefore, the Type 4 BGS extends 729 meters (2,391 feet) upstream, as shown on Plate 3.3.3. The alignment of the BGS corresponds closely to that of a fish guidance curtain that was model studied at WES. As with the Type 3 design, the turbine intakes located behind the BGS will be outfitted with ESBS intake diversion systems which would divert fish into the existing juvenile gallery and eventually to the juvenile facilities downstream. In the case of Ice Harbor, the intakes are currently outfitted with an STS diversion screen system which would be removed and replaced with a new ESBS system.

The RSW is designed to be floated into place and submerged into position on the concrete spillway. The hollow steel structure would be filled with air for floating and towed to the spillway with an assist vessel. When the RSW is in the vicinity of the spillbay, portions of the volume would be selectively filled with water to rotate the structure into a vertical position. Once it is vertical, it can be pushed (or pulled with winches on the deck) into its final position above the existing spillway and further submerged until it rests on support brackets permanently mounted to the upstream face of the spillway. This installation process is similar to that used to install a large maintenance bulkhead at Wanapum and Priest Rapids Dams on the mid-Columbia River and is generally accomplished in less than a single work day. The ability to quickly and inexpensively install, and more importantly remove, the RSW is one of the major advantages of this design over other alternatives considered.

A number of alternatives for providing an overflow spill condition at the spillways were investigated prior to selecting the recommended RSW design. These included:

- an elevated concrete ogee crest with a new internal pier in Spillbay 1, similar to the design utilized in the Type 2 and Type 3 designs
- a new Tainter gate with an integrally constructed overflow gate which would allow flow through the gate onto an independently supported steel chute (This design was furthered in the earlier SBC Conceptual Design Report for application at Lower Granite but not selected for continued development in this report due to concerns about the plunge effects in the tailrace.)
- a new Tainter gate with an integrally constructed overflow gate which would allow flow through the gate onto a raised concrete ogee-shaped chute supported on a single central pier to be mounted on the existing spillway
- overflow/underflow baffles (or bulkheads) installed into the existing stop log slots located in the spillway piers (This approach is being studied by the Portland District of the Corps for testing at John Day Lock and Dam.)

The RSW design has a number of distinct advantages over the other alternatives considered. First, and probably foremost, is the ability to completely remove the structure from the spillway in a reasonably short period of time. By doing this the entire spillway flood design capacity can be restored. Because time is available for preparation prior to a major flood event (generally several days to a week), removing the RSW adequately in advance of a flood event should not present a problem. This feature could allow for installation of the RSW design at multiple spillbays, although it is only shown at one spillbay on Plate 3.3.1 to represent the concept. It should be noted that the historic flood of record is only about half the spillway flood design capacity; therefore, removal should be an extremely rare requirement if only one or a small number of spillbays are outfitted with an RSW. A rating curve was developed for the spillway with the RSW installed in one bay. This rating curve (Figure 8.3) shows an approximate 8 percent reduction in spill capacity at the maximum design flood forebay elevation of 136.1 meters (446.4 feet) if the RSW were not removed.

Although the overflow/underflow baffles also offer the advantage of relatively rapid removal, they have a number of disadvantages when compared to the RSW, including: 1) not all the flow is passed from the surface, 2) the fish which enter at the upper opening must sound rapidly down to the crest of the existing spillway to pass under the Tainter gate, and 3) the concept does not yet have a proven record of success. Either of the two alternatives that entail adding concrete to the existing spillway would result in some permanent reduction in total spillway flood capacity, although the reduction would be small if the modification were limited to a single spillbay. Although the alternative that includes a self-supporting steel chute could result in a design allowing for full spillway capacity, this would require very large capital expense and the use of unprecedented designs with numerous moving parts with limited access and large hoisting systems prone to potential problems. It would also result in a free plunge into the tailrace immediately downstream of the spillway deflector. Additional advantages of the RSW design are relatively low cost of the structure, spreading the attraction flow effects across an entire spillbay width, ability to move the structure to different spillbays to test for the optimum location (assuming mounting brackets are installed at each of the spillbays), a smooth hydraulic transition onto the existing spillway resulting in no free plunge into the tailrace, and proper functioning of existing spillway flow deflectors.

8.4.1 Hydraulics

Removable Spillway Weir Concept

Hydraulic design objectives for the RSW utilized in the Type 4 SBC spillway design included:

- releasing 170 m^3/s (6,000 cfs) through a single spill bay
- generating a uniform spill distribution across the full 15.2 meters (50.0 feet) spillbay width
- creating a gradual, tangential, flow transition to the existing spillway ogee
- fully installing the RSW upstream of the closed Tainter gate
- not interfering with structural members of the Tainter gates either in the closed or open position
- minimizing or eliminating impact on spillway design flood capacity.

Although the RSW depicted on Plate 3.3.2 was developed to release 170 m^3/s (6,000 cfs) through a single spillbay, the RSW concept offers flexibility to satisfy site-specific objectives and criteria. If for example, operating criteria would restrict discharge magnitudes for a particular spillbay, an RSW ogee and crest elevation could be developed to satisfy that criterion. It is conceivable that RSWs could be installed on multiple spillbays and configured to generate a desired spill pattern. A limitation would be space available upstream of the Tainter gates and the ability to transition to the existing spillway in the available space. This limitation would present a particular problem when attempting to design for a higher unit discharge.

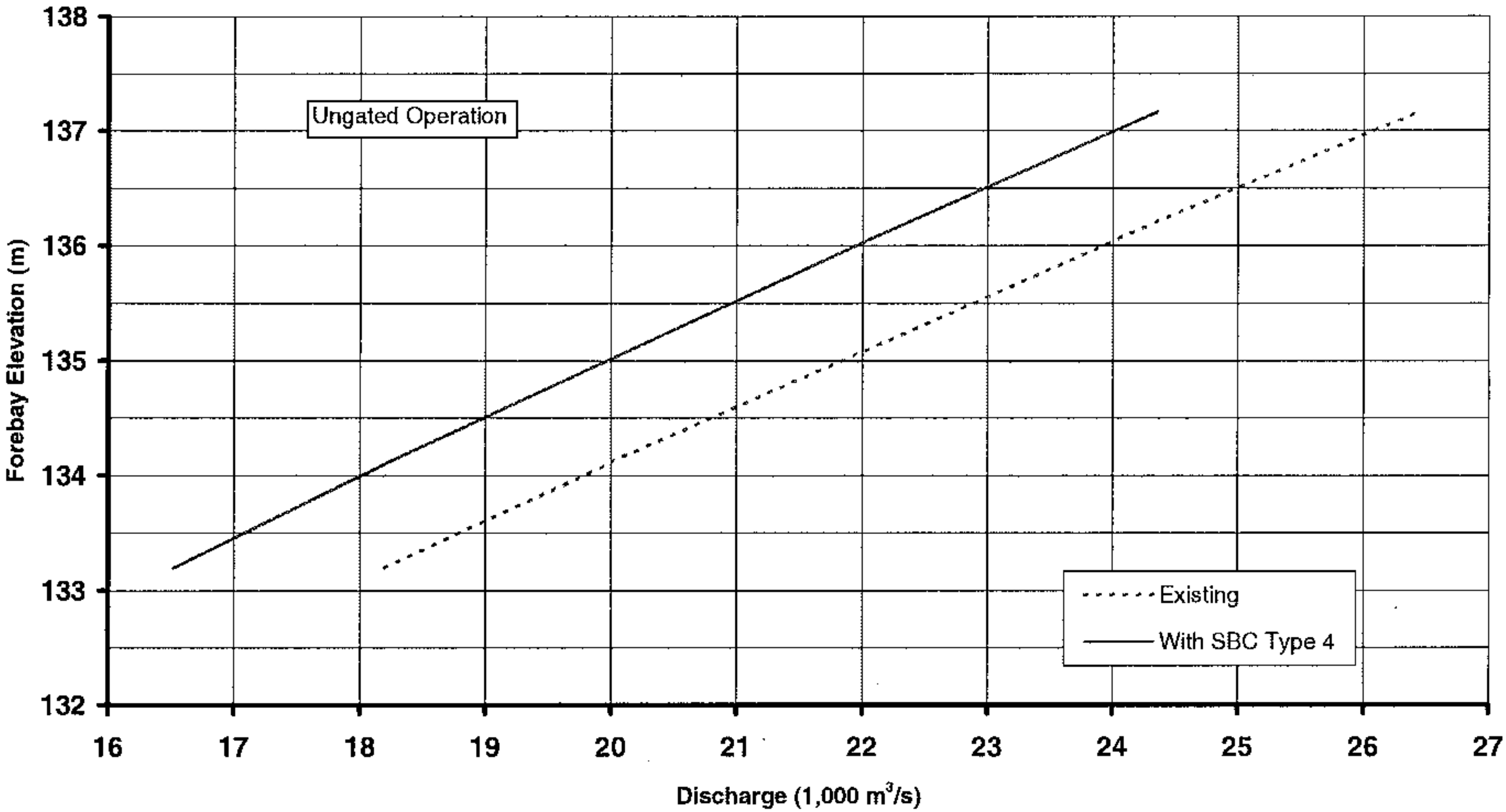

Figure 8.3 - Ice Harbor Lock and Dam - Spill Capacity with One SBC Type 4

App E/Annex B/Figures 7.1 - 8.3.xls

Note that the concept presented includes a 3.66-meter (12.0-foot) transition radius to the existing ogee. This compares to the 15.2-meter (50.0-foot) reverse curve radius that was used in the John Day juvenile facilities and the 4.57-meter (15-foot) reverse radius included in the Ice Harbor deflectors. Criteria is not available which establishes appropriate radius size, although indications are that longer radii may reduce injury to passing fish. It may be possible to lengthen the 3.66-meter (12.0-foot)-radius somewhat by moving the RSW crest further upstream, but there is not much length to be gained before the design becomes impractical. At this site, the generated 11.2-m^3/s/m (120-cfs/ft) unit discharge is pushing the maximum that can be passed in the limited space available upstream of the Tainter gate. It is suggested that modeling be performed to evaluate the hydraulic conditions which would occur at the reverse curve with the goal of optimizing the design to provide safe passage conditions.

Hydraulic Performance and Flow Variability

Discharge over the RSW will vary with forebay elevation. Based on an average discharge coefficient of 3.95 and an ogee crest elevation of 130.6 meters (428.5 feet), the following performance can be expected:

	Forebay Elevation in Meters (feet)		
	133.7 (438.5)	**134.1 (440.0)**	**133.2 (437.0)**
Spillbay discharge, m^3/s (kcfs)	177 (6.25)	217 (7.65)	139 (4.90)
RSW crest submergence, m (ft)	3.1 (10.0)	3.5 (11.5)	2.6 (8.5)
Critical velocity at crest, m/s (ft/s)	4.85 (15.9)	5.19 (17.0)	4.47 (14.7)

Note that performance of the RSW varies substantially with forebay stage. The discharge over the RSW varies from 139 m^3/s (4,900 cfs) to 210 m^3/s (7,650 cfs) as the head on the crest varies from 2.6 meters (8.5 feet) to 3.5 meters (11.5 feet). Corresponding critical velocities over the crest range from 4.47 m/s (14.7 ft/s) to 5.19 m/s (17.0 ft/s).

As the flow passes down the RSW and onto the existing spillbay ogee it will accelerate. Velocities at the toe of the reverse curve (point of tangency with the existing ogee) are dictated by the total drop and will be approximately 16.5 m/s (54 ft/s) for all operations. Corresponding depths are discharge dependent and will range from about 0.86 meter (2.83 feet) to 0.55 meter (1.81 feet) at maximum and minimum operating pool levels, respectively.

The surface weir arrangement may be beneficial with respect to fish attraction in that flow accelerations in the forebay upstream of the weir are less pronounced than those which would be generated through a deeper free-overflow vertical slot. For example, a free-overflow slot operating with a 6.1-meter (20.0-foot) head on the slot crest would generate a critical velocity of 6.77 m/s (22.2 ft/s). This corresponds to the critical velocity of 4.85 m/s (15.9 ft/s) that the RSW generates when operating with a mean head on the crest of 3.05 meters (10.0 feet). Because flow accelerates toward an overflow weir over a relatively short distance, the local accelerations in the vicinity of the deeper weir could be more likely to cause a startle response from the fish resulting in rejection of the weir flow.

Behavioral Guidance Structure

Hydraulic features of the BGS are similar to those discussed in the presentation of the Type 3 concept, with the BGS extending to the shore. However, because the BGS for the Type 4 design is located upstream of all six powerhouse units, it requires sufficient underflow area to accommodate the 2,973 m^3/s

(105,000 cfs) discharge capacity of the powerhouse while maintaining underflow velocities below 0.61 m/s (2.0 ft/s). At MOP, the BGS presented supplies an underflow area of approximately 5,574 m^2 (60,000 ft^2) which yields a underflow velocity of 0.53 m/s (1.75 ft/s).

Issues and features associated with the FLE are similar to those discussed with the Type 3 SBC concepts. However, the location and orientation of the longer BGS requires that the FLE at Ice Harbor be significantly longer than for the Type 3 SBC designs. Because the original design of an FLE was for installation at Ice Harbor, the pump sizing previously discussed should be most applicable to this design.

8.4.2 Structural Design

Spillway and Non-Overflow Dam Stability

The installed configuration of the RSW at the spillways produces loading conditions at the spillway and non-overflow dam structures that differ from those encountered in the original design of the project. Specifically, when the RSW is in an operating configuration with the Tainter gate open, a portion of the water which would normally be over the spillway when the Tainter gate is closed is no longer there. As can be seen on Plate 3.3.2, a significant portion of the area upstream of the Tainter gate is dewatered and would be dewatered on a long-term basis representing a new normal operating condition for the spillway. A review of the stability issues for the spillway monolith under this configuration suggests that the combination of reduced water weight on the structure, plus the added weight of the RSW, results in a slight reduction in the normal operating condition stability. A static evaluation of the spillway monolith stability with earthquake loading also resulted in a slight reduction. Although these reductions were quite small in magnitude, they were based on conceptual layout and estimated weight for the RSW. Given that stability of the structures is a critical item, a more exact analysis of the spillway and central non-overflow monoliths should be performed during any final design of an RSW type bypass system making use of final design weights and locations of the components. In could be possible to add dead weight to the structure at strategic locations to compensate for any undesirable reductions in overall stability. Calculations addressing this issue are included in Attachment A.

Removable Weir Structure

The weir structure proposed for Type 4 SBC is shown as a hollow steel structure which, under normal operating conditions (when the Tainter gate is fully open), is pressed against the upstream faces of the piers by hydrostatic pressure and spans horizontally between these piers. When the pressure is relieved (caused by fully closing the Tainter gate) the weir would rest on support brackets located below the weir on the sloped upstream portion of the spillway and be held back by support arms located at the top of the piers. The advantages of the hollow design is to allow for the structure to be filled with air so that it can be floated away from the spillway area and stored remotely if the full design capacity of the spillway is required.

A conceptual-level design of the structure has been performed and appears in Attachment A. The design approach is to treat the structure as a box structure with internal deep plate members providing the shear and moment resistance, and creating discrete internal compartments. Normal installation of the weir would involve floating it into place and flooding the internal portions of the weir to improve the structural performance of the weir (minimize vibrations during use) and to provide additional mass to the spillway monolith to improve the stability characteristic of the structure due to the internal weight of the water. The compartments form convenient discrete void areas into which air can be introduced to optimize the deployment and retrieval of the weir. Preliminary estimates suggest an overall structure dry weight of approximately 450 tonnes (500 tons) with a buoyancy of approximately 1,043 tonnes (1,150 tons) if all voided areas are filled with air.

Other structural design approaches seem feasible. These include a system of internal stiffeners supporting the exterior steel shell, supported by internal bracing members. The lack of compartmentalization of this approach is a drawback of this design but might reduce overall structure weight and thus, cost. Compartments created by other voided items (e.g., large buoyancy tanks) could be incorporated into the internal areas of the weir. These are seen as final design issues. Cost estimates for the structure were based on the internal plate design described earlier.

The weir fairings and deployment lugs extending above the water surface on either side of the weir (depicted on Plate 3.3.2) are assumed to be stiffened plate structures and would serve to allow the weir to be deployed and retrieved as well as providing a support point for the arms at the top of the piers.

The sealing surfaces of the structure would be along the bottom of the weir against the sloped spillway and along the vertical upstream faces of the piers.

8.4.3 Mechanical Requirements

There are three main features of this installation which involve mechanical systems: FLE, RSW, and the ESBS intake diversion system. Issues related to the FLE and the ESBS systems have been addressed earlier for other projects. The FLE, which was originally developed for Ice Harbor, already has a completed mechanical design which is assumed to be satisfactory for this installation and involves water pumps and piping, hydraulic systems, and water control gates.

The mechanical requirements for the RSW, as conceived for Ice Harbor, involves the design of an air buoyancy/water ballast system which would involve air and water piping, valving, air compressors, and monitoring equipment. Similarly sized large floating devices deployed at spillways have been constructed with variable buoyancy designs (e.g., the floating spillway bulkheads at Wanapum and Priest Rapids Dams) and the design of this type of system is seen as being relatively straight forward. Final design issues associated with proper ballasting could be handled by a naval architect.

8.4.4 Electrical Requirements

There are no dam-based electrical load requirements for the Type 4 SBC except for the water pump and hydraulic pump loads for the FLE which total approximately 160 amperes at 480-volt alternating current. Calculations for estimated electrical loads are provided in Attachment A. There will likely be temporary support boat-based power requirements for a compressed air system to facilitate manipulation of the buoyancy system for the RSW. This would likely be provided by the existing or an auxiliary electrical power system on the assist vessel.

To provide power for the FLE electrical systems at Ice Harbor, the most convenient source would be MCC FCQ3 [24]. FCQ3 is located at about elevation 135.0 meters (443 feet) in a gallery in the south non-overflow section of the dam about 91.4 meters (300 feet) south of the joint with the service bay. A new cubicle would have to be added to this existing 480-volt equipment. To accommodate this additional load, the feeder from FSQ1 to FCQ3 would have to be increased in size, requiring about 213.4 meters (700 feet) of new feeder. From FCQ3, the concrete deck would have to be penetrated to reach the FLE facilities near the fish ladder exit. A one-line diagram illustrating the electrical loads, power sources, and components are provided on Plate 3.3.4.

8.4.5 Operation and Maintenance Issues

Corrosion Protection

Maintenance access to the RSW would be very limited when it is installed on the spillway. Although it could be removed and towed to the shore for periodic inspections and maintenance, including recoating, it is recommended that a thermal spray metal coating system be used to protect this component. In addition to the reduced maintenance requirements this would offer, the use of thermal spray metal coating systems have distinct advantages in the highly abrasive environment associated with spillway flow. A conventional paint system applied to the RSW would likely deteriorate in a relatively short period of time. Thermal spray systems on the other hand have been used successfully in these conditions for relatively long periods of time. However, because access to all system components is possible for repair of coating systems, a cost analysis of both conventional paint and thermal systems would be warranted to compare life cycle costs. Corrosion protection strategies for the BGS component are similar to suggested for the BGS in the Type 3 design.

Emergency RSW Removal

The operation of the RSW includes the assumption that it would be removed prior to design flood events so that the hydraulic capacity of the project could be maximized. This is not anticipated to be a very frequent occurrence since the flood of record on the lower Snake River is 11,600 m^3/s (409 kcfs), which occurred in 1894 before the construction of any flood control dams on the river, and this is about half the hydraulic capacity of the spillways. Nonetheless, there is some concern that if a major flow event occurred, the ability to remove the RSW at higher flows may be hampered by access restrictions in the spillway area for safety reasons. These higher flows, while not yet major flood events, might preclude the removal of the RSW if indications were that a design flood event might occur. Thus, the actual removal of the RSW might be more frequent than anticipated if no other operational plan is implemented to assist in the removal under high flows. One possible resolution of this issue would be to implement an operational plan that would require Lower Granite pool to be drafted to its minimum flood control pool elevation and then allowed to partially fill while temporarily allowing downstream discharge to be reduced, thus enabling the RSW to be removed.

Another possible resolution would be to incorporate explosive bolts at critical connections on the RSW to allow it to be flushed downstream. Still another possibility is to accept the reduction in spillway capacity (approximately 8.3 percent) with the RSW in place at surcharged flood pool.

8.4.6 Construction Issues

All of the major features for Type 4 SBC design are assumed to be fabricated off site and shipped fully assembled to the site if barging is employed. These include the ESBS system, the RSW, the FLE, and the BGS. Construction issues related to installation of the ESBS system, the FLE, and the BGS have been addressed in earlier discussions.

Installation of the RSW will require a one-time underwater installation of large bracket assemblies along the upstream slope of the spillway ogee. These brackets would support the RSW when no hydrostatic pressure is applied and it is fully ballasted. This would be a diver installation. Above-water retainer brackets would be installed at the top of the piers to prevent the RSW from rotating into the forebay under these conditions. The actual installation of the RSW would involve floating the structure into place with the aid of an assist vessel. By flooding select internal cells the RSW would be rotated into its vertical orientation over the spillbay. Finally, the remainder of the internal cells would be flooded and the RSW would sink onto the submerged bracket assemblies. The top brackets would be attached to secure the structure in place. If air piping were provided up the side fairings to above water locations, providing access to the internal cells, the RSW could be floated off its support brackets by the assist vessel without the need for any underwater work.

Construction Duration

Fabrication of the BGS and FLE components should take 3 to 5 months. Fabrication of the RSW would also take about that length of time. Installation of the RSW, BGS, and FLE should take about 3 months. Fabrication and installation of the ESBS system should take 7 to 8 months.

8.4.7 Construction and O&M Costs

Total estimated cost of engineering design and construction for the Type 4 Spillway SBC at Ice Harbor, including a new ESBS intake diversion system, is $40,779,000 in 1998 dollars. The estimated cost of replacing the existing STS intake diversion system with a new ESBS system is an additional $16,058,000. A cost breakdown is presented in spreadsheet format on the following two pages. Annual O&M costs are estimated as follows:

Maintenance	
Mechanical/electrical components	$17,100
Structural components	$112,300
Operations	
Labor requirements	$10,000
Total annual O&M	**$139,400**

These O&M costs do not include costs associated with O&M of the ESBS diversion system, juvenile fish facilities, or transportation costs, as these are considered existing documented costs. Biological study costs are also not included.

8.5 Combination Summary

8.5.1 Combined Construction Issues

Construction of the combined system at the four projects involves the same issues and offers the same construction and contracting efficiency possibilities as were identified in Sections 5.5.1 and 7.5.1.

8.5.2 Summary Construction and O&M Costs

The total combined estimated engineering design and construction cost for the System Combination 3 design is $243,472,000 in 1998 dollars. Additional costs will likely be incurred if prototyping and/or major hydraulic modeling efforts of system components are deemed to be required, as is discussed in Section 4.2. Some savings in cost may be experienced due to efficiency of repetitive design and

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ESTIMATOR: PJC
CHECKED BY: RGW

TYPE 4 SBC - SPILLWAY SBC - ICE HARBOR LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**BEHAVIORAL GUIDANCE STRUCTURE (BGS)**				
	BGS	671	M	18,400	**12,346,400**
	FLE	353	M	8,070	**2,848,710**
	Mechanical Requirements	1	LS	175,000	**175,000**
	ITEM SUBTOTAL				**15,370,110**
2	**REMOVABLE SPILLWAY WEIR (RSW)**				
	Modifications to Spillbay	1	LS	70,000	**70,000**
	Fabrication and Installation of RSW	540	Tonne	5,000	**2,700,000**
	ITEM SUBTOTAL				**2,770,000**
3	**MISCELLANEOUS**				
	Electrical Requirements	1	LS	53,090	**53,090**
	ITEM SUBTOTAL				**53,090**
	Subtotal Direct Construction Costs				**18,193,200**
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	18,193,200	$	5.0%	**909,660**
	General Contractors Overhead and Profit	19,102,860	$	26.5%	**5,062,258**
	CONSTRUCTION SUBTOTAL				**24,165,118**
	Construction Contingency	24,165,118	$	25.0%	**6,041,279**
	TOTAL CONSTRUCTION COSTS				***30,206,397***
	PLANNING AND ENGINEERING	30,206,397	$	22.5%	**6,796,439**
	CONSTRUCTION MANAGEMENT	30,206,397	$	12.5%	**3,775,800**
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				**$40,778,636**

PROJECT: LOWER SNAKE RIVER S.B.C. SYSTEM COMBINATIONS - CONCEPT DESIGN REPORT
DESIGN STATUS: CONCEPTUAL

DATE: Nov-98
ESTIMATOR: PJC
CHECKED BY: RGW

NEW EXTENDED LENGTH SUBMERGED BAR SCREENS - ICE HARBOR LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**ESBS INTAKE DIVERSION SCREENS**				
	Installation of ESBS Diversion Screens	18	EA	398,000	7,164,000
	ITEM SUBTOTAL				7,164,000
	Subtotal Direct Construction Costs				7,164,000
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	7,164,000	$	5.0%	358,200
	General Contractors Overhead and Profit	7,522,200	$	26.5%	1,993,383
	CONSTRUCTION SUBTOTAL				9,515,583
	Construction Contingency	9,515,583	$	25.0%	2,378,896
	TOTAL CONSTRUCTION COSTS				***11,894,479***
	PLANNING AND ENGINEERING	11,894,479	$	22.5%	2,676,258
	CONSTRUCTION MANAGEMENT	11,894,479	$	12.5%	1,486,810
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				**$16,057,546**

construction, as discussed in Section 8.5.1. However, this potential savings has not been estimated as part of this report. A summary of the estimated costs by project is shown in the following table.

Estimated Engineering Design and Construction Cost – System Combination 3

Project	Description	Estimated Construction Cost
Lower Granite	Type 3 SBC (with existing ESBS)	$65,698,000
Little Goose	Type 2 SBC (with existing ESBS)	$43,796,000
Lower Monumental	Type 3 SBC	$60,083,000
Lower Monumental	New ESBS	$16,058,000
Ice Harbor	Type 4 SBC	$40,779,000
Ice Harbor	New ESBS	$16,058,000
	System Combination Subtotal	$242,472,000
	Feasibility Studies	$1,000,000
	Total Estimated Construction Cost	**$243,472,000**

The total annual O&M costs for System Combination 3 are estimated to be $982,800 in 1998 dollars. These O&M costs do not include costs associated with O&M of the ESBS intake diversion systems, existing juvenile fish facilities, or transportation costs. Biological study costs are also not included. A summary of the O&M costs by project is shown in the following table:

Estimated Operation and Maintenance Cost – System Combination 3

Project	Description	Estimated O&M Cost
Lower Granite	Type 3 SBC (with existing ESBS)	$350,300
Little Goose	Type 2 SBC (with existing ESBS)	$156,000
Lower Monumental	Type 3 SBC (with new ESBS)	$337,100
Ice Harbor	Type 4 SBC (with new ESBS)	$139,400
	Total Estimated Annual O&M Cost	**$982,800**

8.5.3 Implementation Schedule

An implementation schedule is included below. The assumptions and rationale used for development of the implementation schedule is provided. The implementation schedule includes time for hydraulic model testing as appropriate, preliminary design, preparation of construction contract documents, and construction. The implementation schedule assumes no funding or manpower restraints. Such restraints would likely affect the schedule included herein.

Lower Granite Dam

The BGS creates a gap between the upstream end of the BGS and the shore. This gap creates an opportunity for juvenile fish to become trapped between the shore and the BGS. The gap must be configured to accommodate upstream movement of adult fish while minimizing trapped juvenile fish. A variety of methods to address the gap problem would be tested; the most successful configuration would be used for the design of the permanent BGS. The existing prototype BGS would likely be used for the tests. Development of a construction contract to provide for testing the BGS gap would be scheduled for the year 2000, and construction and testing would be scheduled for the year 2001. Hydraulic model testing of a raised spillbay would also be scheduled for year 2001; the testing is important to determine the optimum ogee shape. Hydraulic model testing of various dewatering methods would be scheduled for the year 2000. The SBC structure at Lower Granite spans the width of Generator Units 5 and 6. Because a prototype SBC structure would be about the same size as a permanent SBC structure, it is assumed that the prototype test structure would be used for the final structure following the completion of testing. Preliminary and final design leading to development of construction contract documents for the SBC and BGS would be scheduled for the years 2001 and 2002 with construction scheduled for years 2003 and 2004. The SBC would be operational in 2004.

Little Goose Dam

The construction work at Little Goose would be scheduled to occur after completion of work at Lower Granite. The effectiveness of the SBC at Lower Granite would be tested in the year 2005. Results of the testing would be used for development of the final full-flow bypass and modified spillbay at Little Goose. Hydraulic model testing of a modified spillbay for Little Goose would be scheduled for the year 2005. Preliminary and final design leading to the development of construction contract documents for the SBC and modified spillbay would be scheduled for the years 2005 and 2006. Construction would be scheduled for the years 2007 and 2008. The SBC would be operational in the year 2008.

Lower Monumental Dam

Like Little Goose, the final design and construction of the proposed improvements would not be completed until data gathering at Lower Granite are complete. This is important because the improvements proposed for Lower Monumental are similar to those for Lower Granite. Lessons learned from the SBC at Lower Granite may then be incorporated into the design for Lower Monumental. Model testing of the raised spillbay would be scheduled for the year 2005. It is likely that the results from the Lower Granite model testing would be sufficient to minimize model-testing efforts for Lower Monumental. Preliminary and final design leading to preparation of construction contract documents for the SBC, BGS, and modified spillbay would be scheduled for years 2005 and 2006. Construction would be scheduled for years 2007 and 2008. The SBC would be operational in the year 2008.

Ice Harbor Dam

Because the spillway crest would have a RSW, hydraulic model testing of the weir would be required. Also, a model of the forebay with the BGS structure is necessary to determine the optimum layout of the BGS and to check flows in the vicinity of the modified spillbay. Both the modeling efforts would be scheduled for year 2000. Because there is no BGS planned for Ice Harbor, preparation of construction contract documents, as well as construction, can occur prior to evaluation of the effectiveness of the Lower Granite BGS. Preliminary and final design leading to preparation of construction contract documents would be scheduled for year 2001, and construction scheduled in year 2002. The BGS to the modified spillbay would be operational in year 2002.

8.6 System Combination 3 Drawings

Drawings depicting the SBC designs which form System Combination 3 are included on the following pages. These drawings include:

SBC Type 3 – Lower Granite

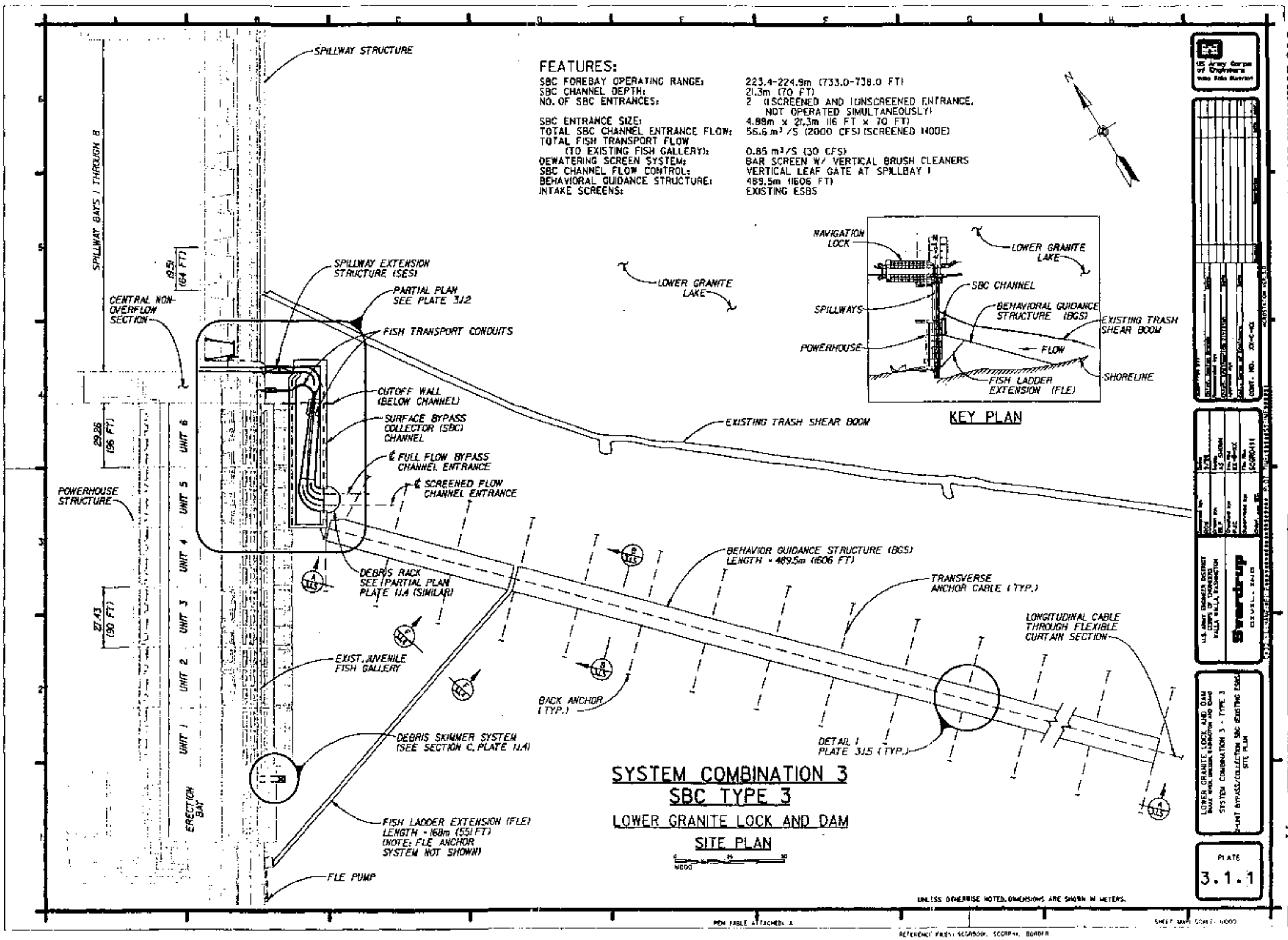
Plate 3.1.1 – SBC Type 3 – 2-Unit Bypass/Collection SBC (Existing ESBS) - Site Plan
Plate 3.1.2 – SBC Type 3 – Unit 5/6 Entrance - Plan
Plate 3.1.3 – SBC Type 3 – Sections and Elevation
Plate 3.1.4 – SBC Type 3 – Spillbay 1 - Section
Plate 3.1.5 – SBC Type 3 – Behavioral Guidance Structure – Profile and Details
Plate 3.1.6 – SBC Type 3 – Electrical One-Line Diagram

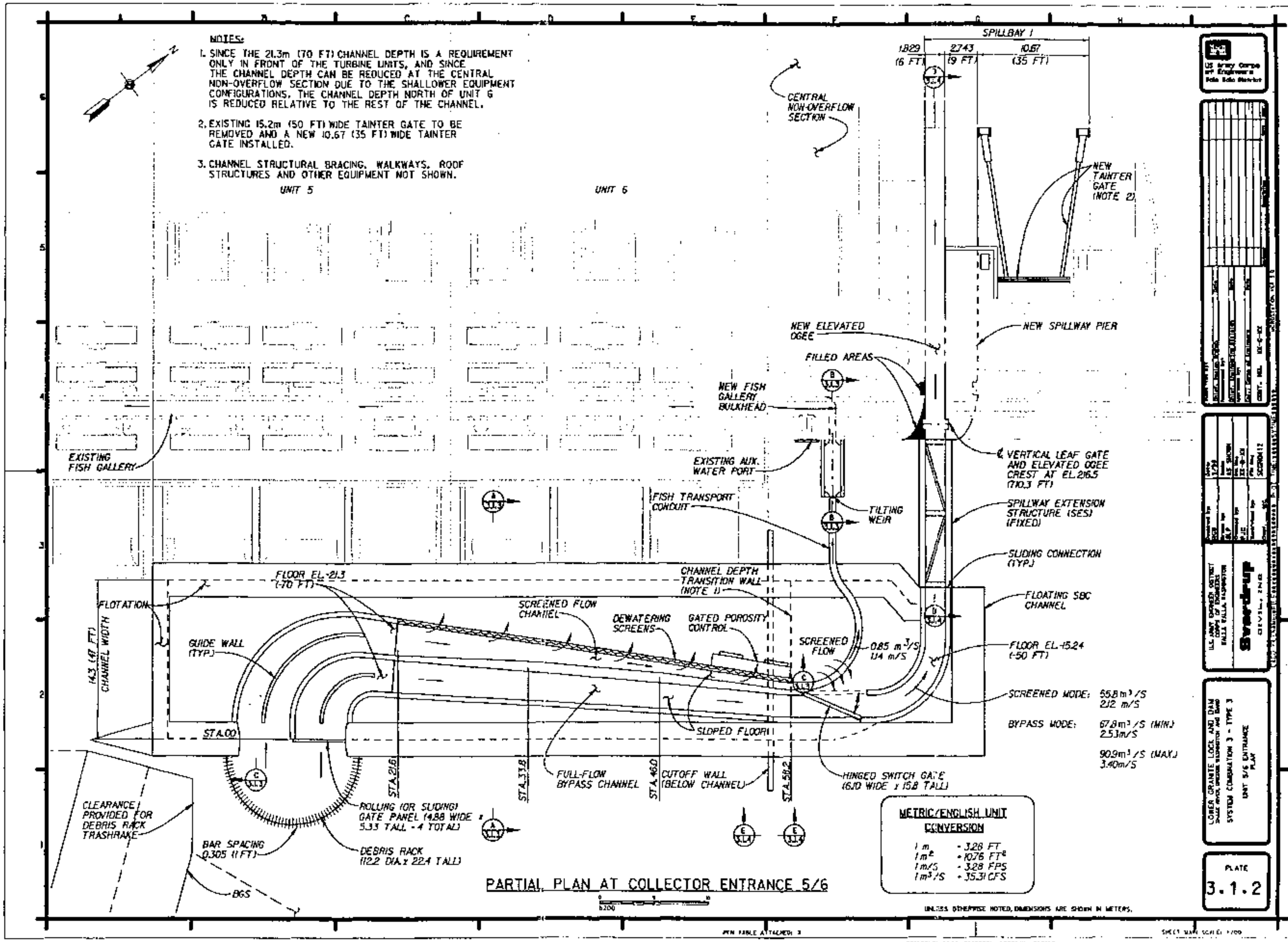
SBC Type 3 – Lower Monumental

Plate 3.2.1 – SBC Type 3 – 2-Unit Bypass/Collection SBC (Existing ESBS) - Site Plan
Plate 3.2.2 – SBC Type 3 – Unit 5/6 Entrance - Plan
Plate 3.2.3 – SBC Type 3 – Section
Plate 3.2.4 – SBC Type 3 – Spillbay 8 - Section
Plate 3.2.5 – SBC Type 3 – Behavioral Guidance Structure - Profile
Plate 3.2.6 – SBC Type 3 – Electrical One-Line Diagram

SBC Type 4 – Ice Harbor

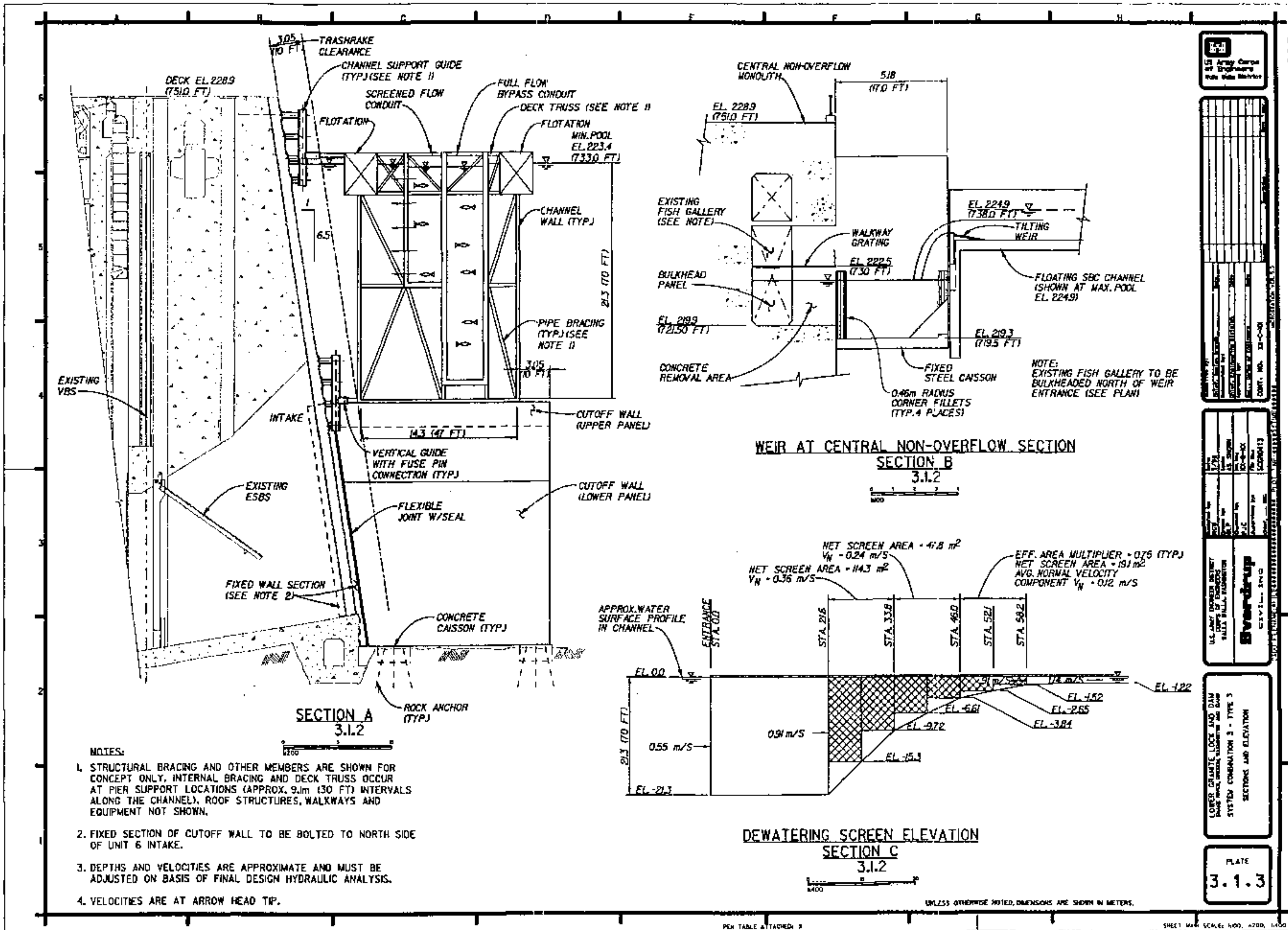
Plate 3.3.1 – SBC Type 4 – Spillway SBC (New ESBS) – Site Plan
Plate 3.3.2 – SBC Type 4 – Spillbay – Plan and Section
Plate 3.3.3 – SBC Type 4 – Behavioral Guidance Structure – Profile
Plate 3.3.4 – SBC Type 4 – Electrical One-Line Diagram

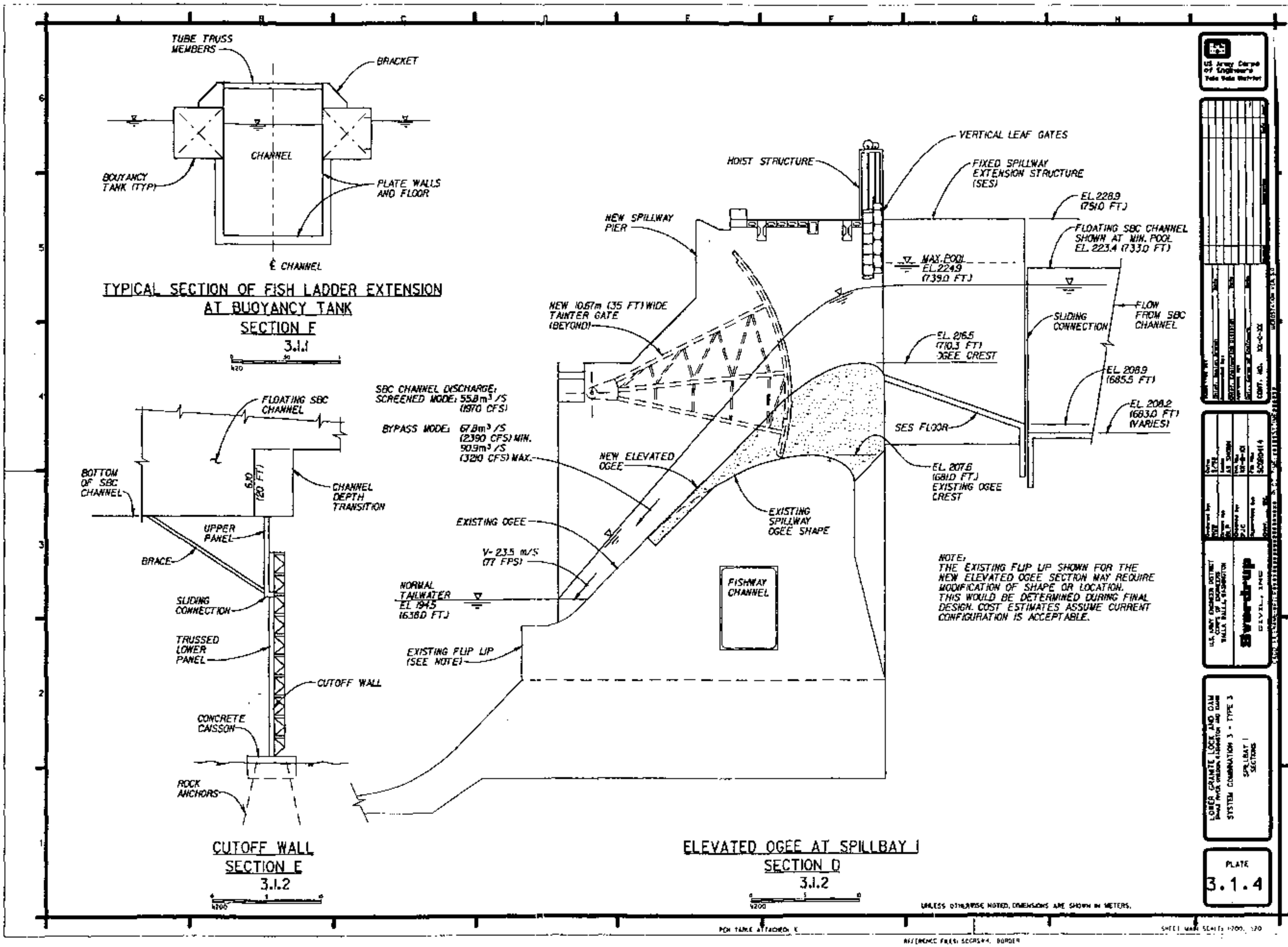

SPILLWAY STRUCTURE
FEATURES:
SBC FOREBAY OPERATING RANGE: 223.4-224.9m (733.0-738.0 FT)
SBC CHANNEL DEPTH: 21.3m (70 FT)
NO. OF SBC ENTRANCES: 2 (SCREENED AND UNSCREENED ENTRANCE, NOT OPERATED SIMULTANEOUSLY)
SBC ENTRANCE SIZE: 4.88m x 21.3m (16 FT x 70 FT)
TOTAL SBC CHANNEL ENTRANCE FLOW: 56.6 m³/S (2000 CFS) (SCREENED MODE)
TOTAL FISH TRANSPORT FLOW (TO EXISTING FISH GALLERY): 0.85 m³/S (30 CFS)
DEWATERING SCREEN SYSTEM: BAR SCREEN W/ VERTICAL BRUSH CLEANERS
SBC CHANNEL FLOW CONTROL: VERTICAL LEAF GATE AT SPILLBAY 1
BEHAVIORAL GUIDANCE STRUCTURE: 489.5m (1606 FT)
INTAKE SCREENS: EXISTING ESBS
SPILLWAY BAYS 1 THROUGH 8
19.51 (64 FT)
CENTRAL NON-OVERFLOW SECTION
SPILLWAY EXTENSION STRUCTURE (SES)
PARTIAL PLAN SEE PLATE 3.1.2
FISH TRANSPORT CONDUITS
LOWER GRANITE LAKE
CUTOFF WALL (BELOW CHANNEL)
SURFACE BYPASS COLLECTOR (SBC) CHANNEL
℄ FULL FLOW BYPASS CHANNEL ENTRANCE
℄ SCREENED FLOW CHANNEL ENTRANCE
29.26 (96 FT)
POWERHOUSE STRUCTURE
UNIT 6
UNIT 5
UNIT 4
UNIT 3
UNIT 2
UNIT 1
ERECTION BAY
27.43 (90 FT)
EXISTING TRASH SHEAR BOOM
DEBRIS RACK SEE PARTIAL PLAN PLATE 3.1.4 (SIMILAR)
BEHAVIOR GUIDANCE STRUCTURE (BGS) LENGTH = 489.5m (1606 FT)
TRANSVERSE ANCHOR CABLE (TYP.)
LONGITUDINAL CABLE THROUGH FLEXIBLE CURTAIN SECTION
EXIST. JUVENILE FISH GALLERY
BACK ANCHOR (TYP.)
DETAIL 1 PLATE 3.1.5 (TYP.)
DEBRIS SKIMMER SYSTEM (SEE SECTION C, PLATE 3.1.4)
FISH LADDER EXTENSION (FLE) LENGTH = 168m (551 FT) (NOTE: FLE ANCHOR SYSTEM NOT SHOWN)
FLE PUMP
NAVIGATION LOCK
LOWER GRANITE LAKE
SBC CHANNEL
SPILLWAYS
BEHAVIORAL GUIDANCE STRUCTURE (BGS)
EXISTING TRASH SHEAR BOOM
POWERHOUSE
FLOW
SHORELINE
FISH LADDER EXTENSION (FLE)
KEY PLAN
SYSTEM COMBINATION 3
SBC TYPE 3
LOWER GRANITE LOCK AND DAM
SITE PLAN
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
Sverdrup
PLATE
3.1.1



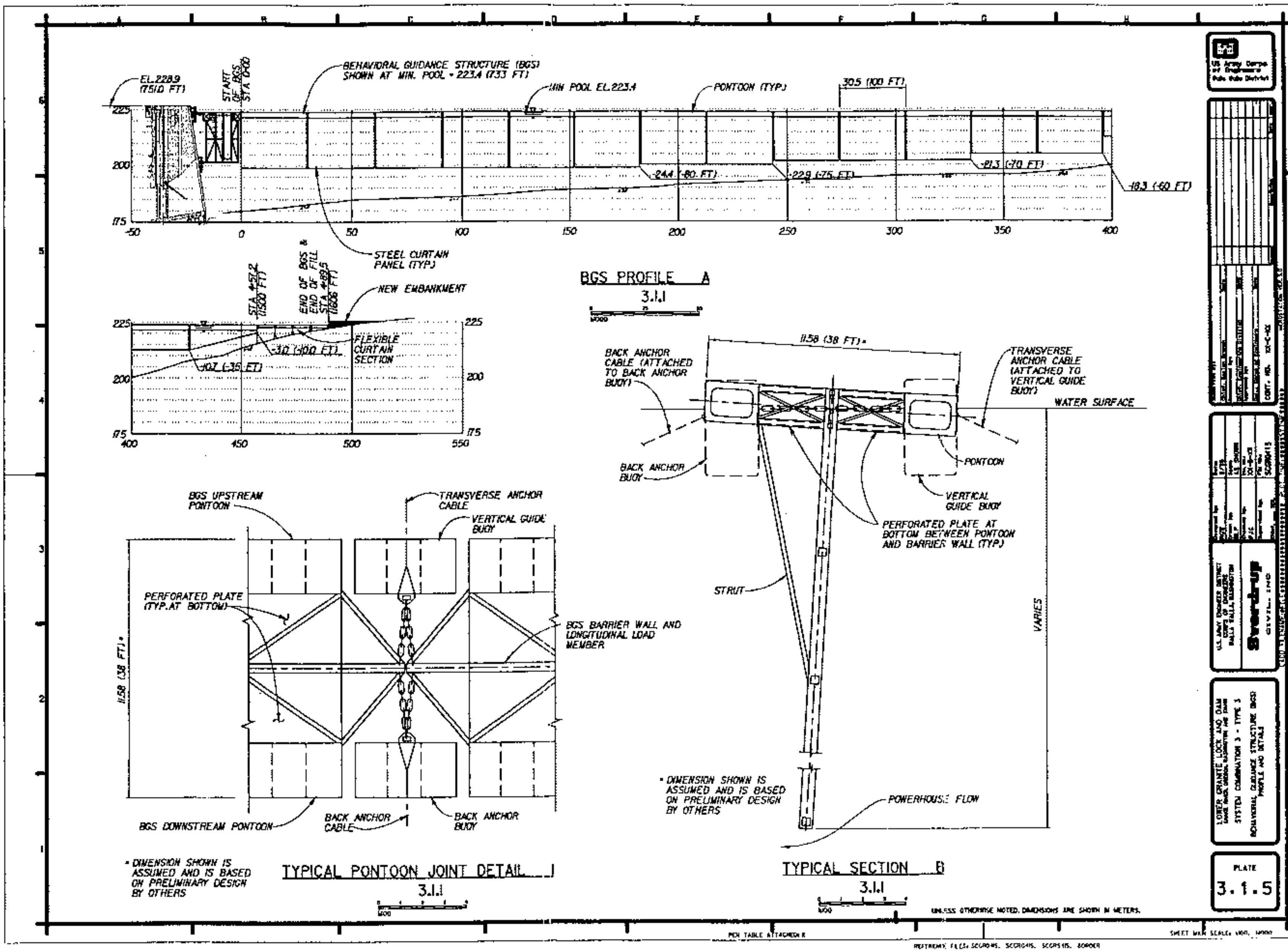
NOTES:
1. SINCE THE 21.3m (70 FT) CHANNEL DEPTH IS A REQUIREMENT ONLY IN FRONT OF THE TURBINE UNITS, AND SINCE THE CHANNEL DEPTH CAN BE REDUCED AT THE CENTRAL NON-OVERFLOW SECTION DUE TO THE SHALLOWER EQUIPMENT CONFIGURATIONS, THE CHANNEL DEPTH NORTH OF UNIT 6 IS REDUCED RELATIVE TO THE REST OF THE CHANNEL.
2. EXISTING 15.2m (50 FT) WIDE TAINTER GATE TO BE REMOVED AND A NEW 10.67 (35 FT) WIDE TAINTER GATE INSTALLED.
3. CHANNEL STRUCTURAL BRACING, WALKWAYS, ROOF STRUCTURES AND OTHER EQUIPMENT NOT SHOWN.
UNIT 5
UNIT 6
SPILLBAY 1
1.829 (6 FT)
2.743 (9 FT)
10.67 (35 FT)
CENTRAL NON-OVERFLOW SECTION
NEW TAINTER GATE (NOTE 2)
NEW ELEVATED OGEE
NEW SPILLWAY PIER
FILLED AREAS
NEW FISH GALLERY BULKHEAD
℄ VERTICAL LEAF GATE AND ELEVATED OGEE CREST AT EL.216.5 (710.3 FT)
EXISTING AUX. WATER PORT
EXISTING FISH GALLERY
FISH TRANSPORT CONDUIT
TILTING WEIR
SPILLWAY EXTENSION STRUCTURE (SES) (FIXED)
SLIDING CONNECTION (TYP.)
CHANNEL DEPTH TRANSITION WALL (NOTE 1)
FLOOR EL.-21.3 (-70 FT)
FLOTATION
14.3 (47 FT) CHANNEL WIDTH
SCREENED FLOW CHANNEL
DEWATERING SCREENS
GATED POROSITY CONTROL
FLOATING SBC CHANNEL
GUIDE WALL (TYP.)
SCREENED FLOW
0.85 m³/S 1.4 m/S
FLOOR EL.-15.24 (-50 FT)
SCREENED MODE: 55.8 m³/S 2.12 m/S
BYPASS MODE: 67.8 m³/S (MIN.) 2.53 m/S
90.9 m³/S (MAX.) 3.40 m/S
STA.0.0
SLOPED FLOOR
STA.21.6
STA.33.8
STA.46.0
STA.58.2
FULL-FLOW BYPASS CHANNEL
CUTOFF WALL (BELOW CHANNEL)
HINGED SWITCH GATE (6.0 WIDE x 15.8 TALL)
CLEARANCE PROVIDED FOR DEBRIS RACK TRASHRAKE
ROLLING (OR SLIDING) GATE PANEL (4.88 WIDE x 5.33 TALL - 4 TOTAL)
BAR SPACING 0.305 (1 FT)
DEBRIS RACK (12.2 DIA. x 22.4 TALL)
BGS
METRIC/ENGLISH UNIT CONVERSION
1 m = 3.28 FT
1 m² = 10.76 FT²
1 m/S = 3.28 FPS
1 m³/S = 35.31 CFS
PARTIAL PLAN AT COLLECTOR ENTRANCE 5/6
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
LOWER GRANITE LOCK AND DAM
SYSTEM CONFIGURATION 3 - TYPE 3
UNIT 5/6 ENTRANCE PLAN
PLATE 3.1.2

Appendix E

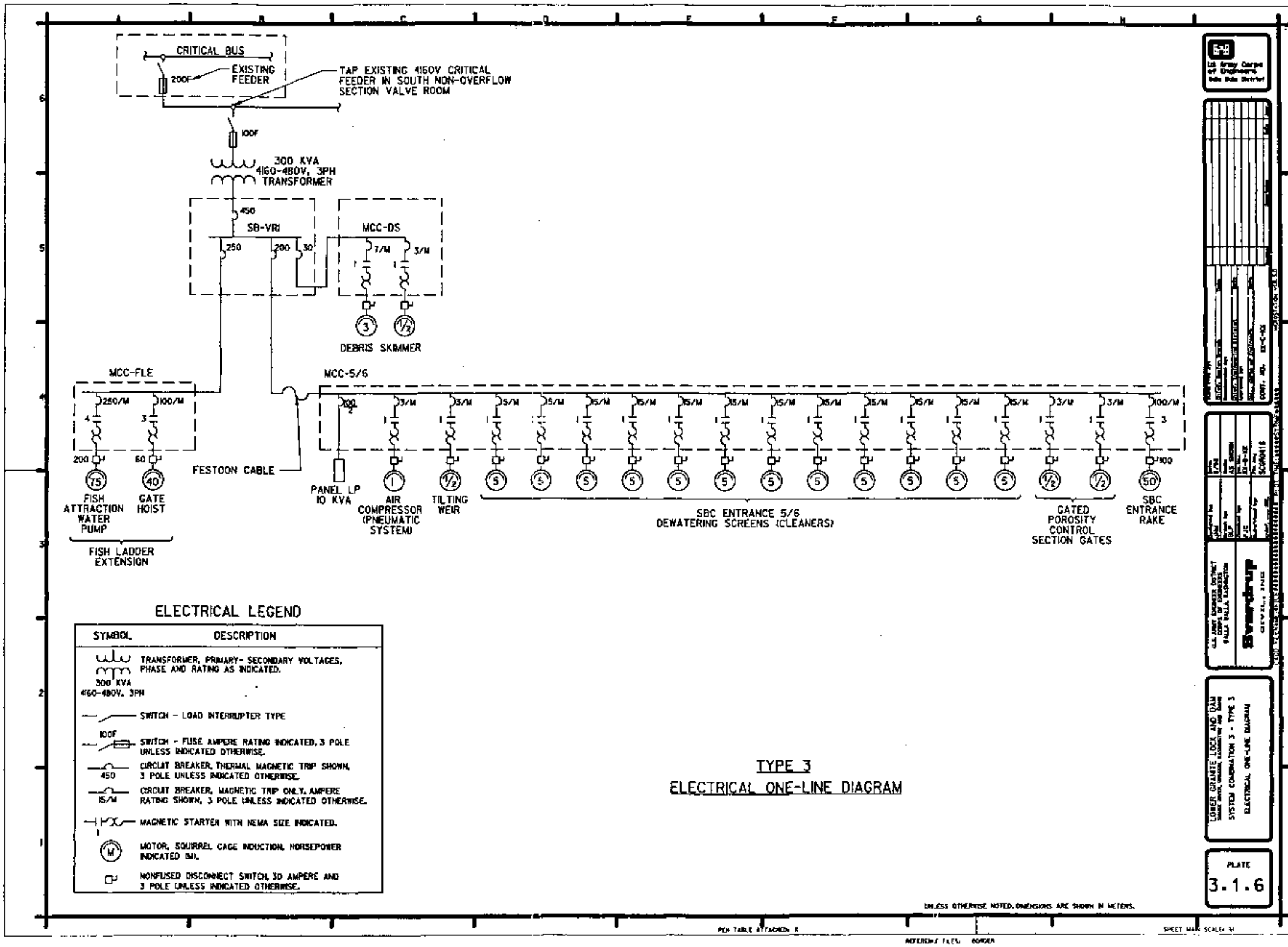

TRASHRAKE CLEARANCE
CHANNEL SUPPORT GUIDE (TYP.) (SEE NOTE 1)
DECK EL 228.9 (751.0 FT)
SCREENED FLOW CONDUIT
FULL FLOW BYPASS CONDUIT
DECK TRUSS (SEE NOTE 1)
FLOTATION
MIN. POOL EL 223.4 (733.0 FT)
CHANNEL WALL (TYP.)
PIPE BRACING (TYP.) (SEE NOTE 1)
EXISTING VBS
INTAKE
14.3 (47 FT)
CUTOFF WALL (UPPER PANEL)
VERTICAL GUIDE WITH FUSE PIN CONNECTION (TYP.)
EXISTING ESBS
FLEXIBLE JOINT W/SEAL
CUTOFF WALL (LOWER PANEL)
FIXED WALL SECTION (SEE NOTE 2)
CONCRETE CAISSON (TYP.)
ROCK ANCHOR (TYP.)
SECTION A
3.1.2
CENTRAL NON-OVERFLOW MONOLITH
EL 228.9 (751.0 FT)
EXISTING FISH GALLERY (SEE NOTE)
WALKWAY GRATING
EL 224.9 (738.0 FT)
TILTING WEIR
BULKHEAD PANEL
EL 222.5 (730 FT)
FLOATING SBC CHANNEL (SHOWN AT MAX. POOL EL 224.9)
EL 219.9 (721.50 FT)
EL 219.3 (719.5 FT)
CONCRETE REMOVAL AREA
FIXED STEEL CAISSON
0.46m RADIUS CORNER FILLETS (TYP. 4 PLACES)
NOTE: EXISTING FISH GALLERY TO BE BULKHEADED NORTH OF WEIR ENTRANCE (SEE PLAN)
WEIR AT CENTRAL NON-OVERFLOW SECTION
SECTION B
3.1.2
NET SCREEN AREA = 47.8 m²
NET SCREEN AREA = 114.3 m²
EFF. AREA MULTIPLIER = 0.75 (TYP.)
NET SCREEN AREA = 19.1 m²
AVG. NORMAL VELOCITY COMPONENT
APPROX. WATER SURFACE PROFILE IN CHANNEL
ENTRANCE STA. 0.0
STA. 21.6
STA. 33.8
STA. 46.0
STA. 52.1
STA. 58.2
EL 0.0
EL -1.22
EL -1.52
EL -2.65
EL -3.84
EL -6.61
EL -9.72
EL -15.3
EL -21.3
0.91 m/S
0.55 m/S
DEWATERING SCREEN ELEVATION
SECTION C
3.1.2
NOTES:
1. STRUCTURAL BRACING AND OTHER MEMBERS ARE SHOWN FOR CONCEPT ONLY. INTERNAL BRACING AND DECK TRUSS OCCUR AT PIER SUPPORT LOCATIONS (APPROX. 9.1m (30 FT) INTERVALS ALONG THE CHANNEL). ROOF STRUCTURES, WALKWAYS AND EQUIPMENT NOT SHOWN.
2. FIXED SECTION OF CUTOFF WALL TO BE BOLTED TO NORTH SIDE OF UNIT 6 INTAKE.
3. DEPTHS AND VELOCITIES ARE APPROXIMATE AND MUST BE ADJUSTED ON BASIS OF FINAL DESIGN HYDRAULIC ANALYSIS.
4. VELOCITIES ARE AT ARROW HEAD TIP.
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
PLATE
3.1.3

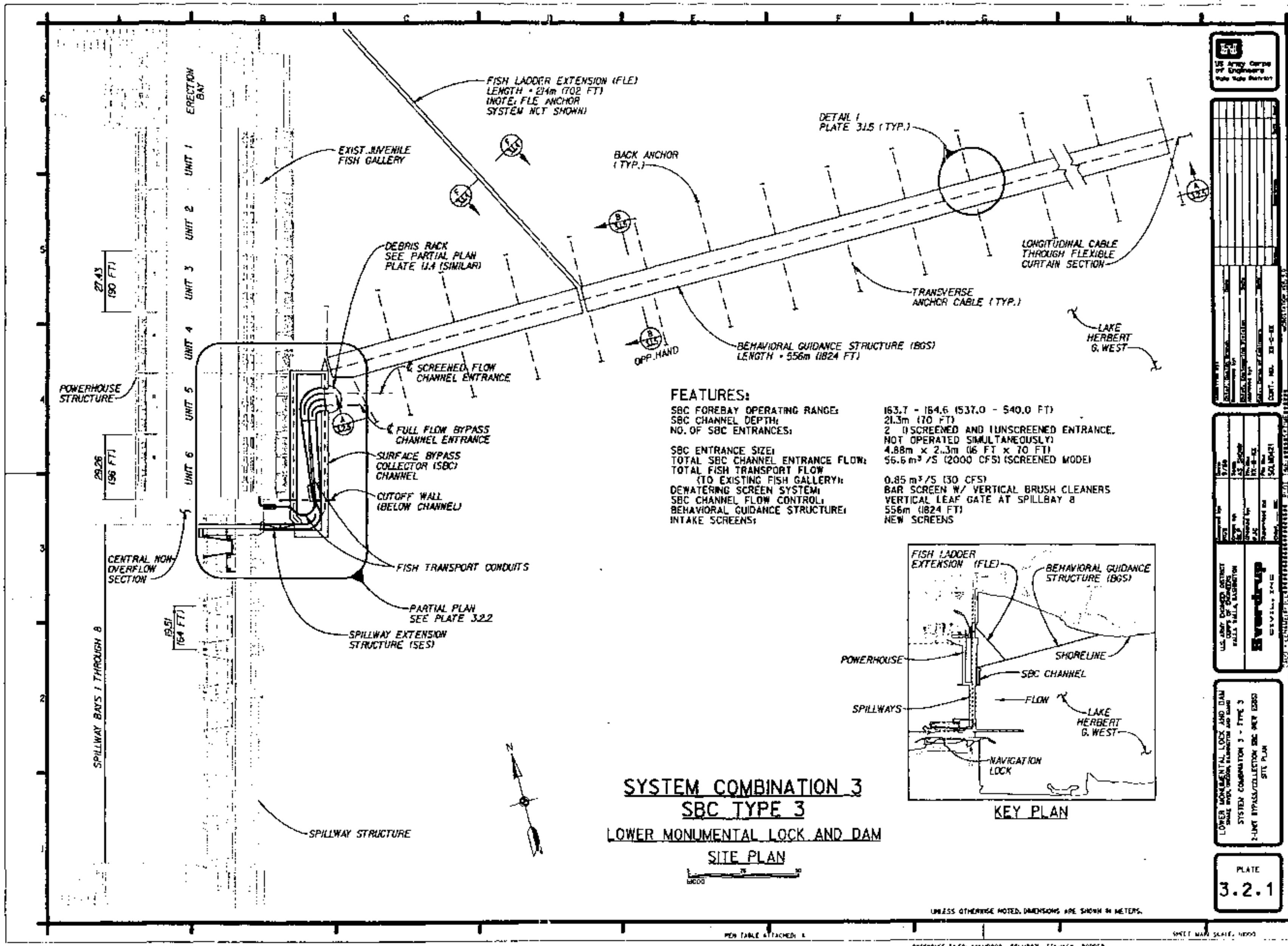

TUBE TRUSS MEMBERS
BRACKET
CHANNEL
BOUYANCY TANK (TYP)
PLATE WALLS AND FLOOR
℄ CHANNEL
TYPICAL SECTION OF FISH LADDER EXTENSION AT BUOYANCY TANK
SECTION F
3.1.1
FLOATING SBC CHANNEL
BOTTOM OF SBC CHANNEL
6.10 (20 FT)
CHANNEL DEPTH TRANSITION
UPPER PANEL
BRACE
SLIDING CONNECTION
TRUSSED LOWER PANEL
CUTOFF WALL
CONCRETE CAISSON
ROCK ANCHORS
CUTOFF WALL
SECTION E
3.1.2
VERTICAL LEAF GATES
HOIST STRUCTURE
FIXED SPILLWAY EXTENSION STRUCTURE (SES)
EL 228.9 (751.0 FT)
NEW SPILLWAY PIER
FLOATING SBC CHANNEL SHOWN AT MIN. POOL EL 223.4 (733.0 FT)
MAX. POOL EL 224.9 (739.0 FT)
NEW 10.67m (35 FT) WIDE TAINTER GATE (BEYOND)
FLOW FROM SBC CHANNEL
SLIDING CONNECTION
EL 216.5 (710.3 FT) OGEE CREST
SBC CHANNEL DISCHARGE: SCREENED MODE: 55.8m³/S (1970 CFS)
BYPASS MODE: 67.8m³/S (2390 CFS) MIN. 90.9m³/S (3210 CFS) MAX.
EL 208.9 (685.5 FT)
EL 208.2 (683.0 FT) (VARIES)
SES FLOOR
NEW ELEVATED OGEE
EL 207.6 (681.0 FT) EXISTING OGEE CREST
EXISTING OGEE
EXISTING SPILLWAY OGEE SHAPE
V- 23.5 m/S (77 FPS)
NORMAL TAILWATER EL 194.5 (638.0 FT)
FISHWAY CHANNEL
NOTE: THE EXISTING FLIP LIP SHOWN FOR THE NEW ELEVATED OGEE SECTION MAY REQUIRE MODIFICATION OF SHAPE OR LOCATION. THIS WOULD BE DETERMINED DURING FINAL DESIGN. COST ESTIMATES ASSUME CURRENT CONFIGURATION IS ACCEPTABLE.
EXISTING FLIP LIP (SEE NOTE)
ELEVATED OGEE AT SPILLBAY 1
SECTION D
3.1.2
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
LOWER GRANITE LOCK AND DAM
SYSTEM COMBINATION 3 - TYPE 3
SPILLBAY 1 SECTIONS
PLATE
3.1.4

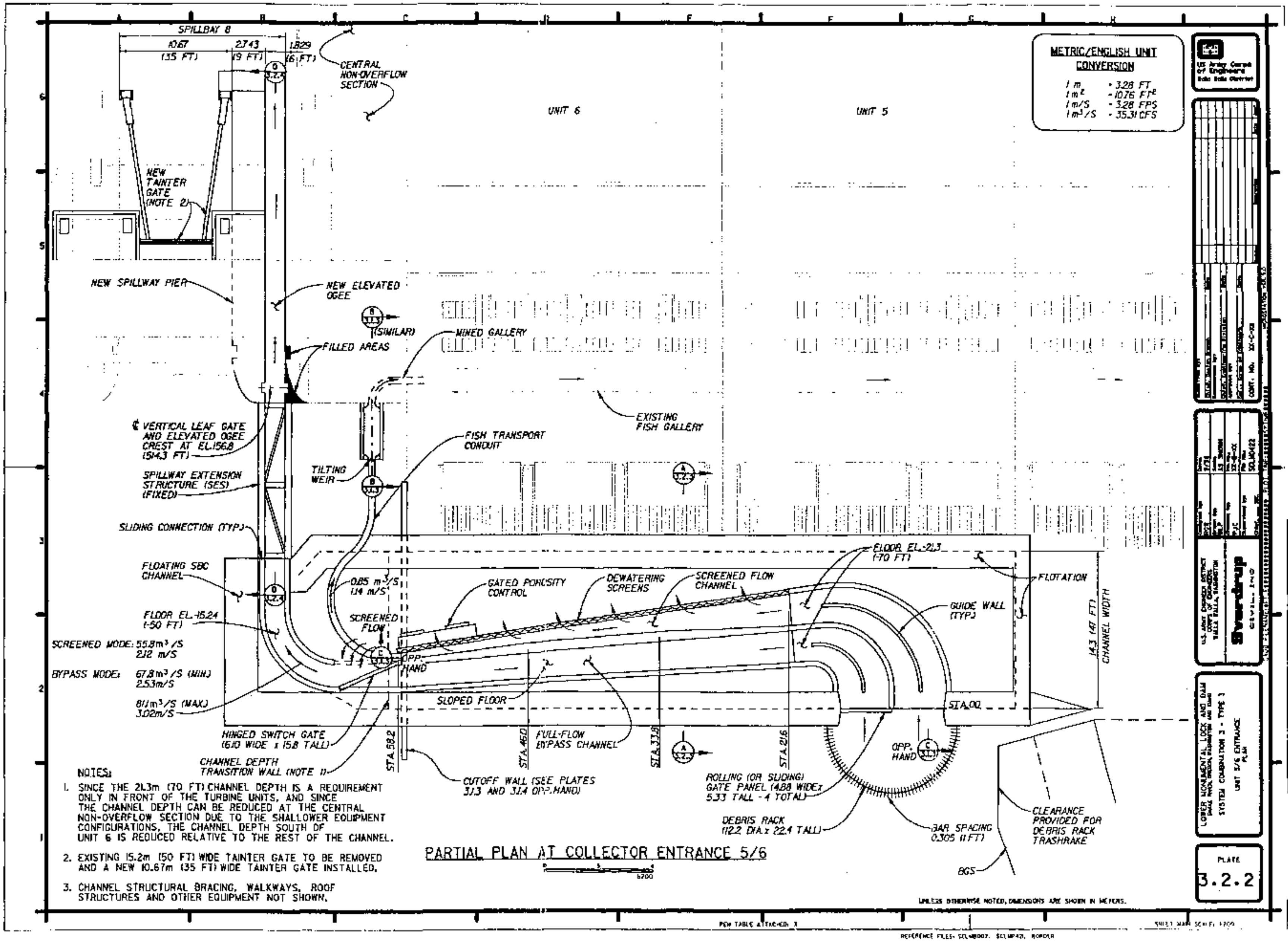
Pre-decisional draft document. Not for distribution or release.

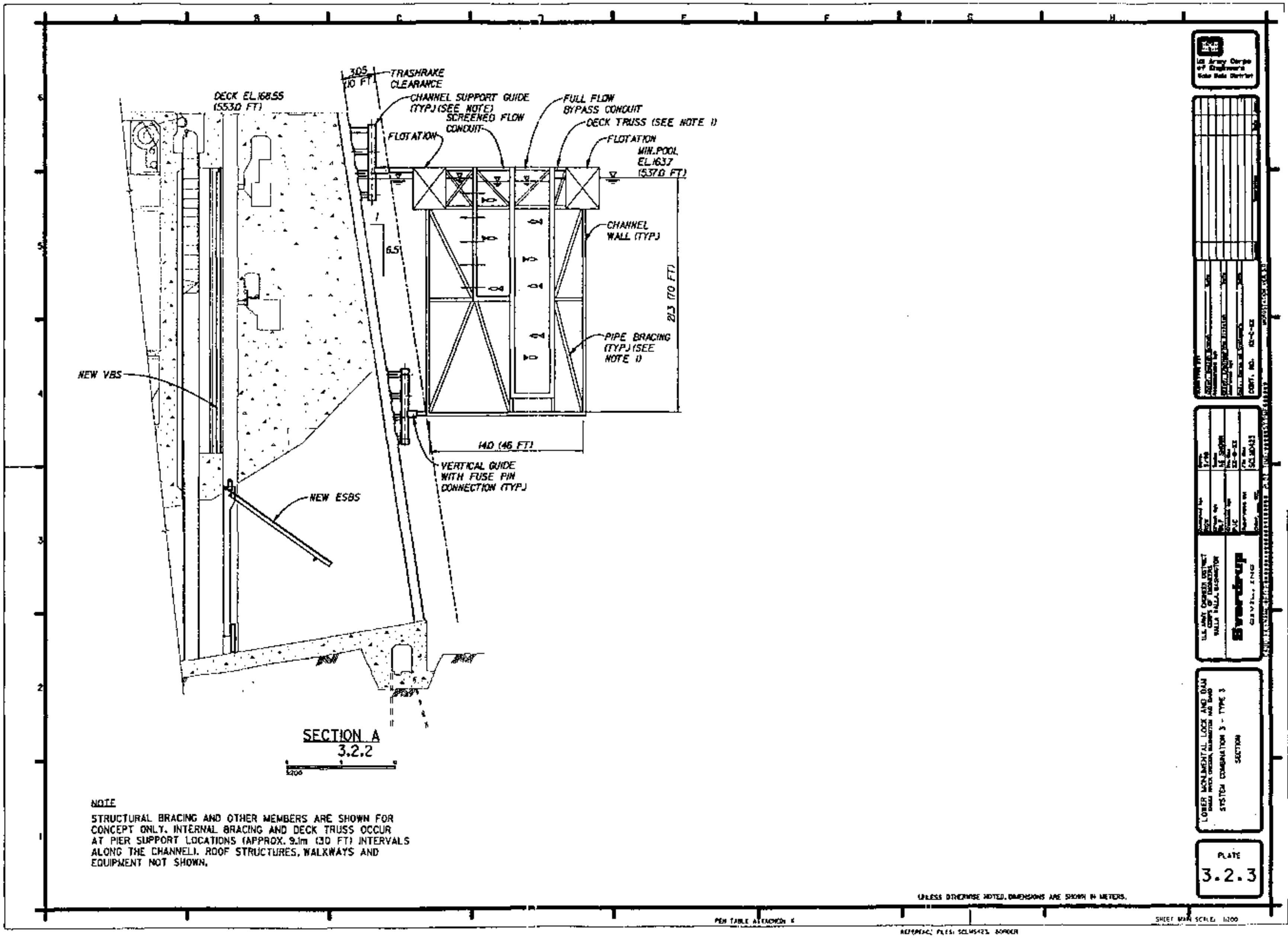


Appendix E

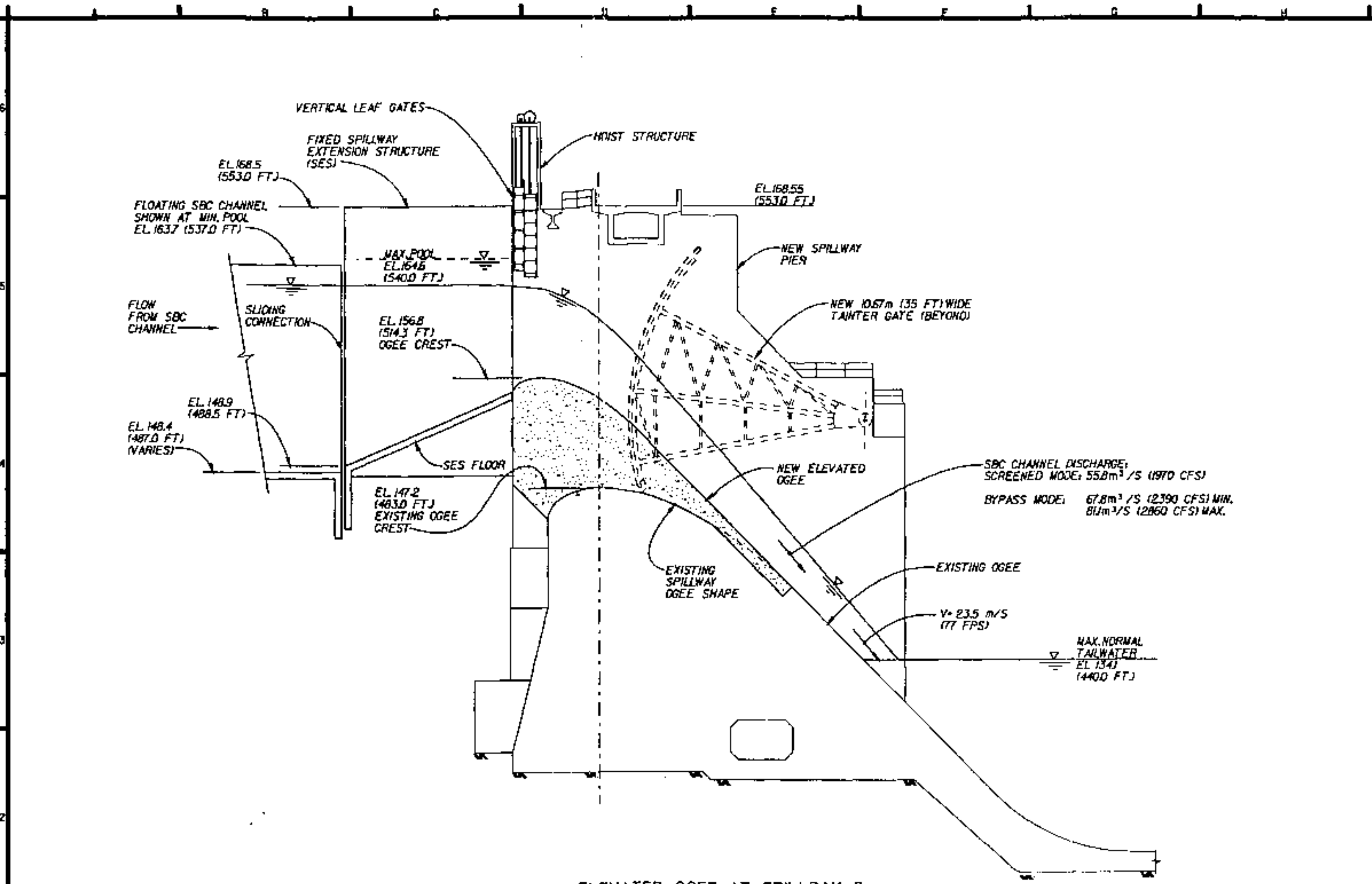

CRITICAL BUS
200F
EXISTING FEEDER
TAP EXISTING 4160V CRITICAL FEEDER IN SOUTH NON-OVERFLOW SECTION VALVE ROOM
100F
300 KVA
4160-480V, 3PH
TRANSFORMER
450
SB-VRI
250
200
30
MCC-DS
7/M
3/M
DEBRIS SKIMMER
MCC-FLE
250/M
100/M
200
60
FISH ATTRACTION WATER PUMP
GATE HOIST
FISH LADDER EXTENSION
FESTOON CABLE
MCC-5/6
PANEL LP 10 KVA
AIR COMPRESSOR (PNEUMATIC SYSTEM)
TILTING WEIR
SBC ENTRANCE 5/6 DEWATERING SCREENS (CLEANERS)
GATED POROSITY CONTROL SECTION GATES
SBC ENTRANCE RAKE
ELECTRICAL LEGEND
SYMBOL
DESCRIPTION
TRANSFORMER, PRIMARY- SECONDARY VOLTAGES, PHASE AND RATING AS INDICATED.
300 KVA
4160-480V, 3PH
SWITCH - LOAD INTERRUPTER TYPE
100F
SWITCH - FUSE AMPERE RATING INDICATED, 3 POLE UNLESS INDICATED OTHERWISE.
450
CIRCUIT BREAKER, THERMAL MAGNETIC TRIP SHOWN, 3 POLE UNLESS INDICATED OTHERWISE.
15/M
CIRCUIT BREAKER, MAGNETIC TRIP ONLY, AMPERE RATING SHOWN, 3 POLE UNLESS INDICATED OTHERWISE.
MAGNETIC STARTER WITH NEMA SIZE INDICATED.
MOTOR, SQUIRREL CAGE INDUCTION, HORSEPOWER INDICATED (M).
NONFUSED DISCONNECT SWITCH, 30 AMPERE AND 3 POLE UNLESS INDICATED OTHERWISE.
TYPE 3
ELECTRICAL ONE-LINE DIAGRAM
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers
Walla Walla District
LOWER GRANITE LOCK AND DAM
SYSTEM COMBINATION 3 - TYPE 3
ELECTRICAL ONE-LINE DIAGRAM
PLATE
3.1.6


FISH LADDER EXTENSION (FLE)
LENGTH = 214m (702 FT)
(NOTE: FLE ANCHOR SYSTEM NOT SHOWN)
EXIST. JUVENILE FISH GALLERY
ERECTION BAY
UNIT 1
UNIT 2
UNIT 3
UNIT 4
UNIT 5
UNIT 6
27.43 (90 FT)
29.26 (96 FT)
19.51 (64 FT)
POWERHOUSE STRUCTURE
CENTRAL NON-OVERFLOW SECTION
SPILLWAY BAYS 1 THROUGH 8
SPILLWAY STRUCTURE
DEBRIS RACK
SEE PARTIAL PLAN PLATE 11.4 (SIMILAR)
℄ SCREENED FLOW CHANNEL ENTRANCE
℄ FULL FLOW BYPASS CHANNEL ENTRANCE
SURFACE BYPASS COLLECTOR (SBC) CHANNEL
CUTOFF WALL (BELOW CHANNEL)
FISH TRANSPORT CONDUITS
PARTIAL PLAN SEE PLATE 3.2.2
SPILLWAY EXTENSION STRUCTURE (SES)
BACK ANCHOR (TYP.)
DETAIL 1 PLATE 3.1.5 (TYP.)
LONGITUDINAL CABLE THROUGH FLEXIBLE CURTAIN SECTION
TRANSVERSE ANCHOR CABLE (TYP.)
BEHAVIORAL GUIDANCE STRUCTURE (BGS)
LENGTH = 556m (1824 FT)
OPP. HAND
LAKE HERBERT G. WEST
FEATURES:
SBC FOREBAY OPERATING RANGE: 163.7 - 164.6 (537.0 - 540.0 FT)
SBC CHANNEL DEPTH: 21.3m (70 FT)
NO. OF SBC ENTRANCES: 2 (1 SCREENED AND 1 UNSCREENED ENTRANCE. NOT OPERATED SIMULTANEOUSLY)
SBC ENTRANCE SIZE: 4.88m x 21.3m (16 FT x 70 FT)
TOTAL SBC CHANNEL ENTRANCE FLOW: 56.6 m³/S (2000 CFS) (SCREENED MODE)
TOTAL FISH TRANSPORT FLOW (TO EXISTING FISH GALLERY): 0.85 m³/S (30 CFS)
DEWATERING SCREEN SYSTEM: BAR SCREEN W/ VERTICAL BRUSH CLEANERS
SBC CHANNEL FLOW CONTROL: VERTICAL LEAF GATE AT SPILLBAY 8
BEHAVIORAL GUIDANCE STRUCTURE: 556m (1824 FT)
INTAKE SCREENS: NEW SCREENS
FISH LADDER EXTENSION (FLE)
BEHAVIORAL GUIDANCE STRUCTURE (BGS)
POWERHOUSE
SHORELINE
SBC CHANNEL
FLOW
SPILLWAYS
LAKE HERBERT G. WEST
NAVIGATION LOCK
KEY PLAN
N
SYSTEM COMBINATION 3
SBC TYPE 3
LOWER MONUMENTAL LOCK AND DAM
SITE PLAN
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers
Walla Walla District
PLATE
3.2.1


SPILLBAY 8
10.67 (35 FT)
2.743 (9 FT)
1.829 (6 FT)
CENTRAL NON-OVERFLOW SECTION
UNIT 6
UNIT 5
METRIC/ENGLISH UNIT CONVERSION
1 m = 3.28 FT
1 m² = 10.76 FT²
1 m/S = 3.28 FPS
1 m³/S = 35.31 CFS
NEW TAINTER GATE (NOTE 2)
NEW SPILLWAY PIER
NEW ELEVATED OGEE
(SIMILAR)
FILLED AREAS
MINED GALLERY
EXISTING FISH GALLERY
℄ VERTICAL LEAF GATE AND ELEVATED OGEE CREST AT EL.156.8 (514.3 FT)
FISH TRANSPORT CONDUIT
SPILLWAY EXTENSION STRUCTURE (SES) (FIXED)
TILTING WEIR
SLIDING CONNECTION (TYP.)
FLOATING SBC CHANNEL
0.85 m³/S 1.4 m/S
SCREENED FLOW
GATED POROSITY CONTROL
DEWATERING SCREENS
SCREENED FLOW CHANNEL
FLOOR EL.-21.3 (-70 FT)
FLOTATION
GUIDE WALL (TYP.)
14.3 (47 FT) CHANNEL WIDTH
FLOOR EL.-15.24 (-50 FT)
SCREENED MODE: 55.8m³/S 2.12 m/S
BYPASS MODE: 67.8m³/S (MIN.) 2.53m/S
81.1m³/S (MAX.) 3.02m/S
OPP. HAND
SLOPED FLOOR
STA.0.0
HINGED SWITCH GATE (6.10 WIDE x 15.8 TALL)
CHANNEL DEPTH TRANSITION WALL (NOTE 1)
STA.58.2
STA.46.0
FULL-FLOW BYPASS CHANNEL
STA.33.8
STA.21.6
CUTOFF WALL (SEE PLATES 3.1.3 AND 3.1.4 OPP.HAND)
ROLLING (OR SLIDING) GATE PANEL (4.88 WIDE x 5.33 TALL - 4 TOTAL)
DEBRIS RACK (12.2 DIA. x 22.4 TALL)
BAR SPACING 0.305 (1 FT)
CLEARANCE PROVIDED FOR DEBRIS RACK TRASHRAKE
BGS
PARTIAL PLAN AT COLLECTOR ENTRANCE 5/6
NOTES:
1. SINCE THE 21.3m (70 FT) CHANNEL DEPTH IS A REQUIREMENT ONLY IN FRONT OF THE TURBINE UNITS, AND SINCE THE CHANNEL DEPTH CAN BE REDUCED AT THE CENTRAL NON-OVERFLOW SECTION DUE TO THE SHALLOWER EQUIPMENT CONFIGURATIONS, THE CHANNEL DEPTH SOUTH OF UNIT 6 IS REDUCED RELATIVE TO THE REST OF THE CHANNEL.
2. EXISTING 15.2m (50 FT) WIDE TAINTER GATE TO BE REMOVED AND A NEW 10.67m (35 FT) WIDE TAINTER GATE INSTALLED.
3. CHANNEL STRUCTURAL BRACING, WALKWAYS, ROOF STRUCTURES AND OTHER EQUIPMENT NOT SHOWN.
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
Sverdrup
LOWER MONUMENTAL LOCK AND DAM
SYSTEM CONFIGURATION 3 - TYPE 3
UNIT 5/6 ENTRANCE PLAN
PLATE 3.2.2


3.05 (10 FT) TRASHRAKE CLEARANCE
DECK EL.168.55 (553.0 FT)
CHANNEL SUPPORT GUIDE (TYP) (SEE NOTE)
SCREENED FLOW CONDUIT
FULL FLOW BYPASS CONDUIT
DECK TRUSS (SEE NOTE 1)
FLOTATION
FLOTATION
MIN.POOL EL.163.7 (537.0 FT)
CHANNEL WALL (TYP)
6.5
21.3 (70 FT)
PIPE BRACING (TYP) (SEE NOTE 1)
NEW VBS
14.0 (46 FT)
VERTICAL GUIDE WITH FUSE PIN CONNECTION (TYP)
NEW ESBS
SECTION A
3.2.2
NOTE
STRUCTURAL BRACING AND OTHER MEMBERS ARE SHOWN FOR CONCEPT ONLY. INTERNAL BRACING AND DECK TRUSS OCCUR AT PIER SUPPORT LOCATIONS (APPROX. 9.1m (30 FT) INTERVALS ALONG THE CHANNEL). ROOF STRUCTURES, WALKWAYS AND EQUIPMENT NOT SHOWN.
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
LOWER MONUMENTAL LOCK AND DAM
SYSTEM COMBINATION 3 - TYPE 3
SECTION
PLATE
3.2.3

Pre-decisional draft document. Not for distribution or release.



ELEVATED OGEE AT SPILLBAY 8
SECTION D
3.2.2

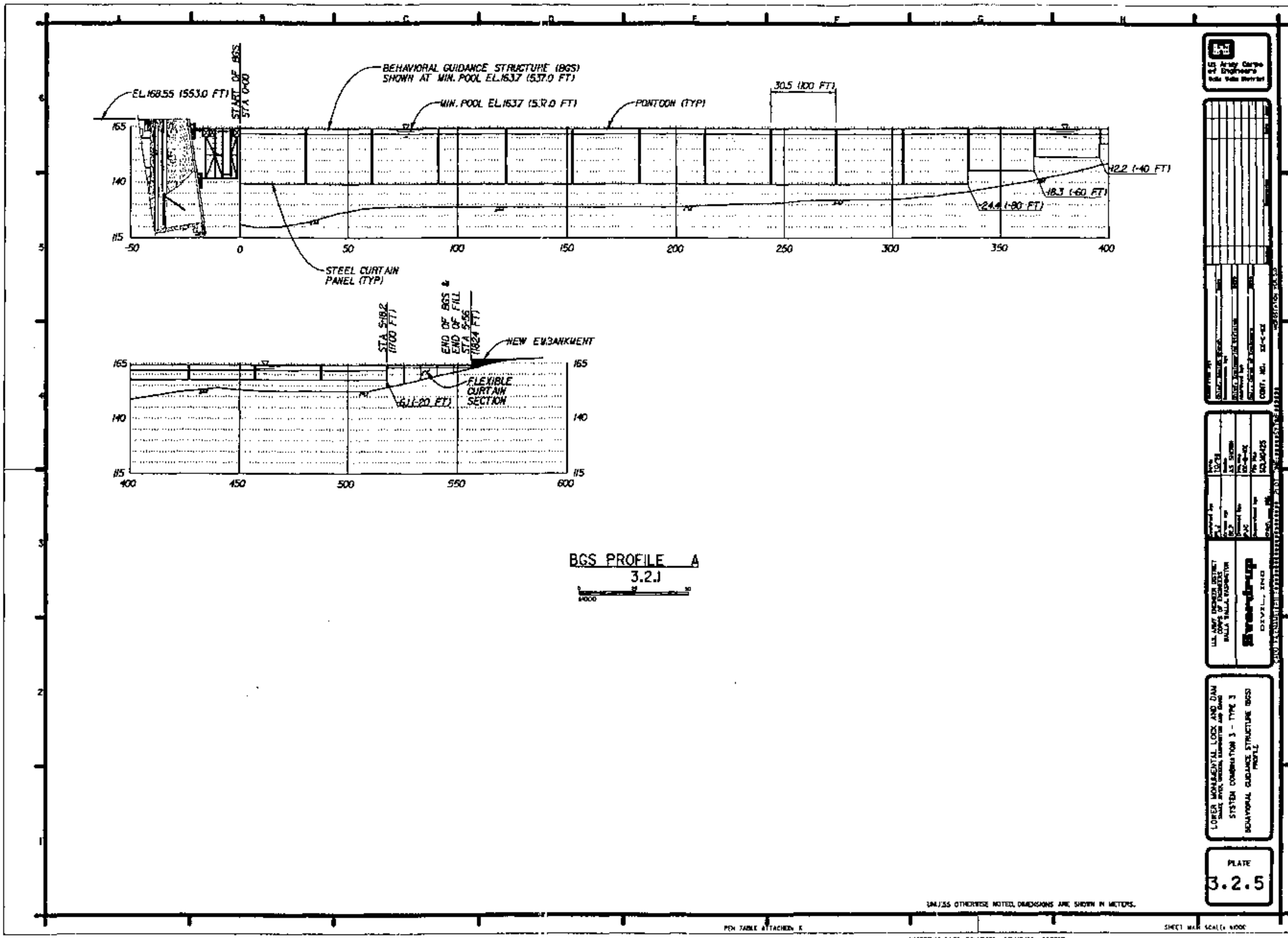
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

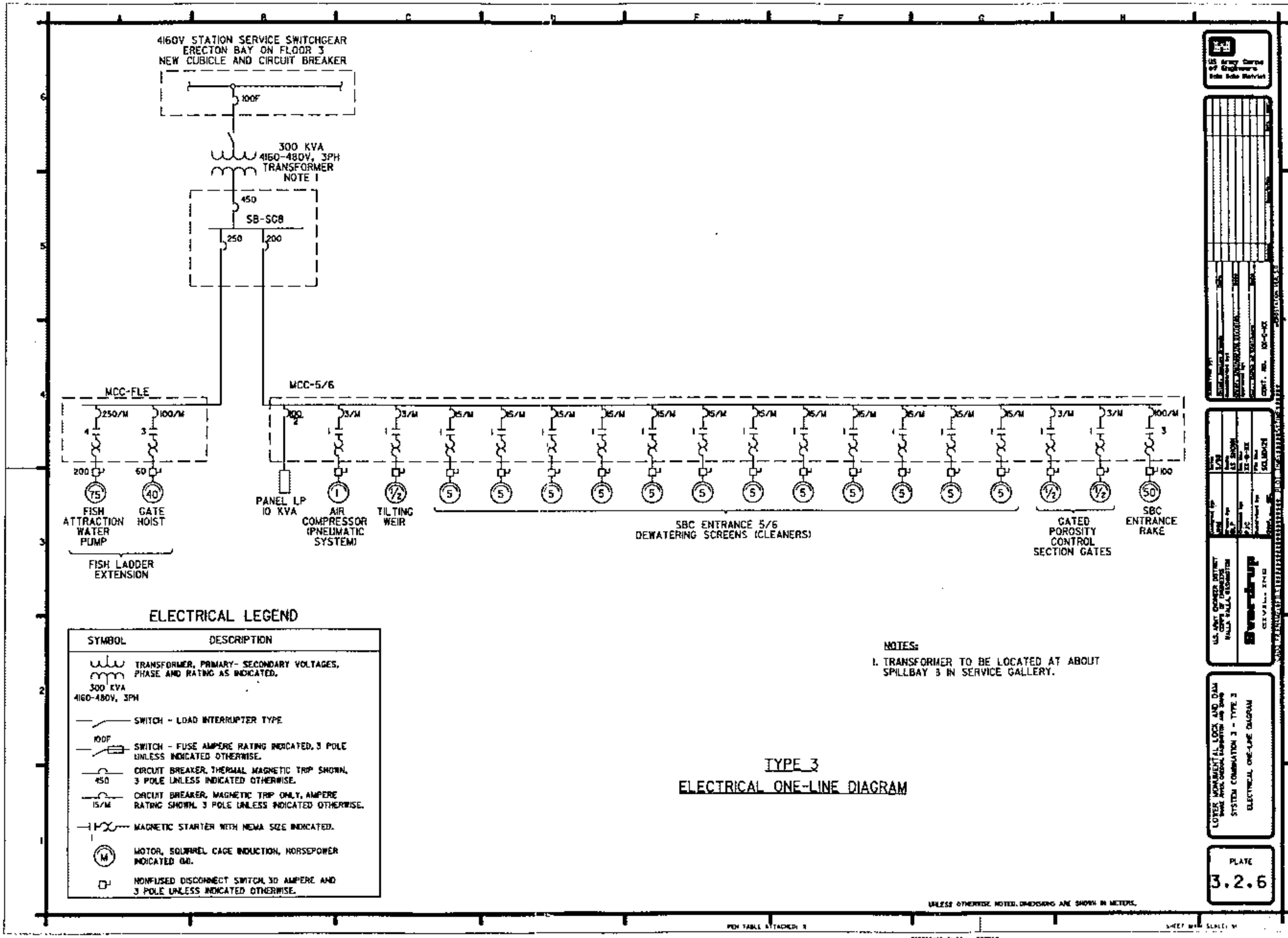
US Army Corps of Engineers Walla Walla District

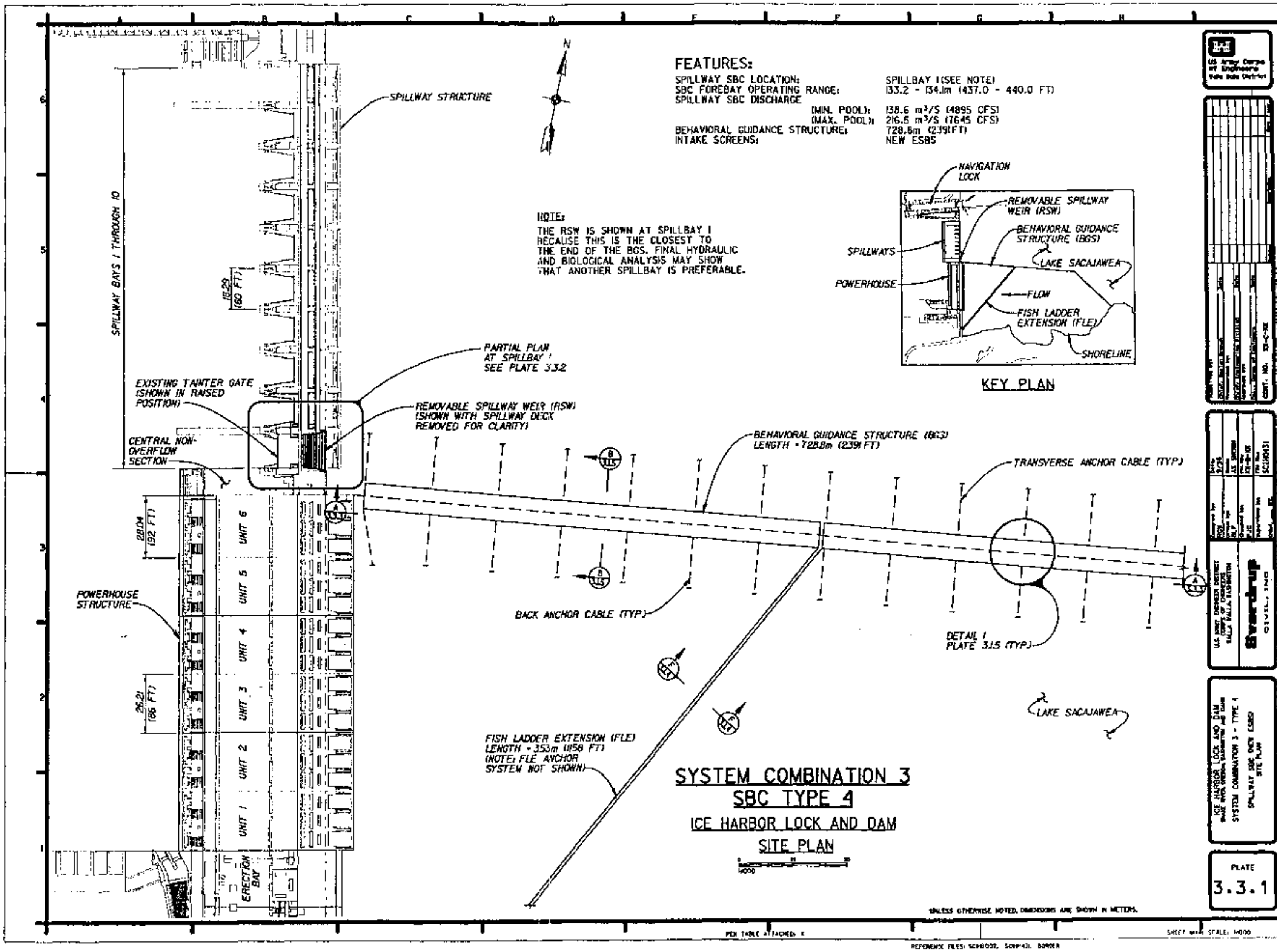
LOWER MONUMENTAL LOCK AND DAM
SYSTEM COMBINATION 3 - TYPE 3
SPILLBAY 8 SECTION

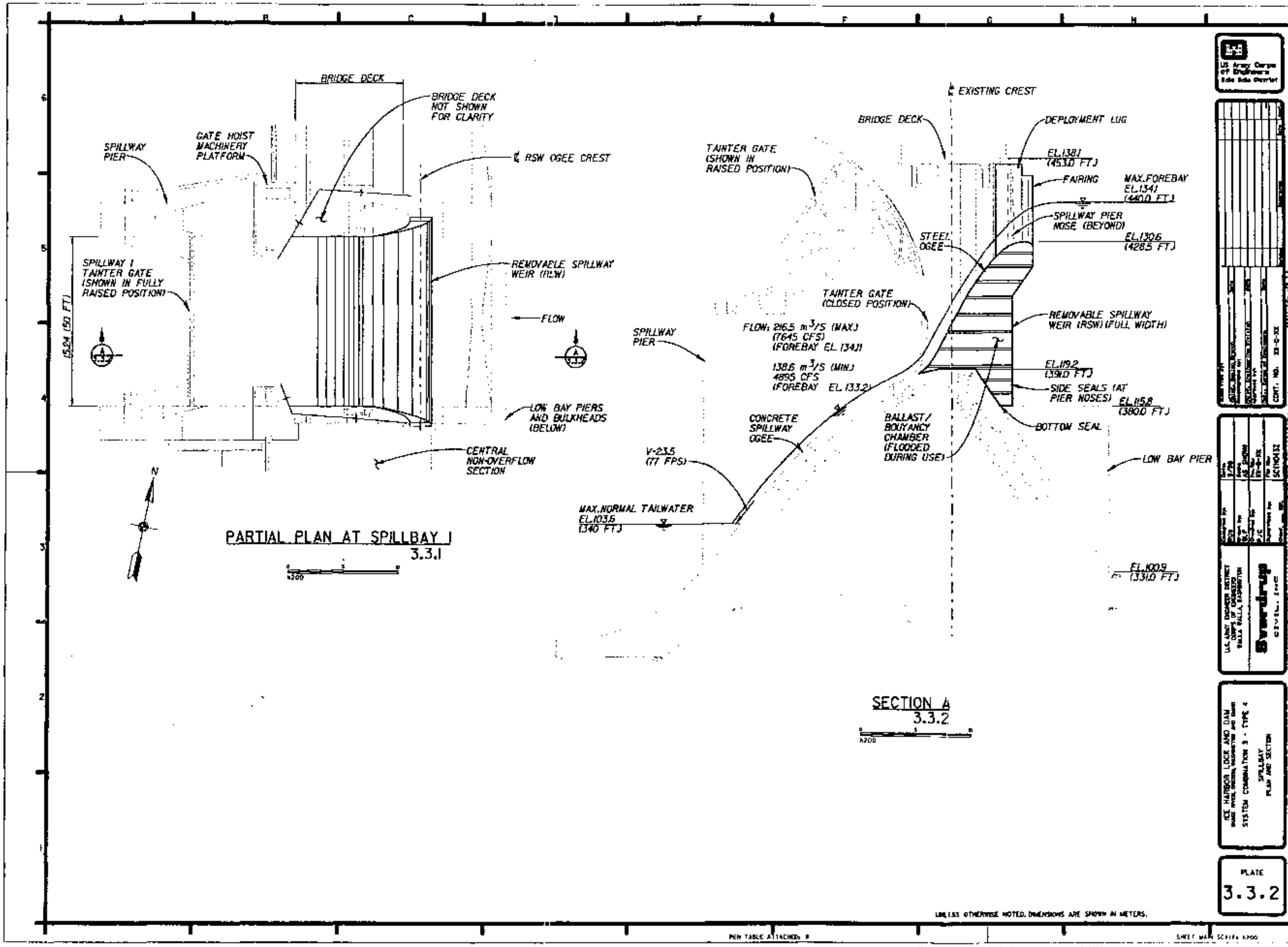
PLATE 3.2.4

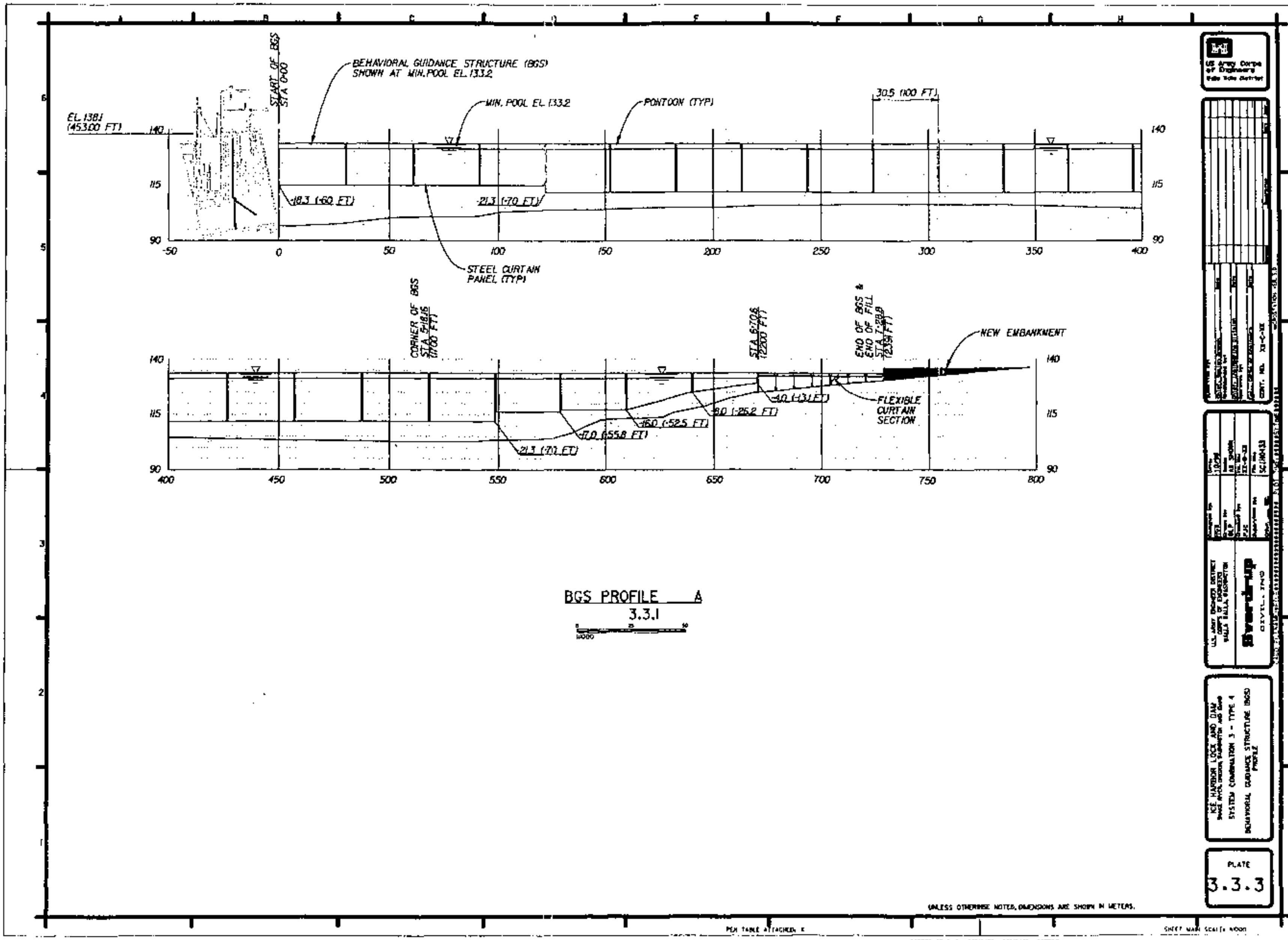
Appendix E


EL.168.55 (553.0 FT)
START OF BGS
STA 0+00
BEHAVIORAL GUIDANCE STRUCTURE (BGS)
SHOWN AT MIN. POOL EL.163.7 (537.0 FT)
MIN. POOL EL.163.7 (537.0 FT)
PONTOON (TYP)
30.5 (100 FT)
12.2 (-40 FT)
18.3 (-60 FT)
24.4 (-80 FT)
STEEL CURTAIN
PANEL (TYP)
STA 5+18.2
(1700 FT)
END OF BGS &
END OF FILL
STA 5+56
(1824 FT)
NEW EMBANKMENT
FLEXIBLE
CURTAIN
SECTION
6.1 (-20 FT)
BGS PROFILE A
3.2.1
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
PLATE
3.2.5

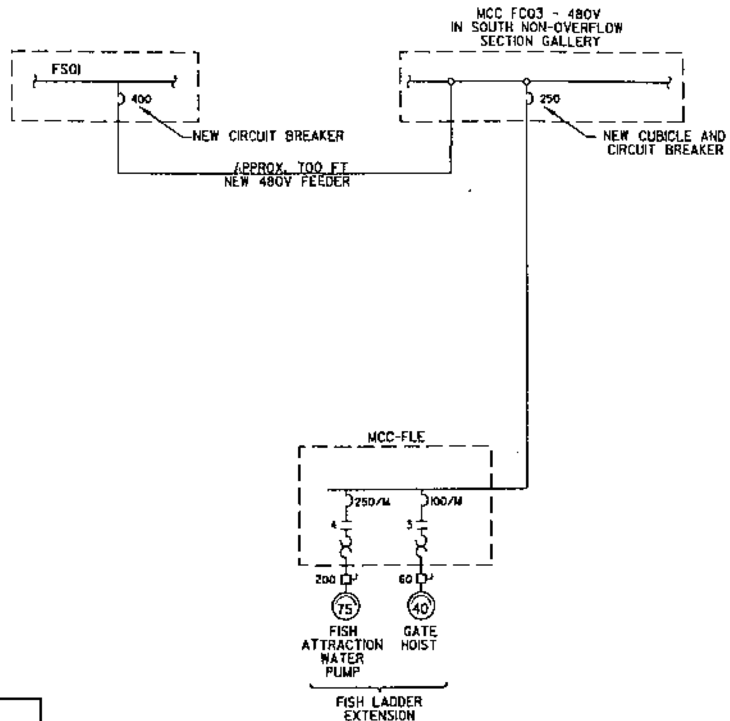

4160V STATION SERVICE SWITCHGEAR
ERECTON BAY ON FLOOR 3
NEW CUBICLE AND CIRCUIT BREAKER
100F
300 KVA
4160-480V, 3PH
TRANSFORMER
NOTE 1
450
SB-SG8
250
200
MCC-FLE
MCC-5/6
250/M
100/M
200
60
75
40
FISH ATTRACTION WATER PUMP
GATE HOIST
FISH LADDER EXTENSION
PANEL LP
10 KVA
AIR COMPRESSOR (PNEUMATIC SYSTEM)
TILTING WEIR
SBC ENTRANCE 5/6
DEWATERING SCREENS (CLEANERS)
GATED POROSITY CONTROL SECTION GATES
SBC ENTRANCE RAKE
ELECTRICAL LEGEND
SYMBOL
DESCRIPTION
TRANSFORMER, PRIMARY- SECONDARY VOLTAGES, PHASE AND RATING AS INDICATED.
300 KVA
4160-480V, 3PH
SWITCH - LOAD INTERRUPTER TYPE
SWITCH - FUSE AMPERE RATING INDICATED, 3 POLE UNLESS INDICATED OTHERWISE.
CIRCUIT BREAKER, THERMAL MAGNETIC TRIP SHOWN, 3 POLE UNLESS INDICATED OTHERWISE.
CIRCUIT BREAKER, MAGNETIC TRIP ONLY, AMPERE RATING SHOWN, 3 POLE UNLESS INDICATED OTHERWISE.
MAGNETIC STARTER WITH NEMA SIZE INDICATED.
MOTOR, SQUIRREL CAGE INDUCTION, HORSEPOWER INDICATED ON.
NONFUSED DISCONNECT SWITCH, 30 AMPERE AND 3 POLE UNLESS INDICATED OTHERWISE.
NOTES:
1. TRANSFORMER TO BE LOCATED AT ABOUT SPILLBAY 3 IN SERVICE GALLERY.
TYPE 3
ELECTRICAL ONE-LINE DIAGRAM
PLATE
3.2.6
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.


FEATURES:
SPILLWAY SBC LOCATION: SPILLBAY 1 (SEE NOTE)
SBC FOREBAY OPERATING RANGE: 133.2 - 134.1m (437.0 - 440.0 FT)
SPILLWAY SBC DISCHARGE
(MIN. POOL): 138.6 m³/S (4895 CFS)
(MAX. POOL): 216.5 m³/S (7645 CFS)
BEHAVIORAL GUIDANCE STRUCTURE: 728.8m (2391FT)
INTAKE SCREENS: NEW ESBS
NOTE:
THE RSW IS SHOWN AT SPILLBAY 1 BECAUSE THIS IS THE CLOSEST TO THE END OF THE BGS. FINAL HYDRAULIC AND BIOLOGICAL ANALYSIS MAY SHOW THAT ANOTHER SPILLBAY IS PREFERABLE.
N
SPILLWAY STRUCTURE
SPILLWAY BAYS 1 THROUGH 10
18.29 (60 FT)
PARTIAL PLAN AT SPILLBAY 1 SEE PLATE 3.3.2
EXISTING TAINTER GATE (SHOWN IN RAISED POSITION)
REMOVABLE SPILLWAY WEIR (RSW) (SHOWN WITH SPILLWAY DECK REMOVED FOR CLARITY)
CENTRAL NON-OVERFLOW SECTION
BEHAVIORAL GUIDANCE STRUCTURE (BGS) LENGTH = 728.8m (2391 FT)
TRANSVERSE ANCHOR CABLE (TYP)
28.04 (92 FT)
UNIT 6
UNIT 5
UNIT 4
UNIT 3
UNIT 2
UNIT 1
26.21 (86 FT)
POWERHOUSE STRUCTURE
ERECTION BAY
BACK ANCHOR CABLE (TYP)
DETAIL 1 PLATE 3.1.5 (TYP)
LAKE SACAJAWEA
FISH LADDER EXTENSION (FLE) LENGTH = 353m (1158 FT) (NOTE: FLE ANCHOR SYSTEM NOT SHOWN)
NAVIGATION LOCK
REMOVABLE SPILLWAY WEIR (RSW)
BEHAVIORAL GUIDANCE STRUCTURE (BGS)
SPILLWAYS
LAKE SACAJAWEA
POWERHOUSE
FLOW
FISH LADDER EXTENSION (FLE)
SHORELINE
KEY PLAN
SYSTEM COMBINATION 3
SBC TYPE 4
ICE HARBOR LOCK AND DAM
SITE PLAN
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
ICE HARBOR LOCK AND DAM
SYSTEM COMBINATION 3 - TYPE 4
SPILLWAY SBC (NEW ESBS)
SITE PLAN
PLATE
3.3.1


BRIDGE DECK
BRIDGE DECK NOT SHOWN FOR CLARITY
SPILLWAY PIER
GATE HOIST MACHINERY PLATFORM
℄ RSW OGEE CREST
SPILLWAY 1 TAINTER GATE (SHOWN IN FULLY RAISED POSITION)
15.24 (50 FT)
REMOVABLE SPILLWAY WEIR (RSW)
FLOW
LOW BAY PIERS AND BULKHEADS (BELOW)
CENTRAL NON-OVERFLOW SECTION
N
PARTIAL PLAN AT SPILLBAY 1
3.3.1
℄ EXISTING CREST
BRIDGE DECK
DEPLOYMENT LUG
EL.138.1 (453.0 FT)
FAIRING
MAX.FOREBAY EL.134.1 (440.0 FT)
TAINTER GATE (SHOWN IN RAISED POSITION)
SPILLWAY PIER NOSE (BEYOND)
EL.130.6 (428.5 FT)
STEEL OGEE
TAINTER GATE (CLOSED POSITION)
REMOVABLE SPILLWAY WEIR (RSW) (FULL WIDTH)
SPILLWAY PIER
FLOW: 216.5 m3/S (MAX) (7645 CFS) (FOREBAY EL.134.1)
138.6 m3/S (MIN) 4895 CFS (FOREBAY EL.133.2)
EL.119.2 (391.0 FT)
SIDE SEALS (AT PIER NOSES)
EL.115.8 (380.0 FT)
BALLAST/ BOUYANCY CHAMBER (FLOODED DURING USE)
BOTTOM SEAL
CONCRETE SPILLWAY OGEE
V-23.5 (77 FPS)
LOW BAY PIER
MAX.NORMAL TAILWATER EL.103.6 (340 FT)
EL.100.9 (331.0 FT)
SECTION A
3.3.2
US Army Corps of Engineers Walla Walla District
ICE HARBOR LOCK AND DAM
SYSTEM COMBINATION 3 - TYPE 4
SPILLWAY PLAN AND SECTION
PLATE
3.3.2
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.



BEHAVIORAL GUIDANCE STRUCTURE (BGS) SHOWN AT MIN. POOL EL. 133.2
START OF BGS STA 0+00
EL. 138.1 (453.00 FT)
MIN. POOL EL. 133.2
PONTOON (TYP)
30.5 (100 FT)
-18.3 (-60 FT)
-21.3 (-70 FT)
STEEL CURTAIN PANEL (TYP)
CORNER OF BGS STA 5+18.15 (1700 FT)
STA 6+70.6 (2200 FT)
END OF BGS & END OF FILL
NEW EMBANKMENT
-4.0 (-13.1 FT)
-8.0 (-26.2 FT)
-16.0 (-52.5 FT)
-17.0 (-55.8 FT)
-21.3 (-70 FT)
FLEXIBLE CURTAIN SECTION
BGS PROFILE A
3.3.1
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
US Army Corps of Engineers Walla Walla District
PLATE
3.3.3



ELECTRICAL LEGEND

SYMBOL	DESCRIPTION
300 KVA 4160-480V, 3PH	TRANSFORMER, PRIMARY- SECONDARY VOLTAGES, PHASE AND RATING AS INDICATED.
100F	SWITCH - FUSE AMPERE RATING INDICATED, 3 POLE UNLESS INDICATED OTHERWISE.
450	CIRCUIT BREAKER, THERMAL MAGNETIC TRIP SHOWN, 3 POLE UNLESS INDICATED OTHERWISE.
15/M	CIRCUIT BREAKER, MAGNETIC TRIP ONLY, AMPERE RATING SHOWN, 3 POLE UNLESS INDICATED OTHERWISE.
	MAGNETIC STARTER WITH NEMA SIZE INDICATED.
M	MOTOR, SQUIRREL CAGE INDUCTION, HORSEPOWER INDICATED (M).
	NONFUSED DISCONNECT SWITCH, 30 AMPERE AND 3 POLE UNLESS INDICATED OTHERWISE.

TYPE 4

ELECTRICAL ONE-LINE DIAGRAM

US Army Corps of Engineers Walla Walla District

ICE HARBOR LOCK AND DAM

SYSTEM COMBINATION 3 - TYPE 4

ELECTRICAL ONE-LINE DIAGRAM

PLATE 3.3.4

UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

9. System Combination 3A—Alternate Adaptive Migration Strategy for Transportation and Bypass

System Combination 3A applies a flexible migration strategy allowing for both transportation and inriver migration. In this regard System Combination 3 and 3A are similar. The main difference between the two alternatives is the method used for inriver migration. System Combination 3 uses surface collectors at Lower Granite, Little Goose, and Lower Monumental Dams to collect the fish and guide them to modified spillbays or through the central non-overflow monoliths. System Combination 3A depends upon RSWS for both attracting the fish to the spillbays and passing the fish downstream when in bypass mode.

At Lower Granite and Lower Monumental Dams, SBC channels would be constructed in front of Turbine Units 5 and 6 to collect juvenile fish for downstream transportation via barge or truck. A RSW would be installed in Spillbays 3 and 5. Each RSW would consist of a removable raised ogee crest placed between the upstream portions of the spillbay piers, spanning the entire spillbay width, with the downstream remainder of the spillbay to remain at its existing elevation. A BGS would be installed to guide the fish away from Powerhouse Units 1 to 4 and towards the SBC or the RSWs. The surface collector, BGS, and RSWs are collectively referred to as SBC Type 5. The SBC Type 5 design allows for either inriver fish passage or collection of juveniles for transportation.

As with the other system combinations, ESBS intake diversion screen systems would be used in conjunction with the Type 5 SBC to collect fish that pass under or around the components of the SBC system and into the turbine intakes. At Lower Granite the existing ESBS would be used, whereas at Lower Monumental there would need to be new ESBS to replace the existing STS diversion screen system. The ESBS would be located in all six turbine intakes.

At Little Goose a full-length powerhouse occlusion structure would be installed to guide fish away from the powerhouse towards RSWs placed in Spillbays 1 and 4. The fish would pass fish directly to the tailrace. The existing ESBS intake diversion systems would be used in all unit intakes. This surface collection system is referred to as SBC Type 6.

At Ice Harbor an RSW would be constructed at Spillbays 1 and 4. A BGS would be included in the forebay to direct fish away from the powerhouse intakes. The RSWs and BGS together are referred to as SBC Type 7. Fish guided by the BGS would be passed directly to the tailrace via the RSW. New ESBS intake diversion screens would replace the existing STS diversion screens in the turbine intakes to offer improved bypass efficiency for any fish which do pass under the BGS.

Detailed descriptions of the specific bypass and collection facilities at each project which make up System Combination 3A are presented in the following text, or referenced to earlier text where applicable.

9.1 Lower Granite: 2-Unit Collection/Transport SBC with Existing ESBS, BGS, and Two RSWs – SBC Type 5

SBC Type 5 is designed to allow for fish collection and transportation using a two unit SBC, and for bypassing the fish over a modified spillway using RSWs. The selected passage method would vary depending on river conditions, etc.

Surface Collector

The goal of the two-unit SBC is to guide fish to a single SBC channel by the use of a physical guidance structure located in the forebay. The collected fish would be directed to the existing juvenile fish gallery and then downstream to the existing juvenile facilities. The option includes the continued use of existing ESBS intake diversion screens in conjunction with the new SBC channel. Fish passing under the BGS and into the turbine intakes would be diverted towards the juvenile fish gallery. The two-unit SBC is depicted on Plates 4.1.1 through 4.1.3.

SBC Type 5 utilizes a shortened SBC channel, which extends only across Turbine Units 5 and 6. The channel is 21.3 meters (70 feet) deep and utilizes similar hydraulic design parameters described for SBC Type 1; therefore, the channel layout is similar to the SBC Type 1 design, however, there are some notable differences. This option includes only one entrance with a corresponding total system flow equal to one-third of that defined for SBC Type 1. The orientation of the internal conduit is in the opposite direction from the channels described for SBC Type 1 in that the flow enters through an entrance near the south end of the channel and then turns 90-degrees to the north. The fish transport flow is passed into the juvenile fish gallery to the north of the existing north auxiliary water port. The auxiliary water port is maintained so that supplemental flow can be added to the gallery as required. Additionally, the use of a single fish transport conduit allows the overall channel width to be reduced by approximately 2.7 meters (9 feet) from that shown for SBC Type 1. Other than these differences, the channel operates in fashion similar to that described for SBC Type 1. Screened flow is discharged over Spillbay 1 via an SES. The SES is similar to the structure described for SBC Type 1.

When the fish passage operational strategy is inriver passage, a bulkhead could be placed in the screened flow/bypass channel to prevent fish passage through the SBC channel. The goal would be to maximize fish passage over the RSWs. Alternatively, the surface collector could be used to collect fish for inriver passage. This would be accomplished by diverting the fish through the bypass doors located in the SBC channel and directing the fish to Spillbay 1 via the SES. The fish would then pass over the spillway while the tainter gate is partially raised. This strategy would likely reduce the number of fish in the vicinity of the collector swimming to the turbine intakes. However, it would also likely reduce the number of fish bypassing over the RSWs.

A cutoff wall would be installed on the underside of the surface collector to prevent fish from swimming underneath the surface collector in the vicinity of Spillbay 1, towards the turbine intakes. The cutoff wall is similar to the cutoff wall included for SBC Type 1, and is described in more detail in Section 5.1.

Alternate Discharge of Screened Water

The design for this option calls for screened water to flow into a SES and then over Spillbay 1. There are alternatives available that would be investigated prior to final design of this SBC type. Each of the alternatives described below would allow an RSW to be placed in Spillbay 1. Because the BGS guides fish to the spillway, it is desirable to have an RSW as close as possible to the end of the BGS. Spillbay 1 is the closest spillbay to the end of the BGS.

One alternative is to provide a channel extending through the central non-overflow monolith, over the tailrace deck, and into the tailrace. The screened water could then be passed through this channel. This concept is similar to that described in Section 7.1 and Attachment A to this report. A number of design issues would have to be addressed, including optimizing the discharge locations and addressing effects to current dam operations. Channeling flow through the central non-overflow would allow the surface collector to be able to collect and bypass fish downstream of the dam.

Another alternative to passing flow over Spillbay 1 is to install a pump-back system to pump the water back into the reservoir. This would allow the 56.6 m^3/s (2,000 cfs) flow to be used for hydropower production. This option would not allow the surface collector to be used for bypassing fish when not in transport mode.

Also, the flow could be routed to the adult fish attraction water channel below the tailrace deck. This would require dissipation of hydraulic head. This option would not allow the surface collector to be used for bypassing fish when not in transport mode.

<u>Behavioral Guidance Structure</u>

Since the channel only extends across Units 5 and 6, a BGS is included in the forebay to guide the fish away from Units 1 through 4. The BGS is shown on Plate 3.1.5. The BGS concept design is the same as that included for SBC Type 3 and included with System Combination 3.

<u>Removable Spillway Weir</u>

An RSW would be placed in Spillbays 3 and 5 to bypass fish when desired. Placing an RSW in both Spillbays 3 and 5 will likely result in more fish being attracted from the north and middle portions of the spillbay to one of the RSWs. The SES prevents the placement of an RSW in Spillbays 1 or 2.

A prototype RSW, similar to that included for SBC Type 4, is scheduled for installation and testing in Spillbay 1 at Lower Granite in Spring 2001. It is hoped more information is learned from this RSW. If this RSW is successful, it may become a permanent structure; however, it would have to be moved to Spillbay 3 or 5 if a SES is installed, as is included with this System Combination. The cost estimate assumes the use of the prototype RSW as a permanent RSW.

A detailed description of the RSW is not included herein, but the purpose and function of the RSW described for SBC Type 4 is similar to the RSW included for SBC Type 5. The layout of the prototype RSW planned for testing in 2001 is shown on Plate 4.1.4. It is anticipated that all permanent RSWs would be similar.

<u>ESBS Diversion</u>

As stated above, this SBC type includes the combined use of an SBC system and existing ESBS diversion screens. The diversion screens are included in this option to guide fish that pass below the channel structure into the turbine intakes.

9.1.1 Hydraulics

Channel Entrances

The SBC entrance hydraulics is the same as those described for SBC Type 1. In this option the entrance has been located south of the joint between Units 5 and 6, in the vicinity of the downstream end of the BGS. This location is considered advantageous in that fish being guided along the upstream face of the BGS would be led directly to the collector entrance.

Dewatering Screens

The dewatering screen section of the conduit would similar to that described in SBC Type 3. No separate secondary dewatering would be required. The screen would reduce the 56.6 m^3/s (2,000 cfs) collection flow to approximately 0.85 m^3/s (30 cfs). Control of flow through the dewatering screens is handled as described for SBC Type 1 using the spillway to adjust flow and uniformly decreasing the screen porosity.

Behavioral Guidance Structure

The hydraulic criteria for the BGS for SBC Type 5 are the same as for SBC Type 3. Flow criteria is described in Section 3.3.1.

Removable Spillway Weir

Hydraulic issues for the RSW design for SBC Type 5 are in many ways similar to that for SBC Type 4.

The prototype RSW to be installed at Lower Granite in 2001 was based on extensive model testing. The selected shape of the RSW was based upon maximizing fish attraction to the RSW in the upper 9.1 meters (30 feet) to 15.2 meters (50 feet) of the water column. Testing of the prototype RSW will provide additional information about the adequacy of the hydraulic criteria. The RSW would pass about 170 m^3/s (6,000 cfs) at MOP and about 311 m^3/s (11,000 cfs) at maximum operating pool.

Fish Ladder Extension

Because the BGS extends to the bank, it may pose a barrier to adult fish passage. An extension to the fish ladder is required to improve the number of adult fish swimming upstream of the BGS. The FLE is the same as that described for SBC Type 3.

9.1.2 Structural Design

SBC and Spillway Extension Structure

The two-unit SBC channel for SBC Type 5 is a floating structure similar to those described for the other SBC types and with similar structural design issues. As is the case for SBC Type 1, a SES with removable bulkheads will be installed in Spillbay 1. The structural design issues for the SES are the same as described in Section 5.1.2.

The single entrance and conduit allows for an additional reduction in the overall width of the channel over that shown for SBC Type 1. In fact, this SBC option has the narrowest channel of any of the other SBC types at 10.7 meters (35 feet) wide. This is an additional reduction of 2.74 meters (9 feet) from the 13.4-meter (44-foot) width shown for SBC Type 1, which further reduces the horizontal inertial force of the channel resulting from an earthquake. This reduction in horizontal load would be approximately 1,570 kN (354 kips) per powerhouse unit monolith. Expressed as a percentage of the combined hydrostatic and hydrodynamic forebay loads applied during an earthquake, if the channel were present, a direct attachment would result in an increase of about 2.7 percent to the horizontal downstream loading, and a corresponding increase in the forebay applied overturning moment of about 6.3 percent. This represents a significant reduction over the loads considered for the wider full powerhouse surface collectors. This would help address the concern for dam stability with a surface collector in place, as described in Section 5.1.2. Nonetheless, the proposed attachment, absent a detailed stability analysis, is a fused connection as proposed for SBC Type 1.

Since the fish transport flow is directed to the north, a penetration in the forebay wall of the central non-overflow section of the dam is made. The proposed design is to cut an opening through the concrete to the north of the existing auxiliary water port and add a steel caisson to receive the conduit flow. This is depicted on Plate 4.1.2. The new opening leads directly to the existing fish gallery in the dam. The caisson would be similar in design to that described for SBC Type 3. The caisson consists of stiffened steel panels designed for a fully dewatered condition at the forebay maximum flood elevation of 227.5 meters (746.5 feet). As for SBC Types 1 and 3, a debris skimmer system like the one previously described would still be required at the gallery downwell in the erection bay where the floating debris would accumulate.

<u>Behavioral Guidance Structure</u>

The BGS for this SBC type is the same as included for SBC Type 3.

<u>Removable Spillway Weir</u>

As was mentioned previously, a prototype RSW is planned for installation in Spillbay 1 at Lower Granite in the Spring 2001. This report assumes the permanent RSWs will be structurally similar to the prototype RSW.

The SBC Type 5 RSW will weigh approximately 810 tonnes (900 tons). Also, the RSW includes an extension of the spillway pier towards the forebay. The pier extension is actually connected with the weir portion of the RSW, not the spillway piers.

A large concrete block will be placed between the upstream face of the spillway and lower portion of the RSW to resist uplift on the RSW. The concrete block will form the lower sealing surface of the RSW.

The RSW is attached to a hinged connection to allow it to be rotated back into the forebay when necessary to allow for the spillbay to pass high flows when necessary. The hinge supports are anchor bolted to the spillway monolith near the bottom of the forebay. When the RSW is deployed, the hinges support the weight of the structure. A pad will rest on the bottom of the forebay to support the RSW when it is lowered.

9.1.3 Mechanical Requirements

<u>Surface Collector</u>

With the exception of the reduced mechanical requirements for the entrance debris rake discussed below, mechanical design issues for SBC Type 5 are similar to SBC Type 1, with a reduced number of vertically sweeping brush bar screen cleaners (10) and control weirs (1) required due to the single fish conduit and dewatering section.

Debris Management Systems

Debris management for SBC Type 5 is similar to the full powerhouse options with a couple of notable exceptions. Because there is only one entrance for SBC Type 5, the debris rake at the entrance would be stationary which will reduce the cost of the machine. The debris removal method would be the same as that described for SBC Type 1 utilizing a muck car; however, with only one entrance the system will be less complex. Since fish conduit flow enters the existing juvenile bypass gallery at the north end, the surface skimmer at the gallery downwell will be mounted in a stand-alone caisson dedicated solely for that purpose. As with SBC Type 1, the use of vertical brush cleaners at the dewatering screens will minimize the debris, which would be passed into the gallery.

Removable Spillway Weir

The mechanical requirements for the RSWs include a hinged connection below the weir to allow the RSW to be rotated upstream during high flows. The spillbay will then be available to pass high flows. Also, an air buoyancy/water ballast system would be included to allow the RSW to be rotated down into the forebay and back and back into normal operating position. It would consist of air and water piping, valving, air compressors and monitoring equipment. A position indicator placed on the RSW communicating with a programmable logic control would work together to carefully control the lowering and raising of the RSW by controlling the amount of air and water in the flotation tanks of the RSW.

Fish Ladder Extension

A FLE is required for SBC Type 5, similar to that required for SBC Type 3. A water pump and a hydraulic pump for the hydraulic cylinders on the two water control gates are required for the FLE.

9.1.4 Electrical Requirements

Surface Collector

Except for the reduced loading of the electrical power distribution for SBC Type 5 (substantially reduced over Type 1) the issues are similar. Electrical power is required for the debris skimmer, screen cleaners, emergency bypass doors, and the SBC entrance rake. Consequently, similar power routing and controls strategies are employed. For SBC Type 5, the total electrical load is approximately 180 amperes.

Removable Spillway Weir

The RSW would require electrical power for lights on the spillway deck, the PLC, and general use receptacles. The power requirements are approximately 4.8 kVA with a 120/240 service voltage for the two RSWs.

Fish Ladder Extension

Like the SBC Type 3, the SBC Type 5 requires a FLE. Electrical power is required for the attraction water pump motor and the hydraulic system pump motor (for the FLE control gates) near the fish ladder exit at the south non-overflow section.

9.1.5 Operation and Maintenance Issues

Surface Collector, FLE, and BGS

Except for the presence of the BGS and FLE, the system operations, corrosion protection, debris maintenance, and mechanical system maintenance issues for SBC Type 5 are similar to SBC Type 1 although reduced in magnitude. With the fixed entrance debris rake (rather than a rail-mounted one) the complexity of that system will be reduced from an O&M standpoint. Also, because the total magnitude of the system is reduced over SBC Type 1 (only one entrance and dewatering area), it is anticipated that one full-time operator will be required to handle the daily operations of the channel. This would represent an average requirement over the operating season. Off-season maintenance requirements would be reduced over the previous options due to the reduction in overall magnitude of the system.

Since the BGS directs fish (and debris) to the SBC entrance, it is likely that the entrance debris rake will operate more frequently to keep the entrance rack clear of debris. Debris management at the BGS is anticipated to be similar to that of the existing trash shear boom, except that the total volume of material should be reduced due to the presence of the trash shear boom upstream of the BGS. Good, unfettered access by boat to both faces of the BGS is possible with the integration of the vertical guide buoy into the pontoon system as shown on Plate 3.1.5. This anchorage attachment design also results in relatively little opportunity for debris to hang up on the BGS pontoon or anchor system.

Emergency RSW Removal

The operation of the RSW includes the assumption that it would be rotated into the forebay prior to design flood events so that the hydraulic capacity of the project could be maximized. The RSW would be raised back into position after the high flows have passed. This is not anticipated to be a very frequent occurrence since the flood of record on the lower Snake River is 11,600 m^3/s (409 kcfs), which occurred in 1894, before the construction of any flood control dams on the river, and this is about half the hydraulic capacity of the spillways. It would take about one-half day to rotate the RSW off the spillway. The rotation of the RSW would utilize a PLC that would control compressed air lines, air, and water valves. Air would be added to or removed from the flotation tanks slowly to provide a controlled descent or ascent of the RSW.

The RSW would need to be exercised occasionally to insure it functions properly and to allow project personnel to practice controlling the ascent/descent process.

9.1.6 Construction Issues

Described below are constructibility issues for each of the SBC Type 5 components. Refer to the implementation schedule for the SBC Type 5 option in Section 9.5.3 for more information.

Surface Collector, BGS, and FLE

Construction issues for the Type 5 SBC design are similar to those discussed for the SBC Type 1 design (as concerning the channel), with the exception of the addition of the BGS and FLE. Thus, installation strategies for the components would be the same, utilizing barged or trucked sub-assemblies erected remotely from the powerhouse for final installation by floating them into position. Final fit-out would be accomplished with the channel in place.

The BGS, being a separate floating structure, could be constructed anywhere sufficient draft is available for the rigid curtain to be assembled, installed, and floated into place. Installation of the anchorage system for the BGS would require the use of barges, cranes, and divers. Assembly and installation of the FLE would be performed in a similar manner and would be most efficiently done in conjunction with the BGS installation. Since the FLE components have considerably less draft than the BGS components, the depth requirements for locations in the river where the construction and initial assembly could take place are less restrictive.

Removable Spillway Weir

The new RSW would be installed in Spillbay 5, and designed so it could be floated. The RSW would be constructed off site and shipped upstream. The hinges, a large concrete closure block spanning the spillway width, and the spillway sealing/bearing surface would be partially installed underwater with divers. The RSW would be floated into position and attached to the hinge.

It is planned to relocate the RSW, which will be used for the prototype testing in 2001, to Spillbay 3. New hinges, a concrete closure block, and a spillway sealing/bearing surface will have to be installed in Spillbay 3. This will all be in-water work.

9.1.7 Construction and O&M Costs

Total estimated cost of engineering design and construction for the Type 5 SBC at Lower Granite is 76,300,000 in 1998 dollars. A cost breakdown is presented in spreadsheet format on the following two pages. Annual O&M costs are estimated to be $260,000.

9.2 Little Goose: Occlusion Structure (with Existing ESBS) and Two RSWs - SBC Type 6

SBC Type 6 is intended to improve inriver passage over the spillway at Little Goose Dam; no major system improvements for transportation are included. The strategy of SBC Type 6 is to reduce the flow patterns that attract fish to the turbine intakes, and direct the flow and fish to RSWs placed in Spillbays 1 and 4. The RSWs are the same as those described for SBC Type 5.

A large box-shaped occlusion structure would be placed in front of the powerhouse. This occlusion would block flow currently directed towards the powerhouse intakes. The theory is that fish in the upper portions of the water column would not experience the large downward flows that draw them into the turbine intakes. Instead, with the RSWs operating, lateral flow patterns would be created, drawing the fish to the RSWs.

The occlusion structure may also provide an additional benefit. Observations during the prototype SBC channel testing at Lower Granite Dam seemed to show that the presence of the SBC improved the fish guidance efficiency (FGE) of the existing ESBS intake diversion screens. However, there has not been a comprehensive test dedicated to confirm these observations; therefore, another possible benefit of the occlusion structure is to improve the FGE, similar to the prototype SBC.

It is uncertain that this strategy would work well. If model testing shows that an occlusion structure is not likely to divert a high percentage of fish to the RSWs, a full powerhouse surface collector (SBC Type 2) could be installed that would collect fish and bypass them through Spillbay 1 or the central non-overflow. Alternatively, a bypass through the north non-overflow section could be considered; however, this option

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CHECKED BY: RGW , BGC

TYPE 5 SBC - FULL POWERHOUSE SBC (with Existing ESBS) - LOWER GRANITE LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**TESTING - BGS GAP**				$ 1,000,000
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS) - {No escalation)				**$1,000,000**
2	**RSW TESTING - (INCLUDED IN ANADROMOUS FISH EVALUATION PROGRAM)**				
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS) - {No escalation)				**$0**
3	**PROTOTYPE ->TYPE - #5, - PARTIAL POWERHOUSE SBC**				
3a	**SURFACE BYPASS COLLECTOR CHANNEL**				
a	Channel Structure - (metal exterior floor and walls, 5' head differential) {Type 3}	4,190	M^2	$ 710	$ 2,974,900
b	Interior Conduit Structures - (floors and walls, minus screens) {Type 3}	1,260	M^2	$ 710	$ 894,600
c	Miscellaneous Walkways, Roof Structures, Trash Racks, Bulkhead Panels (% of costs above 2 items)	$ 3,869,500	$	10%	$ 386,950
d	Channel Flotation Cells {Type 1}	181	M	$ 7,100	$ 1,285,100
e	Dewatering Screen Panels (removable panels stainless steel wedge-wire screen with spare panels)	416	M^2	$ 1,470	$ 611,520
f	Screen Cleaners (vertical brush cleaners)	10	EA.	$ 40,000	$ 400,000
g	Channel Entrance Debris Rake System	1	LS	$ 659,000	$ 659,000
h	Emergency Bypass Doors and Tilting Control Weirs	33.5	M^2	$ 1,640	$ 55,000
I	Cutoff Wall - below Channel (includes foundation)	460	M^2	$ 1,170	$ 538,200
j	Structural Support and Guide System	56	Tonne	$ 5,000	$ 280,000
	ITEM 3, SUBTOTAL				$ 8,085,270
3b	**CHANNEL CONDUIT CONNECTION TO GALLERY (AT CENTRAL NON-OVERFLOW & ERECTION BAY)**				
a	Steel Caissons and Related Structures	280	M^2	$ 1,530	$ 428,400
b	Concrete Removal	45	M^3	$ 1,330	$ 59,850
c	Miscellaneous (Debris Skimmer, Hopper, Existing Caisson Removal, New Gate)	1	LS	$ 170,000	$ 170,000
	ITEM 4, SUBTOTAL				$ 658,250
3c	**SPILLWAY EXTENSION STRUCTURE**				
a	Structure Floor and Wall Panels	774	M^2	$ 1,550	1,200,000
b	Bulkhead Panels	519	M^2	$ 540	280,000
	ITEM 5, SUBTOTAL				$ 1,480,000
3d	**MISCELLANEOUS**				
a	Trash Shear Boom Relocation	1	LS	$ 75,000	$ 75,000
b	Existing Prototype SBC Channel, and Prototype BGS Removal and Disposal	2,770	Tonne	$ 900	$ 2,493,000
c	9.1-Tonne Boom Truck	1	EA.	$ 200,000	$ 200,000
d	Electrical Requirements	1	LS	$ 312,270	$ 312,270
	ITEM 3, SUBTOTAL				$ 3,080,270
	Subtotal Direct Construction Costs				$ 13,303,790
	CONTRACTOR'S RELATED COSTS				
	Mobilization/Demobilization	$ 13,303,790	$	5.0%	$ 665,190
	General Contractors Overhead and Profit	$ 13,968,980	$	26.5%	$ 3,701,780
	CONSTRUCTION CONTRACT - SUBTOTAL				$ 17,670,759
	Construction Contingency	$ 17,670,759	$	25.0%	$ 4,417,690
	06 Account - TOTAL CONSTRUCTION COSTS				*$ 22,088,449*
	30 Account - PLANNING AND ENGINEERING	$ 22,088,449	$	22.5%	$ 4,969,901
	31 Account - CONSTRUCTION MANAGEMENT	$ 22,088,449	$	12.5%	$ 2,761,056

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TYPE 5 SBC - FULL POWERHOUSE SBC (with Existing ESBS) - LOWER GRANITE LOCK AND DAM

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ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS) - {No escalation)				**$29,819,406**
4	**FINAL ->TYPE - #5 SBC - PARTIAL POWERHOUSE SBC, BGS, FLE, & (1 MOVED & 1 NEW) RSW**				
4a	**SURFACE BYPASS COLLECTOR CHANNEL**				
a	Modified Prototype Surface Bypass Collector Channel (Unknown Assume %)	$ 13,303,790	$	10.0%	$ 1,330,379
	ITEM 7, SUBTOTAL				$ 1,330,379
4b	**BEHAVIORAL GUIDANCE STRUCTURE**	457 M - LONG			
a	BGS {Type 3}	457	M	$ 19,700	$ 9,002,900
b	FLE (13m cost added to provide flood adjustability)	181	M	$ 8,070	$ 1,460,670
c	Mechanical Requirements	1	LS	$ 175,000	$ 175,000
	ITEM 8, SUBTOTAL				$ 10,638,570
4c	**REMOVABLE SPILLWAY WEIR STRUCTURE**				
a	Submersible Spillway Weir Structure (Mob/Demob & Overhead & Profit) Cost from Bid Contract	1	EA.	$ 8,432,998	$ 8,432,998
b	Move Existing Submersible Spillway Weir Structure into another spillbay	1	EA.	$ 1,505,741	$ 1,505,741
	ITEM 9, SUBTOTAL				$ 9,938,739
	Subtotal Direct Construction Costs				$ 21,907,688
	CONTRACTOR'S RELATED COSTS				
	Mobilization/Demobilization	$ 21,907,688	$	5.0%	$ 1,095,384
	General Contractors Overhead and Profit	$ 23,003,072	$	26.5%	$ 6,095,814
	CONSTRUCTION CONTRACT - SUBTOTAL				$ 29,098,887
	Construction Contingency (RSW = 15% & Rest is 25%) Composite Shown	$ 29,098,887	$	20.2%	$ 5,869,260
	06 Account - TOTAL CONSTRUCTION COSTS				*$ 34,968,146*
	30 Account - PLANNING AND ENGINEERING	$ 34,968,146	$	20.0%	$ 6,993,629
	31 Account - CONSTRUCTION MANAGEMENT	$ 34,968,146	$	10.0%	$ 3,496,815
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS) - {No escalation)				**$45,458,590**
	TOTAL ESTIMATED COST OF PROJECT CONSTRUCTION (IN 1998 DOLLARS) - {No escalation)				**$76,277,996**

has not been investigated yet. The occlusion structure is included in this option to show a possible alternative to a surface collector at Little Goose. Use of a BGS and a two unit surface collector is not possible because the BGS would have to cross the navigation lock in order to be effective.

Installation of an RSW in Spillbay 1 would require moving the trash boom. A potential location is shown on Plate 4.3.1. The relocated trash boom would have to be analyzed and possibly strengthened to account for different loadings due its new location.

9.2.1 Hydraulics

Removable Spillway Weirs

Hydraulic considerations for the RSWs at Little Goose would be similar to those for Lower Granite (SBC Type 5). The shape of the spillway and piers are similar; however, additional spillbay and forebay modeling is necessary to determine the optimal flow patterns in the forebay and along the RSW.

As described above, the goal of this alternative is to divert flow in the upper portions of the water column from heading towards the turbine intakes. The RSWs would create a surface flow towards the RSWs, and fish would then pass over the RSWs. Additional hydraulic modeling would be required to confirm if this strategy would be effective. Operation of the powerhouse would likely have a significant effect on flow patterns near the powerhouse.

Fish north of the RSWs would likely be attracted to the RSW in Spillbay 3 and would not experience the effects of the powerhouse flow.

Fish Guidance Efficiency Improvements

Although the approach taken in this preliminary design study was to mimic the SBC prototype hydraulic effect, some pertinent questions should be addressed from both a biological and hydraulic model perspective prior to any final design of an ESBS guidance improvement structure. These issues would include:

- Are the SBC observations valid or do they reflect scatter in the data, or the influence of other parameters?
- What features or influences of an occlusion structure might cause improvements in diversion screen FGE?

The occlusion structure could potentially influence FGE of the diversion screens either by improving fish guidance from higher in the forebay to the turbine intake and/or by locally improving flow conditions and fish guidance within the turbine intake, across the screens, and into the bulkhead slots. These flow features could likely be evaluated or confirmed through use of the existing models. Modeling should be pursued if further development of this option is proposed; use of the modeling would allow optimization of the design.

9.2.2 Structural Design

Removable Spillway Weirs

The structural design considerations for the RSWs are the same as for the RSWs included for SBC Type 5. The spillway and pier shapes at Little Goose are similar to those for Lower Granite. It is possible that final design criteria would indicate the design seismic loading is higher at Little Goose than at Lower Granite; however, this should not complicate the design significantly.

Occlusion Structure

The structural system consists of braced structural steel support frames located at the piers with stiffened steel plate panels spanning approximately 9.1 meters (30 feet) between the frames. The panels make up the bottom of the structure and a partial height front wall.

Loads for consideration in the design of the structural system include those from load rejection, static and dynamic forces due to the hydraulic load caused by water passing down and around the structure, seismic inertial loads due to the mass of confined water between the vertical steel wall and the dam, seismic inertial loads due to the mass of the structure itself, and the hydrodynamic Westergaard forces imposed on the structure during a seismic event.

It is conceivable that the structural bracing system could be designed for the full inertial forces described above; however, this is not seen as a reasonable approach to the design of this structure. Rather, it is proposed that the structure be designed to limit the transmission of these forces to the dam. Not only does this result in an overall reduction in the magnitude of the steel structure, but it also reduces concerns about the stability of the powerhouse under additional seismic loads, as previously discussed for other options. To limit the transmission of inertial forces to the structure and the dam, the primary load transfer feature for transfer of inertial forces (the partial height vertical wall) would be designed to yield under seismic loads. To accomplish this yielding, it is proposed that the top of the wall be attached to the frame with fused connections consisting of shear pins designed to shear at a prescribed load with the bottom of the wall attached by large hinged connections. During a major seismic event, the panels would fall onto the structure to be restored to their original position after inspection of the structure. It should be noted that yielding of the panels would be an extremely rare occurrence.

9.2.3 Mechanical Requirements

Removable Spillway Weir

The mechanical requirements for the RSWs are the same as for SBC Type 5.

Occlusion Structure

The mechanical system requirements for the occlusion structure center on the intake trash rake access door and door-opening system. The doors are required in the otherwise solid bottom panel of the guidance structure located just above and upstream of the intake openings across the length of the powerhouse. The doors allow the trash rake to access the trash racks below. The proposed door opening system is a low-tech solution to the problem. A system of winches and cables is installed with the winches located on the parapet wall at deck level, with the cables attached to the doors through a series of fixed pulleys or blocks. Two cables would be required for each door (one on each side) driven by a tandem winch arrangement with a single motor. This could involve two drums connected by a 7.6-meter

(25-foot) shaft or a single split drum with a pulley system. Alternatively, submerged hydraulic or pneumatic cylinders could operate the doors. Selection of a door actuation strategy would be a final design issue, but for the purposes of cost estimating, the cable and winch design is assumed.

9.2.4 Electrical Requirements

Removable Spillway Weir

The electrical requirements are similar to those required for the RSW in SBC Type 5. The RSW would require electrical power for lights on the spillway deck, the PLC, and general use receptacles. The power requirements are approximately 4.8 kVA with a 120/240 service voltage for the two RSWs.

Occlusion Structure

The electrical loads for the occlusion structure come from the 18 electric winches proposed for opening and closing the new trash rake access doors located in the bottom panel of the proposed structure. These winches would be located at the intake deck level along the upstream face of the powerhouse. Because the functioning of these winches is not a critical system issue (they provide access to the trash racks for the intake trash rake), it is anticipated a spare circuit would be used. A manual start switch would provide required control of each door along with an auto-stop switch governed by position limit switches on the doors to indicate when they had reached their fully open or closed positions.

The occlusion structure electrical requirements are approximately 20 amperes.

9.2.5 Operation and Maintenance Issues

Removable Spillway Weir

The O&M issues for the RSW for SBC Type 6 are identical to those for the RSW included for SBC Type 5. Like the RSW included for SBC Type 5, the RSW at Little Goose would have to be rotated onto the bottom of the forebay to allow for passage of high flows.

Occlusion Structure

Operation of the doors is assumed to be a part of the overall trash raking activities at the project and are not accounted for separately in the O&M cost estimate. Occasional inspection of the steel structure would be required; however, because the structure is proposed to be finished with a thermal spray coating (beyond inspection for debris) no major maintenance is anticipated for the structure.

9.2.6 Construction Issues

Removable Spillway Weir

Issues related to the construction of the RSWs are similar to that for the new RSW included for SBC Type 5. The RSWs would likely be fabricated off site and floated to Little Goose.

Occlusion Structure

It is assumed that fabrication of the structure would be accomplished in panels, which could be transported by barge or truck. Through the use of a mobile crane on the intake deck, the panels would be lowered into place for final installation onto pre-installed support steel. Because the construction occurs directly in front of the turbine intakes, turbines at the affected and adjacent intakes would have to be shut down during diving activities.

Construction sequencing issues identified for other options apply to the occlusion structure. These include the in-water work window and other project operations constraints. Except for minor assembly work on the support structure and the panels, most of the installation work would be conducted at the face of the powerhouse in the forebay, thus requiring unit outages. Scheduling of unit outages could be combined with other unit maintenance activities, and because there is no specific advantage from an operations standpoint to complete construction in any particular sequence, flexibility is quite high.

Installation should take about 3 months. Fabrication should take about the same amount of time.

9.2.7 Construction and O&M Costs

Total estimated cost of engineering design and construction for the Type 6 SBC at Little Goose is 42,100,000 in 1998 dollars. A cost breakdown is presented in spreadsheet format on the following page. Annual O&M costs are estimated to be $34,000.

9.3 Lower Monumental: 2-Unit Collection/Transport SBC with New ESBS, BGS, and Two RSWs– SBC Type 5

The design of the Type 5 SBC at Lower Monumental is similar to that described for the SBC Type 5 at Lower Granite (refer to Section 9.1), with some exceptions. One notable exception is that the project layout is reversed at Lower Monumental; the powerhouse is located to the north of the spillway. As a result, the reader should note that references to north and south in the discussions for Lower Granite are reversed in the discussions for Lower Granite. Plans and details of the SBC Type 5, as designed for Lower Monumental, are shown on Plates 4.3.1 and 4.3.2.

Because the SBC Type 5 design for Lower Monumental is similar to the design for Lower Granite, investigation of alternatives to passing screened flow over the spillbay adjacent to the powerhouse, as described in Section 9.1, apply for the Lower Monumental design.

As previously discussed, other differences at Lower Monumental include the 0.91-meter (3.0-foot) normal operating range fluctuation of the forebay and the need to replace the existing STS intake diversion system with a new ESBS diversion system. Details concerning the effects of these differences are discussed in the following sections.

9.3.1 Hydraulics

<u>Surface Collector</u>

The Type 5 SBC installation at Lower Monumental is nearly identical to the Type 5 SBC at Lower Granite. Issues related to collector entrances, dewatering, the cutoff wall, and bypass are the same. Screened water would pass through a SES in Spillbay 8.

<u>Behavioral Guidance Structure</u>

The BGS proposed for the SBC Type 5 at Lower Monumental is identical to that included for the SBC Type 3. Refer to Section 8.3.1 for more information.

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CHECKED BY: RGW , BGC

TYPE 6 - SBC OCCLUSION STRUCTURE - LITTLE GOOSE LOCK AND DAM

ITEM NO.		ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1		**TYPE - #6 SBC - Partial Powerhouse Occlusion Structure & (2 Each) RSW**				
1a		**OCCLUSION STRUCTURE**				
	a	Steel Structure (including wall and floor panels, trash rake access doors and bracing)	4,122	M^2	$ 710	**$ 2,926,620**
	b	Trash Rake Access Door Hoisting System	18	EA.	$ 12,000	**$ 216,000**
	c	Trash Shear Boom Relocation	1	LS	$ 75,000	**$ 75,000**
	d	Electrical Requirements	1	LS	$ 45,240	**$ 45,240**
		ITEM SUBTOTAL				**$ 3,262,860**
1b		**REMOVABLE SPILLWAY WEIR STRUCTURE**				
	a	Submersible Spillway Weir Structure (Mob/Demob & Overhead & Profit) Cost from Bid Contract	2	EA.	$ 8,432,998	**$ 16,865,997**
		ITEM 6, SUBTOTAL				**$ 16,865,997**
		Subtotal Direct Construction Costs				**$ 20,128,857**
		CONTRACTOR'S RELATED COSTS				
		Mobilization/Demobilization	$ 20,128,857	$	5.0%	**$ 1,006,443**
		General Contractors Overhead and Profit	$ 21,135,299	$	26.5%	**$ 5,600,854**
		CONSTRUCTION CONTRACT - SUBTOTAL				**$ 26,736,154**
		Construction Contingency (RSW = 15% & Rest is 25%) Composite Shown	$ 26,736,154	$	16.6%	**$ 4,443,812**
		06 Account - TOTAL CONSTRUCTION COSTS				***$ 31,179,966***
		30 Account - PLANNING AND ENGINEERING	$ 31,179,966	$	22.5%	**$ 7,015,492**
		31 Account - CONSTRUCTION MANAGEMENT	$ 31,179,966	$	12.5%	**$ 3,897,496**
		TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS) - {No escalation)				**$42,092,954**

TOTAL ESTIMATED COST OF PROJECT CONSTRUCTION (IN 1998 DOLLARS) - {No escalation)	**$42,092,954**

DEIS/E - Major Sys Imp/CamRdy/Annexes/Annex B/cost spreadsheet.xls/Type 6 - Goose

Fish Ladder Extension

The hydraulic features of the FLE are as described in Section 8.1.1, including supplemental pumping. A final design analysis may reveal the need for slightly greater pumping capabilities since the FLE at Lower Monumental would be about 46 meters (150 feet) longer.

9.3.2 Structural Design

Structural design issues and criteria for the Type 5 SBC at Lower Monumental are similar to those presented for other SBC types. Although potential wind-driven wave loading is slightly greater than for Lower Granite, it is significantly less than at Little Goose and should not present a problem. Other information for the SBC Type 5 design is similar to that included in Section 9.1.2. Structural issues associated with the new ESBS intake diversion system are as described in Section 5.3.2.

9.3.3 Mechanical Requirements

Mechanical requirements for the Type 5 SBC at Lower Monumental are similar to the SBC Type 5 at Lower Granite except that the debris skimmer is not required, which reduces the system complexity somewhat. Refer to Section 9.1.3 for more information. Mechanical requirements for the new ESBS systems are as described in Section 5.3.3.

9.3.4 Electrical Requirements

The electrical requirements for the Type 5 SBC at Lower Monumental are virtually the same as for the Type 5 SBC at Lower Granite. Power is required for the surface collector, RSW lighting, and FLE pumps.

9.3.5 Operation and Maintenance Requirements

The O&M requirements for the surface collector, FLE, and RSWs are essentially the same as described for SBC Type 5 at Lower Granite. Refer to Section 9.1.5 for more information.

9.3.6 Construction Issues

Issues related to the construction of the BGS, surface collector, FLE, and RSWs are essentially the same as for Type 5 SBC at Lower Granite. Refer to Section 9.1.6 for more information.

9.3.7 Construction and O&M Costs

Total estimated cost of engineering design and construction for the Type 5 SBC at Lower Monumental is $95,700,000 in 1998 dollars, including new ESBS. A cost breakdown is presented in spreadsheet format on the following two pages. Annual O&M costs are estimated to be $260,000.

9.4 Ice Harbor: RSW with New ESBS – SBC Type 7

The goal of the Type 7 SBC design is to provide an SBC facility at the spillway to divert fish away from the powerhouse and toward the spillway. Two spillbays would be modified to each provide an overflow spill of approximately 170 m^3/s (6,000 cfs) at the surface of the forebay to attract and safely pass the fish directly to the tailrace. Two RSW are proposed to serve this function at Ice Harbor, as depicted on Plate 4.4.1. A typical RSW is shown on Plate 4.1.4.

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DESIGN & ESTIMATE STATUS: CONCEPTUAL
PRICE LEVEL 1998

DATE: Nov-98 & Dec 00
ESTIMATOR: PJC, KWP
CHECKED BY: RGW , BGC

TYPE 5 SBC - 2-UNIT BYPASS/COLLECTION SBC - LOWER MONUMENTAL LOCK AND DAM

ITEM NO.		ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1		**TYPE - #5 SBC - Partial Powerhouse SBC, BGS, FLE, & (2 Each) RSW**				
1a		**SURFACE BYPASS COLLECTOR CHANNEL**				
	a	Channel Structure - (metal exterior floor and walls, 5' head differential) {Type 3}	4,190	M^2	$ 710	**$ 2,974,900**
	b	Interior Conduit Structures - (floors and walls, minus screens) {Type 3}	1,260	M^2	$ 710	**$ 894,600**
	c	Miscellaneous Walkways, Roof Structures, Trash Racks, Bulkhead Panels (% of costs above 2 items)	$ 3,869,500	$	10%	**$ 386,950**
	d	Channel Flotation Cells {Type 1}	181	M	$ 7,100	**$ 1,285,100**
	e	Dewatering Screen Panels (removable panels stainless steel wedge-wire screen with spare panels)	416	M^2	$ 1,470	**$ 611,520**
	f	Screen Cleaners (vertical brush cleaners)	10	EA.	$ 40,000	**$ 400,000**
	g	Channel Entrance Debris Rake System	1	LS	$ 659,000	**$ 659,000**
	h	Emergency Bypass Doors and Tilting Control Weirs	33.5	M^2	$ 1,640	**$ 55,000**
	I	Cutoff Wall - below Channel (includes foundation)	460	M^2	$ 1,170	**$ 538,200**
	j	Structural Support and Guide System	56	Tonne	$ 5,000	**$ 280,000**
		ITEM SUBTOTAL				**8,085,270**
1b		**CHANNEL CONDUIT CONNECTION TO GALLERY (AT CENTRAL NON-OVERFLOW)**				
	a	Steel Caissons and Related Structures	139	M^2	1,530	**212,670**
	b	Concrete Removal	60	M^3	1,330	**79,800**
		ITEM SUBTOTAL				**292,470**
1c		**BEHAVIORAL GUIDANCE STRUCTURE**				
	a	BGS {Type 3}	518	M	18,200	**9,427,600**
	b	FLE (13m cost added to provide flood adjustability)	214	M	8,070	**1,726,980**
	c	Mechanical Requirements	1	LS	175,000	**175,000**
		ITEM SUBTOTAL				**11,329,580**
1d		**MISCELLANEOUS**				
	a	Electrical Requirements	1	LS	267,790	**267,790**
		ITEM SUBTOTAL				**267,790**
1e		**REMOVABLE SPILLWAY WEIR STRUCTURE - (RSW)**				
	a	Submersible Spillway Weir Structure (Mob/Demob & Overhead & Profit) Cost from Bid Contract	2	EA.	$ 8,432,998	**$ 16,865,997**
		ITEM 6, SUBTOTAL				**$ 16,865,997**
		Subtotal Direct Construction Costs				**36,841,107**
		CONSTRUCTION RELATED COSTS				
		Mobilization/Demobilization	36,841,107	$	5.0%	**1,842,055**
		General Contractors Overhead and Profit	38,683,162	$	26.5%	**10,251,038**
		CONSTRUCTION SUBTOTAL				**48,934,200**
		Construction Contingency (RSW = 15% & Rest is 25%) Composite Shown	48,934,200	$	20.4%	**9,993,324**
		06 Account - TOTAL CONSTRUCTION COSTS				***58,927,524***
		30 Account - PLANNING AND ENGINEERING	58,927,524	$	22.5%	**13,258,693**
		31 Account - CONSTRUCTION MANAGEMENT	58,927,524	$	12.5%	**7,365,940**
		TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				**$79,552,157**

DEIS/E - Major Sys Imp/CamRdy/Annexes/Annex B/cost spreadsheet.xls/Type 5 - Monumental

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CHECKED BY: RGW , BGC

TYPE 5 SBC - 2-UNIT BYPASS/COLLECTION SBC - LOWER MONUMENTAL LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
2	**ESBS Intake Diversion Screens**				
	Installation of ESBS Diversion Screen:	18	EA	398,000	7,164,000
	ITEM SUBTOTAL				7,164,000
	Subtotal Direct Construction Costs				7,164,000
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilizatio	7,164,000	$	5.0%	358,200
	General Contractors Overhead and Prof	7,522,200	$	26.5%	1,993,383
	CONSTRUCTION SUBTOTAL				9,515,583
	Construction Contingency	9,515,583	$	25.0%	2,378,896
	06 Account - TOTAL CONSTRUCTION COSTS				*11,894,479*
	30 Account - PLANNING AND ENGINEERING	11,894,479	$	22.5%	2,676,258
	31 Account - CONSTRUCTION MANAGEMENT	11,894,479	$	12.5%	1,486,810
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				$16,057,546

TOTAL ESTIMATED COST OF PROJECT CONSTRUCTION (IN 1998 DOLLARS) - {No escalation)	**$95,609,703**

The SBC Type 7 is similar to SBC Type 4, except two RSWs are installed instead of one. RSWs would be placed in Spillbays 1 and 4. Two RSWs would provide twice as much attraction flow, increasing the chances that fish would pass over an RSW (refer to Sections 8.4 and 9.1 for detailed information concerning the RSW). The BGS is the same as included for SBC Type 3 and is described in Sections 8.1 and 8.4.

SBC Type 7 includes replacement of the existing submerged travelling screens in the turbine intakes with new ESBS.

9.4.1 Construction Issues

Construction issues for SBC Type 7 are similar to that for SBC Type 4. The BGS and FLE are expected to take about 3 to 5 months to fabricate. Fabrication of two RSWs is expected to take about 8 months, assuming one fabrication shop performs the work. Installation of the RSW, BGS, and FLE would take about 3 months. Fabrication and installation of the ESBS system should take 7 to 8 months.

9.4.2 Construction and O&M Costs

Total estimated cost of engineering design and construction for the Type 7 SBC at Ice Harbor is $85,400,000 in 1998 dollars. A cost breakdown is presented in spreadsheet format on the following two pages. Annual O&M costs are estimated to be $139,000.

9.5 Combination Summary

9.5.1 Combined Construction Issues

Construction of the combined system at the four projects involves the same issues and offers the same construction and contracting efficiency possibilities as were identified in Sections 5.5.1 and 7.5.1.

9.5.2 Summary Construction and O&M Costs

The total combined estimated engineering design and construction cost for the System Combination 3A design is $300,400,000 in 1998 dollars. Additional costs will likely be incurred if prototyping and/or major hydraulic modeling efforts of system components are deemed to be required, as is discussed in Section 4.2. Some savings in cost may be experienced due to efficiency of repetitive design and construction, as discussed in Section 9.5.1; however, this potential savings has not been estimated as part of this report. A summary of the estimated costs by project is shown below.

Estimated Engineering Design and Construction Cost – System Combination 3A

Project	Description	Estimated Construction Cost
Lower Granite	Type 5 SBC (with existing ESBS)	$76,300,000
Little Goose	Type 6 SBC (with existing ESBS)	$42,100,000
Lower Monumental	Type 5 SBC	$79,600,000
Lower Monumental	New ESBS	$16,100,000
Ice Harbor	Type 7 SBC	$69,300,000
Ice Harbor	New ESBS	$16,100,000
	System Combination Subtotal	$299,400,000
	Feasibility Studies	$1,000,000
	Total Estimated Construction Cost	**$300,400,000**

PROJECT: LOWER SNAKE RIVER S.B.C. SYSTEM COMBINATIONS - CONCEPT DESIGN REPORT
DESIGN & ESTIMATE STATUS: CONCEPTUAL
PRICE LEVEL 1998
TYPE 7 SBC - SPILLWAY SBC - ICE HARBOR LOCK AND DAM

DATE: Nov-98 & Dec 00
ESTIMATOR: PJC, KWP
CHECKED BY: RGW , BGC

ITEM NO.		ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1		**TYPE - #7 BGS to Spillway, FLE, & (2 Each) RSW**				
1a		**BEHAVIORAL GUIDANCE STRUCTURE**				
	a	BGS	671	M	18,400	**12,346,400**
	b	FLE	353	M	8,070	**2,848,710**
	c	Mechanical Requirements	1	LS	175,000	**175,000**
		ITEM SUBTOTAL				**15,370,110**
1b		**MISCELLANEOUS**				
	a	Electrical Requirements	1	LS	53,090	**53,090**
		ITEM SUBTOTAL				**53,090**
1c		**REMOVABLE SPILLWAY WEIR STRUCTURE**				
	a	Submersible Spillway Weir Structure (Mob/Demob & Overhead & Profit) Cost from Bid Contract	2	EA.	$ 8,432,998	**$ 16,865,997**
		ITEM 6, SUBTOTAL				**$ 16,865,997**
		Subtotal Direct Construction Costs				**32,289,197**
		CONSTRUCTION RELATED COSTS				
		Mobilization/Demobilization	32,289,197	$	5.0%	**1,614,460**
		General Contractors Overhead and Profit	33,903,656	$	26.5%	**8,984,469**
		CONSTRUCTION SUBTOTAL				**42,888,125**
		Construction Contingency (RSW = 15% & Rest is 25%) Composite Shown	42,888,125	$	19.8%	**8,481,805**
		06 Account - TOTAL CONSTRUCTION COSTS				***51,369,931***
		30 Account - PLANNING AND ENGINEERING	51,369,931	$	22.5%	**11,558,234**
		31 Account - CONSTRUCTION MANAGEMENT	51,369,931	$	12.5%	**6,421,241**
		TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				**$69,349,407**
2		**ESBS Intake Diversion Screens**				
		Installation of ESBS Diversion Screen	18	EA	398,000	7,164,000
		ITEM SUBTOTAL				7,164,000
		Subtotal Direct Construction Costs				7,164,000
		CONSTRUCTION RELATED COSTS				
		Mobilization/Demobilizatio	7,164,000	$	5.0%	358,200
		General Contractors Overhead and Prof	7,522,200	$	26.5%	1,993,383
		CONSTRUCTION SUBTOTAI				9,515,583
		Construction Contingenc)	9,515,583	$	25.0%	2,378,896
		06 Account - TOTAL CONSTRUCTION COSTS				*11,894,479*
		30 Account - PLANNING AND ENGINEERING	11,894,479	$	22.5%	2,676,258
		31 Account - CONSTRUCTION MANAGEMENT	11,894,479	$	12.5%	1,486,810
		TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLAR!				$16,057,546
		TOTAL ESTIMATED COST OF PROJECT CONSTRUCTION (IN 1998 DOLLARS) - {No escalation)				**$85,406,953**

PROJECT: LOWER SNAKE RIVER S.B.C. SYSTEM COMBINATIONS - CONCEPT DESIGN REPORT
DESIGN STATUS: CONCEPTUAL

DATE: Nov-98
ESTIMATOR: PJC
CHECKED BY: RGW

NEW EXTENDED LENGTH SUBMERGED BAR SCREENS - ICE HARBOR LOCK AND DAM

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	**ESBS INTAKE DIVERSION SCREENS**				
	Installation of ESBS Diversion Screens	18	EA	398,000	7,164,000
	ITEM SUBTOTAL				7,164,000
	Subtotal Direct Construction Costs				7,164,000
	CONSTRUCTION RELATED COSTS				
	Mobilization/Demobilization	7,164,000	$	5.0%	358,200
	General Contractors Overhead and Profit	7,522,200	$	26.5%	1,993,383
	CONSTRUCTION SUBTOTAL				9,515,583
	Construction Contingency	9,515,583	$	25.0%	2,378,896
	TOTAL CONSTRUCTION COSTS				***11,894,479***
	PLANNING AND ENGINEERING	11,894,479	$	22.5%	2,676,258
	CONSTRUCTION MANAGEMENT	11,894,479	$	12.5%	1,486,810
	TOTAL ESTIMATED COST OF CONSTRUCTION (IN 1998 DOLLARS)				$16,057,546

The total annual O&M costs for System Combination 3 are estimated to be $693,000 in 1998 dollars. These O&M costs do not include costs associated with O&M of the ESBS intake diversion systems, existing juvenile fish facilities, or transportation costs. Biological study costs are also not included. A summary of the O&M costs by project is shown below.

Estimated O&M Cost – System Combination 3A

Project	Description	Estimated O&M Cost
Lower Granite	Type 5 SBC (with existing ESBS)	$260,000
Little Goose	Type 6 SBC (with existing ESBS)	$34,000
Lower Monumental	Type 5 SBC (with new ESBS)	$260,000
Ice Harbor	Type 7 SBC (with new ESBS)	$139,000
	Total Estimated Annual O&M Cost	**$693,000**

9.5.3 Implementation Schedule

An implementation schedule is included below, and the assumptions and rationale used for development of the implementation schedule is also provided. The implementation schedule includes time for hydraulic model testing as appropriate, data gathering from prototype structures, preparation of construction contract documents, and construction. The implementation schedule is an optimistic schedule because it assumes no funding or manpower constraints. It assumes a large and uninterrupted commitment to complete all work so System Combination 3A can be operational as soon as reasonably possible. Any policy causing deviation from this commitment would likely affect the schedule included herein.

Lower Granite Dam

Behavioral Guidance Structure Gap Testing

It is important to keep juvenile fish from swimming downstream of the BGS, and it also is critical to ensure adult fish can swim upstream of the BGS. To achieve this, it is assumed in this study the BGS would extend to the shore to block passage of juvenile fish while a FLE would be installed to pass adult fish. However, it may be possible that a gap between the BGS and shore may be developed to allow efficient adult fish passage and would preclude juvenile fish passage downstream of the BGS; this would eliminate the need for the FLE. However, testing of the prototype BGS at Lower Granite is required to verify this. Development of a construction contract to provide for testing of the BGS gap would be scheduled for the year 2002. Construction would take place in 2003 with testing in 2004.

Removable Spillway Weir Testing

The RSW is scheduled to be installed at Lower Granite in Spring 2001. Hydraulic model testing of the RSW is required to determine the optimum ogee shape. It is anticipated model testing would take about 2 years and would be complete at the end of the juvenile fish migration season in 2002.

Surface Bypass Collector Dewatering Testing

Hydraulic model testing of various surface collector dewatering methods would be scheduled for the year 2002. This testing would lead to the development of a prototype surface collector with dewatering. The SBC structure at Lower Granite spans the width of Generator Units 5 and 6. Because a prototype SBC structure would be approximately the same size as a permanent SBC structure, it is assumed the prototype test structure would be used for the final structure following the completion of testing. Design of the prototype and a SES to pass screened flow would be scheduled for 2003 with construction in 2004 and 2005. Testing would take place in 2006.

Final Design and Construction

Plans and specifications would be developed in 2007 and 2008 for the completion of the SBC Type 5 at Lower Granite. Specific items include moving the existing RSW, installation of a second RSW, construction of a permanent BGS, construction of a FLE (if necessary), and modification of the prototype surface collector (if necessary). The narrow 3 month in-water work window significantly affects the schedule; however, because each work item is mostly independent of other work items, it is anticipated fabrication and construction can be completed in one year. Fabrication would occur in 2009 with installation during the in-water work window scheduled for 2010.

Little Goose Dam

Occlusion Structure Model Testing

Model testing of an occlusion structure is required to ensure the concept is feasible. The forebay would have to be modeled to check the effects of the combined flow patterns from the powerhouse and RSW. This testing would take place in 2002.

RSW Model Testing

Information from the prototype RSW testing at Lower Granite would be used to develop an RSW design for Little Goose. Model testing of various ogee shapes to verify the optimum design would be scheduled for 2003.

Final Design and Construction

Development of plans and specifications for two RSWs and occlusion structure would take place in 2003 and 2004, with fabrication in 2005 and installation during the in-water work window in 2006.

Lower Monumental Dam

Like Little Goose, construction of the proposed improvements at Lower Monumental would not start until all lessons learned from data gathering at Lower Granite are complete. This is important because the improvements proposed for Lower Monumental are similar to those for Lower Granite.

Hydraulic Modeling

Information gathered from all BGS testing at Lower Granite, including BGS gap testing, would be used for design of BGSs at Lower Monumental; no additional BGS modeling is anticipated.

The information gathered from the RSW testing at Lower Granite will be used to determine potential ogee shapes for RSWs at Lower Monumental. Model testing would be performed to verify the design concurrently with the RSW modeling for Little Goose in 2003.

Final Design and Construction

As described above, development of plans and specifications for the SBC Type 5 would occur at the same time as for Lower Granite in 2007 and 2008. Fabrication would be scheduled for 2009 with installation during the in-water work window scheduled for 2010.

Ice Harbor Dam

Hydraulic Modeling

Because the spillway crest would have RSWs, hydraulic model testing of RSW ogee shapes would be required. It is worth noting the spillway at Ice Harbor is significantly different than the spillways at the other three lower Snake River dams. The information gathered from the RSW testing at Lower Granite would be used to determine potential ogee shapes for RSWs at Ice Harbor. Model testing would be performed to verify the design concurrently with the RSW modeling for Little Goose and Lower Monumental in 2003.

As is true for Lower Monumental, information learned from the BGS testing at Lower Granite would be used for the final design of a BGS for Ice Harbor; therefore, no additional BGS hydraulic modeling is anticipated.

Final Design and Construction

Plans and specifications for the RSW, BGS, and FLE (if needed) would be scheduled for 2004 and 2005. Fabrication of the RSW would then take place in 2006, with installation completed during the 2007 in-water work window.

9.6 System Combination 3A Drawings

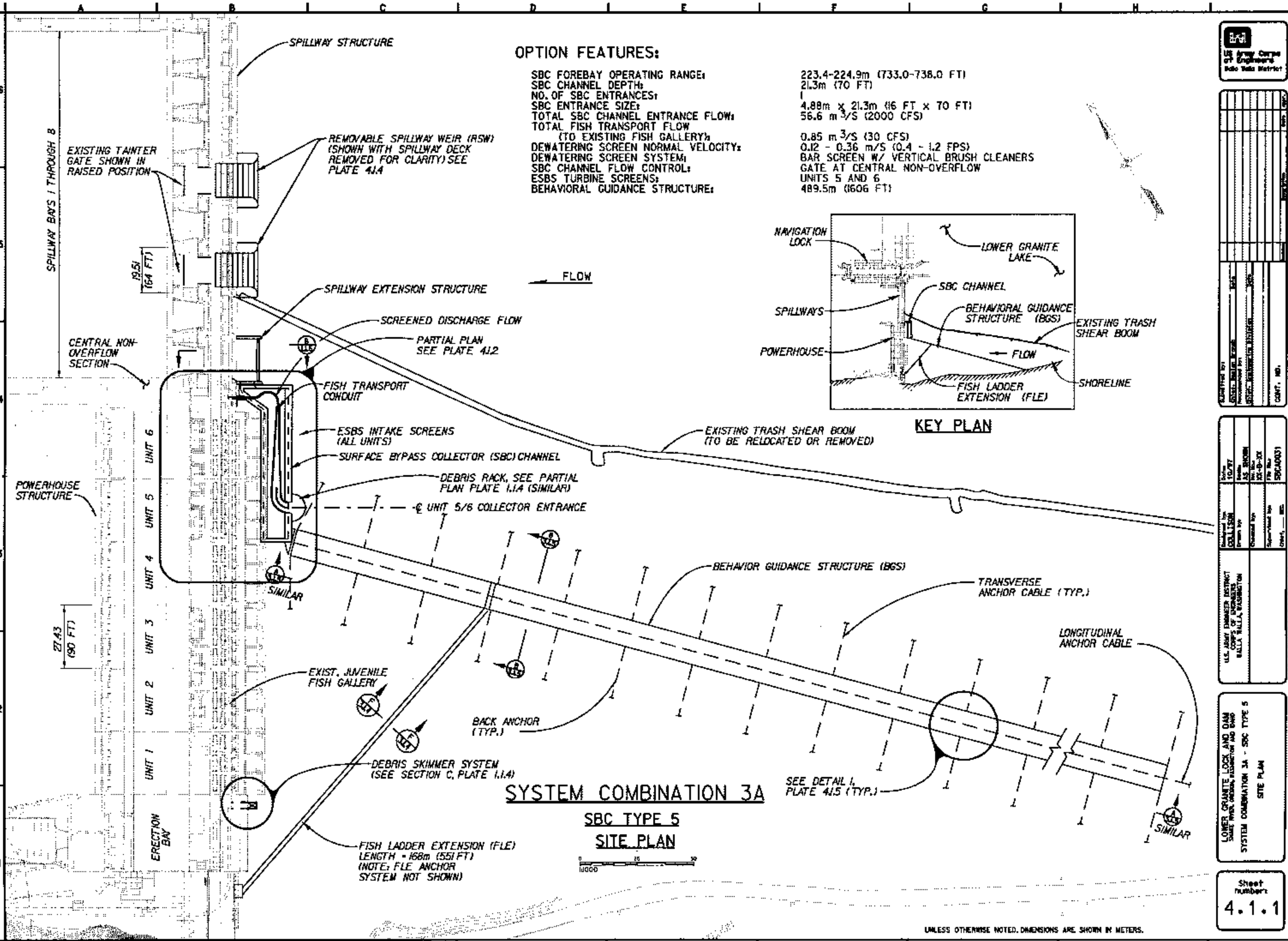
Drawings depicting the SBC designs which form System Combination 3A are included on the following pages. These drawings include:

SBC Type 5 – Lower Granite
Plate 4.1.1 – SBC Type 5 – Site Plan
Plate 4.1.2 – SBC Type 5 – Surface Collector - Plan
Plate 4.1.3 – SBC Type 5 – Sections and Elevation
Plate 4.1.4 – SBC Type 5 – Removable Spillway Weir (RSW) – Plan and Section

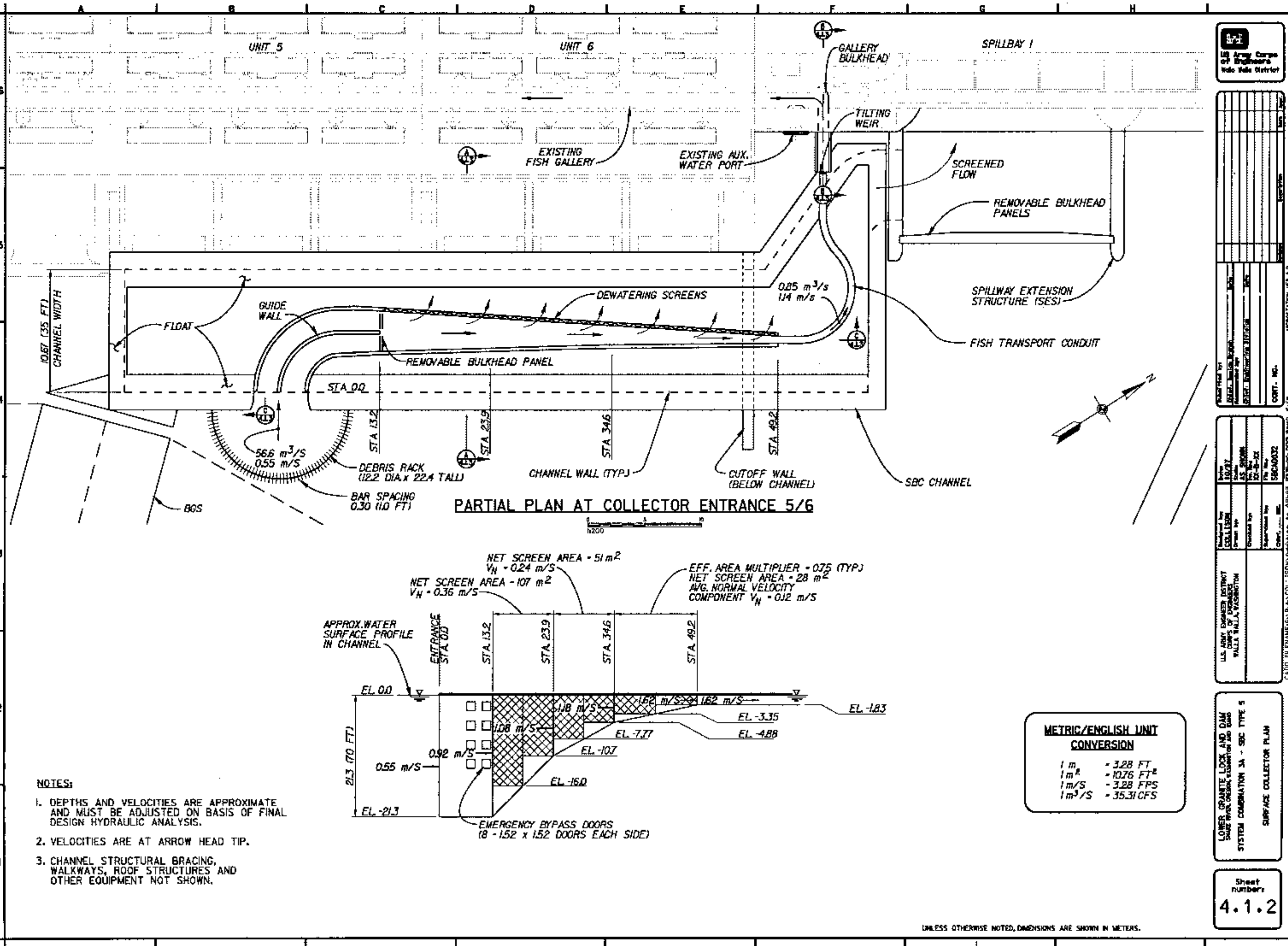
SBC Type 6 – Little Goose
Plate 4.2.1 – SBC Type 6 – Site Plan
Plate 4.2.2 – SBC Type 6 – Occlusion Structure - Section

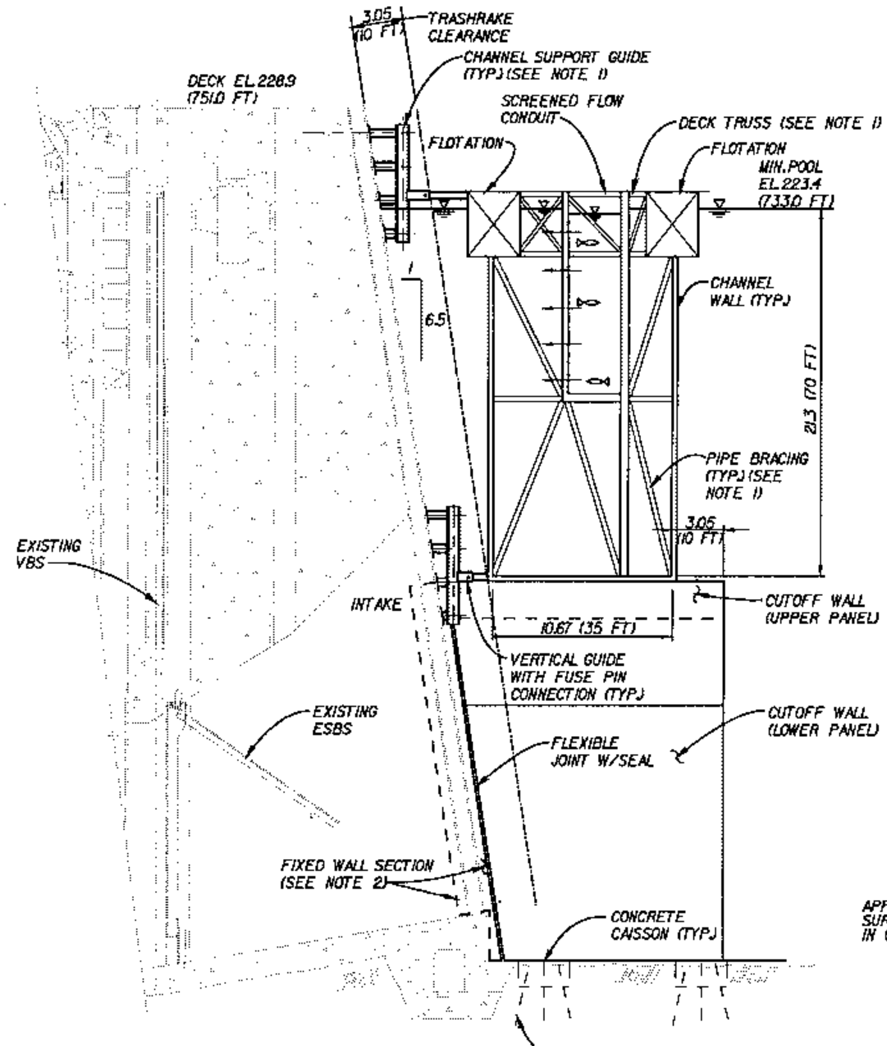
SBC Type 5 – Lower Monumental
Plate 4.3.1 – SBC Type 5 – Site Plan
Plate 4.3.2 – SBC Type 5 – Surface Collector - Plan

SBC Type 7 – Ice Harbor
Plate 4.4.1 – SBC Type 7 – Site Plan



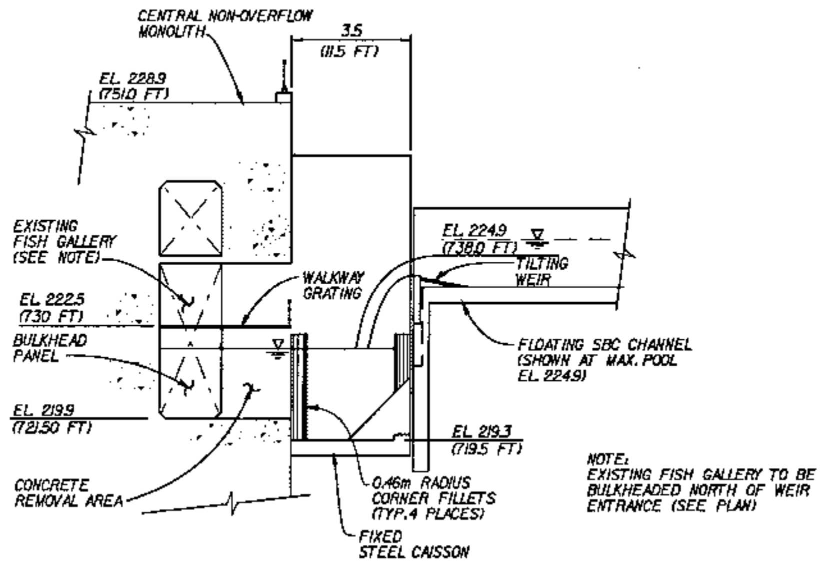
Pre-decisional draft document. Not for distribution or release.


UNIT 5
UNIT 6
SPILLBAY 1
GALLERY BULKHEAD
TILTING WEIR
EXISTING FISH GALLERY
EXISTING AUX. WATER PORT
SCREENED FLOW
REMOVABLE BULKHEAD PANELS
SPILLWAY EXTENSION STRUCTURE (SES)
FISH TRANSPORT CONDUIT
0.85 m³/S
1.14 m/S
DEWATERING SCREENS
GUIDE WALL
FLOAT
REMOVABLE BULKHEAD PANEL
10.67 (35 FT) CHANNEL WIDTH
STA 0.0
STA 13.2
STA 23.9
STA 34.6
STA 49.2
56.6 m³/S
0.55 m/S
DEBRIS RACK (12.2 DIA. x 22.4 TALL)
BAR SPACING 0.30 (1.0 FT)
BGS
CHANNEL WALL (TYP.)
CUTOFF WALL (BELOW CHANNEL)
SBC CHANNEL
PARTIAL PLAN AT COLLECTOR ENTRANCE 5/6
1:200
NET SCREEN AREA = 51 m²
V_N = 0.24 m/S
NET SCREEN AREA = 107 m²
V_H = 0.36 m/S
EFF. AREA MULTIPLIER = 0.75 (TYP.)
NET SCREEN AREA = 28 m²
AVG. NORMAL VELOCITY COMPONENT V_N = 0.12 m/S
APPROX. WATER SURFACE PROFILE IN CHANNEL
ENTRANCE STA 0.0
EL. 0.0
21.3 (70 FT)
EL. -21.3
0.55 m/S
0.92 m/S
1.08 m/S
1.18 m/S
1.62 m/S
1.62 m/S
EL. -1.83
EL. -3.35
EL. -4.88
EL. -7.77
EL. -10.7
EL. -16.0
EMERGENCY BYPASS DOORS (8 - 1.52 x 1.52 DOORS EACH SIDE)
NOTES:
1. DEPTHS AND VELOCITIES ARE APPROXIMATE AND MUST BE ADJUSTED ON BASIS OF FINAL DESIGN HYDRAULIC ANALYSIS.
2. VELOCITIES ARE AT ARROW HEAD TIP.
3. CHANNEL STRUCTURAL BRACING, WALKWAYS, ROOF STRUCTURES AND OTHER EQUIPMENT NOT SHOWN.
METRIC/ENGLISH UNIT CONVERSION
1 m = 3.28 FT
1 m² = 10.76 FT²
1 m/S = 3.28 FPS
1 m³/S = 35.31 CFS
US Army Corps of Engineers
Walla Walla District
U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS WALLA WALLA, WASHINGTON
LOWER GRANITE LOCK AND DAM
SYSTEM COMBINATION 3A - SBC TYPE 5
SURFACE COLLECTOR PLAN
Sheet number:
4.1.2
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
PEN TABLE ATTACHED: X
SHEET MAIN SCALE: 1:200, 1:400



SECTION A
4.1.2

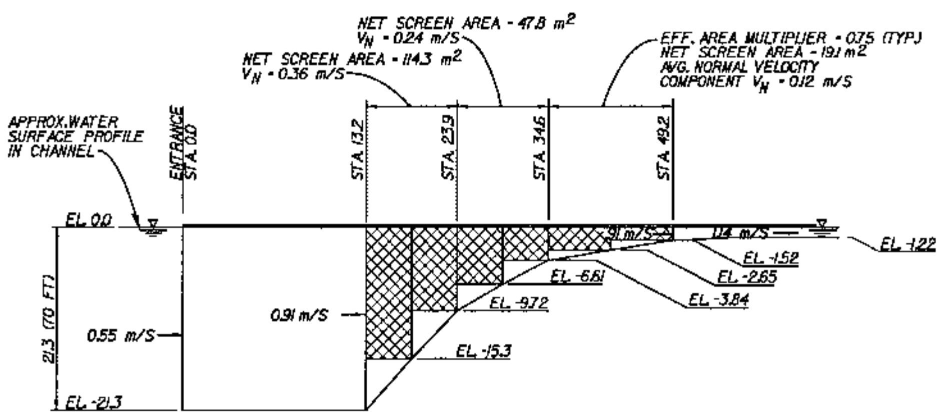
1:200



NOTE:
EXISTING FISH GALLERY TO BE BULKHEADED NORTH OF WEIR ENTRANCE (SEE PLAN)

WEIR AT CENTRAL NON-OVERFLOW SECTION
SECTION B
4.1.2

1:100



DEWATERING SCREEN ELEVATION
SECTION C
4.1.2

1:400

NOTES:

1. STRUCTURAL BRACING AND OTHER MEMBERS ARE SHOWN FOR CONCEPT ONLY. INTERNAL BRACING AND DECK TRUSS OCCUR AT PIER SUPPORT LOCATIONS (APPROX. 9.1m (30 FT) INTERVALS ALONG THE CHANNEL). ROOF STRUCTURES, WALKWAYS AND EQUIPMENT NOT SHOWN.
2. FIXED SECTION OF CUTOFF WALL TO BE BOLTED TO NORTH SIDE OF UNIT 6 INTAKE.
3. DEPTHS AND VELOCITIES ARE APPROXIMATE AND MUST BE ADJUSTED ON BASIS OF FINAL DESIGN HYDRAULIC ANALYSIS.
4. VELOCITIES ARE AT ARROW HEAD TIP.

UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

US Army Corps of Engineers
Walla Walla District

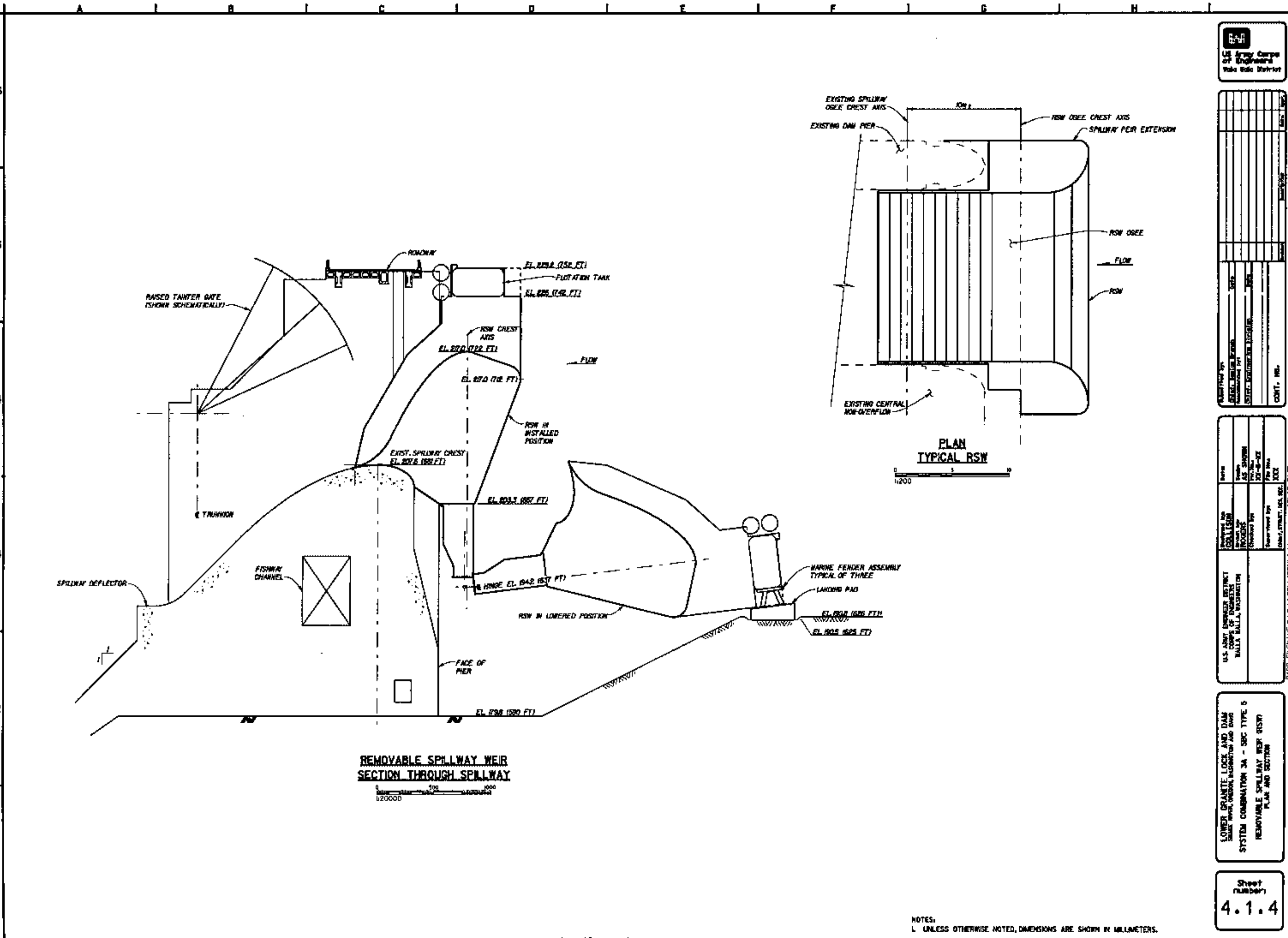
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WALLA WALLA, WASHINGTON

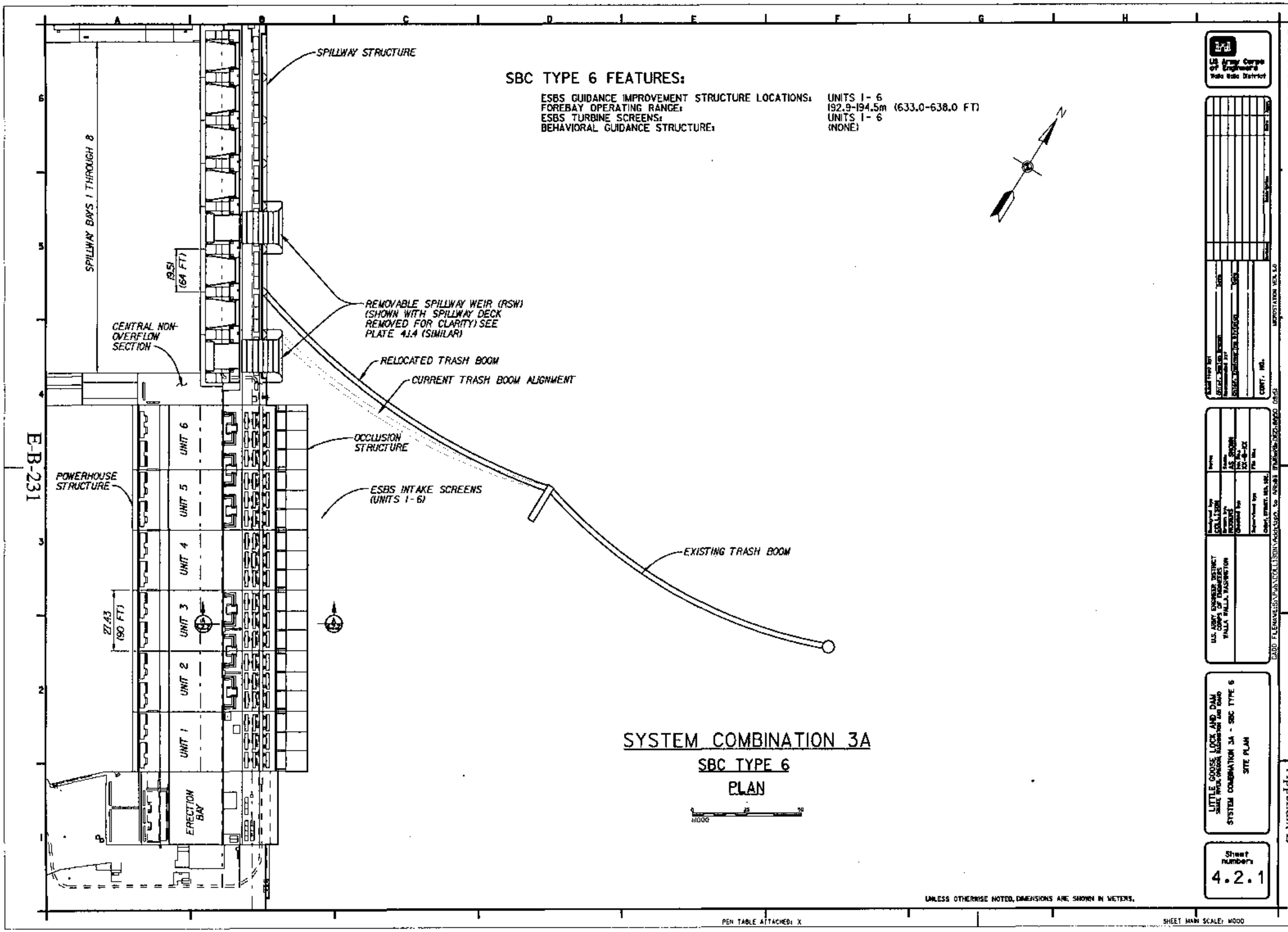
LOWER GRANITE LOCK AND DAM
SYSTEM COMBINATION 3A - SBC TYPE 5
SECTIONS AND ELEVATION

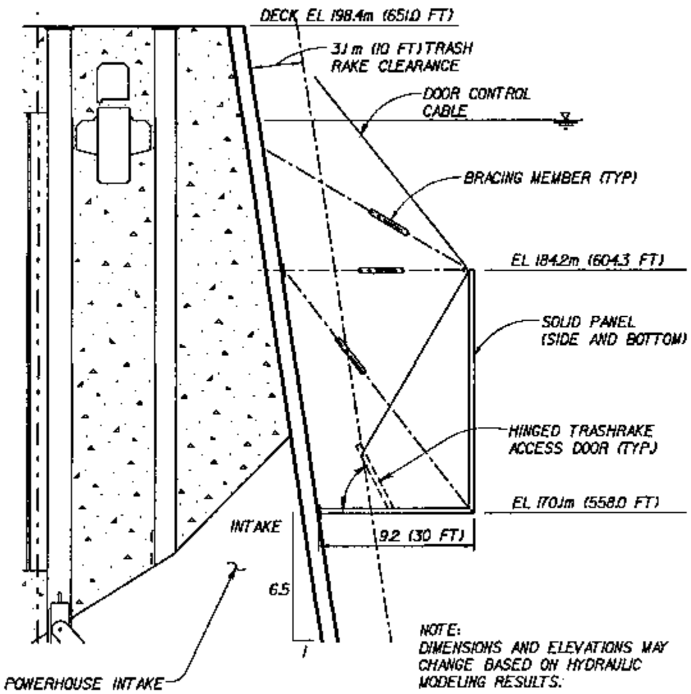
Sheet number:
4.1.3

PEN TABLE ATTACHED: X

SHEET MAIN SCALE: 1:100, 1:200, 1:400


US Army Corps of Engineers Walla Walla District
LOWER GRANITE LOCK AND DAM
SYSTEM COMBINATION 3A - SBC TYPE 5
REMOVABLE SPILLWAY WEIR (RSW)
PLAN AND SECTION
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WALLA WALLA, WASHINGTON
AS SHOWN
CONT. NO.
Sheet number:
4.1.4
EXISTING SPILLWAY OGEE CREST AXIS
EXISTING DAM PIER
RSW OGEE CREST AXIS
SPILLWAY PEIR EXTENSION
RSW OGEE
FLOW
RSW
EXISTING CENTRAL NON-OVERFLOW
PLAN
TYPICAL RSW
1:200
ROADWAY
RAISED TAINTER GATE (SHOWN SCHEMATICALLY)
FLOTATION TANK
RSW CREST AXIS
RSW IN INSTALLED POSITION
EXIST. SPILLWAY CREST
℄ TRUNNION
FISHWAY CHANNEL
SPILLWAY DEFLECTOR
FACE OF PIER
RSW IN LOWERED POSITION
MARINE FENDER ASSEMBLY TYPICAL OF THREE
LANDING PAD
REMOVABLE SPILLWAY WEIR
SECTION THROUGH SPILLWAY
1:2000
NOTES:
1. UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN MILLIMETERS.
PEN TABLE ATTACHED: X
SHEET MAIN SCALE: X


SBC TYPE 6 FEATURES:
ESBS GUIDANCE IMPROVEMENT STRUCTURE LOCATIONS: UNITS 1- 6
FOREBAY OPERATING RANGE: 192.9-194.5m (633.0-638.0 FT)
ESBS TURBINE SCREENS: UNITS 1- 6
BEHAVIORAL GUIDANCE STRUCTURE: (NONE)
SPILLWAY STRUCTURE
SPILLWAY BAYS 1 THROUGH 8
19.51 (64 FT)
REMOVABLE SPILLWAY WEIR (RSW) (SHOWN WITH SPILLWAY DECK REMOVED FOR CLARITY) SEE PLATE 4.1.4 (SIMILAR)
CENTRAL NON-OVERFLOW SECTION
RELOCATED TRASH BOOM
CURRENT TRASH BOOM ALIGNMENT
OCCLUSION STRUCTURE
POWERHOUSE STRUCTURE
ESBS INTAKE SCREENS (UNITS 1- 6)
EXISTING TRASH BOOM
UNIT 6
UNIT 5
UNIT 4
UNIT 3
UNIT 2
UNIT 1
ERECTION BAY
27.43 (90 FT)
N
SYSTEM COMBINATION 3A
SBC TYPE 6
PLAN
0 25 50
1:1000
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
PEN TABLE ATTACHED: X
SHEET MAIN SCALE: 1:1000
US Army Corps of Engineers Walla Walla District
U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS WALLA WALLA, WASHINGTON
LITTLE GOOSE LOCK AND DAM
SYSTEM COMBINATION 3A - SBC TYPE 6
SITE PLAN
Sheet number:
4.2.1



OCCLUSION STRUCTURE

SECTION A
4.2.1

1:200

US Army Corps of Engineers
Walla Walla District

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
WALLA WALLA, WASHINGTON

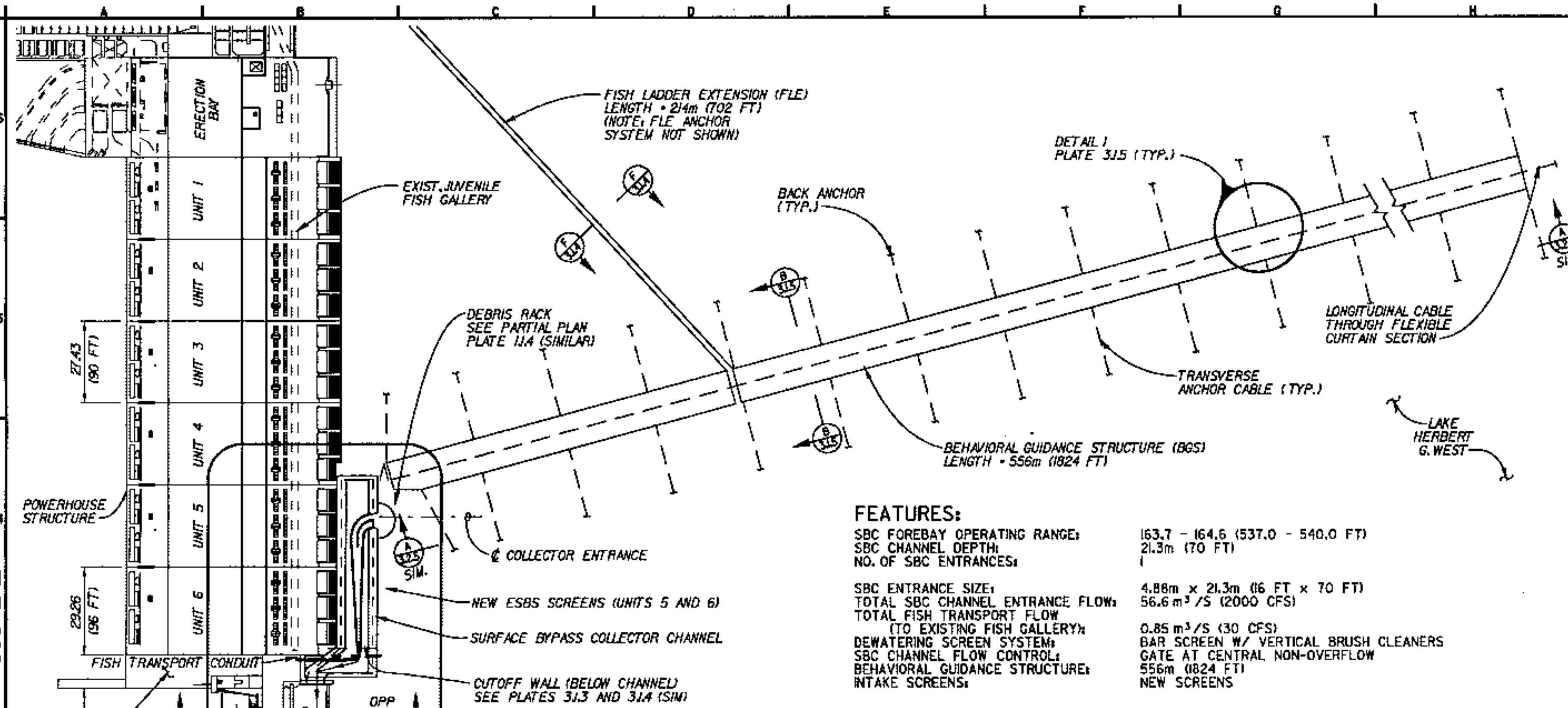
LITTLE GOOSE LOCK AND DAM
SNAKE RIVER, OREGON, WASHINGTON AND IDAHO
SYSTEM COMBINATION 3A - SBC TYPE 6
OCCLUSION STRUCTURE
SECTION

Sheet number:
4.2.2

UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

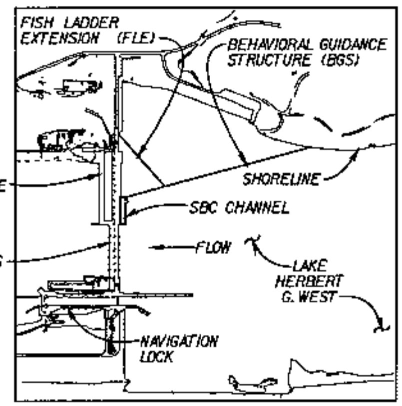
PEN TABLE ATTACHED: N

SHEET MAIN SCALE: 1:200



FEATURES:

SBC FOREBAY OPERATING RANGE:	163.7 - 164.6 (537.0 - 540.0 FT)
SBC CHANNEL DEPTH:	21.3m (70 FT)
NO. OF SBC ENTRANCES:	1
SBC ENTRANCE SIZE:	4.88m x 21.3m (16 FT x 70 FT)
TOTAL SBC CHANNEL ENTRANCE FLOW:	56.6 m^3/S (2000 CFS)
TOTAL FISH TRANSPORT FLOW (TO EXISTING FISH GALLERY):	0.85 m^3/S (30 CFS)
DEWATERING SCREEN SYSTEM:	BAR SCREEN W/ VERTICAL BRUSH CLEANERS
SBC CHANNEL FLOW CONTROL:	GATE AT CENTRAL NON-OVERFLOW
BEHAVIORAL GUIDANCE STRUCTURE:	556m (1824 FT)
INTAKE SCREENS:	NEW SCREENS



KEY PLAN

SYSTEM COMBINATION 3A
SBC TYPE 5
LOWER MONUMENTAL LOCK AND DAM
SITE PLAN

0 25 50
1:1000

UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

PEN TABLE ATTACHED: X

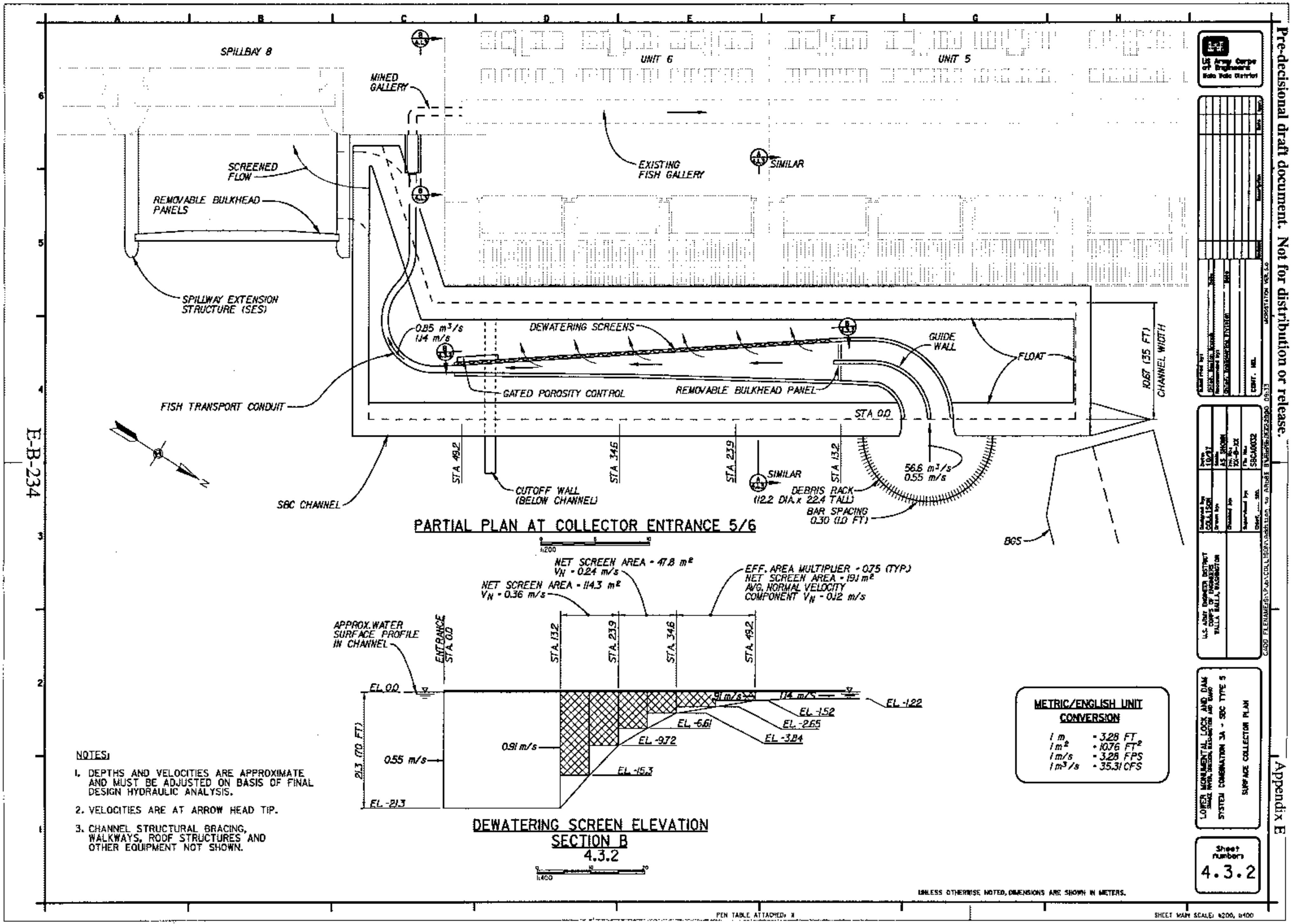
SHEET MAIN SCALE: 1:1000

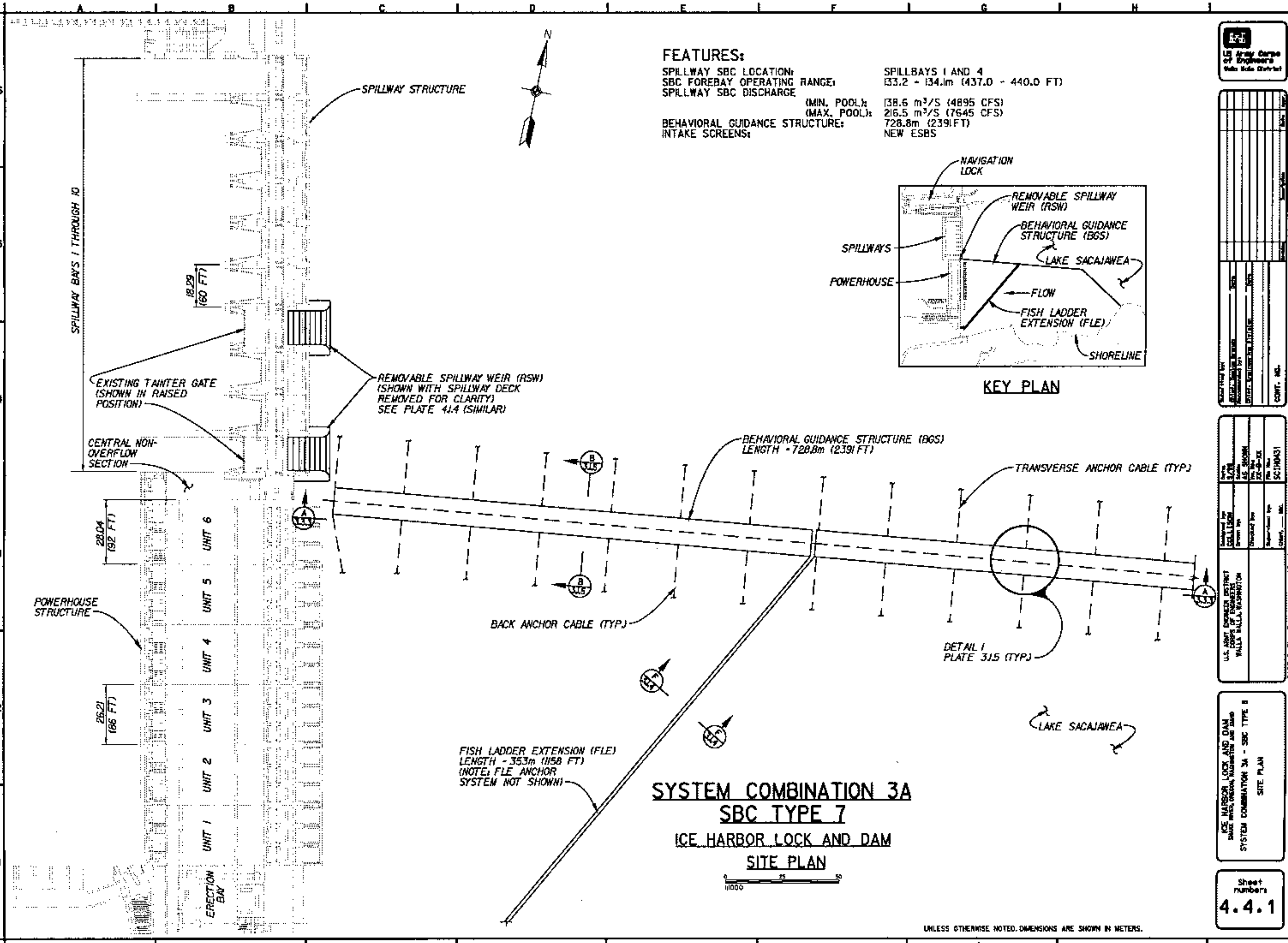
US Army Corps of Engineers
Walla Walla District

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS WALLA WALLA, WASHINGTON

LOWER MONUMENTAL LOCK AND DAM
SNAKE RIVER, OREGON, WASHINGTON AND IDAHO
SYSTEM COMBINATION 3A - SBC TYPE 5
SITE PLAN

Sheet number:
4.3.1


SPILLBAY 8
UNIT 6
UNIT 5
MINED GALLERY
SCREENED FLOW
REMOVABLE BULKHEAD PANELS
SPILLWAY EXTENSION STRUCTURE (SES)
EXISTING FISH GALLERY
SIMILAR
0.85 m³/s
1.14 m/s
DEWATERING SCREENS
GUIDE WALL
FLOAT
10.67 (35 FT) CHANNEL WIDTH
FISH TRANSPORT CONDUIT
GATED POROSITY CONTROL
REMOVABLE BULKHEAD PANEL
STA 0.0
STA 49.2
STA 34.6
STA 23.9
STA 13.2
SIMILAR
56.6 m³/s
0.55 m/s
CUTOFF WALL (BELOW CHANNEL)
DEBRIS RACK (12.2 DIA. x 22.4 TALL)
BAR SPACING 0.30 (1.0 FT)
SBC CHANNEL
BGS
PARTIAL PLAN AT COLLECTOR ENTRANCE 5/6
1:200
NET SCREEN AREA = 47.8 m²
VN = 0.24 m/s
NET SCREEN AREA = 114.3 m²
VN = 0.36 m/s
EFF. AREA MULTIPLIER = 0.75 (TYP.)
NET SCREEN AREA = 19.1 m²
AVG. NORMAL VELOCITY COMPONENT VN = 0.12 m/s
APPROX. WATER SURFACE PROFILE IN CHANNEL
ENTRANCE STA 0.0
EL 0.0
21.3 (70 FT)
EL -21.3
0.55 m/s
0.91 m/s
.91 m/s
1.14 m/s
EL -1.22
EL -1.52
EL -2.65
EL -3.84
EL -6.61
EL -9.72
EL -15.3
DEWATERING SCREEN ELEVATION SECTION B
4.3.2
1:400
NOTES:
1. DEPTHS AND VELOCITIES ARE APPROXIMATE AND MUST BE ADJUSTED ON BASIS OF FINAL DESIGN HYDRAULIC ANALYSIS.
2. VELOCITIES ARE AT ARROW HEAD TIP.
3. CHANNEL STRUCTURAL BRACING, WALKWAYS, ROOF STRUCTURES AND OTHER EQUIPMENT NOT SHOWN.
METRIC/ENGLISH UNIT CONVERSION
1 m = 3.28 FT
1 m² = 10.76 FT²
1 m/s = 3.28 FPS
1 m³/s = 35.31 CFS
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
PEN TABLE ATTACHED: X
SHEET MAIN SCALE: 1:200, 1:400
US Army Corps of Engineers Walla Walla District
U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS WALLA WALLA, WASHINGTON
LOWER MONUMENTAL LOCK AND DAM
SYSTEM COMBINATION 3A - SBC TYPE 5
SURFACE COLLECTOR PLAN
Sheet number:
4.3.2


FEATURES:
SPILLWAY SBC LOCATION: SPILLBAYS 1 AND 4
SBC FOREBAY OPERATING RANGE: 133.2 - 134.1m (437.0 - 440.0 FT)
SPILLWAY SBC DISCHARGE
(MIN. POOL): 138.6 m³/S (4895 CFS)
(MAX. POOL): 216.5 m³/S (7645 CFS)
BEHAVIORAL GUIDANCE STRUCTURE: 728.8m (2391 FT)
INTAKE SCREENS: NEW ESBS
N
SPILLWAY STRUCTURE
SPILLWAY BAYS 1 THROUGH 10
18.29 (60 FT)
EXISTING TAINTER GATE (SHOWN IN RAISED POSITION)
REMOVABLE SPILLWAY WEIR (RSW) (SHOWN WITH SPILLWAY DECK REMOVED FOR CLARITY) SEE PLATE 4.1.4 (SIMILAR)
CENTRAL NON-OVERFLOW SECTION
28.04 (92 FT)
26.21 (86 FT)
POWERHOUSE STRUCTURE
UNIT 6
UNIT 5
UNIT 4
UNIT 3
UNIT 2
UNIT 1
ERECTION BAY
BEHAVIORAL GUIDANCE STRUCTURE (BGS) LENGTH - 728.8m (2391 FT)
TRANSVERSE ANCHOR CABLE (TYP.)
BACK ANCHOR CABLE (TYP.)
DETAIL 1 PLATE 3.1.5 (TYP.)
FISH LADDER EXTENSION (FLE) LENGTH - 353m (1158 FT) (NOTE: FLE ANCHOR SYSTEM NOT SHOWN)
LAKE SACAJAWEA
NAVIGATION LOCK
REMOVABLE SPILLWAY WEIR (RSW)
BEHAVIORAL GUIDANCE STRUCTURE (BGS)
SPILLWAYS
POWERHOUSE
LAKE SACAJAWEA
FLOW
FISH LADDER EXTENSION (FLE)
SHORELINE
KEY PLAN
SYSTEM COMBINATION 3A
SBC TYPE 7
ICE HARBOR LOCK AND DAM
SITE PLAN
1:1000
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
PEN TABLE ATTACHED: X
SHEET MAIN SCALE: 1:1000
US Army Corps of Engineers Walla Walla District
U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS WALLA WALLA, WASHINGTON
ICE HARBOR LOCK AND DAM
SYSTEM COMBINATION 3A - SBC TYPE 8
SITE PLAN
Sheet number:
4.4.1

ATTACHMENT A
Central Non-Overflow SBC Channel Discharge Alternative

I) SCOPE

Evaluate an alternate layout for SBC channel discharge flow routing at the central non-overflow section at Lower Granite Dam for SBC Types 2 and 3 in lieu of the Spillbay 1 discharge location depicted in the report. The objective is to provide a back-up discharge location design if a reduction in hydraulic capacity of the spillway inherent in the Spillbay 1 discharge location is not acceptable.

Also generate a conceptual level cost estimate to compare the cost of this alternate location to the one presented in the report.

II) ASSUMPTIONS

The design flow to be routed through will be about 169.9 m^3/s (6,000 cfs) at minimum operating forebay elevation for the Type 2 SBC and about 56.6 m^3/s (2,000 cfs) for the Type 3 SBC. Discharge may increase at higher forebay elevations.

For SBC Type 2, the section of the fingerling bypass gallery in the central non-overflow section will not be used or needed to be maintained where channel routing would interfere with it. The main portion of the gallery, which passes through the powerhouse, will remain operational. For the Type 3 SBC designs, a small section of the gallery south of the penetration in the non-overflow section should remain operational (including the rest of the gallery in the intake monoliths), and the fish transport flow from the SBC would enter the gallery at this location.

The overflow weir at the north end of the gallery will not need to be maintained.

The elevator shaft may or may not need to be maintained. Review options for keeping the elevator shaft.

Impact to the structure should be minimized if possible. The amount of concrete to be removed should be minimized.

The erosion issues associated with the central non-overflow section spillway chute discharge will be considered in the detailed design and siting of the chute.

Costs for restoring functionality of structures or equipment affected by routing configurations will not be included in the cost estimate due to uncertainties of actual effect or if work-around plans could be developed to reduce effects resulting in minor cost impacts.

III) REVIEW

Review of the sectional plan view of the upper portion of the central non-overflow suggests three primary options for routing of a passageway. The following discussion is relevant to the Type 2 SBC discharge at Lower Granite only, but is similar for the other projects and for the Type 3 SBC designs.

1. Option 1 would be the widest option feasible in the available space. It would be 10.4 meters (34 feet) wide and extend from the construction joint at station 32+27 northward to the spillway pier (south side of Spillway 1). The 4.3-meter (14-foot)-width of the pier would not be reduced for stability reasons and to avoid any interference potential with the trunnion anchorage. This option would preclude any continued use of the existing elevator.

2. Option 2 would try to preserve the elevator shaft so that some type of elevator could be provided for access. The maximum width that could be provided with this option would be about 6.1 meters (20 feet) and would extend from the construction joint at station 32+27 northward for 6.1 meters (20 feet).

With both of the above options, the waterstop and sealing arrangements along the construction joint would be compromised, so a third option was considered.

3. Option 3 would leave about 1.2 meter (4 feet) of wall at the construction joint and reduce the width of the option 2 opening to about 4.9 meters (16 feet). This would maintain the elevator shaft and the waterstop and sealing arrangement at the construction joint. It would further provide a structural support for the remaining deck portion above the passageway.

All of the options presented will interrupt the drainage gallery shaft.

All of the options will interrupt the service gallery and fingerling bypass gallery.

IV) CONCLUSION

The Option 3 routing provides the least concrete area to be removed and causes the least disruption of existing facilities and equipment. It is, therefore, the preferred option.

V) COMMENTS

(Note: Comments are relative to the Type 2 SBC design at Lower Granite. Similar issues exist at the other projects and for the Type 3 SBC designs.)

The discharge chute located on the downstream side of the central non-overflow section will have a number of effects on the fish facilities located underneath the tailrace deck.

The structure will obstruct access to the fishway transverse bulkhead. This bulkhead will need to be relocated to the south to maintain its function.

A number of other fishway gates will also be affected depending on the amount of overhead space required for access and maintenance.

The crane rails at the north end will no longer be accessible because the structure will block access.

The flip lip elevation at the bottom of the chute is set at the same elevation as the rest of the spillway flip lips.

The tailrace at the proposed discharge point is approximately 19.2 meters (63 feet) deep at normal tailwater (elevation 194.5 meters [638 feet]). Erosional issues are considered to be minimal due to the considerable depth at this location; this would be investigated during final design.

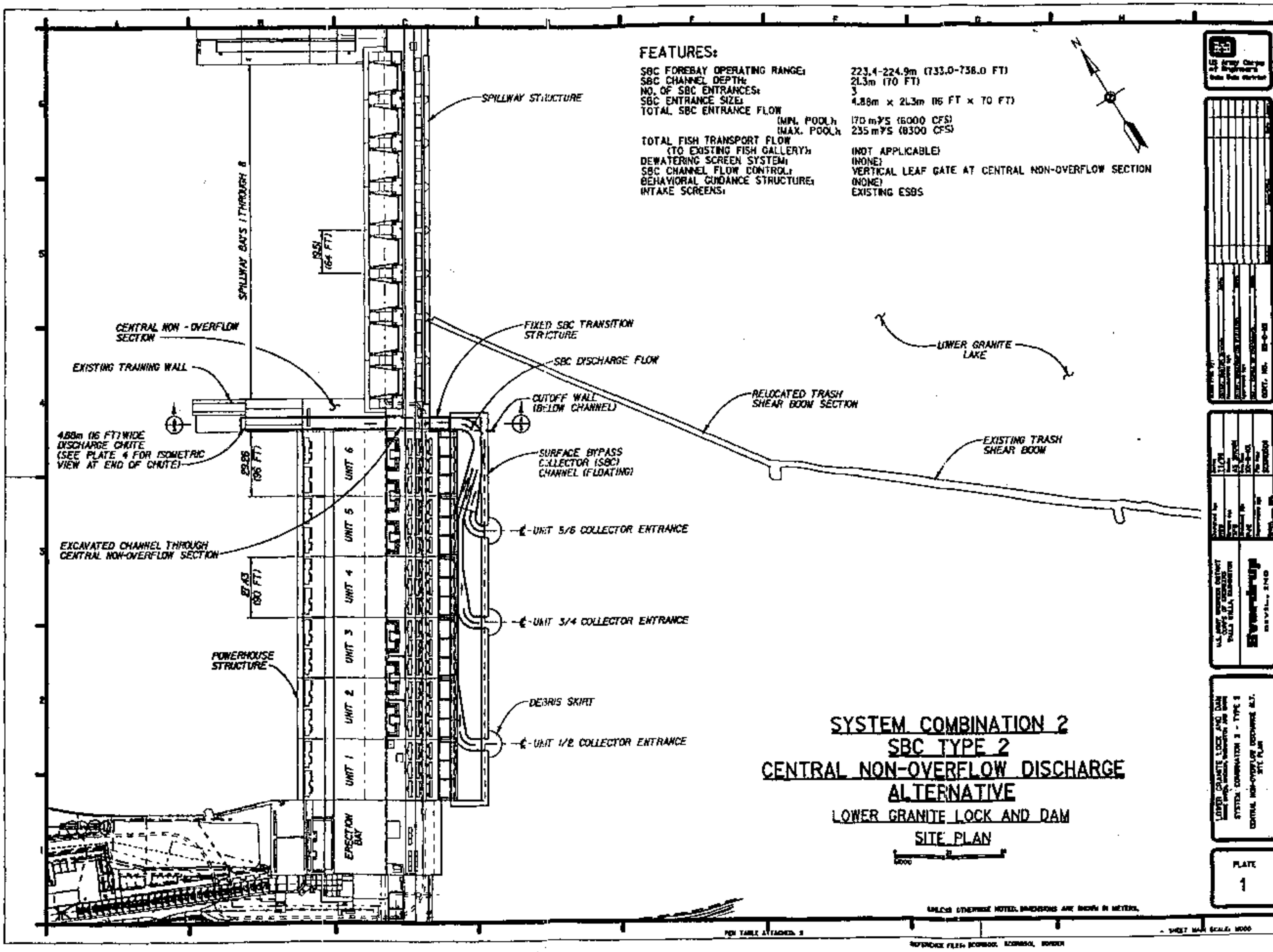
The discharge chute has been routed straight through the non-overflow section and not turned left or right. The current position allows either the spillway or powerhouse unit to be used for training flow if desired.

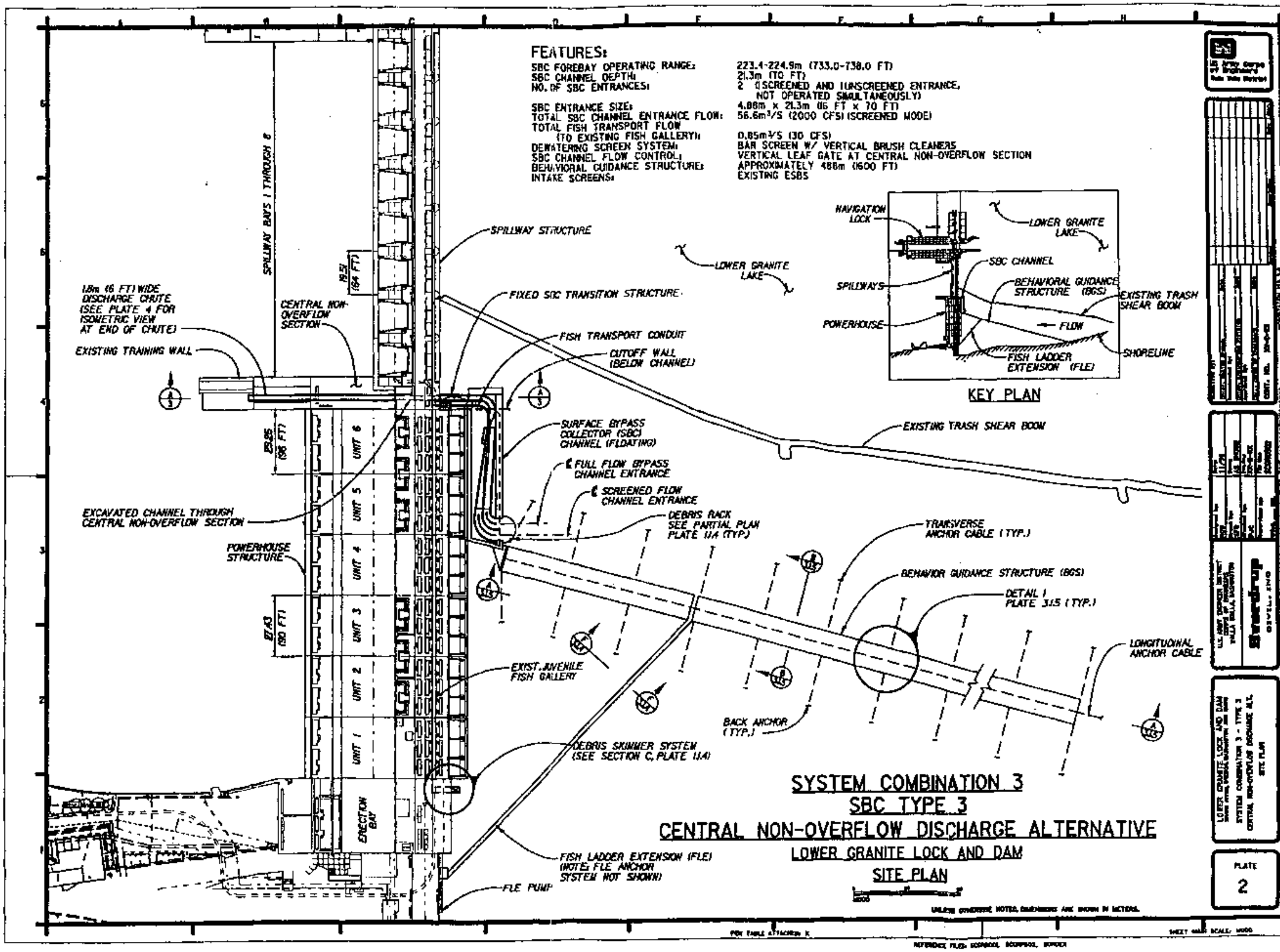
VI) CONCEPTUAL LEVEL LAYOUT SKETCHES

Layout sketches for a central non-overflow routing at Lower Granite for SBC Types 2 and 3 are shown on the following two pages (Plates 1 through 4).

VI) CONCEPTUAL LEVEL COST ESTIMATES

Cost estimates for a central non-overflow routing at Lower Granite for SBC Types 2 and 3 are provided following the layout sketches (Plates 1 through 4). Note that these estimates do not provide costs for restoring functionality of various structures or equipment that may be affected by routing. This would include crane blockage, fishway gate access issues, etc.

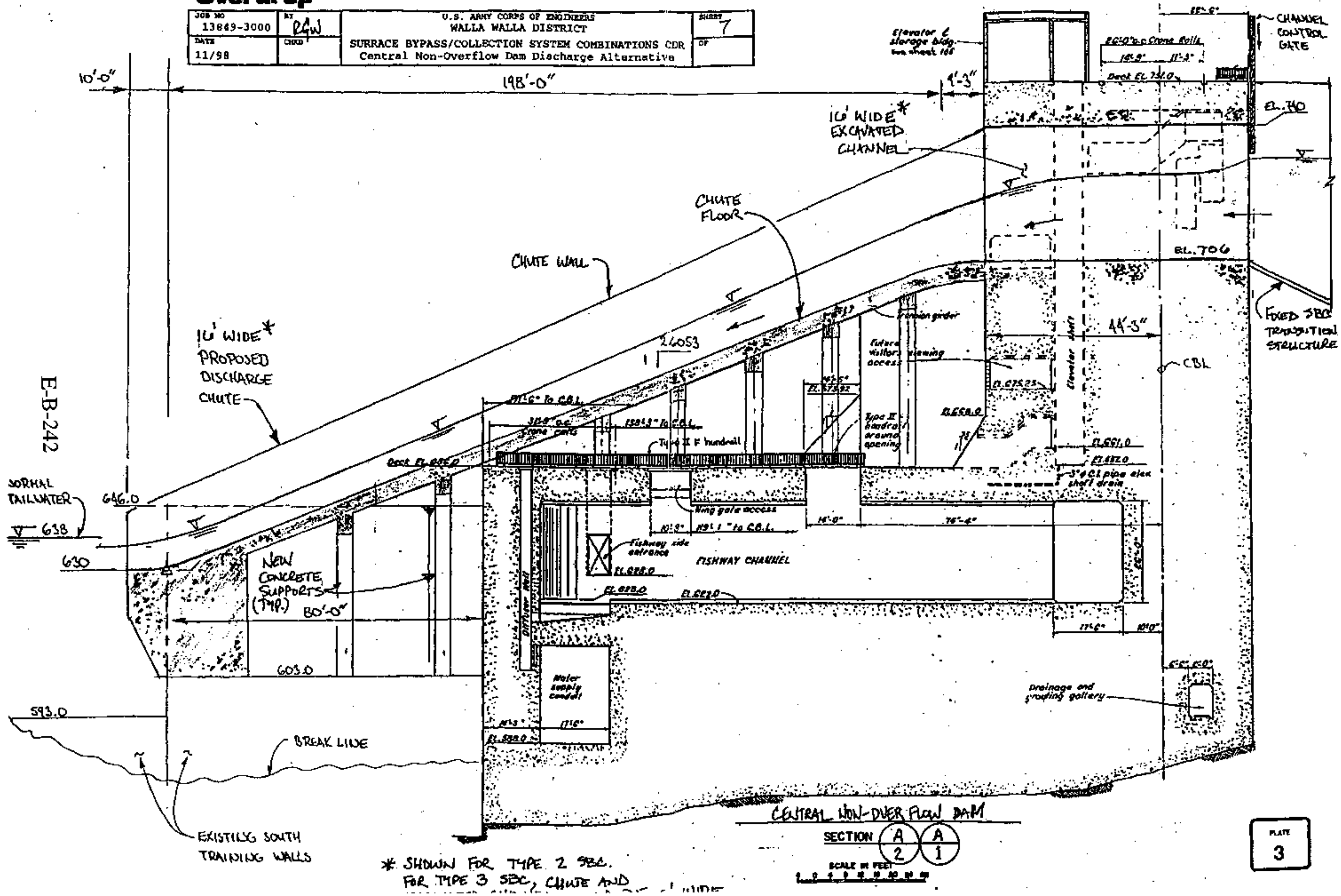

FEATURES:
SBC FOREBAY OPERATING RANGE: 223.4-224.9m (733.0-738.0 FT)
SBC CHANNEL DEPTH: 21.3m (70 FT)
NO. OF SBC ENTRANCES: 3
SBC ENTRANCE SIZE: 4.88m x 21.3m (16 FT x 70 FT)
TOTAL SBC ENTRANCE FLOW (MIN. POOL): 170 m³/S (6000 CFS)
(MAX. POOL): 235 m³/S (8300 CFS)
TOTAL FISH TRANSPORT FLOW (TO EXISTING FISH GALLERY): (NOT APPLICABLE)
DEWATERING SCREEN SYSTEM: (NONE)
SBC CHANNEL FLOW CONTROL: VERTICAL LEAF GATE AT CENTRAL NON-OVERFLOW SECTION
BEHAVIORAL GUIDANCE STRUCTURE: (NONE)
INTAKE SCREENS: EXISTING ESBS
SPILLWAY STRUCTURE
SPILLWAY BAYS 1 THROUGH 8
CENTRAL NON-OVERFLOW SECTION
EXISTING TRAINING WALL
4.88m (16 FT) WIDE DISCHARGE CHUTE (SEE PLATE 4 FOR ISOMETRIC VIEW AT END OF CHUTE)
EXCAVATED CHANNEL THROUGH CENTRAL NON-OVERFLOW SECTION
POWERHOUSE STRUCTURE
FIXED SBC TRANSITION STRUCTURE
SBC DISCHARGE FLOW
CUTOFF WALL (BELOW CHANNEL)
SURFACE BYPASS COLLECTOR (SBC) CHANNEL (FLOATING)
UNIT 5/6 COLLECTOR ENTRANCE
UNIT 3/4 COLLECTOR ENTRANCE
UNIT 1/2 COLLECTOR ENTRANCE
DEBRIS SKIRT
RELOCATED TRASH SHEAR BOOM SECTION
EXISTING TRASH SHEAR BOOM
LOWER GRANITE LAKE
UNIT 1
UNIT 2
UNIT 3
UNIT 4
UNIT 5
UNIT 6
ERECTION BAY
SYSTEM COMBINATION 2
SBC TYPE 2
CENTRAL NON-OVERFLOW DISCHARGE ALTERNATIVE
LOWER GRANITE LOCK AND DAM
SITE PLAN
UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
PLATE 1



Pre-decisional draft document. Not for distribution or release.

Sverdrup

JOB NO	BY		SHEET
13849-3000	RGW	U.S. ARMY CORPS OF ENGINEERS WALLA WALLA DISTRICT	7
DATE 11/98	CHKD	SURFACE BYPASS/COLLECTION SYSTEM COMBINATIONS CDR Central Non-Overflow Dam Discharge Alternative	OF



* SHOWN FOR TYPE 2 SBC.
FOR TYPE 3 SBC, CHUTE AND

PLATE 3

E-B-242

Pre-decisional draft document. Not for distribution or release.

Sverdrup

JOB NO 13849-3000	BY RGW	U.S. ARMY CORPS OF ENGINEERS WALLA WALLA DISTRICT	SHEET 8
DATE 11/98	CHKD	SURRACE BYPASS/COLLECTION SYSTEM COMBINATIONS CDR Central Non-Overflow Dam Discharge Alternative	OF

ISOMETRIC VIEW AT END OF PROPOSED DISCHARGE CHUTE

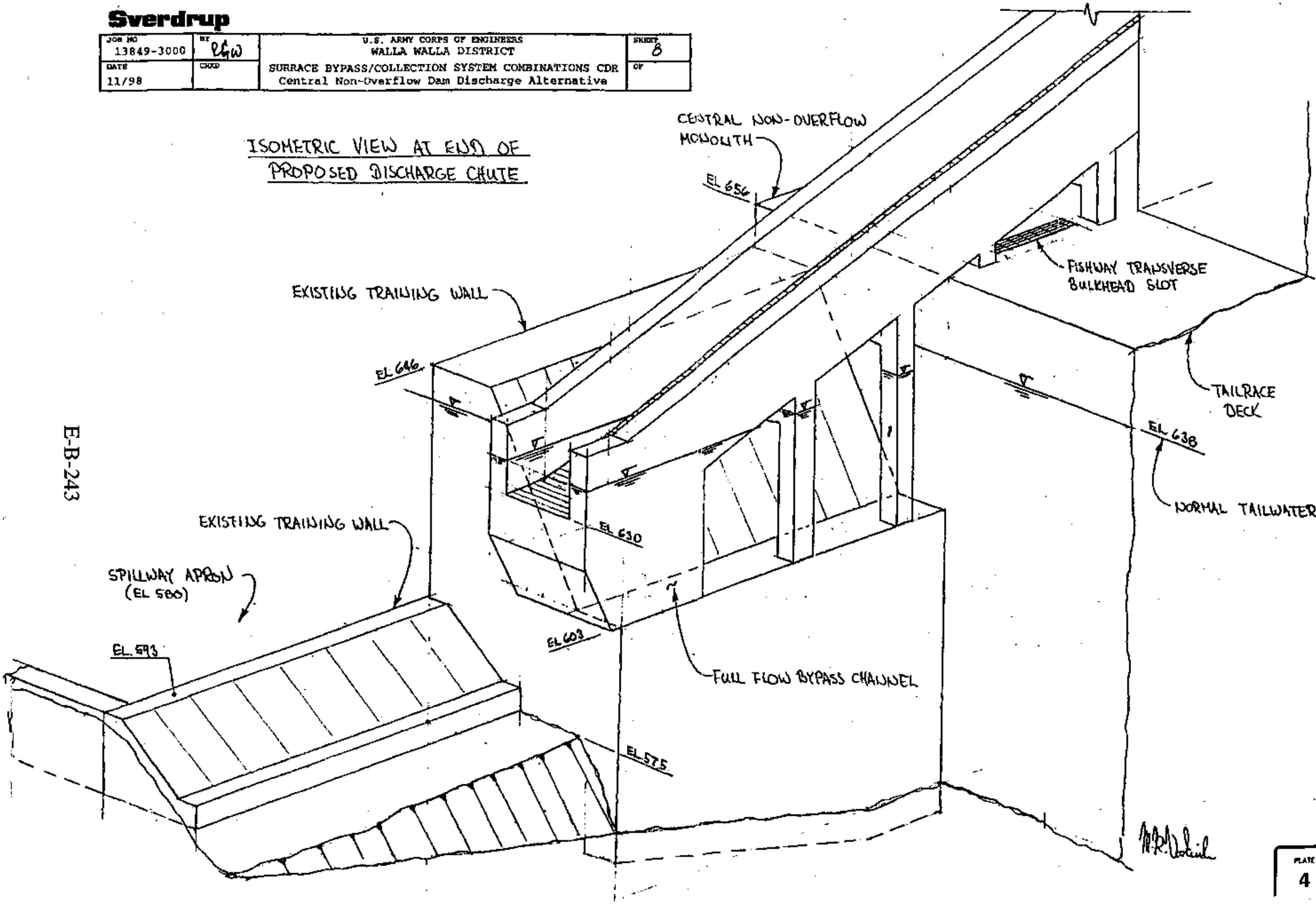


PLATE 4

Sverdrup

Job No. 013849-3100	By PJC	Subject SYSTEM COMBINATIONS C.D.R. COST ESTIMATE FOR ALTERNATIVE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 9
Date 11/98	Checked HGW		of

CE-03-0180

SCOPE

THE PREFERRED ALTERNATIVE FOR THE TYPE 2 AND TYPE 3 SBC SYSTEMS CALLS FOR THE CHANNEL DISCHARGE TO BE THROUGH A RAISED SPILLWAY OGEE CONSTRUCTED IN SPILLBAY 1 (SPILLBAY 8 AT LOWER MONUMENTAL). IN THE EVENT THAT THIS BECOMES UNACCEPTABLE DUE TO ITS IMPACT ON PROJECT SPILLWAY CAPACITY, AN ALTERNATIVE DISCHARGE LOCATION WAS DEVELOPED THROUGH THE CENTRAL NON-OVERFLOW SECTION. THIS CALCULATION DEVELOPS A CONCEPTUAL LEVEL COST ESTIMATE FOR CONSTRUCTION OF THIS ALTERNATIVE DISCHARGE LOCATION.

REFERENCES

1. CALCULATION CE-03-0510, CONSTRUCTION UNIT COST ESTIMATES
2. CALCULATION CE-03-0520, CONSTRUCTION MATERIAL QUANTITY ESTIMATES
3. CALCULATION CE-01-1120 (FROM DELIVERY ORDER #1 - INCLUDED IN APPENDIX PART B)
4. CALCULATION CE-01-1110 (FROM DELIVERY ORDER #1 - INCLUDED IN APPENDIX PART B)

Sverdrup

Job No. 013849-3100	By PJZ	Subject SYSTEM COMBINATIONS C.D.R. COST ESTIMATE FOR ALTERNATIVE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 10
Date 11/98	Checked RGW		Of

APPROACH

THE COST ESTIMATES GENERATED IN REF'S ① AND ② ARE REVIEWED AND ONLY ITEMS WHICH WOULD BE DIFFERENT FOR THE ALTERNATIVE DISCHARGE WILL BE ADDRESSED. THIS WILL RESULT IN AN ESTIMATE OF THE CHANGE IN COST (EITHER POSITIVE OR NEGATIVE).

TYPE Z DESIGN

LOWER GRANITE:

A PLAN VIEW OF THE TYPE Z DESIGN WITH THE ALTERNATIVE DISCHARGE IS SHOWN ON THE ATTACHED PLATE 1, AS IT WOULD BE AT LOWER GRANITE. A SECTION VIEW OF THE DISCHARGE CHUTE IS SHOWN ON PLATE 3, AND AN ISOMETRIC VIEW ON PLATE 4. THIS DESIGN IS COMPARED TO PLATES 2.1.1 THROUGH 2.1.5 IN THE BODY OF THE REPORT.

COST ITEMS FOR THE LOWER GRANITE TYPE Z DESIGN ARE ADDRESSED POINT BY POINT

$\boxed{1.0}$ CHANNEL WALLS AND FLOOR:

THE ORIGINAL DESIGN WAS ESTIMATED ON PAGE 31 OF REF. ③ AT 9850 m^2

THE CHANNEL IS REDUCED IN LENGTH BY 44 FT. THIS REDUCTION IS IN THE SHALLOWER NORTH END OF THE CHANNEL.

Sverdrup

Job No. 073849-3100	By PJL	Subject SYSTEM COMBINATION C.D.R. COST ESTIMATE FOR ALTERNATIVE DISCHARGE THRU CENTRAL N/B SECTION	Sheet 11
Date 11/98	Checked RGW		of

THE SHALLOW PORTION OF CHANNEL WAS
ORIGINALLY ESTIMATED TO INCLUDE

(2)(40.3)(64) = 5158 FT^2 (FRONT + BACK WALLS)
(35)(64) = 2240 FT^2 (FLOOR)
TOTAL 7398 FT^2

THE ALTERNATE DESIGN IS FULL WIDTH (46 FT) AND INCLUDES
(2)(40.3)(20) = 1612 FT^2 (FRONT + BACK WALLS)
(46)(20) = 920 FT^2 (FLOOR)
2532 FT^2

THIS IS A REDUCTION OF 7398 − 2532 = 4866 FT^2
= 452 m^2

FROM REF ① THIS IS PRICED AT \$568/m^2

COST CHANGE = (568)(−452) = \$ − 256,736

2.0 INTERNAL WALLS + FLOOR:
2 INTERNAL WALLS EACH 74 FT HIGH
ARE REDUCED BY 44 FT IN LENGTH

AREA = (74)(44)(2) = 6512 FT^2
= 605 M^2

FROM REF ① THIS IS ALSO PRICED AT \$568/M^2

COST CHANGE = (568)(605) = \$ − 343,640

Sverdrup

Job No. 013849-3100	By PJC	Subject SYSTEM COMBINATION C.D.R. COST ESTIMATE FOR ALTERNATE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 12
Date 11/98	Checked RGW		of

3.0 MISCELLANEOUS CHANNEL STRUCTURES:

FOR TYPE 2 DESIGNS THIS IS ESTIMATED AS 4% OF THE FIRST 2 ITEMS

COST CHANGE = (0.04)(-256736 - 343640) = $-24,015

4.0 FLOTATION CELLS:

A REDUCTION OF 44 FT IN LENGTH WOULD RESULT IN AN 88 FT REDUCTION IN THE LENGTH OF FLOTATION CELLS

88 FT = 26.8 M

FROM REF (1) THE FLOTATION CELLS ARE PRICED AT $6520/M

COST CHANGE = (6520)(-26.8) = $-174,736

ITEMS 5.0 THROUGH 8.0 NOT USED IN TYPE 2

9.0 CHANNEL CUTOFF WALL:

- NO CHANGE FROM ORIGINAL DESIGN

10.0 STRUCTURAL SUPPORT AND GUIDE SYSTEM:

IN REF (4) (PAGE 64) THE SUPPORT/GUIDE SYSTEM WAS ESTIMATED BASED ON 20 GUIDE STRUCTURES (19 AT POWERHOUSE AND ONE AT CENTRAL NON-OVERFLOW), SINCE THE ONE AT THE CENTRAL NON-OVERFLOW IS NOW REPLACED BY THE FIXED TRANSITION STRUCTURE THIS COST CAN BE REDUCED BY 1/20

COST CHANGE = -(1/20)(615,000) = $-30,750

Sverdrup

Job No. 013849-3100	By PJR	Subject SYSTEM COMBINATION C.D.R. COST ESTIMATE FOR ALTERNATE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 13
Date 11/98	Checked RGW		Of

11.0 FIXED S.B.C. TRANSITION STRUCTURE:
THIS IS ESSENTIALLY THE SAME AS THE SPILLWAY EXTENSION STRUCTURE IN THE ORIGINAL DESIGN. HOWEVER DUE TO LAYOUT CONSIDERATIONS AT THE CENTRAL NON-OVERFLOW SECTION IT WOULD BE ABOUT 1/3 SHORTER.
ORIGINAL COST = $ 872,100

COST CHANGE = (-1/3)(872,100) = $-290,700

12.0 CONNECTION TO JUVENILE GALLERY:
-NOT REQUIRED FOR TYPE 2-

13.0 TRASHBOOM RELOCATION:
-NO CHANGE IN COST-

14.0 REMOVAL OF EXISTING SBC AND BGS PROTOTYPES
-NO CHANGE IN COST-

15.0 NO ADDITIONAL EQUIPMENT REQUIRED FOR TYPE 2

16.0 ELECTRICAL COSTS:
-NO CHANGE IN COST-

17.0 ESBS SCREENS
-NO CHANGE IN COST-

Sverdrup

Job No. 013849 - 3100	By PJC	Subject SYSTEM COMBINATIONS C.D.R. COST ESTIMATE FOR ALTERNATE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 14
Date 11/98	Checked RGW		of

18.0 DISCHARGE CHUTE:

THE DISCHARGE CHUTE REPLACES THE SPILLWAY MODIFICATIONS IN THE ORIGINAL DESIGN. EACH SUBITEM IS ADDRESSED AS TO WHETHER IT IS STILL REQUIRED, AND THEN THE NEW ITEMS FOR THE CHUTE WILL BE ADDED.

18.1 RAISED OGEE CREST
NOT REQUIRED $- 246,980

18.2 MID-SPILLBAY PIER
NOT REQUIRED $- 1,076,400

18.3 TAINTER GATE REMOVAL
NOT REQUIRED $- 342,000

18.4 NEW 25-FT TAINTER GATE
NOT REQUIRED $- 613,000

18.5 NEW VERTICAL LEAF GATE
- NO CHANGE - STILL REQUIRED
IN THIS CASE IT WOULD BE INCORPORATED INTO THE FIXED TRANSITION STRUCTURE BUT THE COST WOULD BE THE SAME

18.6 STOP LOGS FOR NEW TAINTER GATE
NOT REQUIRED $- 95,400

18.7 DEWATERING BULKHEAD FOR CONSTRUCTION
- NO CHANGE - STILL REQUIRED

Sverdrup

Job No. 013849-3100	By PJC	Subject SYSTEM COMBINATIONS C.D.R. COST ESTIMATE FOR ALTERNATIVE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 15
Date 11/98	Checked RGW		of

ESTIMATE OF NEW WORK FOR DISCHARGE CHUTE

18.8 CONCRETE REMOVAL FROM NON-OVERFLOW SECTION
FROM ATTACHED PLATES 1 THRU 4

HEIGHT OF REMOVED VOLUME = 740 − 706 = 34 FT
LENGTH " " " = 44.25 + 22.5 = 66.75 FT
WIDTH " " " = 16 FT

TOTAL VOLUME = $(34)(66.75)(16) = 36{,}312\ FT^3$
$= 1028\ M^3$

FROM REF ① ITEM 12.2 USE $1330/$M^3$

COST = (1330)(1028) = $ + 1,367,240

19.9 CONCRETE DISCHARGE CHUTE:

THE FOLLOWING PAGE ESTIMATES THE DEPTH OF FLOW AT THE DOWNSTREAM END OF THE CHUTE (WITH FOREBAY AT MAX. OPERATING POOL OF 738) AS 7.06 FT DEEP. THEREFORE ASSUME THE WALLS OF THE CHUTE ARE 10 FT HIGH AT THE DOWNSTREAM END AND TAPER UPTO FULL HEIGHT OF THE OPENING (34 FT) AT THE UPSTREAM END. FURTHER, ASSUME THE WALLS ARE 18" THICK (or 1.5 FT)

THE HORIZONTAL PROJECTION LENGTH OF THE CHUTE IS 10 + 198 + 9.25 = 217.25 FT

ACTUAL LENGTH $\approx \left(\dfrac{\sqrt{(2.6053)^2+1^2}}{2.6053}\right)(217.25) = 233$ FT

Max. Pool

LOWER GRANITE DISCHARGE CHUTE THROUGH CENTRAL NON-OVERFLOW SECTION

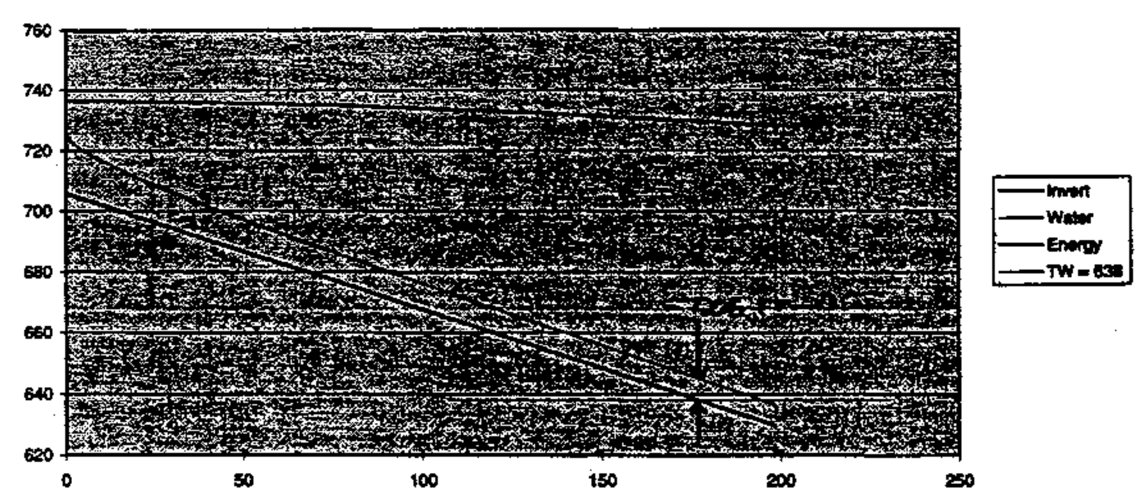
Initial Energy	[redacted]	ft
Invert Elevation	[redacted]	ft
Channel Width	[redacted]	ft
Weir Coefficient	[redacted]	
Weir Width	[redacted]	ft
US Slope	[redacted]	
DS Slope	[redacted]	
Mannings n	[redacted]	
Tailwater Elev	[redacted]	ft
Depth Step	[redacted]	ft

Flow	8341.533	cfs
Q/Width	521.3458	cfs/ft
Critical D	20.36098	ft
Critical V	25.60515	fps
E at Critical	736.5415	
R at Critical	5.74	ft
S at Critical	0.004852	
L to Initial E	106.561	ft

Note: Initial energy assumes Maximum Pool @ 738 with 1.2 ft loss in channel.

Location	Invert	Depth	Velocity	Vel. Head	Energy	Hyd. Radius	Energy S	Avg. S	Length	Total Length
Critical	706.00	20.36	25.61	10.18	736.54	5.74	0.004852			0
	705.92	19.36	26.93	11.26	736.54	5.66	0.005471	0.005162	0.21	0.21
	705.66	18.36	28.39	12.52	736.54	5.57	0.006213	0.005842	0.69	0.90
	705.16	17.36	30.03	14.00	736.53	5.48	0.007111	0.006662	1.28	2.18
	704.38	16.36	31.87	15.77	736.51	5.37	0.008214	0.007663	2.03	4.21
	703.24	15.36	33.94	17.89	736.49	5.26	0.009585	0.008899	2.99	7.20
	701.62	14.36	36.30	20.46	736.44	5.14	0.011316	0.010450	4.23	11.42
	699.37	13.36	39.02	23.64	736.37	5.00	0.013542	0.012429	5.86	17.29
	696.26	12.36	42.18	27.62	736.25	4.86	0.016464	0.015003	8.08	25.36
	691.98	11.36	45.89	32.70	736.04	4.69	0.020394	0.018429	11.16	36.52
	686.01	10.36	50.32	39.32	735.68	4.51	0.025833	0.023113	15.57	52.09
	677.50	9.36	55.69	48.16	735.02	4.31	0.033626	0.029729	22.16	74.26
	665.00	8.36	62.35	60.37	733.74	4.09	0.045276	0.039451	32.55	106.81
	645.75	7.36	70.83	77.89	731.01	3.83	0.063643	0.054460	50.15	156.96
	638.00	[redacted]	73.80	84.58	729.65	3.75	0.071132	0.067388	20.19	177.15

Maximum Pool (min. depth = 7.06 ft)



Sverdrup

Job No. - 013849-3100	By PJC	Subject SYSTEM COMINATIONS C.D.R. COST ESTIMATE FOR ALTERNATIVE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 17
Date 11/98	Checked RGW		Of

AREA OF WALLS $= \left(\frac{10+34}{2}\right)(233) = 5126\ FT^2$

FOR 2 WALLS EACH 1.5 FT THICK THE TOTAL
VOLUME $= (3)(5126) = 15378\ FT^3$
$= 435\ m^3$ (WALLS)

AREA OF FLOOR $= (16+3)(233) = 4427\ FT^2$
ASSUME THE FLOOR IS 2 FT THICK
VOLUME $= (2)(4427) = 8854\ FT^3$
$= 251\ M^3$ (FLOOR)

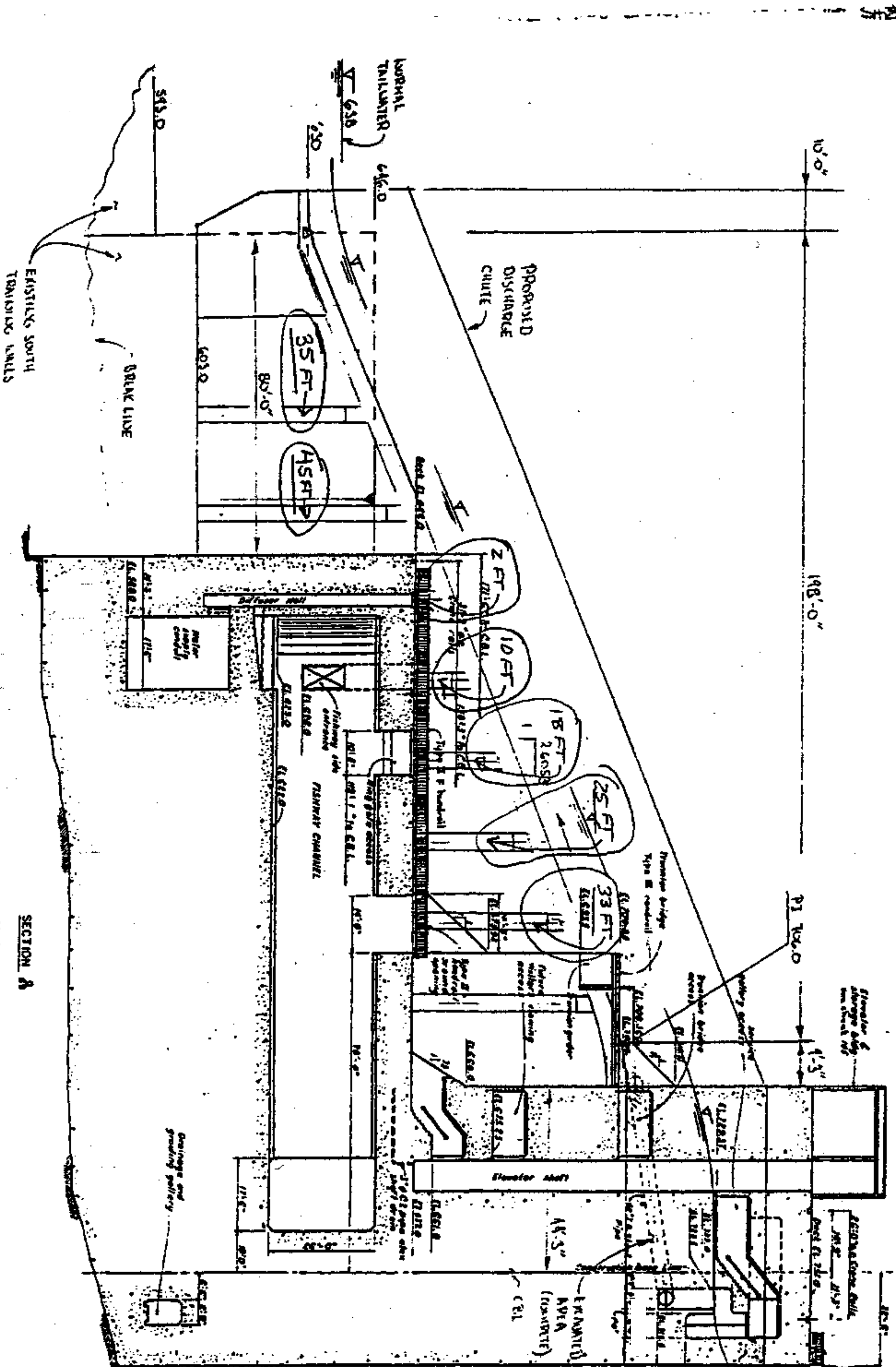
CONCRETE SUPPORT PIERS
ASSUME THE PIERS ARE 3 FT SQUARE
THERE ARE 7 PAIRS OF PIERS AS
SHOWN AND ESTIMATED IN HEIGHT ON
THE FOLLOWING PAGE
TOTAL LENGTH OF PIERS $= (2)(35+45+2+10+18+25+33)$
$= 336$ FT
FOR 3'x3' PIERS VOLUME $= (9)(336) = 3024\ FT^3$
$= 86\ m^3$ (PIERS)

SUPPORT BEAMS AT PIERS
ASSUME 3'x3' BEAMS EACH 19 FT LONG
VOLUME $= (7)(9)(19) = 1197\ FT^3$
$= 34\ M^3$ (BEAMS)

TOTAL VOLUME FOR STRUCTURAL CONCRETE
$= 435 + 251 + 86 + 34 = 806\ M^3$

FROM REF. 1 ITEM 18.2 USE \$598/M^3 FOR STRUCTURAL CONCRETE

COST $= (598)(806) = \$ + 481,988$



Sverdrup

JOB NO	BY		SHEET
013849/1100	MRV	WALLA WALLA DISTRICT CORPS OF ENGINEERS LOWER GRANITE LOCK AND DAM - SURFACE BYPASS SYSTEM OPTIONS	6
DATE	CHECKED	Full Flow Bypass - Option 7	OF
12/97			

Sverdrup

Job No. 013849-3100	By PJZ	Subject SYSTEM COMBINATIONS C.D.R. COST ESTIMATE FOR ALTERNATE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 19
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18.10 MASS CONCRETE THRUST RESTRAINT AT END OF CHUTE

VOLUME ≈ (25)(30)(19) = 14250 FT^3
(HEIGHT) (LENGTH) (WIDTH)

= 404 M^3

FROM REF. ① ITEM 18.1 USE \$466/M^3 FOR MASS CONCRETE

COST = (466)(404) = \$ + 188,264

18.11 DIVE TIME:

SINCE THE WORK IN THE TAILRACE FOR THE MASS CONCRETE THRUST BLOCK AND 2 PAIRS OF PIERS WILL REQUIRE SOME SHALLOW DIVING TO PREPARE FORMWORK

ASSUME 3 WEEKS (15 DAYS) AT \$4,500/DAY

[4 MAN DIVE TEAM @ \$1000/DIVER AND ONE TENDER @ \$500]

COST = (15)(4500) = \$ + 67,500

NOTE: DIVE TIME AT UPSTREAM END IS INCORPORATED INTO THE COST OF THE DEWATERING BULKHEAD

Sverdrup

Job No. 013849-3100	By PJR	Subject SYSTEM COMBINATIONS C.D.R. COST ESTIMATE FOR ALTERNATE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 20
Date 11/98	Checked RGW		Of

SUMMARY OF COST CHANGE FOR TYPE Z SBC AT LOWER GRANITE WITH ALTERNATE DISCHARGE

ITEM	COST CHANGE
1.0	−256,736
2.0	−343,640
3.0	− 24,015
4.0	− 174,736
10.0	− 30,750
11.0	− 290,700
18.1	− 246,980
18.2	− 1,076,400
18.3	− 342,000
18.4	− 613,000
18.6	− 95,400
18.8	+ 1,367,240
18.9	+ 481,988
18.10	+ 188,264
18.11	+ 67,500
	$ −1,389,365

INCREASE COST REDUCTION FOR THE FOLLOWING ITEMS

MOB/DEMOB 5% (1,389,365)(1.05) = 1,458,833

CONTRACTORS O/P 26.5% (1,458,833)(1.265) = 1,845,424

CONTINGENCY 25% (1,845,424)(1.25) = 2,306,780

PLAN., ENG., + MAN. 35% (2,306,780)(1.35) = 3,114,153

∴ GROSS CHANGE IN ESTIMATED CONSTRUCTION COST = $ −3,114,153

RESULTING FINAL ESTIMATED COST = 49,552,884 − 3,114,153 = $46,438,731

Sverdrup

Job No. 013849-3100	By PJC	Subject SYSTEM COMBINATIONS C.D.R. COST ESTIMATE FOR ALTERNATE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 21
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TYPE 2 SBC AT LITTLE GOOSE

ASSUME THE OVERALL CHANGE AT LITTLE GOOSE IS THE SAME AS AT LOWER GRANITE

∴ FINAL ESTIMATED COST = 43,795,680 − 3,114,153 = $\boxed{\$40,681,527}$

TYPE 2 SBC AT LOWER MONUMENTAL

ASSUME THE OVERALL CHANGE AT LOWER MONUMENTAL IS THE SAME AS AT LOWER GRANITE

∴ FINAL ESTIMATED COST = 59,824,469 − 3,114,153 = $\boxed{\$56,710,316}$

TYPE 2 SBC AT ICE HARBOR

AT ICE HARBOR THE CHANNEL IS SHALLOWER AND THE COSTS FOR THE SPILLWAY MODIFICATIONS ARE DIFFERENT. THEREFORE, AN APPROXIMATE COST CHANGE AT ICE HARBOR IS DEVELOPED AS FOLLOWS:

FOR ITEMS 1.0 THRU 4.0 ASSUME THE REDUCTION IN CHANNEL COST IS PROPORTIONAL TO THE TOTAL CHANNEL COST

AT LOWER GRANITE THE SUM OF THESE COSTS IS

	ORIGINAL	SAVINGS	
1.0)	5,594,800	256,736	
2.0)	4,913,200	343,640	
3.0)	420,320	24,015	
4.0)	2,608,000	174,736	
TOTAL	13,536,320	799,127	⟹ 5.9%

Sverdrup

Job No. 013849-3100	By PJC	Subject SYSTEM COMBINATIONS C.D.R. COST ESTIMATE FOR ALTERNATE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 22
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TOTAL FOR ICE HARBOR: ORIGINAL

1.0	4,532,640
2.0	4,106,640
3.0	345,571
4.0	2,310,400
	11,295,251

SAVINGS = (11 295 251)(0.059) = $ - 666,824

10.0 STRUCTURAL SUPPORT

SAME SAVINGS = $ - 30,750

11.0 FIXED S.B.C. TRANSITION STRUCTURE

A REVIEW OF PLATE 2.4.1 INDICATES THAT THE REDUCTION IN COST FOR THIS ITEM AS COMPARED TO THE S.E.S. WOULD NOT BE AS GREAT REPRESENTING ABOUT A 1/6 REDUCTION IN LENGTH

COST CHANGE = (1/6)(872,100) = $ - 145,350

18.0 DISCHARGE MODIFICATIONS

USE COSTS FROM ICE HARBOR ESTIMATE (REF. 2)

18.1)	$ - 214,360
18.2)	$ - 879,060
18.3)	$ - 296,000
18.4)	$ - 530,000
18.6)	$ - 82,680

TOTAL = $ - 2,002,100

Sverdrup

Job No. 013849-3100	By PJC	Subject SYSTEM COMBINATIONS C.D.R. COST ESTIMATE FOR ALTERNATE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 23
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WITHOUT DEVELOPING A DISCHARGE CHUTE FOR ICE HARBOR SPECIFICALLY, ASSUME THE INCREASES IN COST FOR THIS INSTALLATION ARE THE SAME

18.8)	1,367,240
18.9)	481,988
18.10)	188,264
18.11)	67,500

TOTAL = \$+2,104,992

SUMMARY OF COST CHANGE FOR ICE HARBOR:

ITEMS	COST CHANGE
1.0-4.0	- 666,824
10.0	- 30,750
11.0	- 145,350
18.1-18.7	- 2,002,100
18.8-18.11	+ 2,104,992
	\$ - 740,032

INCREASING FOR ITEMS IDENTIFIED ON PAGE 20

(-740,032)(1.05)(1.265)(1.25)(1.35) = \$ - 1,658,724

FINAL COST AT ICE HARBOR = 53,882,597 - 1,658,724 = $\boxed{\$52,223,873}$

FINAL COST FOR SYSTEM COMBINATION 2

REDUCTION = (3)(3,114,153) + 1,658,724 = \$ 11,001,183

208,055,630 - 11,001,183 = $\boxed{\$ 197,054,447}$

Sverdrup

Job No. 013849-3100	By PJL	Subject SYSTEM COMBINATIONS C.D.R. COST ESTIMATE FOR ALTERNATIVE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 24
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TYPE 3 DESIGN

LOWER GRANITE:

A PLAN VIEW OF THE TYPE 3 SBC DESIGN WITH THE ALTERNATIVE DISCHARGE IS SHOWN ON THE ATTACHED PLATE 2, AS IT WOULD BE AT LOWER GRANITE. THIS DESIGN IS COMPARED TO PLATES 3.1.1 THROUGH 3.1.6 IN THE BODY OF THE REPORT.

COST ITEMS FOR THE LOWER GRANITE TYPE 3 DESIGN ARE ADDRESSED POINT BY POINT

1.0 CHANNEL WALLS AND FLOOR:

IN THIS CASE THE NORTH END OF THE CHANNEL IS REDUCED IN LENGTH BY 34 FT

THIS IS AN AREA WHERE THE CHANNEL IS 50 FT DEEP. FROM REF (2) PAGE 28 THE WALL IN THIS SECTION IS $54-14.6=39.4$ FT HIGH. ∴ REDUCED WALL AREA IS

$(2)(39.4)(34) = 2679\ FT^2$

REDUCED FLOOR AREA $= (34)(47) = 1598\ FT^2$

TO ACCOMMODATE THE SHIFT TO THE SOUTH THE UPSTREAM WALL IS EXTENDED AT THE SOUTH END BY ABOUT ½ THE REDUCED LENGTH OR 17 FT. THIS IS THE 70 FT DEEP SECTION WITH WALL HEIGHT OF $74-15.7=58.3$ FT

INCREASED WALL AREA $= (17)(58.3) = 991\ FT^2$

INCREASED FLOOR AREA $= (\frac{1}{2})(17)(47) = 400\ FT^2$

THE ANGLE ON THE SOUTH END WALL INCREASES ITS LENGTH BY ABOUT 3 FT ∴ AREA $\Delta = (3)(58.3) = 175\ FT^2$

Sverdrup

Job No. 013849-3100	By PJL	Subject SYSTEM COMBINATIONS C.D.R. COST ESTIMATE FOR ALTERNATIVE DISCHARGE THRU CENTRAL N/o SECTION	Sheet 25
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TOTAL CHANGE IN WALLS AND FLOOR AREA

$= -2679 - 1598 + 991 + 400 + 175 = -2711 \text{ FT}^2$

$= -252 \text{ m}^2$

FROM REF ① THE UNIT COST IS $710/M²

COST CHANGE = (710)(-252) = $-178,920

2.0 INTERNAL WALLS + FLOOR:

-NO CHANGE-

3.0 MISCELLANEOUS CHANNEL STRUCTURES:

THE SHORTER CHANNEL WILL REQUIRE LESS WALKWAY LENGTH, ETC... RESULTING IN SOME SMALL REDUCTION. USING THE 10% COST ESTIMATE APPROACH RESULTS IN COST CHANGE = $-17,892

4.0 FLOTATION CELLS:

REDUCTION IN FLOTATION CELLS IS

$-(2)(34) + 17 + 3 = -48 \text{ FT}$

$= 14.6 \text{ m}$

FROM REF ① THE UNIT COST IS $7660/M

COST CHANGE = (7660)(-14.6) = $-111,836

ITEMS 5.0 THROUGH 9.0

-NO CHANGE-

Sverdrup

Job No. 03849-3100	By PJL	Subject SYSTEM COMBINATIONS C,D,R, COST ESTIMATE FOR ALTERNATIVE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 26
Date 11/98	Checked RGW		of

10.0 STRUCTURAL SUPPORT AND GUIDE SYSTEM:

GUIDE SYSTEM AS ESTIMATED IN REF (4) PAGE 66 CONSISTED OF 8 GUIDES WITH ONE AT THE CENTRAL NON-OVERFLOW SECTION. SINCE THIS ONE WOULD NO LONGER BE REQUIRED REDUCE THE COST BY 1/8

COST CHANGE $= -(1/8)(250,000) = \$ -31,250$

11.0 FIXED SBC TRANSITION STRUCTURE:

IN THIS CASE THE LENGTH OF THE STRUCTURE IS THE SAME AS IN THE ORIGINAL SES DESIGN ∴ NO CHANGE

12.0 CONNECTION TO JUVENILE GALLERY:

THE LOCATION FOR THIS CONNECTION IS SHIFTED SLIGHTLY SOUTH BUT SHOULD NOT CHANGE THE COST. ONE ITEM WHICH MAY ADD SOME COST HERE IS THE DECOMMISIONING OF THE EXISTING AUXILIARY WATER PORT WHICH WILL NO LONGER BE FUNCTIONAL. FOR GATE REMOVAL AND SOME CONCRETE PATCHING SAY $ +30,000

ITEMS 13.0 THROUGH 17.0

– NO CHANGE –

Sverdrup

Job No. 013849-3100	By PJC	Subject SYSTEM COMBINATIONS C.D.R. COST ESTIMATE FOR ALTERNATIVE DISCHARGE THRU CENTRAL N/O SECTION	Sheet 27
Date 11/98	Checked RGW		of

18.0 DISCHARGE CHUTE:

AS WITH THE TYPE 2 ALTERNATE DESIGN ITEMS 18.1 THROUGH 18.4 AND ITEM 18.6 ARE NO LONGER REQUIRED. ∴ REDUCED COSTS ARE AS FOLLOWS:

18.1) \$ - 93,200
18.2) \$ - 1,076,400
18.3) \$ - 342,000
18.4) \$ - 835,000
18.6) \$ - 178,640

TOTAL REDUCTION FOR SPILLBAY MOD'S = \$ - 2,525,240

ESTIMATE OF NEW WORK FOR DISCHARGE CHUTE

18.8 CONCRETE REMOVAL FROM NON-OVERFLOW SECTION

TOTAL VOLUME = (34)(66.75)(6) = 13,617 FT^3
= 386 M^3

COST CHANGE = (1330)(386) = \$ + 513,380

18.9 CONCRETE CHUTE

VOLUME OF WALLS SAME AS TYPE 2 = 435 M^3 (PAGE 10)

VOLUME OF FLOOR = $\left(\frac{6+13}{16+13}\right)(251)$ = 119 m^3
(PAGE 17)

FOR THE SUPPORT PIERS ASSUME THE SMALLER LOADS ASSOCIATED WITH THE THINNER CHANNEL REQUIRE 2'x2' PIERS (RATHER THAN 3'x3')

VOLUME = (4/9)(86) = 38 m^3
(PAGE 17)

Sverdrup

Job No. 013849-3100	By PJC	Subject SYSTEM COMBINATIONS C.D.R. COST ESTIMATE FOR ALTERNATIVE DISCHARGE THRU CENTRAL NO SECTION	Sheet 28 of 28
Date 11/98	Checked LGW		

FOR SUPPORT BEAMS ASSUME 2' WIDE × 3' HIGH (RATHER THAN 3'×3' BEAMS)

VOLUME = (6/9)(34) = 23 m^3
(PAGE 17)

TOTAL VOLUME FOR STRUCTURAL CONCRETE
= 435 + 119 + 38 + 23 = 615 m^3

COST CHANGE = (598)(615) = $ + 367,700

18.10 MASS CONCRETE
VOLUME = $\left(\frac{6+3}{16+3}\right)$(404) = 191 m^3
(PAGE 19)
COST CHANGE = (466)(191) = $ + 89,006

18.11 DIVE TIME:
ASSUME SAME AS FOR TYPE 2
$ + 67,500 (PAGE 19)

SUMMARY OF COST CHANGE FOR TYPE 3 SBC AT LOWER GRANITE WITH ALTERNATE DISCHARGE

= 178,920 − 117,892 − 111,836 − 31,250 + 30,000 − 2,525,240 + 513,380 + 367,700 + 89,006 + 67,500 = $ −1,797,552

INCREASING COST CHANGE FOR ITEMS IDENTIFIED ON PAGE 20
(1,797,552)(1.08)(1.265)(1.25)(1.35) = $ − 4,029,072

ASSUME DIFFERENCE IS THE SAME FOR LOWER MONUMENTAL

ALTERNATE TOTAL FOR LOWER GRANITE = 65,654,833 − 4,029,072 = $61,625,761
" " " LOWER MONUMENTAL = 76,098,066 − 4,029,072 = $72,068,994

ALTERNATE TOTAL FOR SYS. COMB. #3 = 243,384,762 − (2)(4,029,072) = $ 235,326,618

ANNEX C

DISSOLVED GAS ABATEMENT STUDY

[Note: This is a draft version of the Dissolved Gas Abatement Study. The final version has not yet been released at the time of this printing.]

[This annex contains a report prepared for other purposes and includes word tenses that are outdated for this FR/EIS. This report is incorporated into Appendix E simply because of its applicability.]

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1. Introduction

1.1 General

The Columbia River Fish Mitigation Program (CRFMP) is a program of measures aimed at improving the survival of anadromous fish in the lower Snake and Columbia river system. Investigative studies, to improve passage and resulting survival of juvenile and adult fish, within the CRFMP include: 1) Dissolved Gas Abatement Study (DGAS); 2) reservoir drawdown; 3) surface collection and bypass (SCB); 4) improvements to existing juvenile fish bypass systems; 5) juvenile fish transportation; 6) turbine improvements to reduce turbine induced mortality; and 7) others.

The DGAS was initiated in 1994 to examine potential methods for reduction of TDG produced by spillway operations on the Corps' eight dams on the lower Snake and Columbia rivers. (Note: The final version of the Dissolved Gas Abatement Study has not yet been released at the time of this printing.) The study was also called for by the National Marine Fisheries Service (NMFS) Biological Opinion on Operation of the Federal Columbia River Power System (1995). NMFS prescribed two reasonable and prudent measures (RPA 16 and 18) that directed the Corps' to address means to measure, evaluate, and prescribe alternatives to reduce Total Dissolved Gas (TDG) at Lower Snake and Columbia river projects.

1.2 Authorization

This study is an element of the CRFMP and is being conducted under the existing authorities for the eight Corps projects on the lower Columbia and lower Snake Rivers. For Bonneville Dam, that authority is the Rivers and Harbors Act of 1935, Public Law 74-409, dated August 30, 1935. For John Day and The Dalles Dams, the authority is the Rivers and Harbors Act of 1950, Public Law 81-516, dated May 17, 1950. The authority for McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite is the Rivers and Harbors Act of 1945, Public Law 79-14, dated March 2, 1945.

1.3 Scope

This document provides information about the DGAS as it relates to the Major Systems Improvement Alternative within the Lower Snake River Feasibility Study. While the DGAS addresses the eight Corps dams on the lower Snake and Columbia rivers, this document presents engineering information about some possible alternative measures which could be used to reduce total dissolved gas production at each of the lower Snake River dams.

This information is an excerpt from the draft final report, Phase II of the DGAS. Only portions of this part of report are presented here. Evaluations of fish passage cost or benefits are not presented since they remain incomplete in the DGAS. However, potential risks are subjectively identified in discussions of individual alternatives.

The overall DGAS reports will include other information such as: 1) TDG field research; 2) biological research; 3) the development of the numerical models; and, 4) associated system-wide evaluations. These tasks are summarized in the following paragraphs for information purposes only.

1.4 TDG Research

This portion of the DGAS identifies and describes the physical field data gathered during the study. This critical information was used: a) to further the understanding of the TDG performance of existing structures; b) to identify additional structural alternatives; c) to provide information for estimating the gas performance of proposed structures; and, d) to provide calibration and verification data sets for development of the 1D and 2D numerical flow models.

1.5 Biological Research

This portion of the DGAS presents information gathered from biological field and laboratory studies. This information was developed to allow understanding and evaluation of the complex relationships between TDG and risk to salmonids. This part of the study was originally intended to develop enough information, such as mortality coefficients and fish distribution simulations, for the numerical model.

1.6 Numerical Models

This report describes and documents the development of the numerical models. These models were developed as decision tools to assist in the selection of the combination of system-wide structural alternatives which will provide the highest or optimum system-wide biological benefits. The models were also used to provide information about the order of implementation of the selected alternatives.

1.7 System-wide Analysis

This report documents the results of the system-wide analysis of the proposed gas abatement alternatives. The analysis presents the estimated effects of a variety of system-wide alternatives in terms of TDG reductions.

Decisions about which alternative gas abatement measure should be implemented at a particular dam must be made through a system-wide analysis of alternatives while factoring in biological consequences.

2. Design Criteria

2.1 General

Discharge through the spillways of the four lower Snake River dams often results in high levels of TDG saturation. Water discharged through the spillways entrains air bubbles while plunging into the stilling basin (refer to Figure 2-1). Hydrostatic pressure due to water depth in the stilling basin forces air bubbles into solution, thus raising total dissolved gas pressures within the water.

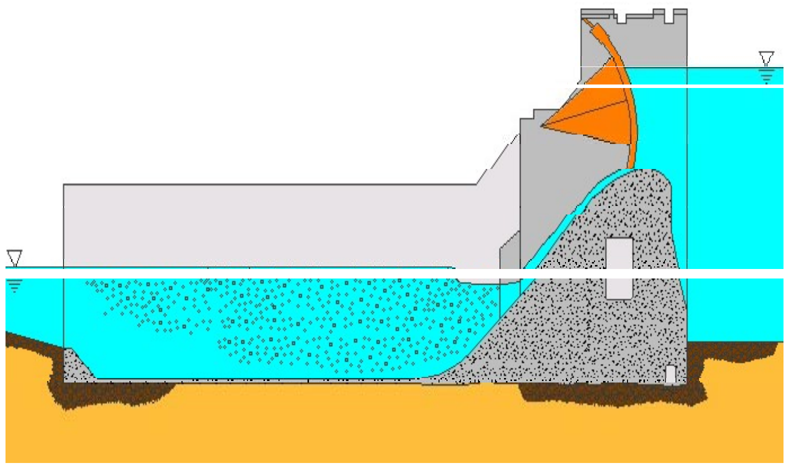

Figure 2-1. Cross Sectional View of a Typical Spillway

Based on the laws of physics and chemistry, there are three basic ways to reduce the supersaturation. The gas abatement alternatives must achieve one or more of the following:

- Reduce or eliminate the volume of air being entrained. This can be achieved by submerging the discharge so there is no contact with air during the water's passage from the forebay to the tailrace.
- Reduce or eliminate the hydrostatic pressure acting on the entrained air. This can be achieved by reducing the plunge depth of the water. The hydrostatic pressure is directly proportional to the depth of water. With reduced depth, the hydrostatic pressure and the transfer of air into solution are both reduced.
- Reduce the exposure time of entrained air to high pressures. Field tests indicate that supersaturation occurs almost instantaneously at the existing spillways. Therefore, exposure time most likely cannot be reduced to the degree required for reducing supersaturation.

2.2 Design Criteria

The gas abatement alternatives must meet the following criteria.

- The alternative must reduce TDG supersaturation for a significant range of discharge. The original goal was to reduce supersaturation to 110 percent or less for total river flows up to the 10-year, 7-day event (230,000 cfs for the Lower Snake River and 498,000 cfs for the Lower Columbia River). However, after investigating structural and operational alternatives, the original goal was found to be unattainable for the large design flows. Therefore, the study plan was changed to include all alternatives that provide total dissolved gas reduction benefits, even though they may not meet 110 percent.

- The alternative must allow adequate energy dissipation of the spillway design discharge. Without adequate energy dissipation, downstream channel erosion could compromise the structural integrity of the dam and create significant safety risks.

- The alternative must provide safe fish passage with high survival. Recommended gas abatement alternatives should not reduce gas supersaturation at the expense of safe fish passage.

- The alternative must be reasonable to construct, operate, and maintain. The Corps will not recommend gas abatement alternatives that cannot be reasonably and safely constructed, operated, and maintained.

2.3 Target Design Discharge

The states of Oregon and Washington have adopted similar standards for total dissolved gas concentrations. The standards state that the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection shall not exceed 110 percent of saturation, except when stream flow exceeds the 10-year, 7-day average flood discharge. During very large natural runoff events, the resulting high river flows make it impossible for dam operators to abate dissolved gas. Both Oregon and Washington's water quality standards exempt these occurrences, since they are of natural origin and occur relatively infrequently. The typical criterion for expressing the water quality standard exemption is called the 7Q10, which is the average peak annual flow for 7 consecutive days that has a recurrence interval of 10 years. Historical, average daily flow data from water year 1974 to the present are recommended for use in developing the statistical information to derive the 7Q10 discharge for each project.

Table 2-2 shows the target design discharges for development of structural alternatives with the goal of achieving state and Federal water quality standards as measured at the tailrace fms.

Table 2-2. Target Design Discharges

Project	10 year – 7 Day Discharge (cfs) (1)	Powerhouse Hydraulic Capacity (cfs) (2)	Spill Capacity to 110% (cfs) (3)	Additional Required Capacity (cfs) (4)
Lower Granite	230,000	108,000	24,000	98,000
Little Goose	230,000	108,000	20,000	102,000
Lower Monumental	230,000	108,000	20,000	102,000
Ice Harbor	230,000	88,000	30,000	112,000
McNary	480,000	215,000	56,000	209,000
John Day	498,000	310,000	60,000	128,000
The Dalles	498,000	290,000	23,000	185,000
Bonneville	498,000	305,000	44,000	149,000

Note: All figures have been rounded to the nearest 1,000 cfs.

Column (1) Statistical analysis of historical discharge data.

Column (2) Powerhouse hydraulic capacity assumes that units are operating at highest hydraulic capacity within 1 percent of peak efficiency for fish passage and that one unit is out of service on Snake River Projects and two units out of service on Columbia River Projects.

Column (3) identifies the amount of water that can be passed over the existing spillways without exceeding 110 percent total dissolved gas at the tailrace fixed monitoring station. This spill volume assumes incoming forebay TDG is 110 percent or less and is based on current existing conditions which is about 3 kcfs per deflected spillbay and 1 kcfs per non-deflected bay. This number will change as additional deflectors are added to existing spillways.

Column (4) is the additional required water which must be passed by the project in some manner so as to not exceed the 110 percent TDG value as recorded at the tailrace fixed monitoring station. Column (4) is calculated as (4)= (1) – (2) – (3).

The design discharges from column 4 are conservative values which could be used as target flow for design of new structures.

2.4 Alternatives

The following potential gas abatement alternatives have been identified.

- Additional/modified spillway flow deflectors
- Raised negative-stepped stilling basin
- Raised tailrace channel and deflectors
- Baffled chute spillway

- Side-channel spillway
- Pool and weir channel
- Additional spillway bays
- Submerged conduit with deflectors
- Powerhouse/Spillway separation wall
- Submerged spillway gates

The alternatives can be grouped into two categories: 1) category one, and; 2) category two.

Category one alternatives are those with potential to reduce the production of gas saturation due to spillway operations but alone are not likely to achieve the current state and federal TDG water quality standards. The category one alternatives include: 1) additional/modified spillway flow deflectors; 2) raised (negative-stepped) stilling basin; 3) raised tailrace channel; 4) additional spillway bays; and 5) powerhouse/spillway flow separation wall. These alternatives are described in more detail in the following Section 3.0.

Category two alternatives have the potential to meet the state and Federal water quality standards. They include: 1) submerged conduits; 2) baffled chute spillways; 3) side channel spillways; 4) pool and weir spillways; and 5) submerged spillway gates. These alternatives are described in more detail in Section 4.0.

3. Category One Alternatives

This section describes those alternatives with potential to reduce the production of gas saturation due to spillway operations but alone are not likely to achieve the State and Federal water quality standards.

3.1 Additional/Modified Deflectors

3.1.1 General

Spillway flow deflectors have been installed at seven of the eight lower Snake and Columbia river dams. Deflectors consist of a horizontal concrete lip 8 to 12.5 feet long placed on the spillway face just below or near the minimum tail water elevation (Figure 3-1). They are designed to force the spill flow to skim over the water surface of the stilling basin limiting the plunge depth of the aerated flow. Deflectors are very effective and have reduced the saturation of spill discharges by as much as 15 to 25 percent TDG over a wide range of voluntary spill rates.

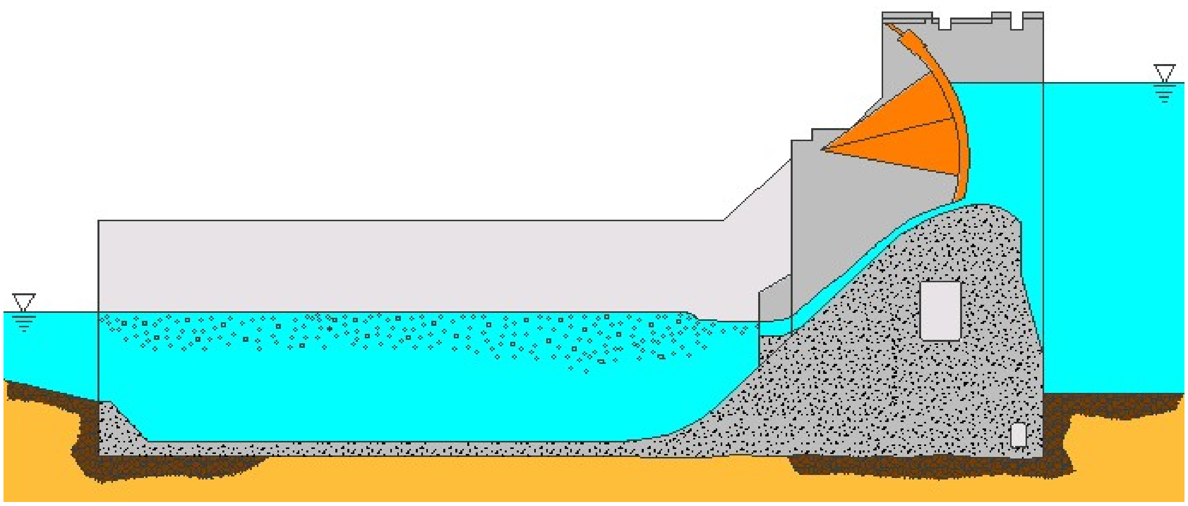

Figure 3-1. Conventional Spillway with Deflectors

In the 1970s deflectors were added to Lower Granite, Little Goose, Lower Monumental, McNary, and Bonneville spillways and in most cases were left off the outside spillbays because of concerns that deep spill is required next to fish ladders to help direct adult migrants to the ladders. As part of the DGAS, deflectors were modeled, designed, and constructed on the John Day and Ice Harbor spillways. These deflectors were designed and optimized for a spill discharge between 6,000 and 14,000 cfs per bay.

Deflectors in the outside spillway bays, adjacent the adult fishway channel entrances, were believed to potentially create flow conditions that would hinder adult migrants from finding ladder entrances. Evaluations of adult fish passage were conducted at Little Goose and Lower Monumental Dams. The study was designed to determine if adult passage through entrances adjacent the spillway was influenced by hydraulic conditions considered by fish managers to be unfavorable. The study evaluated passage with spillway flows distributed according to the adult fish passage patterns (those developed in the 1970s) and passage with spillway flows distributed evenly across the deflected spillbays only. There were no identifiable delays associated with the uniform distribution of spill over the deflected spillbays. In addition, investigations of adult passage through the Lower Granite spillway entrances indicate there are no delays associated with operation of end bay deflectors at Lower Granite.

Results of this study lead to the installation of flow deflectors in end bays of the Ice Harbor spillway and the discontinued use of non-deflected bays at Little Goose and Lower Monumental. Non-deflected end bays at these projects were shown to produce high levels of TDG without any offsetting fish passage benefits for adult migrants. Adult passage counts at Ice Harbor during the 1998 and 1999 passage season show no sign of delayed passage following the installation of end bay deflectors. The adult migrant delay studies have shown that concerns for adult migrant passage delay due to changes in the hydraulic environment related to the installation of spillway flow deflectors adjacent to fish ladder entrances were not well founded.

Flow deflectors at Ice Harbor increased the 120 percent TDG spill cap from 25,000 cfs without deflectors to near 80,000 cfs with eight deflectors and up to 110,000 cfs with 10 deflectors. The success of the Ice Harbor deflectors has led to the evaluation and implementation of additional spillway flow deflectors on those projects without deflectors on all bays. Model investigations and design of additional deflectors at Little Goose, Lower Monumental, McNary, and Bonneville are being conducted under a fast-tracked implementation program entitled “Deflector Optimization Program”.

3.1.2 Design

The effectiveness of spillway flow deflectors is dependent on the geometry of the deflector, target discharge, and deflector submergence (tailwater elevation minus deflector elevation). Performance is optimized when the elevation of the deflector (associated with a design discharge and tail water elevation) is set to provide a smooth skimming flow. If the tailwater elevation relative to the deflector is too low, the deflected discharge generates a plunging flow, subjecting aerated flow to higher pressures. If the tailwater elevation is too high, the deflected discharge generates a highly aerated undular flow that may also draw air deep into the stilling basin.

The performance of existing deflectors may be improved by modifying the spillway/deflector transition, adding spillway pier nose extensions, extending the deflectors, and optimizing the deflector elevation for specific ranges of voluntary spill discharge. The new John Day and Ice Harbor deflectors were constructed with some of these improvements and generate TDG levels a few percent lower than most other deflectors.

3.1.3 Model Study Investigations

Sectional and general model studies were completed for the John Day and Ice Harbor projects, resulting in the construction of 12.5-foot-long deflectors with 15-foot-radius transitions. The deflector length was optimized to provide a stable deflected jet for the design flow range, while allowing the deflector to be overridden during the spillway design flood. This design maintains the stilling basin’s capacity to adequately dissipate the energy of flow during flood flow conditions. The deflector elevations were established to provide a smooth stable skimming flow jet for the design discharge and expected operating tailwater elevation.

Other deflector model study investigations include a stepped spillway flow deflector and an extended length spillway flow deflector. The stepped deflector concept was intended to provide skimming flow over a very wide range of tail water elevations. This design consisted of an upper and lower deflector connected by a smooth transition. The upper deflector elevation would be set to provide ideal flow conditions for the design discharge at high tail water, and the lower deflector would provide the good skimming flow conditions at low tail water elevations. The application of this deflector was thought to be most suited to the Bonneville spillway due to the extreme fluctuations in tail water elevations experienced there. This deflector was modeled in the Bonneville 1:40 scale sectional model. The transition from the upper deflector began with a parabolic curve, following the natural trajectory of the jet, then went into a reverse curve leading to the lower deflector. The performance of the stepped deflector was very poor and efforts to improve on the design were unsuccessful.

Deflectors lengths of 12.5 feet, 17 feet, and 30 feet were evaluated using the John Day sectional spillway model. The 17- and 30-foot deflectors appeared to provide a smoother deflected flow jet over a wider range of tailwater elevations but did not significantly improve the hydraulic performance beyond that of the 12.5-foot deflector. Longer deflectors tend to focus the impact of the deflected jet further downstream and appeared less likely to be overridden during high spill events. With the exception of the Little Goose, which has 8-foot deflectors, it is not likely that longer deflectors will provide any significant improvement in TDG reductions.

Additional model investigations are either underway or scheduled for the Bonneville, McNary, Lower Monumental, and Little Goose projects under the deflector optimization program. Sectional spillway model investigations are being used to develop the deflector design and elevation. General model investigations will be used to verify the deflector performance given the 3-dimensional flow patterns established by the large general models and to develop operational spill distribution patterns.

3.1.4 The TDG performance

Deflected spill flow, will generally produce saturated gas levels as shown in Figure 3-2. These estimates are based on near-field test data and fixed-monitor data from they eight lower Snake and Columbia river projects. Figure 3-2 indicates the performance of a single deflected spillway bay. The total spillway performance is project specific and will vary depending on the distribution of total spill discharge over non-deflected and deflected spillbays and the interaction of these flows with powerhouse releases.

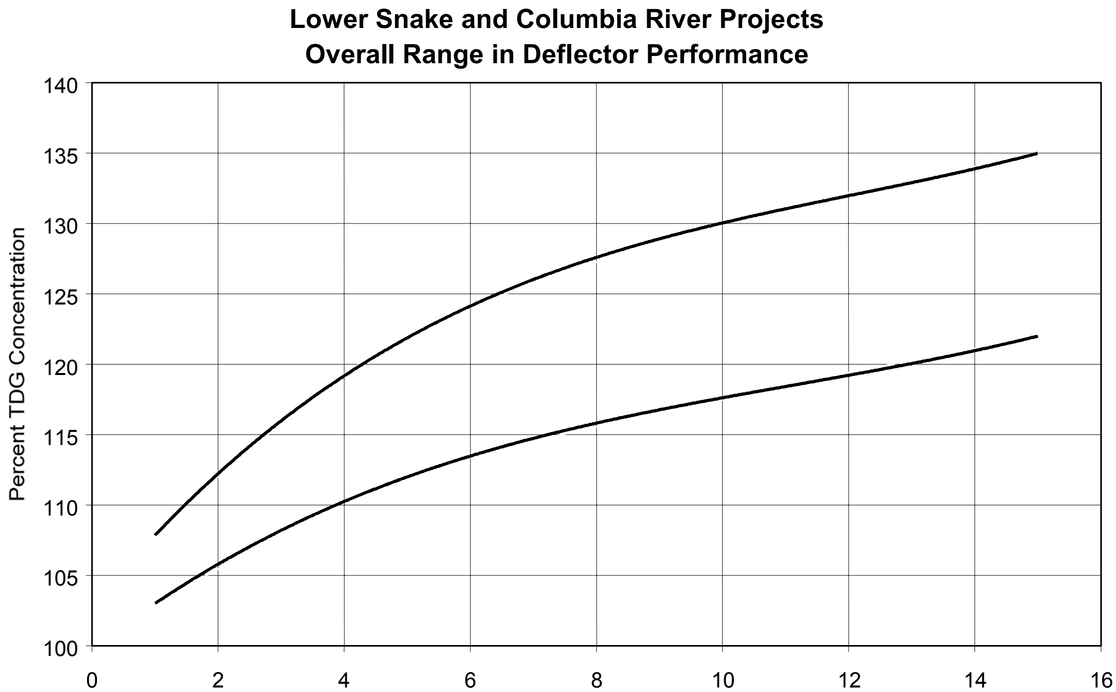

Figure 3-2. Unit Spillway Discharge (kcfs)

3.1.5 Risk Assessment

The impacts of any spillway or deflector modifications on juvenile and adult fish passage, navigation, channel erosion, and the structural integrity of the dam must be considered. The addition or modification of spillway flow deflectors may potentially affect any or all of the following elements:

3.1.5.1 Adult Fish Passage

Model studies and prototype evaluations have shown deflectors in the outside spillbays create strong cross-currents (or lateral flows) immediately downstream of the adult fishway entrances. Tailrace conditions altered by modified or additional deflectors may disorient and delay adult fish seeking passage through the fishway entrances adjacent to the spillways. The affect of additional or modified flow deflectors on adult fish passage must be evaluated on a project-by-project basis accounting for differences in project configurations (e.g., relative location of fishway entrances, channel bathymetry, and the existence of guide walls separating the entrances from the stilling basin). However, studies of adult migrant delay conducted to date following installation of deflectors on spillbays adjacent to fish ladder entrances have not shown any delay in adult migrant passage associated with operation of these newly modified bays.

3.1.5.2 Juvenile Fish Passage

The hydraulic conditions generated by deflected spill flow may directly impact survivability of juvenile salmonids migrating downstream. Turbulence in the vicinity of stilling basin baffle blocks and endsill may be increased with additional or modified flow deflectors. Increased turbulence in the vicinity of these structures may result in increased mechanical injury. Though many of the projects are similar, the influence of spillway modifications on juvenile fish passage must be evaluated on a project-by-project basis. There have been studies of direct mortality of spill passed juvenile migrants that indicate higher mortality for juvenile fish passed through spillbays with deflectors.

3.1.5.3 Navigation

Flow deflectors decrease the amount of energy dissipated within the stilling basin, increasing the velocity of flow in the downstream channel. The extent that deflectors influence navigation conditions downstream of the lock entrances depends on the channel configuration, bathymetry, and the relative location of the navigation lock to the spillway. Increased velocity and cross-channel flows may cause difficulty for tow operators to maintain proper alignment and speed as they approach and exit the downstream lock entrance. Potential impacts of additional or modified deflectors on navigation must also be evaluated on a project-by-project basis.

3.1.5.4 Stilling Basin and Channel Erosion

The ability of the spillway and stilling basin to adequately dissipate energy of spillway design flows must not be compromised with any spillway modifications. Model studies show the standard 12.5-foot-long flow deflectors will be over ridden by the spillway design flood discharges. When this happens, the hydraulic jump generated by spillway design flood flows is fully contained within the stilling basin. Extending the deflector length may result in insufficient energy dissipation of the project design flows, forcing the hydraulic jump and high-energy flow into the downstream channel, potentially causing erosion of the downstream channel and shoreline.

3.1.6 Operations

Adding or modifying spillway flow deflectors at any of projects should not impact or increase project operations and maintenance (O&M) cost. This alternative is a passive system with no electrical or mechanical features. The only operational changes that might occur would be an increase in the amount of water that can be voluntarily spilled, changes in spillway distribution patterns, and possible changes to turbine operation priorities. These changes may be adjusted to provide optimum tailrace flow patterns for juvenile and adult fish passage.

3.1.7 Project Application

Additional flow deflectors can be installed at most of the lower Snake and Columbia river projects. The benefit of added deflectors is dependent on the hydraulic performance of the deflector and the ratio of deflected to non-deflected spill flow. The incremental benefits diminish as the ratio of deflected to non-deflected spill discharge increase. Table 3-1 identifies the total number of spillbays and the total number of deflectors currently installed at each of the eight Corps projects on the lower Snake and Columbia rivers.

Table 3-1. Total Number of Spillway Bays and Deflectors

	No. Spillway Bays	No. Deflectors	Deflector Elevation	Deflector Length	Deflector Transition
Bonneville	18	13	14.0	12.0	6.0-ft radius
The Dalles	23	0			
John Day	20	18	148.0	12.5	15.0-ft radius
McNary	22	18	256.0	12.0	Flat
Ice Harbor	10	10	338.0 [1/]	12.5	15.0-ft radius
Little Goose	8	6	532.0	8.0	Flat
Monumental	8	6	434.0	12.5	Flat
Lower Granite	8	8	630.0	12.5	15.0-ft radius

1/ Deflectors in spillway bays 1 and 10 are at el. 336 for improved adult fishway entrance conditions.

3.1.8 Recommendations for Further Development

The development of additional and/or modified deflectors is underway for all projects with the exception of Ice Harbor.

3.2 Raised (Negative-Stepped) Stilling Basin

3.2.1 General

Raising the stilling basin floor by filling and capping the basin with concrete will reduce the plunge depth and expose the heavily aerated discharge to lower hydrostatic pressures (Figure 3-3). Because this alternative compromises the basin's ability to dissipate the energy of flow, a secondary or negative-stepped basin immediately downstream of the primary basin is necessary to provide for energy dissipation of the probable maximum flood (PMF).

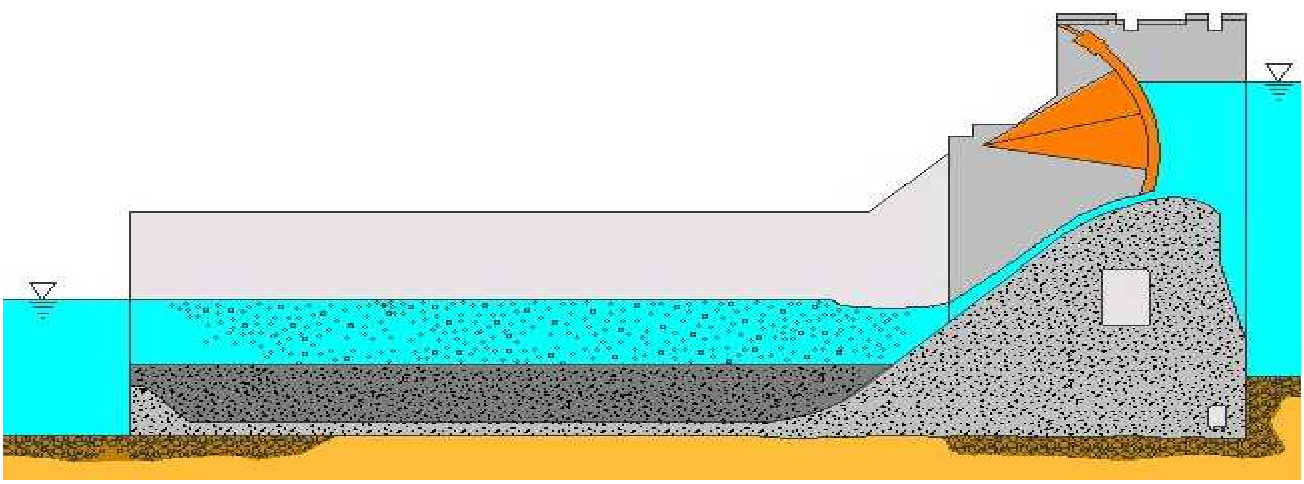

Figure 3-3. Negative-Stepped Stilling Basin

3.2.2 Design

The spillway's stilling basin serves to dissipate the kinetic energy of water passed over a spillway and is necessary to prevent excessive erosion and undesirable hydraulic conditions in the tailrace channel. To function properly, the basin must be designed with the appropriate length and depth to create and contain the formation of a hydraulic jump. Stilling basins on the lower Snake and Columbia river projects are designed to dissipate the energy of all spillway discharges up to the PMF. The normal stilling basin depths of these projects range from near 40 feet to more than 60 feet deep and fluctuate with river discharge.

Based on the TDG performance of The Dalles, the recommended stilling basin depth for this alternative is 20 feet but must be established for a target river flow and associated tailwater elevation. Raising the basin floor to provide an average (normal) depth of 20 feet will allow large spillway discharges to sweep through the basin. This requires construction of a negative-stepped or secondary basin to prevent downstream erosion. The stepped basin design allows the hydraulic jump of lower, more frequently occurring discharges to form on the elevated upstream (primary) apron and that of larger discharges to form partially on the primary apron and the lower secondary apron.

All of the Corps projects currently have most or all spillbays equipped with spillway deflectors with the exception of The Dalles. The design issues of raised stilling basin remain the same with or without spillway deflectors. The optimum stilling basin elevation however may change when these to alternatives are combined. A spillway with flow deflectors and an elevated stilling basin will dissipate less energy than either structure alone. The stepped stilling basin would be designed to provide the best hydraulic and dissolved gas conditions in combination with the existing deflectors.

3.2.3 Model Study Investigations

The negative-stepped stilling basin was modeled in the John Day 1:40-scale sectional spillway model. The study was developed to define the energy dissipation characteristics of the negative-stepped basin. Unit spillway discharges of 5,000, 14,000, 25,800, and 34,000 cfs, and the PMF of 112,500 cfs per bay were evaluated. The hydraulic jump was formed at the toe of the spillway and was completely contained on the primary basin with a unit spill bay discharge of 5,000 cfs. At 14,000 cfs the jump was forced into the secondary basin. The hydraulic jump was fully contained within the secondary basin for all other flows up to the PMF of 112,500 cfs per bay.

There have been no general model studies of this alternative. General model investigations of each project would be necessary to determine the influence of this alternative on adult passage, juvenile egress through the tailrace and navigation.

3.2.4 The TDG Performance

The raised stilling basin reduces the plunge depth of spill discharge and exposes air entrained flow to lower hydrostatic pressures. The gas performance of the raised stilling basin alternative will be dependent on the target design discharge and the stilling basin and downstream channel depths. This alternative will not allow the projects to meet the state and Federal water quality standards, but should pass unit discharges of up to 240 cfs/ft (12,000 cfs per bay) without exceeding 120 percent TDG, and 100 cfs/ft (5,000 cfs per bay) without exceeding 115 percent TDG. These estimates are based on the stilling basin depths necessary to force and contain a hydraulic jump for the given unit discharges, and the general performance of the Ice Harbor and The Dalles spillway.

The gas production estimates do not account for the high concentration of aerated flow that will be drawn into the deeper secondary basin. The increased hydrostatic pressures in the secondary basin may further saturate the flow and reduce the benefits of the raised stilling basin. Model studies can be used to determine the hydraulic conditions and the potential for aerated flow to drawn into the secondary basin but the air bubbles cannot be accurately modeled. Prototype testing of similar structures is the only means of verifying the TDG estimates.

3.2.5 Risks Assessment

A properly designed negative-stepped-stilling basin will adequately dissipate the energy of flow for all spillway discharges up to the standard project design flood. It should not compromise the structural integrity of the project or increase the potential for downstream erosion. Raising the primary stilling basin floor will alter tailrace flow conditions and may impact navigation as well as juvenile and adult fish passage. These concerns must be addressed on a project-by-project basis and will require both sectional spillway and general model investigations. Aspects of TDG production as well as juvenile and adult fish safety and passage issues can only be accurately assessed through evaluation of a prototype structure.

3.2.5.1 Adult Fish Passage

Raising the stilling basin floor will increase channel velocities downstream of the stilling basin may result in a hydraulic flow barrier to adult fish seeking upstream passage. General model studies would be required to evaluate the influence on adult fish passage. The fishway entrance channels may have to be extended downstream of the primary basin with multiple entrances along the length of the extended channel.

3.2.5.2 Juvenile Fish Passage

The raised stilling basin will provide turbulent shallow water conditions that may increase the risk of injury and direct mortality to juvenile fish. Shallow turbulent flow conditions following spill passage could also increase the risk of indirect mortality, primarily by avian predators. Turbulent, high velocity flow may not permit juvenile migrants to recover very quickly from any temporary disability sustained during spill passage thereby increasing the total period of time they are vulnerable to predation. The high velocities in the tailrace would likely limit the presence of predators to the periphery of the tailrace or displacement downstream. The potential for injury and mortality must be thoroughly investigated in a prototype structure.

3.2.5.3 Navigation

The raised stilling basin may impact navigation if installed at projects that have the navigation lock located near the spillway. Higher downstream channel velocities could make it difficult for tow operators to maintain proper alignment and control as they approach and exit the lock entrance. Model studies would be required to evaluate the influence on navigation. Additional structural and operational improvements may be required.

3.2.6 Operations

Raising the stilling basin floor at any of the study projects should not impact or increase project O&M cost. This alternative is a passive system with no electrical or mechanical features. The only operational changes that might occur would be changes in spillway distributions and turbine priorities adjusted to provide optimum tailrace flow patterns for juvenile and adult fish passage. However, if mitigating features such as navigation improvement structures and additional fish passage facilities are required, then additional O&M resources may be necessary.

3.2.7 Project Applications

The raised stilling basin concept can be applied to any of the eight lower Snake and Columbia river projects. However, some may require more excavation for a secondary basin than others. The raised basin may be constructed across the entire spillway or a portion of the spillway depending on the target design flows and desired tailwater flow conditions. The construction sequence and methods as defined in the design report for the John Day and Ice Harbor would be similar for all projects.

The Bonneville spillway has a lower secondary basin with very deep holes in the tailrace channel. As a result, the construction of a raised stilling basin with an appropriate sized secondary basin may require very little excavation. The spillway channel is confined by Bradford and Cascade islands so there should be no impact to navigation. The high velocity flow across and exiting the primary basin may cause passage problems for adults. The fishway channels could be extended beyond the lip of the primary basin with multiple entrances along the length of the channel.

The Dalles' spillway stilling basin is already very shallow with an average depth of approximately 24 feet. It is unlikely any additional benefit would be gained. The tailrace channel is very shallow attributing to a very high rate of de-gassing of supersaturated saturated flow.

The design and layout of John Day, McNary, and the four lower Snake River projects are very similar with the exception of Little Goose. Little Goose does not have a conventional stilling basin. Because of the original channel depth, a roller bucket was constructed rather than the typical stilling basin with a horizontal apron. The invert depth of the Little Goose roller bucket is approximately 75 feet. A raised stilling basin at this project would require a significant volume of fill, but little if any excavation for a secondary basin. The powerhouse and a large peninsula separate the Little Goose navigation lock from the spillway. As a result of this separation, it is unlikely a raised stilling basin would adversely impact navigation.

The impact to navigation and adult passage at each project would have to be evaluated separately through general model investigations, specific to each project. All of these projects would likely require modifications to the adult fishway channels and, with the exception of the Bonneville and Little Goose, either operational of structural improvements for navigation.

3.2.8 Conclusions

The negative-stepped spillway is likely to reduce the saturation of spillway discharges by reducing the plunge depth of spilled water but alone will not allow the project to meet water quality standards. The performance of the negative-stepped spillway is expected to be slightly better than spillway flow deflectors. A number of biological issues must be resolved before any additional effort should be expended on the design and construction of the raised (negative-stepped) stilling basin alternative. However, it is unlikely that biological issues could be adequately evaluated without construction and biological testing of a prototype spillway. Because of the biological issues, limited potential for gas reduction and lack of regional support this alternative is not recommended for further evaluation.

3.3 Additional Spillway Bays

3.3.1 General

All eight of the lower Snake and Columbia river projects have sufficient room to construct additional spillbays (Figure 3-4). Additional spillbays would reduce the generation of TDG by reducing the unit spill discharge requirements and necessary stilling basin depths. The ability of this alternative to meet water quality standards is limited by the number of spillbays that can be constructed, the design discharge per bay, and the stilling basin depth necessary to dissipate the energy of flow. Unlike conventional spillways designed to pass and adequately dissipate the energy of flow for the PMF (also referred to as the spillway design flood), the additional spillbays could be designed for much lower spill levels. This spillway would be designed specifically to reduce the saturation of TDG for normal or voluntary spill flows, while improving the spill passage efficiency and survival of juvenile fish.

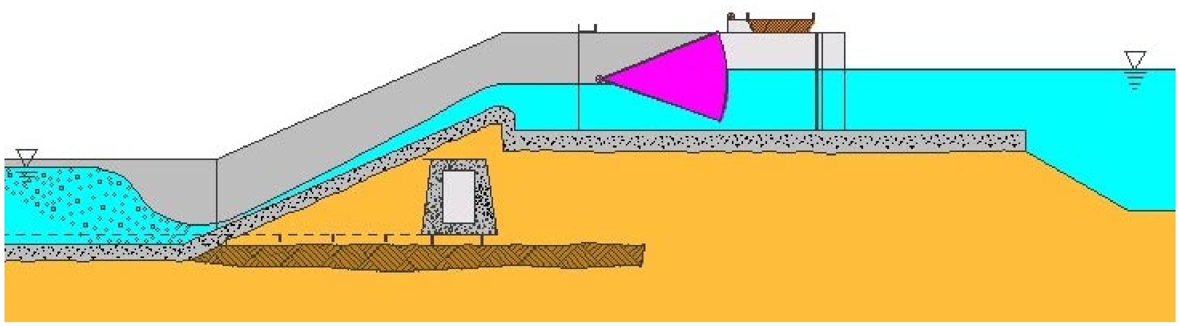

Figure 3-4. Additional Spillway Bays

Additional spillbays can be constructed in place of the earthen non-overflow embankments of many of the lower Snake and Columbia river projects. Numerous possible geometric configurations could be constructed ranging from conventional shapes to the shape identified in Figure 3-5. Because the existing spillways are designed to pass the PMF, the new spillways would be designed to pass a much lower unit discharge typical of normal operations. The energy dissipation requirements would be less, requiring a much shallower stilling basin. Both the shallow stilling basin and the lower unit discharge will result in lower TDG concentrations.

Concept level designs of the additional spillway alternative have been developed for each of the eight lower Snake and Columbia River projects. Plates 1 to 8 show the general layout for each project. The designs for each project are similar with the exception of spillway location relative to the existing structures. Each spillway has been developed for 100,000 cfs and includes nine (9) 50-foot-wide spillbays. A conventional spillway designed for 80 feet to 90 feet of hydraulic head with a discharge capacity of 8,000 cfs +/- per bay (160 cfs/foot) would require a basin depth of approximately 20 feet; less than half the depth typically experience at the eight Corps study projects. This depth may be reduced even more if armoring for downstream channel protection is provided.

The additional spillway design presented is conceptual and intended only to illustrate a cost and TDG benefit for relative comparison of alternatives. The design of a spillway for a specific project would be refined to better fit the project configuration and topographic features. Other design refinements may include changing the spillway location or geometry for improved juvenile fish passage efficiency and fish safety. The new spillway design may include a longer stilling basin on a gradual slope with the absence of baffle blocks and endsills. Other features may include a shallow overflow spillway crest or downward operating drum gates to safely and efficiently attract fish over the spillway. Adequate biological evaluation of design alternatives to optimize passage conditions for juvenile migrants and adult fallbacks and kelts throughout the spill passage route, from the spill gate through egress from the spill tailrace, would likely require construction and biological testing of a prototype structure.

3.3.2 The TDG Performance

The gas performance of the additional spillbays will be dependent on the target design discharge and the stilling basin and downstream channel depths. This alternative will not allow the projects to meet the state and Federal water quality standards, but should to pass unit discharges of up to 240 cfs/ft (12,000 cfs per bay) without exceeding 120 percent TDG, and 100 cfs/ft (5,000 cfs per bay) without exceeding 115 percent TDG. These estimates are based on the stilling basin depths necessary to force and contain a hydraulic jump for the given unit discharges, and the general performance of the Ice Harbor. The Ice Harbor project has the lowest gas producing spillway and tailrace channel on the lower Snake and Columbia river system. It is likely that additional improvements can be made with a spillway system designed specifically for the benefit of reducing TDG concentrations for normal or voluntary spill levels.

3.3.3 Risk Assessment

This alternative will not limit or restrict the capacity of existing spillways. If properly designed, spillway and stilling basin should adequately discharge and dissipate the energy of flow without causing downstream erosion or threat to the stability of the spillway structure. The new spillway bays may impact navigation as well as adult and juvenile fish passage requiring some additional mitigating features such as adult fishway ladders.

3.3.3.1 Adult Fish Passage

Adult fish will be attracted to the spill releases of additional spillway bays. Additional fishway channels will likely be required to prevent delay and provide adequate adult passage.

3.3.3.2 Juvenile Fish

Direct injury and mortality of juveniles passing in spill through new spillbays may not be any different than that of existing spillways. However, because of design differences between existing spillbays and likely designs for additional spillbays, for a given spill discharge, the shallower stilling basin will dissipate approximately the same amount of energy in a much smaller basin volume resulting in higher energy dissipation densities. The increased turbulence may result in higher rates of fish injury and mortality due to increased shear and impact within the basin. In addition to higher rates of direct injury and mortality, exposure of juvenile fish to higher energy dissipation densities may result in higher levels of temporary disability and, depending on the abundance of predators, higher rates of indirect injury and mortality. Investigation, using physical models, of operating patterns to facilitate egress of juvenile migrants out of the spill tailrace would likely be necessary.

3.3.3.3 Navigation

Impacts to navigation will depend on the discharge of the new spillbays relative to the location of the navigation channel and must be evaluated on a project-by-project basis.

3.3.4 Operations

Any new spillway structure would require additional O&M resources. The equipment, manpower, and dollars necessary to maintain and operate the system have not been developed but would likely be similar to those required for the existing spillway system and adult fishway systems. The control of the new spillway would likely be operated from the existing powerhouse control room. A new spillway gantry crane for the installation of bulkheads would be required as well as a larger maintenance crew. The O&M requirements would be identified with associated cost during the design documentation phase should this alternative be considered further.

3.3.5 Model Study Investigations

A model study of the additional spillbay alternative has not been conducted. Both sectional and general model investigations would be required for further development. General models exist or are currently being constructed for each of the eight study projects. All of these models will have the capability for modeling additional spillway bays. In addition, there are numerous sectional models and model flumes that can be modified and used for the development of the additional spillway bay designs. General model investigations would be required to evaluate influence on tailwater flow patterns and resulting effects on juvenile and adult fish passage as well as navigation.

3.3.6 Project Application

The design and construction of additional spillbays at Lower Granite and Little Goose is straightforward. Both of these projects have large earthen non-overflow sections that could easily accommodate a spillway of nine or more 50-foot spillbays. Projects such as Lower Monumental, Ice Harbor, and McNary all have fish facilities located below the earthen non-overflow sections. Unless these facilities are removed/relocated then the shoreline adjacent to the navigation locks would be excavated to accommodate the new spillbays. An additional spillway at McNary could also be constructed in the location that has previously been proposed for the second powerhouse.

The additional spillway alternative at John Day would also require the excavation of the north shoreline adjacent the navigation lock to accommodate the nine new spillbays. In addition, John Day has four skeleton bays available between the powerhouse and spillway dam. A spillway design for the skeleton bays has been developed as part of the Corps' Portland District's Surface Collection and Bypass Study.

A new spillway at The Dalles could be located along the north shore adjacent the navigation lock or on the island between the powerhouse and spillway as shown on Plate 2. A new spillway with nine or more spillbays could be constructed at Bonneville on the Cascade Island between the second powerhouse and existing spillway as shown on Plate 1.

3.3.7 Conclusions

The additional spillway alternative has been developed only as a concept of a conventional type spillway and stilling basin. These spillways could be designed for low unit discharges with gas abatement and safe fish passage as the predominant design criteria rather than capacity for the probable maximum flood. The basin depths and tailwater channels could be relatively shallow. Energy dissipation could be extended over a longer concrete basin, eliminating the need for baffle blocks and end sills. Changes in energy dissipation strategies and similar modifications would require careful assessment of biological impacts. In general, increased turbulence in shallow stilling basins and tailrace sections could produce unacceptable biological impacts, particularly for subyearling juvenile migrants.

Many other options within this alternative exist. If a safe stilling basin environment, both hydraulically and biologically, can be provided, the spillway might be controlled with overflow drum gates that would draw flow from the surface, possibly enhancing the attraction of juvenile fish. Or, larger capacity spillbays could be constructed that would allow modifications to the existing spillbays, potentially enhancing passage and gas abatement without compromising the projects' spillway capacity. These new spillbays would operate only during the high involuntary spillway flows, leaving the modified spillways to operate as a safe juvenile passage route. Recommendations for further development include refinement of designs and cost estimates for specific projects, refinement of gas estimates based on those designs and investigations into other fish passage benefits and refinement of cost estimates for specific projects.

3.4 Raised Tailrace Channel

3.4.1 General

Investigations of the TDG exchange below project spillways have consistently identified the spillway tailrace channel to be a region of active exchange of atmospheric gases. The tailrace channel is an area where the high concentration of air bubbles strip gasses from the water column as they vent to the surface. The Dalles and Ice Harbor near-field studies show shallow tailrace channel conditions have a moderating effect on TDG exchange. The Dalles and the Ice Harbor spillway tailrace channels force aerated flow into shallow depths improving the degas process, as turbulence levels are high, the air to water interface large, and the effective depth of the bubbles small.

By raising the tailrace channel elevation (see Figure 3-5) downstream of a deflected spillway, the generation of shallow, turbulent flow with high concentrations of air entrainment can be enhanced. Flow deflectors benefit this process because they generate high velocity surface flows that typically extend well downstream of the stilling basins. This combined deflector and raised tailrace (RTR) design could significantly supplement deflector performance to further reduce generated TDG levels.

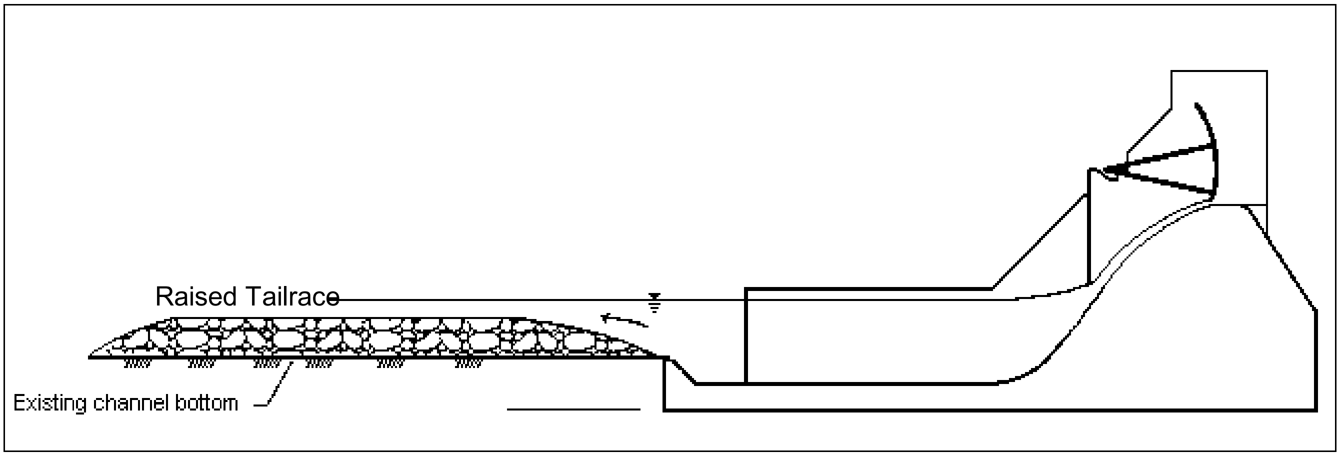

Figure 3-5. Raised Tailrace

3.4.2 Design

The design of a raised tailrace channel must take into consideration TDG reduction benefits, fish passage concerns, navigation objectives, and channel and structural stability concerns. The objective of maximizing the TDG benefits by minimizing the depth of flow immediately downstream of the stilling basin is often at odds with other design considerations.

The target flow range and associated tail water elevation are project specific and must be identified to establish the optimum channel elevation. The tailwater elevation will be a function of the total river flow and forebay elevation of the downstream project. Field tests indicate the tailrace depth should be 15 feet or less for the design flow range. Once the flow range and elevations have been established, the fill material would be sized to withstand the design flood flow or a lesser flow at which point failure of the RTR channel may be acceptable. A heavily armored slope along the upstream face of the elevated tailrace channel will be required, possibly with a concrete cap to maintain stability and provide acceptable conditions for juvenile passage. Biologists suggested a minimum channel depth for summer low-flow conditions of 8 to 10 feet, although a deeper channel may be preferred to prevent or reduce physical injury to juveniles. The resource agencies have indicated that large rock fill may provide predator habitat. NMFS and the USGS recommend a design with roughness elements no greater than 1.0-foot high.

Preliminary designs for the RTR alternative were developed for the John Day and Ice Harbor facilities. Because Ice Harbor has a relatively shallow tailrace channel and the volume of fill (and associated costs) required to generate flow conditions similar to The Dalles appeared reasonable, a more detailed design and model study investigations for an Ice Harbor prototype were proposed as a prototype structure. When the decision to continue with development of a prototype design was made, the Ice Harbor spillway had no deflectors. Deflectors have since been installed, and in 1998 a post construction evaluation of the deflector performance was conducted. The field test showed the Ice Harbor deflectors with the existing shallow tailrace channel are highly effective in reducing generated TDG levels. The benefits of further reducing the channel depth at Ice Harbor appear negligible, and doing so may increase the potential for predation and risk of injury to juveniles.

3.4.3 Physical Hydraulic Model Studies

The RTR alternative was evaluated within the existing Ice Harbor 1:55 scale model following completion of the deflector investigation. As a result, the RTR investigations were largely conducted in parallel with the deflector installations. This study was directed at evaluating and developing a design for a RTR that would be used in conjunction with deflectors, specifically as a prototype design for Ice Harbor. Although the Ice Harbor model was used, the study was approached as a generic development of the RTR concept. The RTR model demonstrated an effective design that would reduce TDG levels. It was concluded that features of the Ice Harbor design characterized by various degrees of tailwater depths might be economically and logistically achievable at other Snake and Columbia river structures.

3.4.4 The TDG Performance

The operation of Ice Harbor in its current configuration represents a prototype test of flow deflectors with a shallow tailrace channel. The operational changes associated with the installation of flow deflectors has resulted in a significant increase in the percentage of the total river flow spilled during the fish passage season. The range in project operations during the fish passage season has resulted in a wide range of project spill discharges and accompanying tailwater elevations.

A review of the TDG data collected below Ice Harbor indicates a strong correlation between TDG production and depth of flow. Project discharges exceeding 10 kcfs per bay have been observed at Ice Harbor without exceeding the tailwater TDG criteria of 120 percent saturation. The spill cap at Ice Harbor is significantly greater than the spill caps at the other Snake River projects with similarly designed flow deflectors but with much deeper tailwater channels. This evidence reflects a proof of concept of the raised tailrace channel alternative and provides information regarding the relative TDG abatement benefits of this alternative. In general, the Ice Harbor spillway can release 8,000 to 10,000 cfs per bay without exceeding 120 percent TDG. Other Lower Snake and Columbia river projects similar in design to the Ice Harbor spillway and stilling basin (with deflectors) easily exceed 120 percent TDG when discharging 6,000 to 8,000 cfs per bay.

3.4.5 Risk Assessment

Raising the tailrace channel below a spillway with flow deflectors may reduce the channel's capacity to dissipate energy. A deep channel will dissipate the residual energy exiting the stilling basin with little or no impact on navigation or adult fish passage.

3.4.5.1 Adult Fish Passage

Raising the channel bottom may compound the affects of the deflector, further limiting the ability of the system to adequately dissipate energy. Increased channel velocities downstream of the stilling basin may result in a hydraulic flow barrier to adult fish seeking upstream passage. General model studies would be required to evaluate the influence on adult fish passage and, if necessary, to develop or refine the raised tailrace design to provide favorable adult attraction flow conditions. Ice Harbor may serve as a prototype for evaluation of a raised tailrace on adult fish passage.

3.4.5.2 Juvenile Fish Passage

Sectional and general model tests of the Ice Harbor spillway indicate the RTR channel tends to increase the re-circulation of flow and generates greater turbulence within the stilling basin near the baffle blocks and end sill. These conditions combined with higher velocities across the shallow channel may result in increased injury to juvenile fish passed through the system. The potential for injury and mortality over a range of discharge and tailwater conditions at Ice Harbor must be thoroughly investigated before constructing a RTR channel at any project. As in the case of adult migrants, Ice Harbor could serve as a prototype for the raised tailrace alternative.

3.4.5.3 Navigation

An RTR channel may impact navigation if installed at projects that have the navigation lock located near the spillway. A raised channel may increase the velocity of cross-channel flows downstream of the navigation lock. This condition could make it difficult for tow operators to maintain proper alignment and control as they approach and exit the lock entrance. Model studies would be required to evaluate the influence on navigation and, if necessary, mitigation may be required to provide favorable navigation conditions.

3.4.6 Operations

Raising the tailrace channel below any of the study projects should not impact or increase project O&M cost. This alternative is a passive system with no electrical or mechanical features. The only operational changes that might occur would be changes in spillway distributions and turbine priorities; adjusted to provide optimum tailrace flow patterns for juvenile and adult fish passage.

3.4.7 Project Applications

An assessment of the Ice Harbor and John Day designs was conducted to determine how this alternative may be applied at other projects. Table 3-3 shows the existing channel bottom elevation, the recommended raised channel elevation, and the expected tailwater elevations associated with the average summer low flow discharge and the peak daily average discharge for each project. The raised tailrace alternative would provide the greatest benefit below projects such as Bonneville, John Day, McNary, and Little Goose. These projects have large deep holes and spill patterns that draw air into them. The Dalles tailrace channel is extremely shallow so there would be little or no benefit by decreasing its channel depth.

Table 3-3. Raised Tailrace Design Parameters

Project	Existing Elevation	Design Elevation	Flow Range	TW Elevation	Design Channel Depth
Lower Granite	571 to 600	624	30–140	633–640	9–16
Little Goose	450 to 485	527	30–140	537–543	10–16
Lower Monumental	383 to 416	428	30–140	437–444	9–16
Ice Harbor	324 to 330	327	30–140	335–340	8–13
McNary	175 to 146	255	110–300	264–270	9–15
John Day	100 to 140	150	120–300	160–166	10–16
The Dalles	68 +/-	NA	120–300	75–84	NA
Bonneville	-60 to -16	5	120–300	14–24	9–19

3.4.8 Conclusions

Biological issues must be resolved before any additional effort should be expended on the design and construction of the RTR. This alternative would likely require use of an alternative design to rock fill, such as concrete or rock with a concrete cap and grout between voids. If relative smooth RTR surfaces are required, economical designs, and construction options should be evaluated.

Other issues that would require further investigation include the optimum depth of fill, or desired elevation, and refinement of the TDG estimates and total costs. General model investigations of each specific project would be require to evaluate the impact to downstream channel stability, navigation and adult and juvenile fish passage. The displacement of habitat to other fish species such as sturgeon that utilize the deep holes below the spillways must also be considered. Ice Harbor, and to some extent, The Dalles can be used as prototypes for evaluation of biological impacts to both juvenile and adult migrants of the raised tailrace options.

3.5 Powerhouse/Spillway Flow Separation Wall

3.5.1 General

Deflected spillways on the lower Snake and Columbia rivers have a strong potential to entrain lateral flow into the stilling basin. This flow is drawn from the sides of the stilling basin below the unbounded spillbays and is pulled beneath the deflected skimming flow. A large percentage of powerhouse flow released adjacent to the spillway's stilling basin supplies this demand. The entrainment of powerhouse flows into the stilling basin is visually evident in general physical hydraulic models of Ice Harbor, Lower Granite, and John Day, as well as in the field at the four lower Snake River facilities, John Day, and McNary during spillway operations. Near-field tests at Little Goose and Ice Harbor indicate as much as 100 percent of the powerhouse flow can be drawn into the stilling basin under certain operating conditions. Results from near-field TDG performance test conducted below John Day, McNary, Ice Harbor, Lower Monumental, and Little Goose show the powerhouse flows entrained within in the spillway are exposed to aeration and pressures that cause this flow to become saturated to TDG levels typical of the spillway flow itself.

A wall constructed between the powerhouse and spillway will prevent powerhouse flows from becoming entrained and aerated within the spillway's stilling basin. The resulting partitioning of project flows will also provide the lower TDG content of powerhouse discharges to dilute the high TDG pressures generated during spillway operations within the developing mixing zone. This alternative does not reduce the level to which the spill flows become saturated with dissolved gasses but reduces the total volume of flow exposed to aeration and elevation of TDG pressure. In this way, it reduces the total mass of TDG produced by spill. This alternative has been described as the powerhouse/spillway separation wall but may also be considered as an extension of the existing powerhouse/spillway training wall.

In addition to the gas reduction benefits of the flow separation wall, the wall will prevent juvenile fish passed through the turbines from being drawn into the spillway, as observed at McNary during the 1999 turbine survival studies. The separation wall will streamline flow released from the powerhouse improving current flow patterns below the fishway outfall pipe locations and will reduce or eliminate large eddies that might otherwise delay juvenile fish egress from both powerhouse and spillway tailrace regions.

3.5.2 Design Parameters

Both the Lower Granite and Ice Harbor general models were used to establish the wall length necessary to prevent the entrainment of powerhouse flow into the spillway stilling basins. Observations of dye released in the models indicate a wall length of approximately 150 feet extending downstream from the existing powerhouse/spillway training walls and will prevent powerhouse flows from becoming entrained within the spillways stilling basin over the entire operating range.

Because the Little Goose facility has the greatest potential for powerhouse flow entrainment, preliminary designs were developed for a powerhouse/spillway flow separation wall for this project. The design relies on field observation and results from the Lower Granite and Ice Harbor model investigations to determine the overall wall length. Two concept level designs were developed. Both designs include two 75-foot-long concrete monolithic structures that are post tensioned. The mass concrete walls are founded on bedrock. The top of the wall would be level with the existing spillway/powerhouse training wall. The first design concept utilizes sheet pile to construct the wall forms and fills the form with mass tremie concrete. This wall would have a full width of 50 feet. The second design concept utilizes pre-cast concrete cells set in place then filled with tremie concrete. This wall varies in width from 50 feet at the base to 14 feet at the surface. A variety of other designs and materials could also be used.

Although these design concepts may be applied generically to other projects, project specific model studies are needed to verify the wall length and to determine the hydraulic design loads. Tailrace conditions must also be evaluated for adult fish passage and channel erosion concerns. The design must assure the wall will not be undermined causing failure by continued erosion of the tailrace channel.

3.5.3 Model Study Investigations

The measurement of lateral entrainment flow into the stilling basin was conducted in the 1:55 scale Ice Harbor general model. The general model reflects the current “as built” conditions with flow deflectors at elevation 338 on spillbays 2 through 9 with end bay deflectors (bays 1 and 10) at elevation 334. Results from this study at Ice Harbor found that the entrainment rate was highly dependent upon the spill discharge and to a much lesser degree tailwater elevation and deflector flow regime. Conservative estimates of entrainment discharge were found to range from 9.7 to 18.3 kcfs or from 15 to 24 percent of the spillway discharge. The degree of entrainment was found to be relatively insensitive to powerhouse operation. If powerhouse discharge is not sufficient to satisfy the stilling basin demand, an eddy just downstream of the powerhouse is formed and all powerhouse flows pass through the highly turbulent and aerated flow below the stilling basin.

An evaluation of the separator wall on the Ice Harbor general model shows that the wall prevents flow from being drawn into the stilling basin and eliminates the formation of eddies below the powerhouse. The wall improves overall tailrace flow patterns by directing all powerhouse flows downstream.

3.5.4 The TDG Performance

The TDG performance of a separation wall is best quantified by changes to the TDG loading generated at a project. The project TDG loading is dependent upon both powerhouse and spillway discharges. The separation wall will provide the greatest degree of improvement at projects where there is a large entrainment of powerhouse flow into the stilling basin and the ambient background TDG pressures are low. By the same token, the degree of improvement at a project will vary in response to project operation and TDG conditions.

The fate of powerhouse flows entrained into the stilling basin was explored during the Little Goose TDG exchange field study conducted in February 1998. The average TDG saturation in the Columbia River at the tailwater FMS below Little Goose was observed to be about 125.8 percent during a 60 kcfs adult spillway release with no powerhouse flow (100-percent spill). The test was repeated by adding a 60 kcfs powerhouse discharge with a TDG saturation of 101 percent along with the 60 kcfs adult spillway (50-percent spill). The 50-percent spill event resulted in an average TDG saturation of 125.4 percent or about the same conditions that were generated during the 100-percent spill event. The observations from this study support the conclusion that powerhouse flows entrained into the stilling basin can experience the same degree of TDG exchange as water passing over the spillway.

The separation wall will prevent powerhouse flows from being exposed to aerated conditions in the stilling basin. In addition, powerhouse releases will retain the TDG levels transported to the project from upstream allowing the dilution of spillway releases in the developing mixing zone downstream of the highly aerated flow conditions. The mixing of powerhouse discharges into aerated spillway flows downstream of the separator wall is anticipated with this design. However, the TDG content of powerhouse releases are not expected to be significantly influenced by this interaction since the volume and vertical distribution of entrained bubbles should not promote high TDG exchange rates. The benefits of this alternative are derived by not gassing up powerhouse releases. If the entrainment of powerhouse flows is small or background TDG levels high, the benefits of partitioning project flows with a separator wall will be small.

This alternative will not improve the TDG performance of an existing spillway (i.e., readings at tailrace FMS will likely remain the same for the same spill level and total river discharge unless the FMS is positioned to read powerhouse water, then, you might expect to see a lower reading due to lower forebay levels). However, preventing entrainment of powerhouse flow will limit the total volume of flow being supersaturated with dissolved gasses and should result in lower observed pressures in the receiving pool following complete mixing. The divider wall will allow the mixing and dilution of powerhouse flows with spillway flows to occur further downstream where there is little or no exposure to heavily aerated flow and high hydrostatic pressures. Uncertainties of this alternative include the following: 1) the influence of laterally entrained flows on deflector performance; 2) the extent of gassing and or mixing and dilution of laterally entrained flows that occur within the basin; 3) the total volume of flow being entrained under various spillway and powerhouse operations; and 4) the lateral gradient, rate, and extent of mixing and dilution that will occur downstream. Intensive model investigations may further define the hydraulic conditions and interactions of spillway and powerhouse flows and, thereby, assist in defining the dissolved gas benefits of this alternative. However, verification of the TDG reduction benefits can be obtained only through prototype testing.

3.5.5 Risk Assessment

This alternative does not restrict the project design flood capacity or threaten project stability. It should not adversely effect navigation. In fact, it may improve navigation by more uniformly directing powerhouse and spillway flows downstream. The divider wall will prevent any juvenile salmonids passing through the powerhouse or bypassed and released into the tailrace from becoming entrained within the turbulent and possibly high gas spill releases. By streamlining the powerhouse flows, eddies below the powerhouse that may delay juvenile fish egress are eliminated and the current flow patterns below the juvenile fish outfall location are likely to be directed downstream. If the divider wall is properly designed and constructed with adequate adult fish passage facilities, there may be no negative impacts to adult salmonids.

3.5.6 Operations

The installation of the flow separation wall should not impact or increase project O&M cost. This alternative is likely to be a passive system with no electrical or mechanical features. The only operational changes that might occur would be changes in spillway distributions and turbine priorities. These changes would be adjusted to provide optimum tailrace flow patterns for juvenile and adult fish passage.

3.5.7 Project Applications

The powerhouse/spillway flow separation wall may be effectively installed at all study projects configured with the spillway adjacent the powerhouse. Bonneville and The Dalles projects are the only study projects that would not benefit from the installation of the flow separation wall "need consistency in names for this alternative." The design and construction costs would be similar for all projects, however, the length and height may vary.

3.5.8 Conclusions

The spillway/powerhouse separation wall alone will not allow the projects to meet the water quality standard. It will not reduce the saturation of spillway flow, but it will reduce the total gas loading of the project by preventing the saturation of powerhouse flows. Other advantages of this alternative include its relatively low cost and improved tailrace flow patterns that may provide more rapid egress of juvenile fish through powerhouse and spill tailrace regions. Special consideration will be required during the design process to limit the possibility to impacts on adult fish passage.

It has been recommended that the divider wall alternative be developed further for the Little Goose project as an element of the Dissolved Gas Abatement Fast-track Program. The Little Goose project has the greatest propensity to entrain powerhouse flow and the greatest potential to reduce the TDG loading. A 1:40 scale sectional spillway/powerhouse model and a 1:55 scale general model will be constructed at WES. These models will be used to develop the design for additional spillway flow deflectors and to evaluate the design and hydraulic flow conditions of a powerhouse/spillway divider wall.

4. Category Two Alternatives

4.1 General

Category two alternatives have the potential to meet the state and Federal water quality standards. They include: 1) submerged conduits; 2) baffled chute spillways; 3) side channel spillways; 4) pool and weir spillways; and 5) submerged spillway gates.

The target design discharge for these alternatives are shown in Section 2.0. None of the alternatives meet all design criteria, but all are expected to pass the target design discharge without exceeding TDG supersaturation levels of 110 percent (assuming forebay concentrations do not exceed 110 percent) without compromise to the structural integrity or operations of the existing system. However, some may not be biologically acceptable passageways for fish.

This section presents preliminary investigation results, discussion, and general layout of the design concepts and their application at each project.

4.2 Submerged Conduits

4.2.1 General

Submerged conduits constructed through the concrete spillway monoliths are expected to pass without increasing the TDG concentrations (Figure 4-1). The conduit intake must be designed to prevent the formation of vortices and the outlet must be deep enough to minimize surface turbulence. In addition, the submerged outlet must be designed to maintain near positive pressures across the control gate and throughout the conduit to prevent cavitation.

There is concern this alternative would be detrimental to juvenile fish passing through the system. However, it may be possible, during operation of the conduits, to simultaneously provide sufficient flow over the spillway crest as attraction flow for the juveniles. Because of this expected operation, and the ability of flow deflectors to minimize the saturation of spill flow, this alternative would most likely be developed with flow deflectors. It is not clear if spill above a submerged conduit would reduce to acceptable levels the risk that a significant portion of fish, either resident or migratory, would not pass through the submerged conduit. Extensive field trials using a prototype structure would be necessary to adequately assess the relative risk to fish health of this alternative.

4.2.2 Design

Preliminary designs and analyses of the submerged conduits were completed for Ice Harbor, John Day, and Bonneville spillways. The conduit cross-sections were initially designed with a gradual expansion to reduce exit velocities to near or below 30 feet per second (ft/s). The conduits are intended to operate fully open or fully closed to minimize internal turbulence and potential for cavitation at the gate lip. Operation with the gates in a partially open position will generate low pressures and result in cavitation unless air is added just below the gate. If air were added, then TDG supersaturation would occur. Operation with partially open gates would also add to fish injury concerns. Additional required features not shown in Figure 4-1 include a secondary gate or bulkhead system used to isolate the upstream gate for maintenance and a downstream bulkhead system used to isolate the conduit for inspections and any required lining repairs.

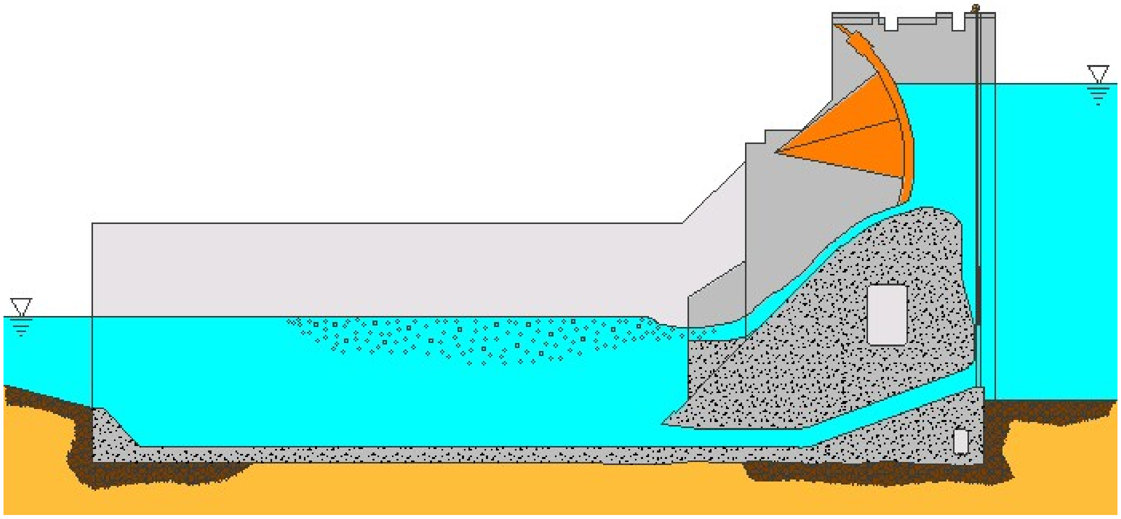

Figure 4-1. Submerged Discharge with Deflected Spill

4.2.3 Physical Hydraulic Model Studies

Physical model experiments were conducted of the Ice Harbor design and of a revised John Day design. These experiments were conducted to determine the discharge characteristics of the conduit, to examine the upstream approach velocities in the vicinity of the intakes, and to investigate the pressure gradient within the conduit. The Bonneville design has not been modeled.

4.2.3.1 Ice Harbor

The Ice Harbor design consisted of a single conduit extending partially through the spillway, gradually expanding into three outlets at the toe of the spillway. Observations were made both with and without deflected spill. When operated without spill discharge, the outlet flows remained fully submerged with virtually no air entrainment. When operated with deflected spill, the submerged jet appeared to support the deflected flow and appeared to improve deflector performance. Very little air was entrained with low levels of deflected spill. However, higher levels of deflected flow are likely to aerate the submerged flow, potentially increasing its TDG saturation levels.

Ice Harbor model photos are shown in Figure 4-2. The top photo shows 5,000 cfs per bay plunging to the stilling basin floor without deflectors or submerged flow. The center photo shows the same discharge spilling over deflectors with significant air entrainment at the surface but little entrained air deep in the stilling basin. The bottom photo shows submerged flow with very little air entrainment at the surface and virtually no air bubbles below the surface. Approximately 3,200 cfs is passed through the submerged conduit and 1,700 cfs per bay over the spillway.

Figure 4-2. Ice Harbor Sectional Spillway Model - Visual Comparison of Non-deflected Spill, Deflected Spill, and Submerged Discharge

The Ice Harbor model did not include a detailed gate design and was at a scale that may have been too small to accurately measure pressure gradients. However, piezometers were installed and extremely negative pressures were measured within the conduit. A negative pressure of minus 20 feet of water indicates a potential for cavitation; negative pressures much greater than this were recorded.

4.2.3.2 John Day

Because of extreme negative pressures measured in the Ice Harbor model, the original designs were revised and modeled in a larger 1:25 scale sectional model of the John Day spillway. This design has two conduits constructed within a single spillbay. The flow enters each conduit through a corbel entrance converging to 26-foot-long rectangular section that expands laterally and contracts vertically to the toe of the spillway to provide an opening 4 feet high and 18 feet wide. The contraction is necessary to maintain positive pressures throughout the conduit. The control gates are located at the downstream end of the rectangular section. The total maximum discharge through two conduits is 10,200 cfs with a head differential of 110 feet and an exit velocity of 71 ft/s. Pressures measured throughout the conduits were sufficient to prevent cavitation.

Spillway stability is a concern of this alternative. A stability analysis of the revised John Day design was not completed but an assessment by Corps' structural engineers concluded that deficiencies could be overcome through the design process and that this alternative would be feasible to construct.

4.2.4 The TDG Performance

The TDG performance of the submerged spillway discharge in combination with deflected flow will be dependent on the ratio and interaction of submerged spill to deflected spill. The submerged outlet design, project operations, and TDG performance estimates are project specific. This alternative could meet the water quality standards if sufficient capacity were provided with very little or no discharge over the spillway. Such an operation developed for reducing gas saturation would also minimize or eliminate spill passage, potentially exposing all of the migrating population to either turbines or submerged conduits, neither of which are preferred dam passage alternatives at this time.

4.2.5 Risk Assessment

The submerged discharge alternative does not affect the spillway flow capacity or the stilling basin capacity to dissipate energy. It is not expected to cause any adverse impacts to navigation or the upstream migration of adult salmon. The energy of flow from the submerged outlets is adequately dissipated within the stilling basin and may release less turbulent energy into the downstream channel than deflected spillway discharges. As a result it should not increase the potential for stilling basin or downstream channel erosion.

4.2.5.1 Cavitation and Maintenance

If properly designed, high-head-submerged sluiceways should not have extreme negative pressures. Extremely tight construction tolerances will be required to minimize local discontinuities that can contribute to extreme negative pressures. Many high-head conduits have severe cavitation problems caused by high, negative pressures. Unchecked, cavitation can lead to catastrophic failure. In addition to a potential for cavitation, there are safety concerns associated with the feasibility of inspecting and maintaining submerged conduits. Inspection and maintenance essentially requires placement of bulkheads and de-watering the structure. The intake depth and potential for unexpected spill requirements make this a costly and possibly a risky undertaking.

4.2.5.2 Juvenile Fish

Regional biologists are concerned for juvenile fish passing through submerged conduits. A study by the Oregon Department of Fish and Wildlife in 1992 at Fall Creek in the Willamette River suggested 70-percent mortality of spring chinook juveniles that passed through submerged sluiceways at high-head discharge, and a 30-percent mortality at low-head discharge. Mortality may occur from injuries associated with high shear zones created by flow separation at the intake gates and outlets, and abrupt changes in pressure gradient. Because it is not possible to isolate the cause of mortality experienced within the Fall Creek conduits, a direct comparison and assessment of the conceptual submerged conduit designs is not possible using existing information. The depth of the intake may limit juvenile fish passage through the conduits, and surface spill above the conduit may further reduce the number of juvenile fish drawn into the submerged flows. However, it is unreasonable to expect, with the large volume of flow through the conduits that juvenile passage would not be a concern. An analysis of the benefits of submerged flow at low TDG concentration versus the risk of direct and indirect mortality to fish passing through conduits would be necessary prior to implementation and would require studies on prototype structures since available information is inadequate.

4.2.6 Operations

As currently designed, a single gate controls flow to each conduit. This allows for a great deal of flexibility in operations. The submerged conduits would most likely operate in conjunction with deflected spill but could also be operated without spill. One potential operational strategy is to spill up to the 120 percent spill cap, then simultaneously open the submerged sluices and increase spill while maintaining 120 percent TDG at the downstream fixed monitor.

The submerged conduits will require frequent inspections and will increase O&M costs.

4.2.7 Project Applications

Submerged conduits similar to those modeled in the John Day 1:25 scale sectional spillway model can be constructed on each of the four lower Snake River facilities and John Day. The total project head at McNary, The Dalles, and Bonneville is lower than John Day so it is likely these projects would require larger or additional conduits to pass similar volumes of discharge. Table 4-1 has been developed using the discharge rating curve developed for the John Day conduit design. This table shows the number of spillbays that would be modified with submerged conduits to approach or achieve the design discharge criteria shown.

Table 4-1. Submerged Conduit Design Discharges

Project	Project Head	Discharge Per Conduit (pair)	No. of Bays Modified	Total Conduit Discharge	Target Design Discharge
L. Granite	100	9,600	8	76,800	98,000
L. Goose	100	9,600	8	76,800	102,000
L. Monumental	100	9,600	8	76,800	102,000
Ice Harbor	100	9,600	10	96,000	112,000
McNary	85	8,850	22	194,700	209,000
John Day	100	9,600	14	134,400	128,000
The Dalles	80	8,700	22	191,400	185,000
Bonneville	55	7,300	18	131,400	139,000

Although the total conduit discharge shown may fall short of meeting the target design discharge for some projects, this design could easily be modified to meet the project specific design discharges.

4.2.8 Conclusions

Submerged conduits can be constructed through the existing spillway bays of each of lower Snake and Columbia river projects. Although these conduits have been sized to pass the required discharge, it is uncertain that they will pass this flow without exceeding the state and Federal water quality standards. Because of observed negative fish impacts for other submerged conduits and the need for extended biological testing of prototype structures prior to accurate assessment of risks to passing fish, there are no recommendations to further develop this alternative unless fish passage issues are resolved through biological testing.

4.3 Baffled Chute Spillway

4.3.1 General

A baffled chute spillway (see Figure 4-3) dissipates flow energy along the spillway slope and prevents aerated flow from plunging deep into the receiving channel. Offset rows of baffle blocks partially obstruct the flow generating turbulence as the water flows down the chute. The velocity and energy of flow entering the downstream channel is relatively low and limits the depth to which air can be entrained. Baffled chute spillways can lower the TDG concentrations of forebay water by aerating the entire water column at shallow depths.

However, the turbulent flow conditions and potential impact with baffles were judged to pose unacceptable risk for high rates of injury to downstream migrating juvenile fish and adult upstream migrants that might fall back through the spillway.

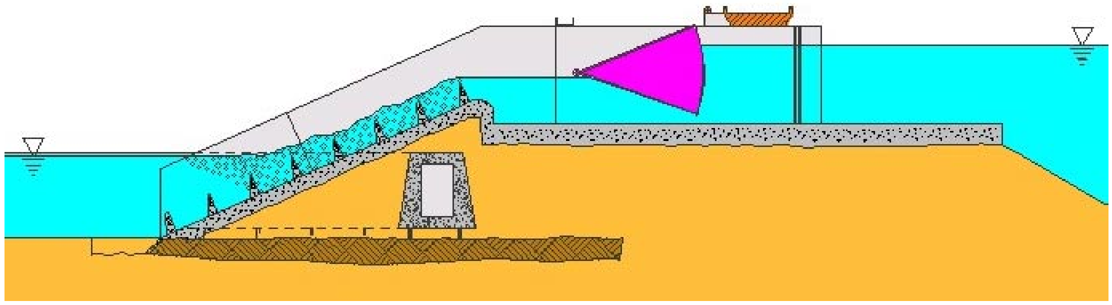

Figure 4-3. Baffled Chute Spillway

4.3.2 Design

A 500-foot wide baffled chute spillway was designed for the earthen non-overflow section of Little Goose. The spillway designed for Little Goose has a maximum unit discharge of 200 cfs/ft and a total design discharge of 100,000 cfs. It has a gated intake structure with a short deep channel leading to the spillway chute. The spillway chute has a 2.3 horizontal to 1 vertical slope and includes 13 rows of baffles with 17 baffles per row. The base of the chute would be founded on bedrock. No stilling basin is required with this type of spillway because the energy of flow is dissipated on the baffles. Though the design is specific to Little Goose, the concept and baseline cost estimates would be similar for the other lower Snake and Columbia river projects with large, earthen non-overflow sections.

4.3.3 Model Study Investigations

A model study of the baffled chute spillway has not been conducted. Should this alternative be developed further, both sectional and general model investigations will be required. The sectional model investigations could be completed within a 1:40 scale model flume. This model would be used to:

- Develop the spillway intake and control structures.
- Define the baffle block geometry, size, and arrangement.
- Define the necessary spillway chute width and slope.
- Evaluate the energy dissipation characteristics and develop any necessary additional channel protection features.
- Evaluate general hydraulic flow conditions and potential for TDG production.

It is likely that a single sectional model study could be conducted for the four lower Snake River projects, McNary, and John Day. Separate investigations would be required for The Dalles and Bonneville because of significant differences in total hydraulic head and general project layout.

General or comprehensive model investigations would be necessary for each individual project. These models would be used to:

- Verify the baffled chute spillway location.
- Evaluate tailrace flow patterns and potential influence on adult and juvenile fish passage and navigation.
- Develop additional structural features such as adult fishway channels and navigation improvement structures.
- Evaluate approach flow conditions and development of juvenile screening and bypass structures if needed.
- Establish project operations for the benefit of juvenile and adult passage as well as navigation.

4.3.4 Project Applications

The Little Goose baffled chute spillway design can easily be applied to any of the lower Snake and Columbia river projects with a large earthen non-overflow section. However, because of fish passage issues, no additional effort has been given to evaluate this alternative beyond the design of Little Goose.

4.3.5 The TDG Performance

The baffled chute spillway generates extremely turbulent and highly aerated flow down the spillway chute and has potential to reduce TDG concentrations below that of the forebay water entering the spillbay. The residual energy of flow entering the receiving pool is reduced and limits the depth of air entrainment. Though the actual performance of a baffled chute spillway can only be determined through prototype testing, it is expected that flows through the structure would be de-gassed to concentrations equal to or below 105-percent TDG, and the saturation of flows entering the receiving pool should not exceed 110-percent TDG.

4.3.6 Risk Assessment

Biologists believe a baffled chute spillway would be harmful to juvenile and adult fish. However, there is little information to either directly support or contradict this opinion. A prototype structure would be required to test assumptions about the biological performance of baffled chute spillways. This alternative will not limit or restrict the capacity of existing spillways. The energy of flow would be adequately dissipated so there would be no threat to the structural integrity of the project or concern for downstream erosion.

4.3.6.1 Adult Fish Passage

The relatively low-velocity flow exiting the baffled chute spillway could attract adult fish towards the spillway and could delay the migration of these fish. The baffled chute would need to incorporate design features that could minimize migratory delay of adult fish. Effective designs could be difficult to accomplish due to the overall width of the spillway chute and the low flow velocities exiting the chute. In addition to the upstream migration delay concerns, adult fish could suffer fatal injuries caused by impact with baffle blocks.

4.3.6.2 Juvenile Fish Passage

Injury may result to juvenile fish passing through the baffled chute spillway from direct impact with the concrete baffle blocks and shear within the extremely turbulent flow. There may also be an unacceptable high indirect mortality of juvenile fish. Juvenile fish may be exposed to high level of predation by birds and fish in the tailrace downstream of the spillway. The relatively low-velocity flow existing the spillway and tailrace channel may not be sufficiently high to act as a velocity barrier for predators such as pike minnows and may not provide adequate egress of temporarily disabled fish from the tailrace resulting in a tailrace environment very risky to juvenile migrants. Unless juvenile fish could be excluded or guided away from the structure or the direct and indirect injury and mortality resulting from the baffled spillway would be offset by TDG reduction benefits, this alternative will not likely be accepted. Information to assess tradeoffs between TDG reduction benefits and direct and indirect biological impacts does not exist and would have to be acquired by biological studies using a prototype structure.

4.3.6.3 Navigation

Impacts to navigation will depend on the relative location of the spillway release to the navigation channel and must be evaluated on a project-by-project basis. A baffled spillway constructed within the earthen non-overflow section adjacent a navigation lock will likely have a greater influence on navigation than one constructed away from the navigation lock.

4.3.7 Operations

Unless juvenile fish are prevented from entering the structure during operation, or unless testing of the biological performance of a prototype structure demonstrated acceptable biological performance, it is not likely the baffle chute spillway would be operated until the existing spill system begins to generate lethal levels of dissolved gas. The spillway will require additional O&M facilities as well as an increased O&M budget.

4.3.8 Conclusions

The baffled chute spillway has not been accepted as a gas abatement alternative by the regional fisheries agencies because of the potential for injury to juveniles and adults that may pass or fall-back through the system. However, the baffled chute spillway would be very effective at preventing saturation of TDGs and would have the potential to provide spill flows without exceeding the spillcaps. It could be considered for the prevention of high gas saturation during extremely high involuntary spill events, if the gas reduction benefits, which would provide a safer river environment for resident and migratory fish, outweigh the risk of injury to juveniles and adults during passage through the spillway. Because of the high risk of injury to juvenile and adult fish that might pass through the spillway, there are no recommendations to further develop this alternative.

4.4 Side Channel Spillway

4.4.1 General

A side channel spillway can be used in conjunction with an existing spillway to limit dissolved gas concentrations below dams and assist in passing large project design flows. The side channel spillway is designed to pass low unit discharges into a shallow stilling basin where energy dissipation occurs over the slope of the spillway and within the shallow basin. A stilling basin depth of 10 feet is expected to limit the saturation of dissolved gasses to 110 percent TDG or less.

4.4.2 Design

Two concept designs for the side channel spillway at Lower Granite have been developed. One features a smooth spillway slope (Figure 4-5), and the other consists of a stepped slope (Figure 4-6). The designs are similar with exception of the spillway slope and overall crest length. The stepped spillway allows a higher unit discharge and reduces the crest length necessary to pass the design flows. As designed, the intake gates would be constructed within the existing earthen non-overflow section of the dam. Both designs were developed for a total hydraulic head of 80 feet and a maximum discharge of approximately 100,000 cfs. The design consists of a gated intake structure leading to a side distribution channel with an uncontrolled spillway crest. The spillway crest would be constructed along the north shore. A stilling basin with an end sill is required to adequately dissipate the energy of flow. The stepped spillway can release higher unit flows with lower energy into the stilling basin and would require half the spillway length of the smooth sloped spillway. Both spillway types have been designed for a maximum required stilling basin depth of 10 feet.

4.4.2.1 Smooth Sloped Spillway

The maximum stilling basin depth criteria of 10 feet restricts the unit discharge over the smooth sloped spillway to 30 cfs/ft. A spillway crest length of approximately 3,300 feet would be required to pass a design flow of 100,000 cfs. The 80-foot drop results in highly aerated water on the spillway chute. The exit velocity and depth at the toe of the spillway are approximately 68 ft/s and 0.4 feet, respectively. A tail water depth of 10 feet will force the hydraulic jump at the toe of the spillway (Figure 4-4).

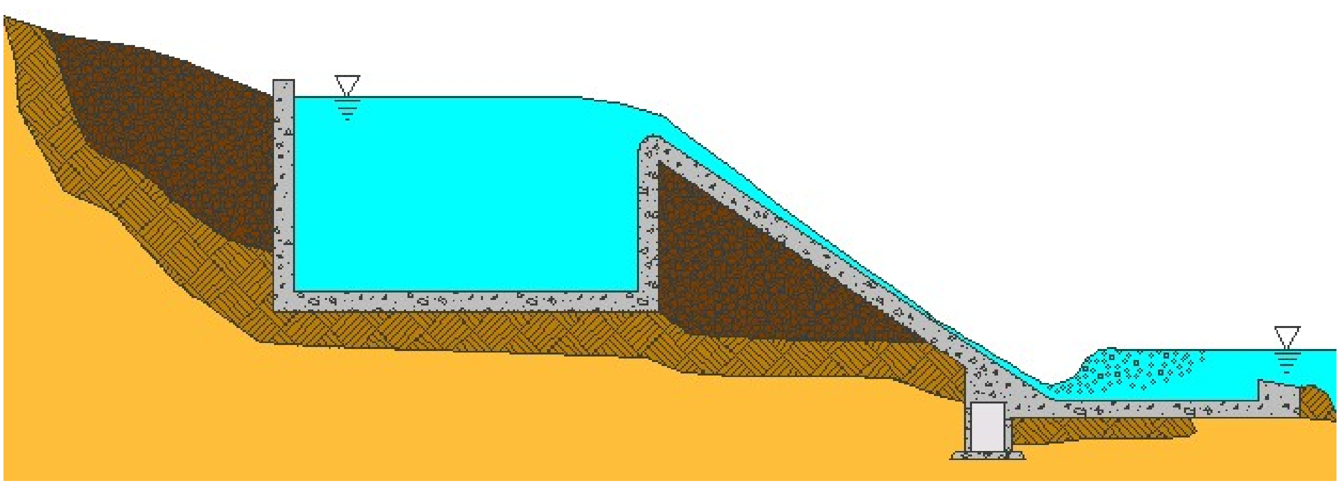

Figure 4-4. Side Channel with a Smooth Slope Spillway

4.4.2.2 Stepped Sloped Spillway

The stepped spillway dissipates much more energy over the spillway steps. Because of the increased rate of energy dissipation, higher unit discharges can be achieved without increasing the depth required to force and contain the hydraulic jump. The stepped spillway with 4-foot high steps on a 2h;1v slope can discharge up to 60 cfs/ft without exceeding the necessary tailwater depth of 10 feet. This spillway would require a crest length of approximately 1,600 feet for a discharge of a 100,000 cfs (Figure 4-5).

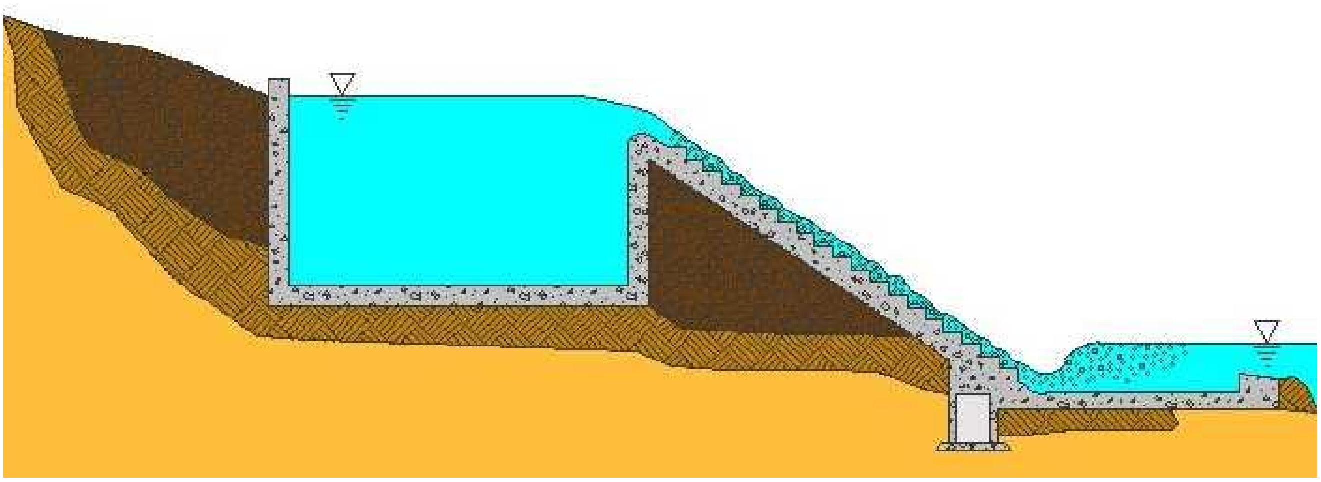

Figure 4-5. Side Channel with a Stepped Slope Spillway

4.4.3 Physical Hydraulic Modeling

The stepped spillway chute was modeled at a 1:8 scale. The model was constructed with horizontal to vertical slopes of 1:1, 2:1, and 3:1, with step heights of 2 and 4 feet. A maximum discharge of 85 cfs/ft with a total hydraulic head of 80 feet was tested. In an effort to improve juvenile fish passage conditions, fillets were later added to the 2:1 and 3:1 sloped spillways to reduce eddies that form within the step pockets. The 2:1 and 3:1 sloped spillways, with and without the fillets, were able to pass a maximum discharge of 60 cfs/ft without exceeding a 10-foot jump depth. The mean velocities measured at the end the spillway chute ranged from 30 to 40 ft/s. For both the fillet and non-fillet, the spill flow reached a normal flow condition well above the tailwater surface indicating the design would produce similar hydraulic flow conditions for higher head projects. General model study investigations and a detailed model of the spillway intake structure would be required for a complete design and evaluation of this alternative.

4.4.4 The TDG Performance

The side channel spillway alternatives are designed with low unit discharges that allow shallow stilling basin depths to adequately dissipate the energy of flow. The shallow depths limit the hydrostatic pressures acting on the aerated flow and reducing the potential for supersaturated TDG. Theoretically, a maximum saturation level of 110 percent can be achieved in 1 meter of depth, increasing 10 percent with each additional meter. If fully saturated, the mean TDG concentration through a 2-meter column of water would be 110 percent. However, flow discharging into a stilling basin becomes extremely turbulent and heavily aerated. The turbulent, aerated flow conditions near the surface, increases the rate of degassing and may allow air to be entrained at depths greater than 2 meters without exceeding a mean saturation level of 110 percent. In addition, the aeration of flow down the spillway chute would provide for degassing of high forebay TDG concentrations.

4.4.5 Risk Assessment

The construction of a side channel spillway may have negative impacts to juvenile and adult fish passage and navigation. The side channel spillways do not limit or restrict the capacity of existing spillways. With a properly designed stilling basin, there should be no threat to the structural integrity of the project or concerns for downstream erosion.

4.4.5.1 Adult Fish Passage

Adult fish seeking upstream passage through the lower Snake and Columbia river projects respond to tailrace hydraulic conditions below each dam. Ideally, river currents guide adult fish to the fishway entrances adjacent the spillways and powerhouses. Cross current flows discharging from a side channel spillway may change the tailrace flow conditions. Relatively low velocity flow exiting the spillways' stilling basin may attract adults toward the spillway possibly resulting in passage delays. The side channel spillways may need to be designed with adult fish passage structures to minimize delay. The shallow flow down the chute of the smooth sloped spillway might pose a greater threat of injury from abrasion to adult fallbacks and kelts that to considerably smaller juveniles.

4.4.5.2 Juvenile Fish Passage

The smooth sloped spillway has a maximum unit discharge of 30 cfs/ft. The maximum velocity and depth of flow down the chute of the spillway is 64 ft/s and 0.4 feet, respectively. The high velocity combined with the shallow depths may cause abrasion and de-scaling of juvenile fish passing over the spillway. The potential for injury would likely increase as the depth of flow decreases with less spill discharge.

The stepped spillway has a maximum unit discharge of 60 cfs/ft. The flow over the spillway develops into a cascading flow with mean velocities down the chute of 30 to 40 ft/s. The mean depth of normal flow (y_n) ranges from 2 to 2.9 feet for the 2:1 and 3:1 slopes. Though the velocity of flow is less than, and the depth of flow greater than that of the smooth spillway, injury may result from turbulence. Parabolic fillets inserted in the pocket of the steps may improve fish passage conditions by eliminating the formation of intense eddies that could otherwise entrain and retain juvenile fish.

4.4.5.3 Navigation

As currently designed, the side channel spillways would release discharge perpendicular to the river channel. The cross channel flows may significantly change tailrace hydraulic conditions and may impede navigation, depending on the spillway layout. The effect on navigation must be evaluated on a project-by-project basis. This evaluation would require additional design efforts and general model study investigations.

4.4.6 Operations

The side channel spillway would most likely be operated when TDG levels generated by the existing spillway discharge begin to exceed acceptable concentrations. The two systems would then be operated in a manner that provides the lowest combined gas levels while maintaining acceptable tailrace conditions for both adult and juvenile fish passage. Because of the potential for very shallow flow down the chute for the smooth sloped spillway and overflow depth for the step crests, it is likely that a threshold on unit discharge would be a feature of operation of these types of spillways. The side channel spillway might allow greater spill levels for juvenile fish passage and may result in reduced powerhouse generation during the spring and summer out-migration period.

The new structure will require additional O&M facilities as well as O&M cost.

4.4.7 Project Applications

The side channel spillway, either smooth sloped or stepped sloped, could be constructed at most Lower Snake and Columbia river projects. Because of the general project layout and space constraints of the Bonneville it would be difficult to construct a side channel spillway of the magnitude required to meet the water quality standards.

4.4.8 Conclusions

Side channel spillways, can be designed to meet the state and Federal water quality standards. However, impacts to juvenile and adult passage are uncertain. Clarification of potential impacts to fish would require construction and biological testing for delay of upstream migration, injury to adult fallbacks and kelts, and injury to downstream migrating juvenile fish. The shallow stilling basins and shallow tailrace could expose juvenile migrants to indirect passage impacts greater than those observed for current spillway designs. Indirect passage impacts would include increased exposure to avian and fish predators, which might be exacerbated by a slow egress from the shallow stilling basin and tailrace regions. The consensus of opinion by fish passage biologists is that these types of structures have the potential for unacceptable high injury and other biological impacts to adult and juvenile fish. Because of these biological concerns, there are no recommendations to develop this alternative further.

4.5 Pool and Weir Channel

4.5.1 General

The pool and weir channel (drop pool spillway) alternative is intended to reduce the generation of dissolved gas while providing safe fish passage. The design concept incrementally dissipates the energy of flow by discharging over low head weirs into large receiving pools. The incremental drop structures limit the energy of flow entering the receiving pools and the potential for aerated water to be drawn to depth.

This alternative was addressed in the Phase I Gas Abatement Report as a means of reducing voluntary spill requirements by providing an alternate fish passage route. The concept did not appear feasible except for relatively low design discharges and, therefore, was not recommended for further evaluation. The alternative was revived at the request of the state and Federal water quality agencies and evaluated for design discharges that would achieve water quality standards. A concept level design of a pool and weir channel was presented to regional fishery agencies who unanimously ruled out this alternative, because of the potential for juvenile and adult fish delays within the series of pool areas. In general, these types of fish passage designs also pose the risk of providing habitat for predators within the pools thereby increasing the risk of direct injury and mortality to juvenile migrants and poor egress of juvenile migrants through tailrace regions which also increases the potential for indirect injury and mortality. This alternative is discussed but will not be developed further.

4.5.2 Design

This concept is conceived as a large fish ladder, designed to meet water quality standards while providing hydraulically safe juvenile and adult fish passage conditions. The additional channel capacity required to meet water quality standards is as much as 100,000 cfs for the lower Snake River projects and as high as 200,000 cfs for the Columbia River projects and must be passed without generating TDG levels greater than 110 percent.

Current accepted design criteria for adult fish ladders limit the head differential between pools to 1 foot or less and the rate of energy dissipation to 10 foot-pounds per second (ft-lbs/s) per cubic foot of pool volume. This requires between 75 and 100 pools, depending on the specific project, or one pool for each foot of head differential between forebay and tail water elevations. With a submerged weir depth between pools of 25 feet, the weir crests would need to be nearly 625 feet wide to pass 100,000 cfs and 1,250 feet wide to pass 200,000 cfs. To meet the fish passage energy dissipation criteria, each receiving pool would require a total volume of nearly 1,600,000 cubic feet for 100,000 cfs flows and 3,200,000 cubic feet for 200,000 cfs flows.

A 40-foot-deep pool would have to be nearly 65 feet long for a total channel length of over 6,500 feet, assuming a project head differential of 100 feet. These pool dimensions are the minimum required to meet the NMFS's head differential and energy dissipation criteria and are given only to indicate the magnitude and size of this alternative. The channel pools may need to be significantly longer and deeper to obtain a normal flow condition and prevent high velocity sheeting flow over the weirs. The overall depth, width, and channel length make this a very unrealistic alternative.

A concept design was developed of the pool and weir channel alternative for the John Day. The design criteria were lessened to allow a 4-foot head differential between pools and 40 ft-lbs/sec of energy per cubic foot of pool volume. This alternative includes a gated intake structure located near the axis of the dam and a large rectangular channel with a total of 20 pools formed by submerged weirs and orifices. The alternating weirs and orifices are designed to produce a 4-foot head loss between pools and prevent skimming flow characteristics that would occur if all pools were controlled by weirs. The pool and weir/orifice channel would operate with a maximum unit discharge of 270 cfs/ft. The channel would be about 285 feet wide and 40 feet deep to pass a total design discharge of 101,000 cfs. Though the design is specific to John Day, the concept may be applicable to other lower Snake and Columbia river projects.

4.5.3 The TDG Performance

The pool and weir/orifice channel incrementally dissipates the energy of flow across each control structure. Air entrainment and the saturation of TDG may be reduced by the limited turbulence associated with the incremental pool drops and the deep submergence of the weirs and orifices. The only method of verifying the TDG performance of such a structure is through prototype testing. However, physical hydraulic model studies would define the hydraulic conditions of flow passing over the weirs and through the orifices and may help to develop more accurate gas performance estimates. For the purpose of alternative evaluation, it is expected that a design could be developed where the TDG levels would not exceed 110 percent. This assumption is based on measured TDG levels within existing adult fish ladders that are typically below 110 percent.

4.5.4 Risk Assessment

The construction of a pool and weir/orifice channel may have negative impacts to juvenile and adult fish passage. This alternative will not limit or restrict the capacity of existing spillways. It is designed to adequately dissipate the energy of flow within the channel pools so there is no threat to the structural integrity of project or concerns for downstream erosion.

4.5.4.1 Adult Fish Passage

A pool and weir channel designed to meet fish ladder criteria and water quality standards, though extremely large, should provide adequate passage for adult fish. A structure designed with 4-foot drops between pools (with alternating weir and orifice control) may delay adult fish attempting to pass through the system. However, the size of the spillway would be considerably greater than that of any existing fish ladder. It is unclear whether adult migrants would behave similarly in this large spillway as they have been observed to behave in existing fish ladders. Additional adult fish facilities may be required.

4.5.4.2 Juvenile Fish

Turbulence through the large pool and weir/orifice channel is minimized by the relatively small incremental drops between pools and should not injure juvenile fish. Vertical circulation cells may, however, develop within the large pools as a result of the alternating weir and orifice flow and could delay juvenile fish passage. The pools might provide habitat for both avian and fish predators. The relatively low-velocity discharge from the spillway would not permit rapid egress of juvenile fish through the spillway tailrace where shallow and relatively slow velocity water could expose juvenile to increased levels of predation.

4.5.4.3 Navigation

Impacts to navigation will depend on the relative location of the channel discharge to the navigation channel and must be evaluated on a project-by-project basis. Large volumes of flow entering directly into the navigation channel from a side channel discharge may restrict navigation traffic. This could likely be mitigated by additional structural measures or through design. However, this would affect costs and construction schedules.

4.5.5 Project Applications

Although a concept design has only been developed for the John Day project, the design concept could be applied similarly to the four lower Snake River projects and McNary.

4.5.6 Conclusions

The NMFS has rejected this option because of the overall magnitude of this structure and the potential for delay and predation of juvenile fish within the pools. Further development of the structure is not recommended.

4.6 Submerged Spillway Gates

4.6.1 General

This option modifies the existing spillway with extended spillway piers and very large radial gates such that the gate sill is well below the tail water surface elevation (Figure 4-6). The discharge from under the gate would remain submerged, reducing the potential for air entrainment. A concept level design of the large tainter gate alternative has been developed for Bonneville.

4.6.2 Design

The Bonneville submerged spillway gates are designed such that a discharge of 10,000 cfs per bay will remain fully submerged with a tailwater elevation of 10.0 feet National Geodetic Vertical Datum (NGVD). They would be 78 feet high by 50 feet wide and have a 100-foot radius. The gate sill is near the toe of the spillway at elevation 0.0 fmsl. The 10-foot wide spillway piers would be extended approximately 140 feet downstream to support the large gates.

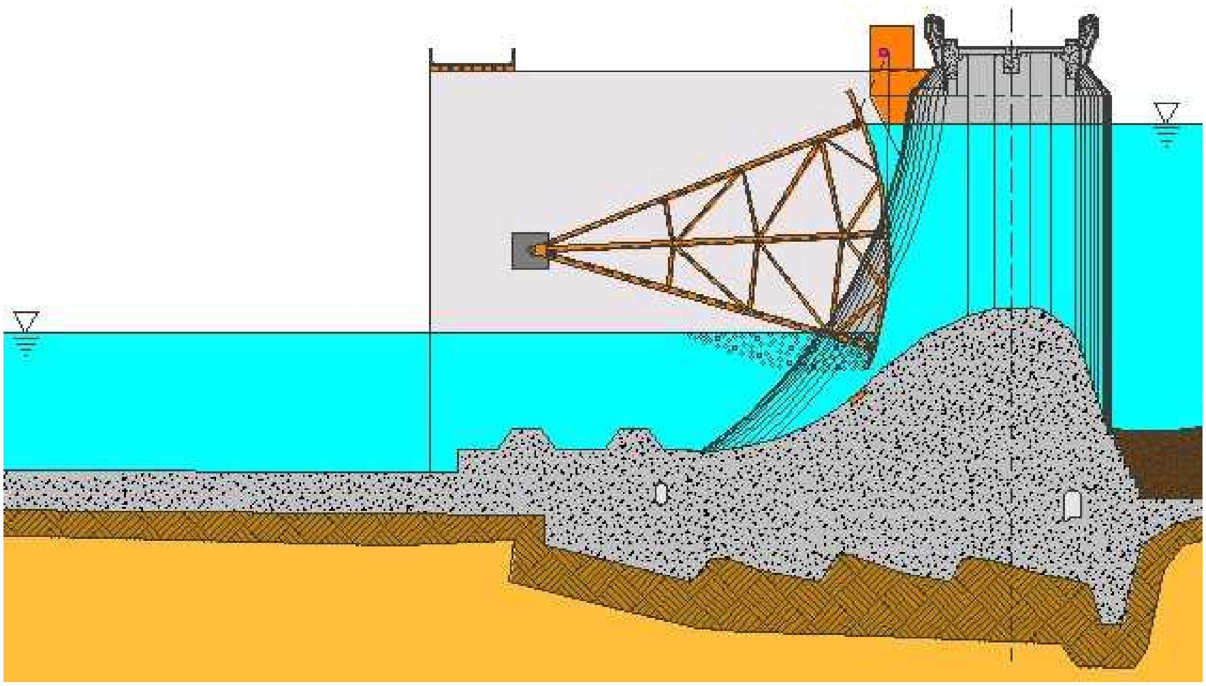

Figure 4-6. Bonneville Spillway with Submerged Spillway Gates

4.6.3 Model Study Investigations

The submerged spillway gate was modeled at a 1:40 scale at WES. Hydraulic conditions were evaluated with the gate sills at revised elevations of 0.0 and –8.0 feet NGVD. The submerged discharge from the large gate showed relatively good energy dissipation with or without baffle blocks positioned in the stilling basin. Once the discharge was submerged, the entrained air content was nearly eliminated with some entrainment from surface turbulence. However, the model study indicates that for the normal range in tailwater fluctuations, spill releases up to approximately 10,000 cfs per bay will be exposed because of insufficient tailwater depth. The model study report summarizes the gate submergence, or tailwater elevation, necessary to maintain a submerged discharge jet over a range of unit spillbay discharges.

4.6.4 The TDG Performance

The submerged spillway gates are not expected to increase the TDG concentrations above that of the forebay if the discharge remains fully submerged. However, based on model study results, submerged flow conditions cannot be obtained for spill discharges over 10,000 cfs per bay and, for many cases, the normal tailwater elevation may not be high enough to maintain submergence for even the low flows. An estimate of TDG performance for the unsubmerged flow conditions is not possible without prototype testing. Although this alternative was intended to meet water quality standards, it is unlikely that the higher flows would remain submerged increasing the potential for gas saturation.

4.6.5 Evaluation of Impacts

The submerged spillway gates should not restrict the capacity for energy dissipation within the stilling basin. Physical injury to juvenile fish passing through the spillway may increase, as the discharge has a more direct impact on the stilling basin baffle blocks. Potential impacts to fish passage efficiency and adult passage delay time is unknown.

4.6.6 Operations

Management of the spillway discharge would be more complicated than it is with the existing system. The gate discharge flow conditions, tailwater flow patterns, and TDG concentrations would be much more sensitive to tailwater fluctuations. The gates would be controlled and operated from the control room just as are the existing gates. A more intensive inspection and maintenance schedule would be required because of the complicated gate design, mechanical operating system, and overall size of the spillway gates and control structure.

4.6.7 Project Application

The submerged gate option is not likely a feasible alternative for the other projects because of the higher head differences. The total maximum head at Bonneville is about 68 feet while the maximum head differential of the other Lower Snake and Columbia river projects is closer to 100 feet. The design and construction costs associated with a spillway gate of this size combined with the with the inability of the structure to maintain submerged flows and uncertainties in the gas production estimates make this option unreasonable to consider for other project applications.

4.6.8 Conclusions

The submerged spillway gates will not likely meet water quality standards under all flow conditions because of extreme fluctuations in the Bonneville tailwater elevation. The submerged spillway gates do have the potential to reduce saturation by maintaining submerged flow conditions for certain high tailwater elevations. The biological impact of submerged gates, particularly for juvenile migrants, is not clear and could only be resolved with some certainty through biological testing of a prototype structure. The increased depth of discharge would cause flow to more directly approach stilling basin baffle blocks and could result in higher water velocities at the blocks, particularly under low tailwater conditions. This alternative, while providing some potential for TDG reduction under some operating conditions, will not reduce the energy dissipation rates in the stilling basin and may alter the distribution of energy dissipation, resulting in a tailrace environment quite different from that of the existing spillways at Bonneville. Exposure to locally higher energy dissipation densities could increase the rates of disorientation and temporary disability of juvenile migrants and result in increased rates of indirect injury and mortality during tailrace egress.

Additional gate designs and control structures should be considered if this option is developed further. A two-part vertical lift gate similar to the existing gate may be feasible although the total hydraulic head on the gate would be much greater. The lower gate may possibly be designed to operate independently of the upper gate and would be used for normal operations while the upper gate in combination with the lower gate would be used to regulate the extreme spillway flows. Total reconstruction of the existing spillway crest may also be feasible. This would allow the gate and spillway crest and control structure to be developed as a single operating system rather than limiting the gate design to a retrofit of the existing system. A tailwater control structure should also be considered to regulate (control) the extreme fluctuations in tailwater elevation.

5. System-wide Evaluations

5.1 General

The category one and two options described in Sections 3 and 4 can be grouped as short-term and long-term alternatives. Short-term options are those which are being considered in the deflector optimization program and are relatively easy to implement and inexpensive when compared to other options. Long-term options are those which are considered to be very expensive and will require long duration construction periods.

The short-term options include:

- Operational changes
- Additional/modified deflectors
- Powerhouse/spillway flow separation wall
- Raised tailrace channel.

The long-term options include:

- Submerged conduits
- Baffled chute spillway
- Side channel spillway
- Pool and Weir Channel
- Submerge spillway gates
- Raised/negative-stepped spillway
- Additional spillbays.

In general, each of these options can be applied at each of the eight Corps projects within the study area. An alternative applied at an individual project, combined with a projected operation, may have an impact or benefit on the river system as a whole. A system option is defined as a grouping of individual options applied at specific projects with specific operational rules. To assess the potentially large combination of system alternatives, a numerical mass transport water quality model was developed. The model was used to compare selected system alternatives to the existing system. To limit the total number of individual project alternatives and associated system alternatives, a pre-screening process was used. This section describes the screening process and presents the individual project alternatives and their combinations which were used in defining the system-wide alternatives which were evaluated in the numerical model.

5.2 Screening Process

The process relied on analysis and evaluation of structural and operational options completed during the Phase I and Phase II Dissolved Gas Abatement Studies as well as regional agency review, comment, and recommendations. The first step in the process was to rate and select the options based on established criteria. The next step was to determine which options would be applied to each project and the order in which they would be implemented.

5.3 Criteria

Criteria used for rating included: 1) ability to reduce the saturation of TDG; 2) ability to safely pass fish; 3) magnitude or ease of design and construction; and 4) overall impact to operations and maintenance.

5.3.1 TDG Performance

An alternative's TDG performance was given a rating of low (-) moderate (√) or high (+). Low reflects an uncertainty in performance but a potential for improvement without the ability to meet water quality standards. Moderated reflects confidence in TDG reductions without the ability to achieve water quality standards or uncertainty in the ability of the alternative to meet water quality standards. High reflects a high degree of certainty that the alternative can achieve water quality standards.

5.3.2 Fish Passage

The alternative's impact on adult and juvenile passage was given a rating of acceptable (+), uncertain/unacceptable without biological testing (√) or detrimental (-). Acceptable reflects a condition known to be safe or a condition expected to be no worse than existing spillway flow conditions. Uncertain/unacceptable without testing reflects a condition that may or may not be safe for fish passage and would require testing and proof of safe passage before implementation. Detrimental reflects a condition known or believed to be harmful to fish based on the judgment of fish passage experts.

5.3.3 Design and Construction

The design and construction of an alternative was given a rating of straightforward/accomplished (+), complex (√) or difficult (-).

5.3.4 Operations and Maintenance

An alternatives impact on operations and maintenance will be given a rating of low (+), moderate (√), or high (-).

5.4 Option Ratings

Table 5-1 illustrates the results of the individual option ratings based on the established criteria. Any option that received (-) for TDG production or fish passage was eliminated from further consideration. Each of the alternatives rated for short-term implementation was selected for numerical model evaluations. The additional spillbays and the submerged spillway gate options were the only long-term options remaining following the screening process.

Table 5-1. Option Rating

	TDG	Fish Passage	Design and Construction	Operation and Maintenance
Short-term Options				
Operational changes	√	√	+	+
Additional deflectors	√	+	+	+
pH/spillway wall	√	+	+	+
Raised tailrace	√	√	√	+
Long-term Options				
Submerged conduits	√	-	-	-
Baffled chute spillway	+	-	√	√
Side channel spillway	+	-	√	√
Pool and weir channel	-	-	√	-
Submerged spillway gates*	√	+	−	+
Raised stilling basin	-	√	√	√
Additional spillbays	√	+	√	√

*applied only at Bonneville

5.5 System Options

The options remaining from the screening process were then combined into system options for evaluation using the numerical model. These are summarized in Tables 5-2 and 953 and described in detail in the following paragraphs.

5.5.1 Short–term Options

1. The short-term system option 1 consist of baseline conditions. This includes the existing spillway configurations with the existing spill patterns.
2. Short-term option 2 is strictly an operational alternative. It includes the existing spillway configuration with changes in spill distribution. All spillway flows are released uniformly across existing deflected bays only. The exception of The Dalles, which currently does not have flow deflectors.
3. System option 3 is the most likely alternative for immediate short-term improvements. It includes the installation of additional spillway flow deflectors at Lower Monumental, Little Goose, McNary, John Day, and Bonneville. Because Lower Granite and Ice Harbor already

have a full implementation of spillway flow deflectors with specified spillway flow patterns for the full arrangement of deflectors, these projects will operate with those spill patterns. Because it is not possible to predict the spill patterns without model testing, the operation of those projects with added deflectors assumes a uniform spill pattern.

4. System option 4 expands on option 3 with the addition of the powerhouse/spillway divider wall at Lower Granite, Little Goose, Lower Monumental, and McNary. Option 4 also includes the addition of 23 spillway flow deflectors at The Dalles. Because the spillway flow patterns cannot be predicted for spillways modified with additional deflectors and/or the divider wall, a uniform spill distribution has been assumed for those projects.
5. Short-term system option 5 is similar to option 4 with the addition of the raised tailrace channel below the Bonneville spillway.

5.5.2 Long-term Options

1. The long-term system option 6 includes all the improvements of option 5 but adds six new spillbays to John Day.
2. Option 7 builds on option 6 with new spillways consisting of nine additional spillbays at Lower Granite, Little Goose, and McNary.
3. Option 8 is similar to 7 with the reconstruction of large submerged spillway gates at Bonneville.

Table 5-2. Short-term System Options

Project	No. 1	No. 2	No. 3	No. 4	No. 5
Lower Granite	Standard spill (8/8)*	Un-spill (8/8)	Existing Condition	Un-spill (8/8) pH/spill wall	Un-spill (8/8) pH/spill wall w/RTR
Little Goose	Uniform spill (6/8)	Un-spill (6/8)	Un-spill (8/8)	Un-spill (8/8) pH/spill wall	Un-spill (8/8) phH spill wall w/RTR
Lower Monumental	Uniform spill (6/8)	Un-spill (6/8)	Un-spill (8/8)	Un-spill (8/8) pH/spill wall	Un-spill (8/8) pH/spill wall w/RTR
Ice Harbor	Standard spill (10/10)	Un-spill (10/10)	Existing Condition	Existing Condition	Existing Condition
McNary	Standard spill (18/21**)	Un-spill (18/22)	Un-spill (22/22)	Un-spill (22/22) pH/spill wall	Un-spill (22/22) pH/spill wall
John Day	Standard spill (18/20)	Un-spill (18/20)	Stan-spill (20/20)	Un-spill (20/20)	Un-spill (20/20)
The Dalles	Standard spill (0/23)	Un-spill (0/23)	Existing condition	Un-spill (23/23)	Un-spill (23/23)
Bonneville	Standard spill (13/18)	Un-spill (13/18)	Un-spill (18/18)	Un-spill (18/18)	Un-spill (18/18) w/RTR

* Indicates the number of deflected spillbays/number of total spillbays.

** McNary currently operates with only 21 of the 22 total spillbays.

Table 5-3. Long-term System Options

Project	**No. 6**	**No. 7**	**No. 8**
Lower Granite	Un-spill (8/8) pH/spill wall	Un-spill (8/8) pH/spill wall 9 new spillbays	Un-spill (8/8) pH/spill wall 9 new spillbays
Little Goose	Un-spill (8/8) pH/spill wall	Un-spill (8/8) pH/spill wall 9 new spillbays	Un-spill (8/8) pH/spill wall 9 new spillbays
Lower Monumental	Un-spill (8/8) pH/Spill wall	Un-spill (8/8) pH/spill wall	Un-spill (8/8) pH/spill wall 9 new spill bays
Ice Harbor	Un-spill (10/10)	Un-spill (10/10)	Un-spill (10/10) pH/spill wall
McNary	Un-spill (22/22)	Un-spill (8/8) 9 new spillbays	Un-spill (8/8) 9 new spillbays
John Day	Un-spill (20/20) 6 new spillbays	Un-spill (20/20) 6 new spillbays	Un-spill (20/20) 6 new spillbays
The Dalles	Un-spill (23/23)	Un-spill (23/23)	Un-spill (23/23)
Bonneville	Un-spill (18/18) RTR	Un-spill (18/18) RTR	Un-spill (18/18) 18 submerged gates

6. Summary and Conclusions

6.1 Summary of Biological and Engineering Evaluation of Gas Abatement Alternatives

Ten structural dissolved gas abatement alternatives were evaluated for TDG abatement improvements on the lower Snake and Columbia river projects during the Phase II Dissolved Gas Abatement Study. The options include:

- Additional/modified spillway flow deflectors
- Raised negative-stepped stilling basin
- Raised tailrace channel and deflectors
- Baffled chute spillway
- Side channel spillway
- Pool and weir channel
- Additional spillbays
- Submerged conduit with deflectors
- Powerhouse/spillway separation wall
- Submerged spillway gates

An engineering evaluation of each option was conducted to determine the feasibility of design and construction, and to establish baseline cost estimates. Biological evaluations were conducted to assess the direct and indirect impacts of each option's implementation and operation on juvenile and adult salmonid passage and survival.

All options were determined feasible to design and construct. The baffled chute spillway, side channel spillway, and submerged conduits alternatives have the greatest potential to achieve state and Federal water quality standards. However, the only options expected to achieve safe or acceptable fish passage conditions while providing for significant gas reduction benefits include the additional/modified deflectors, powerhouse/spillway separation wall, submerged spillway gates, and additional spillbays. Because of the high risk to juvenile and adult salmonids, none of the other options have been recommended for further consideration or development.

6.2 Summary of System-wide Analysis

Application of the MASS1 and MASS2 numerical models for hydrodynamics and dissolved gas transport produced a broad range of metrics that were used to compare the performance of different gas abatement alternatives. The alternatives analyzed were primarily structural modifications to the dams, but operational changes such as the use of uniform spill patterns were also included. Eight system options were evaluated utilizing these numerical models coupled with predictive gas production equations. The system options were grouped as either short-term options or long-term options. The short-term options are those which are considered to be less controversial, less expensive, and can be implemented more quickly than long-term options. A summary of model derived observations are discussed in the following paragraphs.

6.2.1 Summary Short–term Option Analysis

For the short-term options (system options 1 through 5), the added deflectors appear to yield the most improvements in TDG water quality parameters on the lower Columbia River projects whereas the addition of flow training walls are forecasted to be the most beneficial for the lower Snake River projects. This indicates the current deflector optimization program for installing deflectors will probably result in the quickest and most TDG reductions throughout the river system. This would correspond to system options 3 and 4.

System options 3 includes: 1) added deflectors at Little Goose, Lower Monumental, McNary, John Day, and Bonneville, and; 2) changing spill patterns from existing patterns to a more uniform patterns at Little Goose, Lower Monumental, McNary, and Bonneville. System option 4 includes those features and operations proposed by system option 3 plus: 1) a uniform spill pattern at Lower Granite, John Day, and The Dalles; 2) new spillway deflectors at The Dalles, and; 3) powerhouse/spillway divider walls at Lower Granite, Lower Monumental, Little Goose, and McNary.

Improvements from the addition of deflectors at The Dalles also provides some associated benefits below Bonneville in the estuary. In regards to the evaluation criteria, the observed system wide benefits in TDG conditions for the model output are listed below.

Utilizing the TDG loading evaluation criteria, approximately 60 percent of the decreases in TDG load was realized by system option 4. For the aquatic habitat improvement criteria, approximately 60 percent of the increases in aquatic habitat (for either depth compensated of uncompensated) by volume in the receiving waters occur with completion of system option 4. Approximately a 2/3 reduction in the exceedances of 110 percent would be realized in conjunction with system option 3 and 4.

6.2.2 Summary Long-term Option Analysis

Long-term system options 6, 7, and 8 were also modeled with the MASS1 and MASS2 numerical models. System option 8 was the most successful at achieving water quality standards and in minimizing downstream TDG loading. For the hydrologic conditions simulated, over 90 percent of the water quality standard exceedances of 110 percent were eliminated with option 8. This option consists of: 1) the presence of deflectors on all spillbays for each of the eight Snake/Columbia river Corps projects; 2) uniform spill patterns implemented at each of the eight projects; 3) powerhouse/spillway divider walls installed at Lower Granite, Little Goose, and Lower Monumental; 4) new spillway structures (9 bays) installed at Lower Granite, Little Goose, and McNary; 5) new spillway structure (6 bays) installed at John Day, and; 7) submerged spillway gates at Bonneville Dam.

6.2.3 Project Specific Observations

From the system wide perspective, certain trends or response patterns have emerged which can be used to characterize major reaches but in general there is a high degree of variation in forecasted responses between the lower Snake River and the lower Columbia River projects. This trend is at least partly due to the high spill ratios for Ice Harbor and confluence with the Middle Columbia and lower Snake rivers in the McNary pool. The lower Columbia flows normally double that found in the Snake River.

The numerical simulations project with the addition of deflectors at Bonneville and at The Dalles will result in significant improvements in TDG. The addition of submerged spillway releases at Bonneville (option 8) show the greatest potential for improvement in downstream TDG conditions at that project.

Simulations of the operation of an additional 6-bay spillway at John Day (option 6) and a 9-bay spillway at McNary (option 7) produced significant improvements in water quality below these two dams. At McNary, the greatest improvements in TDG were associated with the combination of uniform spill patterns, additional spillway deflectors, a powerhouse/spillway training wall, plus the addition of a 9-bay spillway.

Very little change at Ice Harbor is observed from the simulations for any but the last alternative or system option 8. The dominant feature at Ice Harbor is that the model simulations were completed with fairly effective flow deflectors in place at the project. This, coupled with a high ratio of spill to powerhouse discharge, tended to reset or re-establish TDG conditions for the Snake River to reflect Ice Harbor conditions and operations. This effectively overrode any major TDG impacts from the upstream projects on the Snake River and may be responsible for the noticeable difference in forecasted responses between the two rivers. The addition of a powerhouse/spillway divider wall resulted in limited improvements in TDG at Ice Harbor.

Alternatives applied on the lower Snake River projects appear to give similar responses in TDG forecasted measures. The three upper river projects, Lower Monumental, Little Goose, and Lower Granite, all respond similarly and favorably to the addition of a powerhouse/spillway divider wall. As would be expected, additional spillways with 9 spillbays each at these same three projects result in significant improvements in downstream water quality. Modest water quality benefits are also forecasted from the deflector additions at Lower Monumental and Little Goose.

It should be noted that the conclusions above only consider the potential water quality benefits associated with the various gas abatement alternatives. Final decisions or recommendations should also incorporate potential impacts on migration of anadromous fishes (both juvenile and adults), other resident biological communities, power production, navigation, and any of the other intended uses of projects on the lower Columbia and lower Snake rivers.

6.3 Conclusions

Maximizing powerhouse flow is the simplest method of reducing the saturation of TDG. Powerhouse flows are determined by load demand but are often restricted by voluntary spill requirements and by operational limitations restricting turbine generation to within one percent of the peak efficiency. Allowing turbine units to operate outside this range will increase the hydraulic capacity of the powerhouses by more than 30 percent.

Operational measures in the form of spill pattern shaping have been used and should continue to be used to effectively reduce the TDG exchange associated with spillway operations. However, spill flow distribution patterns have been established to provide optimum conditions for efficient egress of downstream migrating juvenile salmonid and for the attraction of upstream migrating adult salmonids to the fishway entrances. Operational improvements for the reduction of TDG saturation will not be accepted at the risk of juvenile and adult passage and survival.

The current ongoing deflector optimization program is a major step in the right direction for reducing TDG production. This program will evaluate and provide for installation of deflectors on spillbays that currently do not have deflectors. This program also provides for evaluating changes in operational spill patterns with the goal of attempting to provide as uniform of spill level as possible for reduction of TDG production. Development of operational spill patterns, however, must also consider the biological factors of adult fish passage and juvenile fish tailrace egress. Therefore, while the goal would be to achieve a flat or uniform spill pattern for TDG reductions, it may not be possible to fully implement this operational change. The ability to achieve this will vary on a project-by-project basis.

Once the deflector optimization program has been completed, it is recommended that post construction evaluations both biological and physical be conducted to re-establish baseline system performance. This is a critical checkpoint which can provide a measure of performance improvement and can then be used to improve the forecasted performance improvements of additional more costly changes.

If additional TDG reductions are considered necessary following the post construction assessments, then adding powerhouse/spillway divider walls at appropriate projects would be the next logical step to further TDG reductions.

Finally, new spillway structures installed at appropriate dams will ultimately reduce production of TDG to a level much closer to current water quality standards. All of these proposed features are compatible and build one upon another. Every feature present in this proposed sequence must be constructed and operated in the fashion proposed to achieve the model projected outcomes.

6.4 Implementation

6.4.1 System Costs – Lower Snake River Projects

The following system costs have been estimated for three optional levels of TDG improvement. These costs include overhead; profit; construction bond; planning; engineering and design; construction supervision; and administration and contingencies.

Project	**Option – 1 Additional Deflector Only (millions)**		**Option 2 – pH/spillway Splitter Wall and Additional Deflectors (millions)**		**Option 3 – Deflectors and pH/spillway Splitter Wall and 9 Spillbays (millions)**	
	Low	High	Low	High	Low	High
Lower Granite	$0	$0	$19	$31	$295	$472
Little Goose	$8	$8	$27	$39	$307	$487
Lower Monumental	$10	$10	$29	$41	$442	$701
Ice Harbor	$0	$0	$19	$31	$331	$530
Total System Costs	**$18**	**$18**	**$94**	**$142**	**$1,375**	**$2,190**

6.4.2 Water Quality Benefits

Benefits of the optional structural changes are illustrated on a project basis in Figures 6-1 through 6-4. Implementation of option 3 will approach but not meet the state and Federal water quality standards of 110 percent at the 7 day, 10 year discharge. Option 3 is the only system alternative likely to meet approval by regional fishery agencies with regard to acceptable fish passage criteria.

6.4.3 Implementation Schedules

Option 1. Additional Deflectors.

Installation of additional deflectors is currently scheduled for Lower Monumental and Little Goose in fiscal years 2003 and 2004, respectively, as a part of the current deflector optimization program.

Option 2. Installation of the powerhouse/spillway splitter wall and deflectors.

Deflectors will be installed by 2004 on all Snake River dams. Installation of the powerhouse/spillway splitter wall will require the following process with the anticipated durations. The first powerhouse/spillway splitter wall would be installed on a single project such as Lower Granite. Following construction, an evaluation (physical and biological) of the performance of the wall would be conducted to assess the success of the splitter wall. Once the wall is proven, then construction of the splitter wall will occur at the other three lower Snake projects, Little Goose, Lower Monumental, and Ice Harbor. The durations are identified in the following table:

Project/Activity	**Years**
TMDL Development	2
Decision Document + NEPA	2
Lower Granite	
Design Documentation Report	1
Appropriations	1
Contract Documents	1
Construction	2
Post Construction Evaluation	1
Little Goose/Lower Monumental/Ice Harbor	
Design Documentation Reports	1
Appropriations	1
Contract Documents	1
Construction	2
Post Construction Evaluations	1
Total	**16**

Option 3. Additional deflectors and powerhouse/spillway splitter wall and additional 9 spillbays.

If option 3 is selected for implementation, the installation of all features will likely follow the following sequence: 1) develop TMDLs; 2) prepare a decision document with NEPA documentation

(EIS); 3) obtain appropriations; 4) design and build the modifications to the first selected dam; 5) conduct post construction evaluations both biologically and physically to achieve a proof of concept; and 6) design and build modifications to the remaining dams. This process could take up to 30 years if each dam were to be modified in a sequential process. However, if funds can be made available, this could be reduced to a 15 to 18 year process by design and construction of modifications to more than one dam simultaneously.

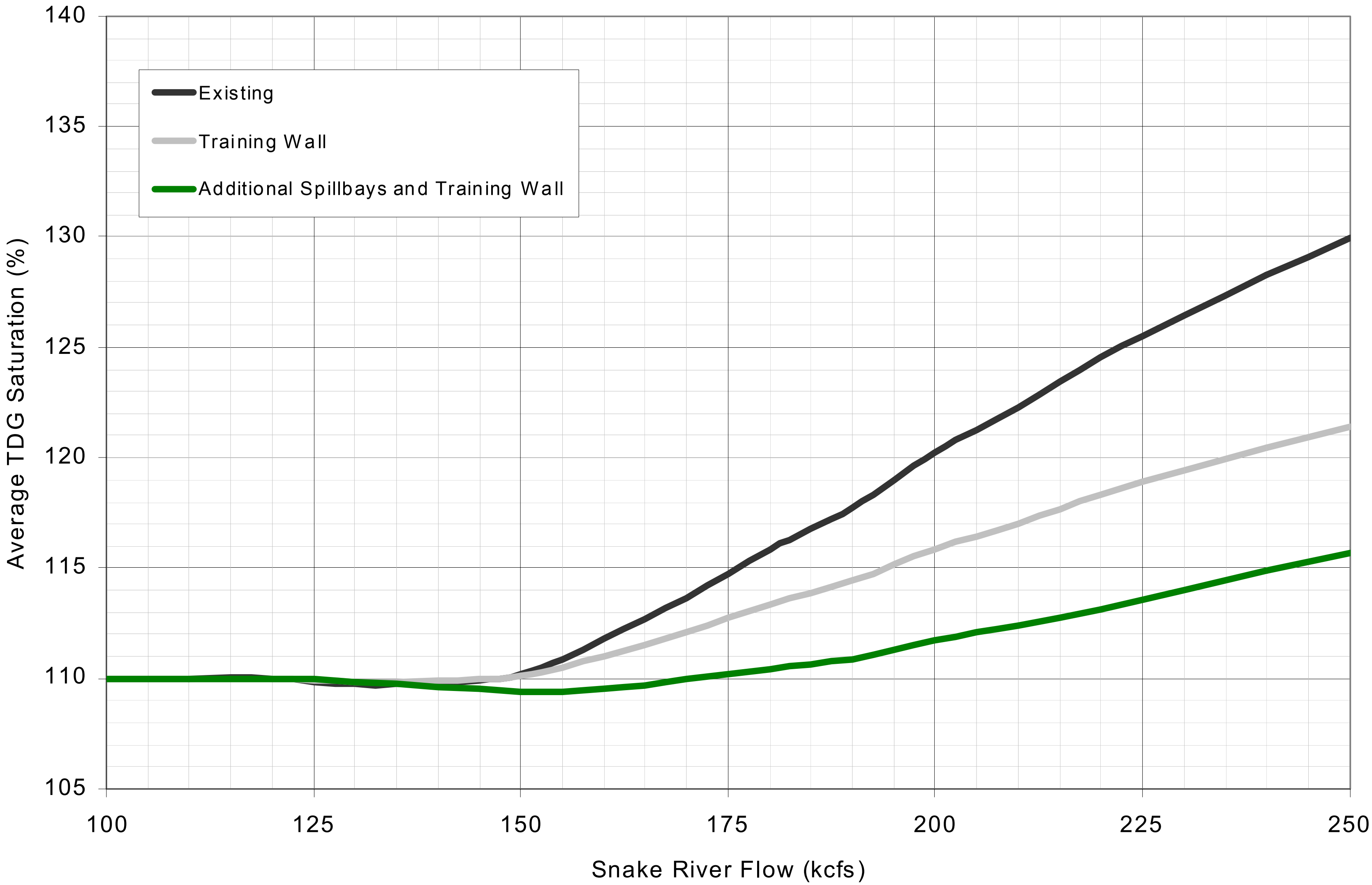

Figure 6-1. Lower Granite Dam DGAS Alternatives

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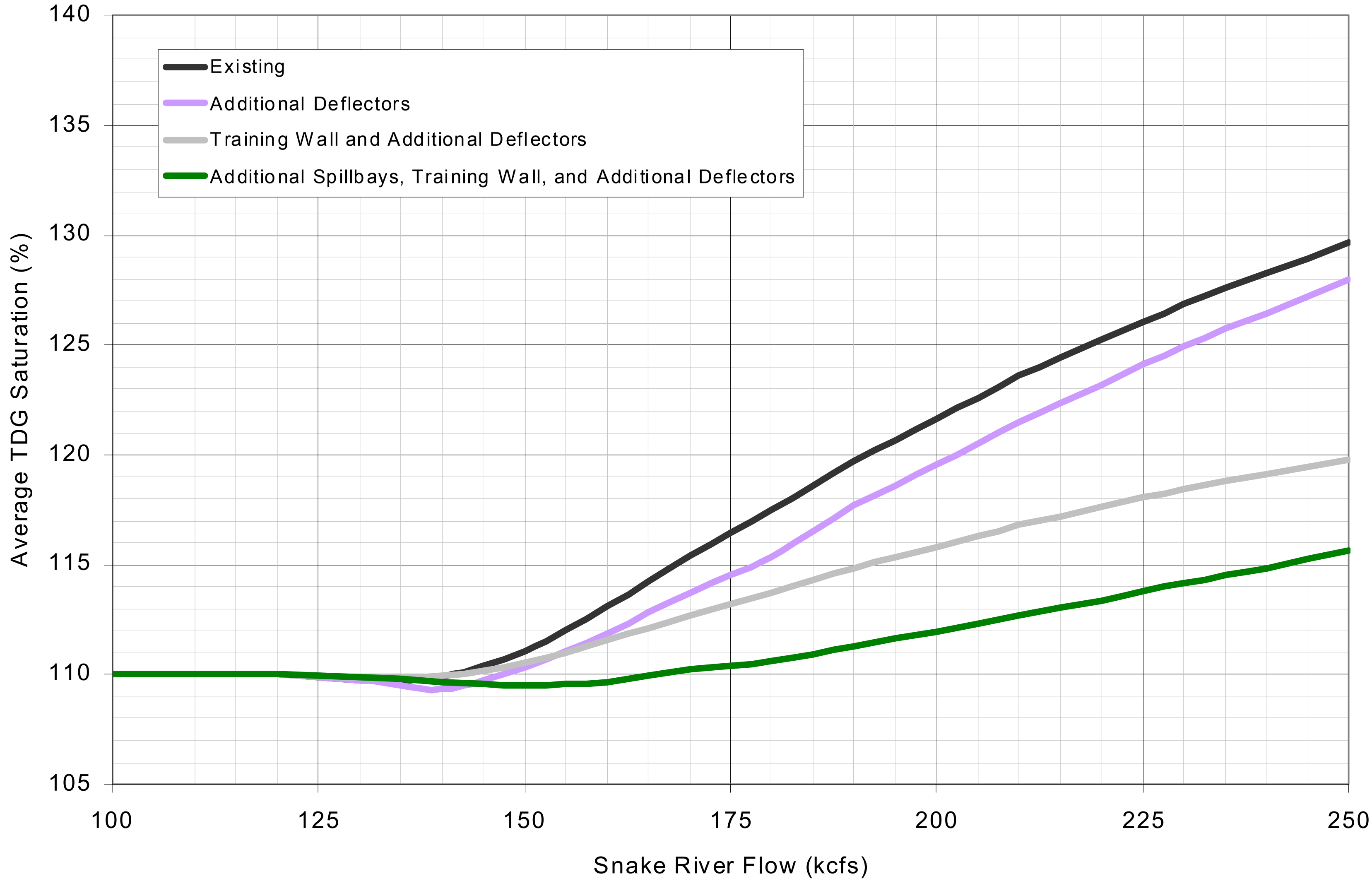

Figure 6-2. Little Goose Dam DGAS Abatement Alternatives

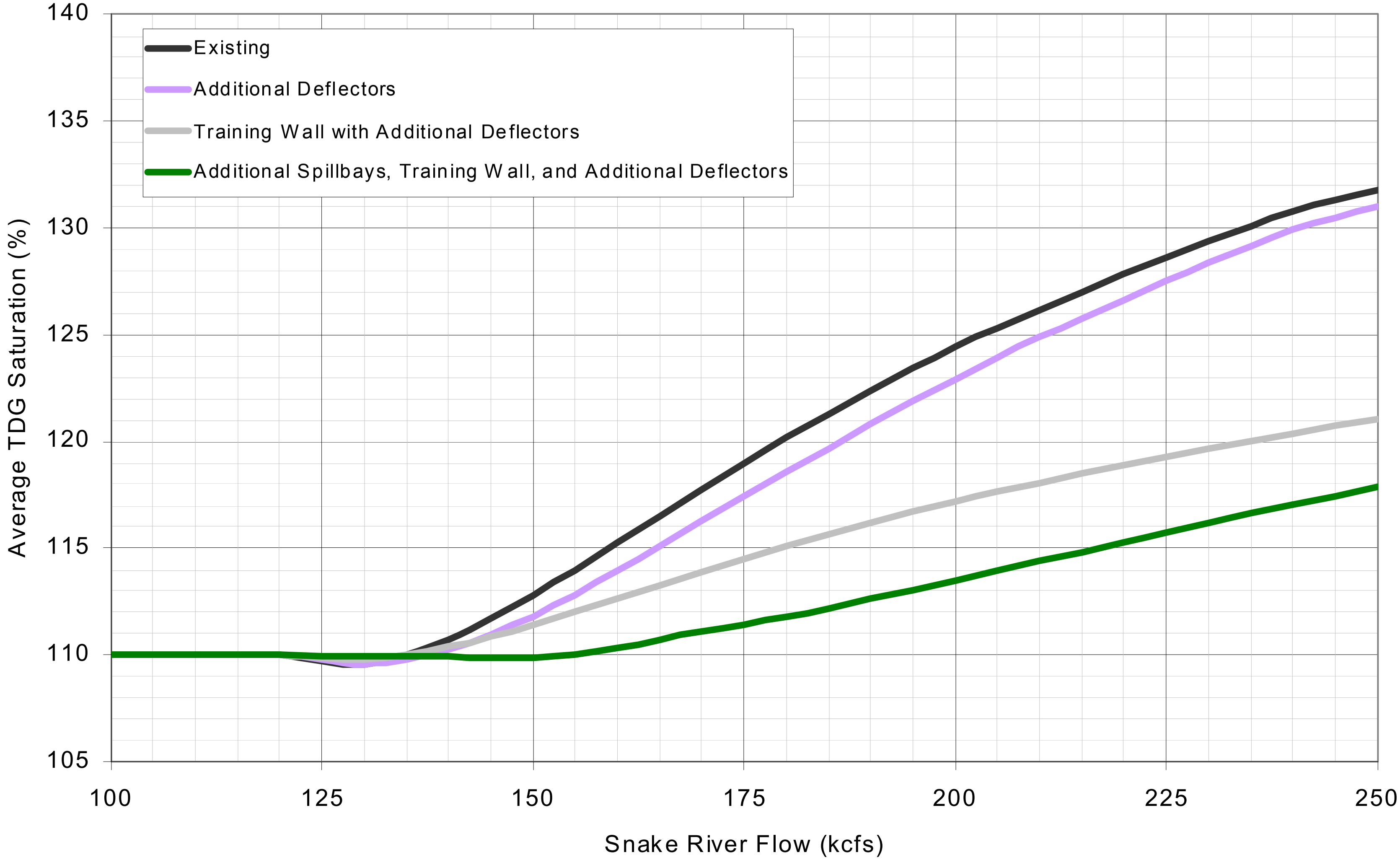

Figure 6-3. Lower Monumental Dam DGAS Alternatives

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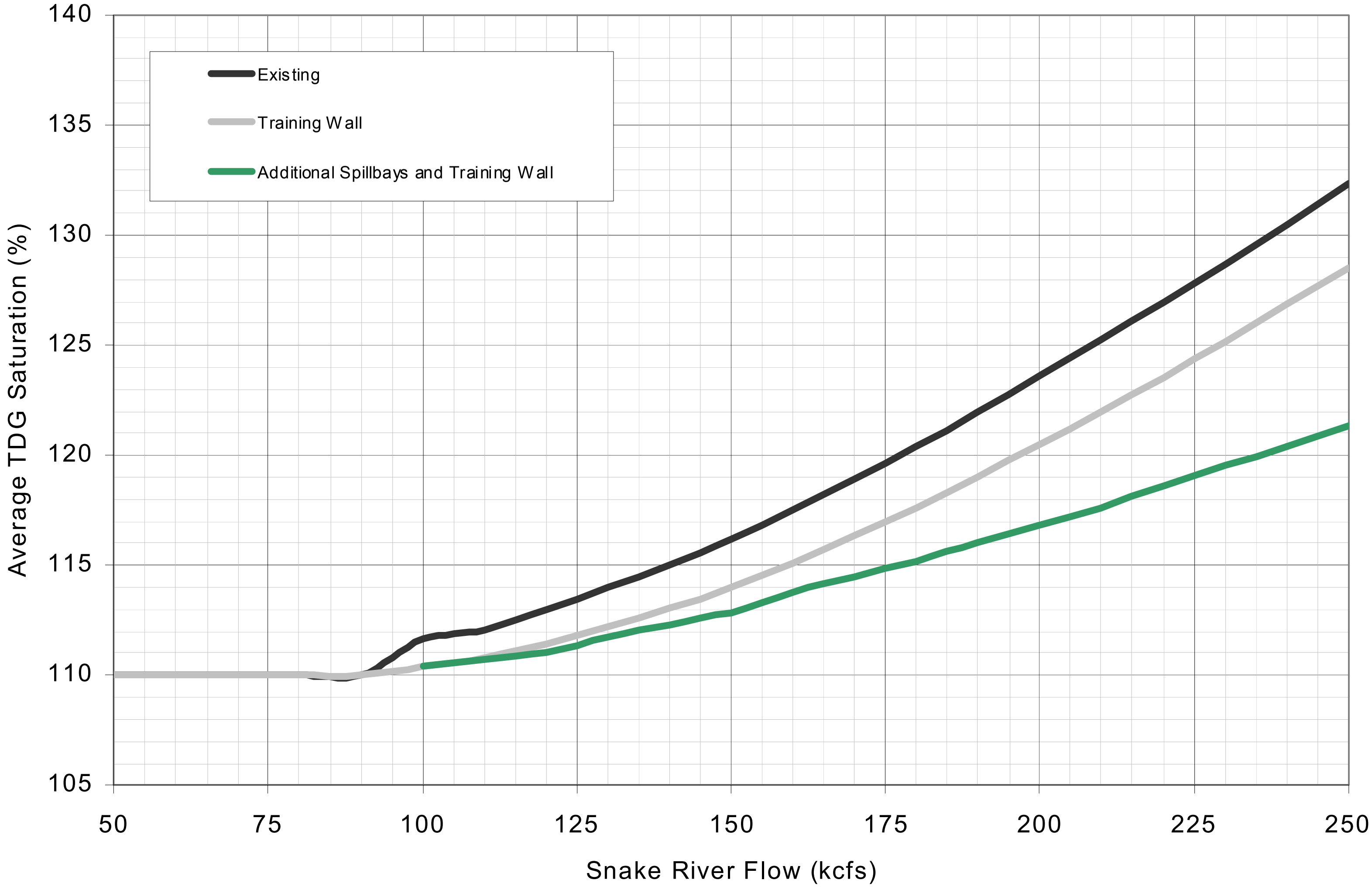

Figure 6-4. Ice Harbor DGAS Abatement Alternatives

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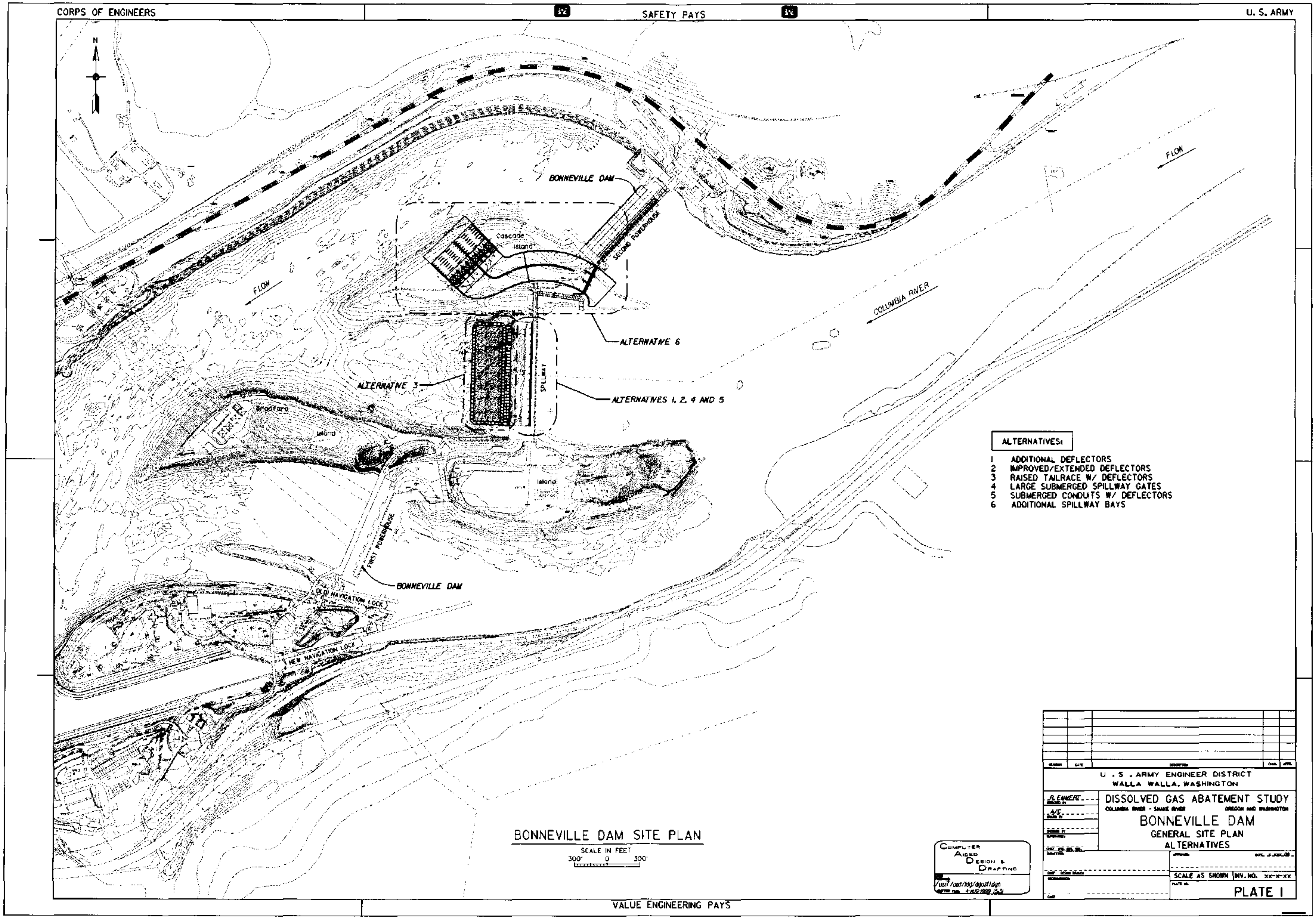

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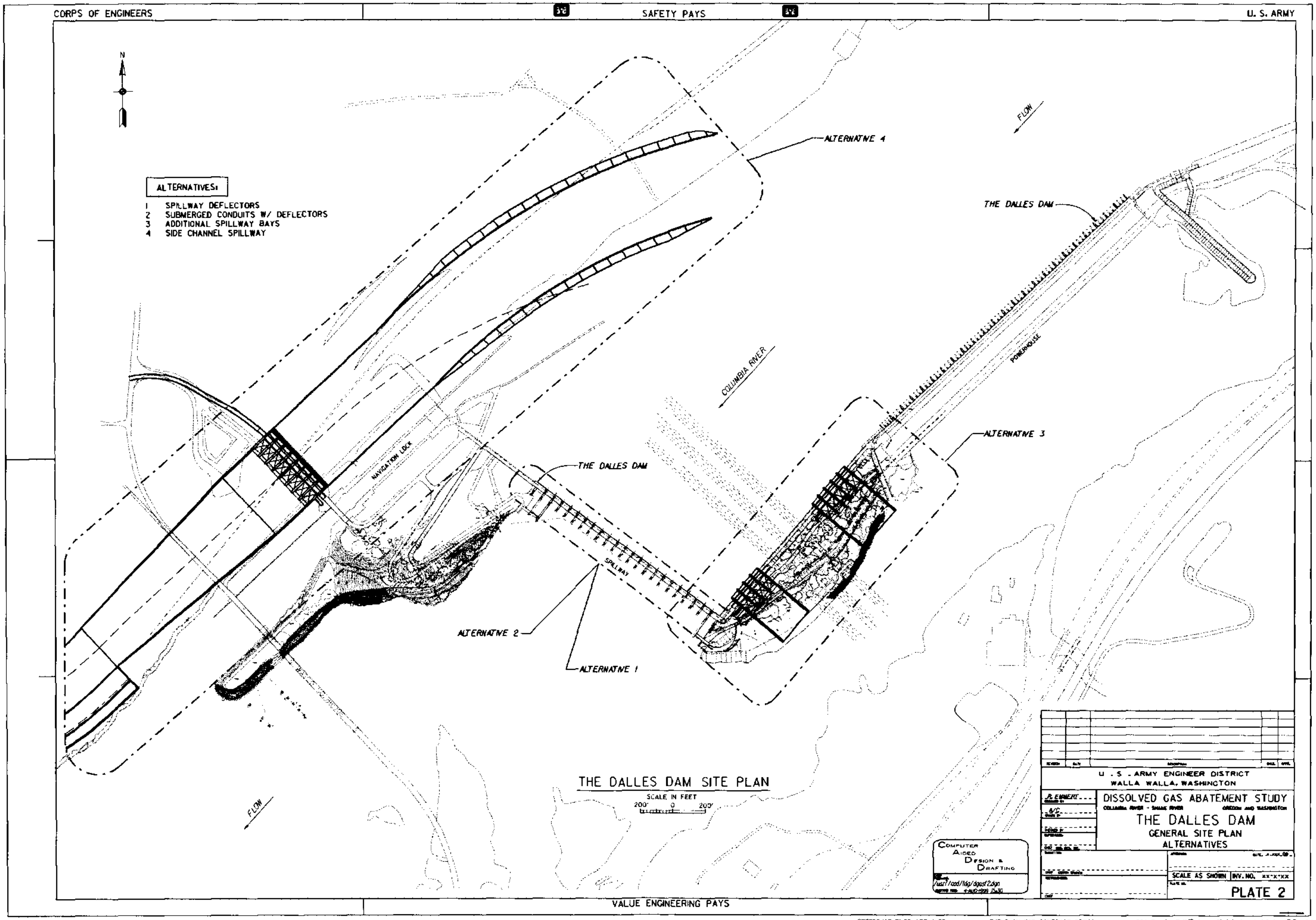

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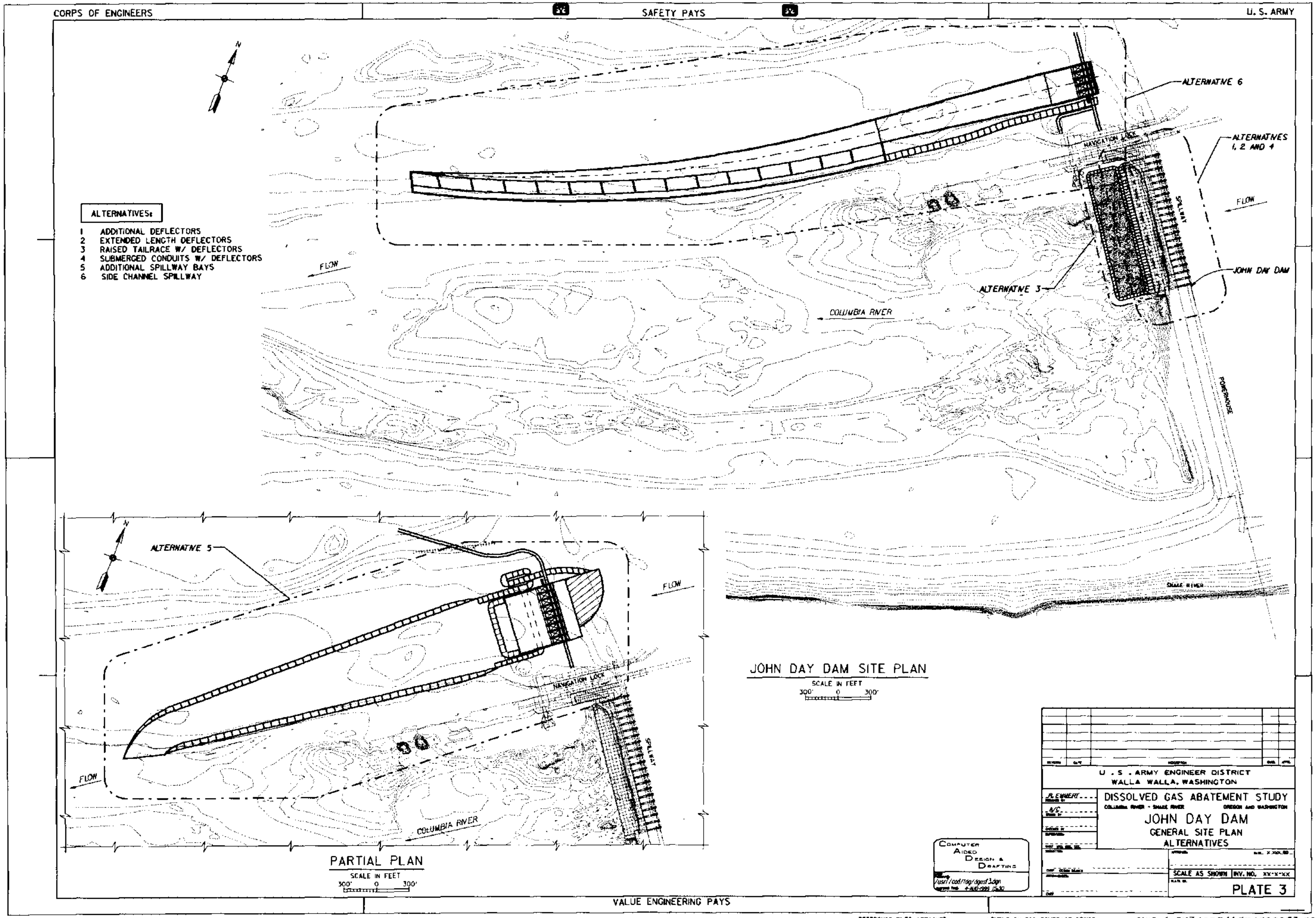

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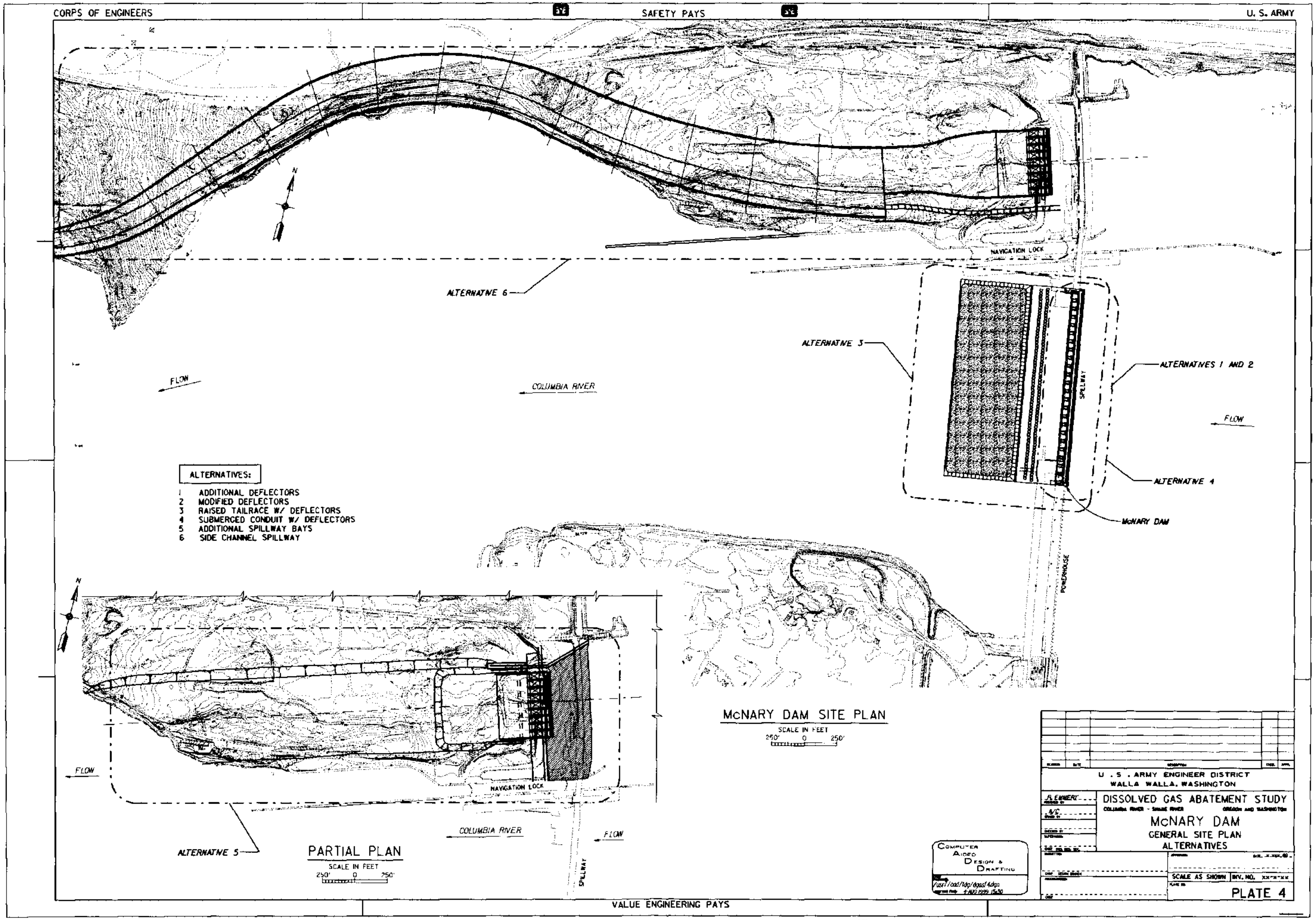

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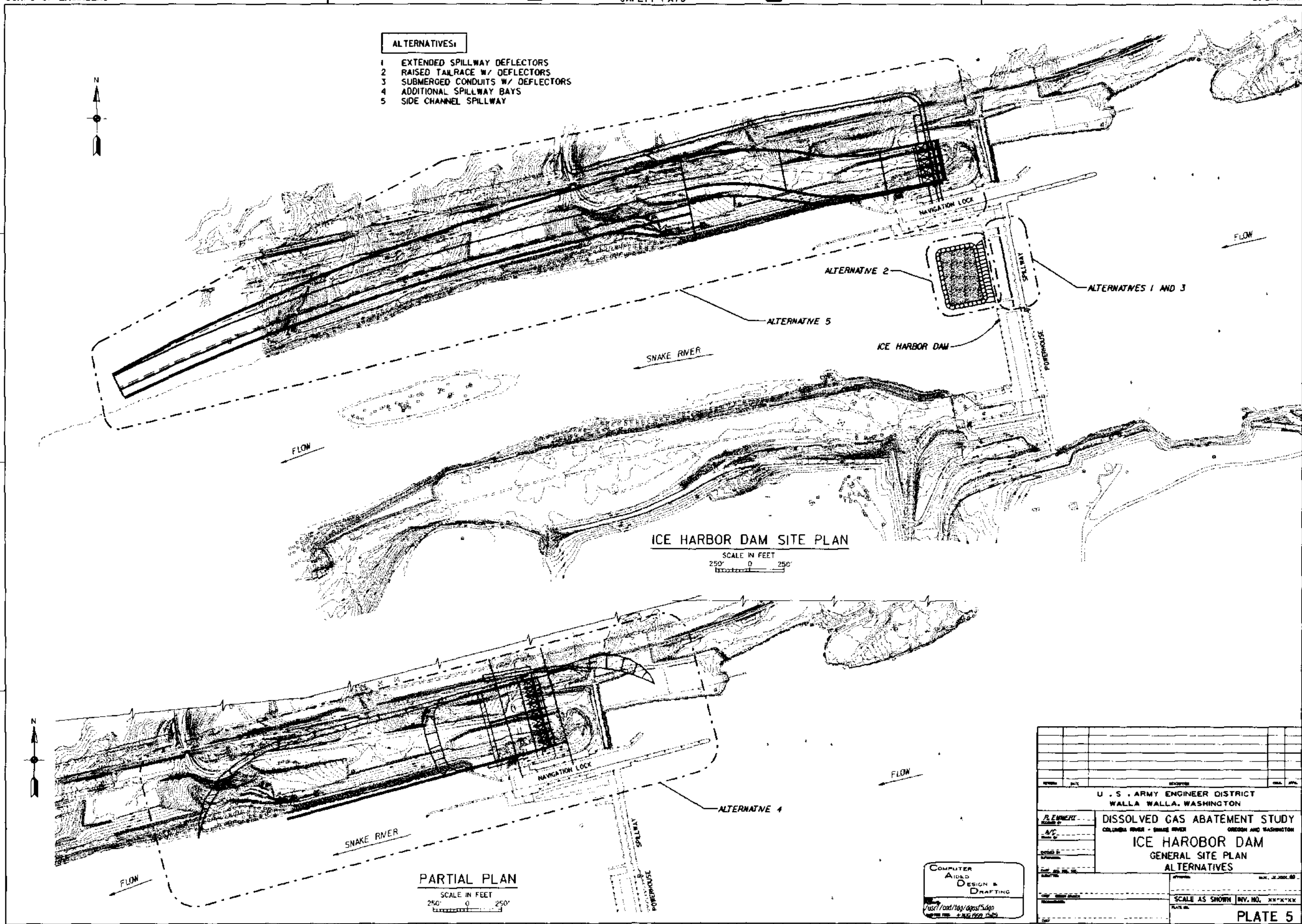
CORPS OF ENGINEERS SAFETY PAYS U. S. ARMY



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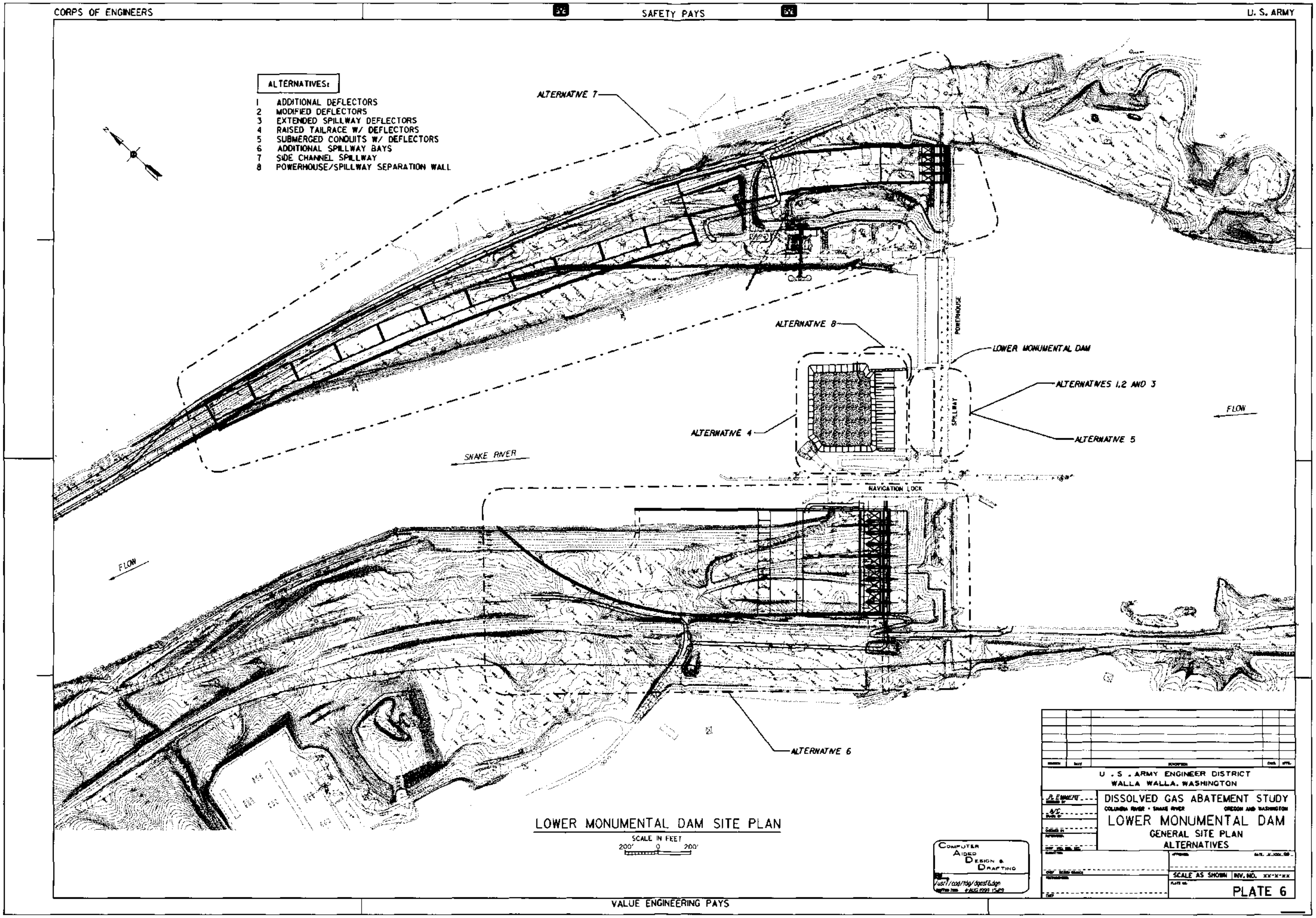

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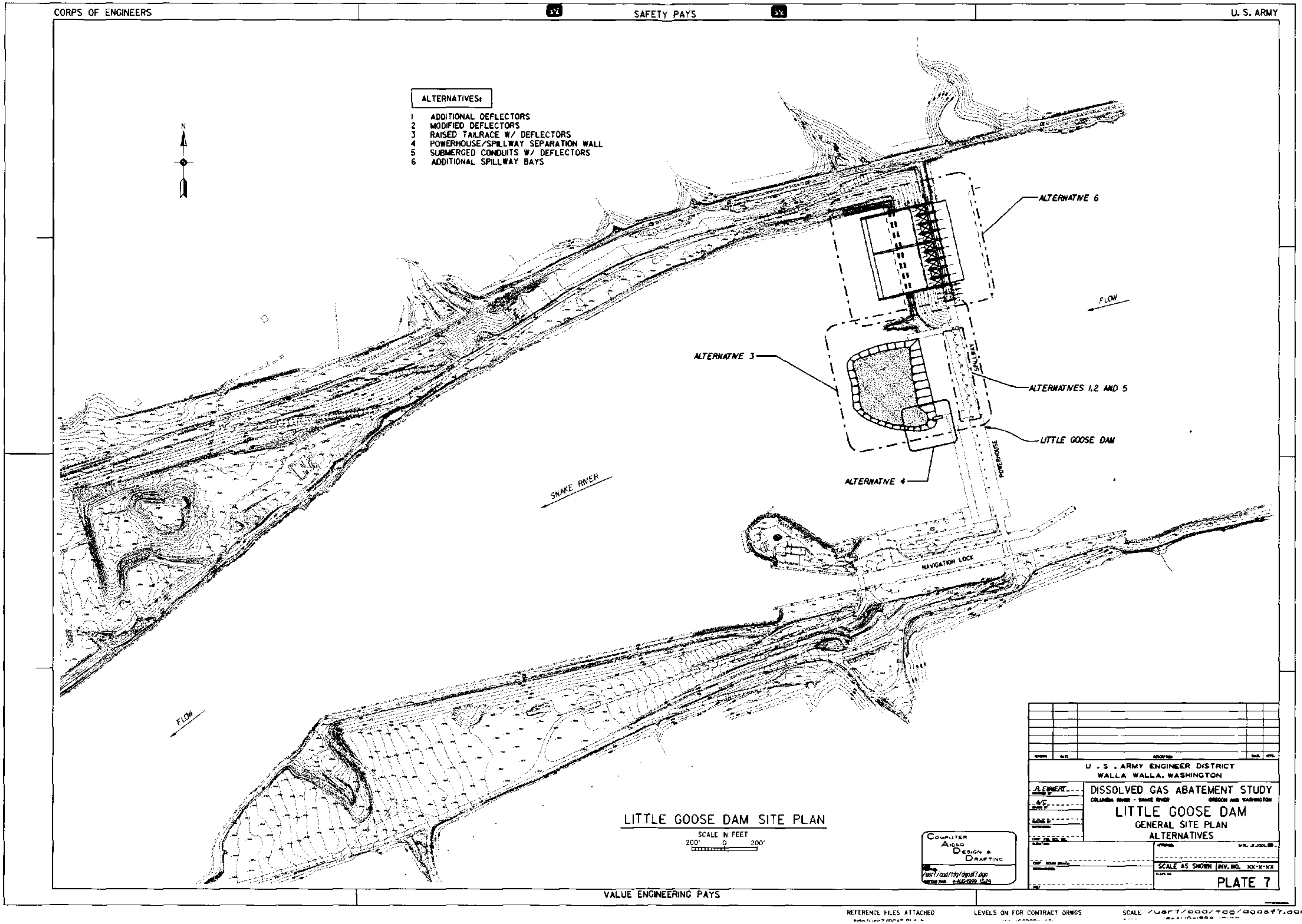
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U. S. ARMY
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2 MODIFIED DEFLECTORS
3 RAISED TAILRACE W/ DEFLECTORS
4 POWERHOUSE/SPILLWAY SEPARATION WALL
5 SUBMERGED CONDUITS W/ DEFLECTORS
6 ADDITIONAL SPILLWAY BAYS
N
ALTERNATIVE 6
FLOW
ALTERNATIVE 3
SPILLWAY
ALTERNATIVES 1,2 AND 5
LITTLE GOOSE DAM
POWERHOUSE
ALTERNATIVE 4
SNAKE RIVER
NAVIGATION LOCK
FLOW
LITTLE GOOSE DAM SITE PLAN
SCALE IN FEET
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U . S . ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON
R. EMMERT
A/C
DISSOLVED GAS ABATEMENT STUDY
LITTLE GOOSE DAM
GENERAL SITE PLAN
ALTERNATIVES
SCALE AS SHOWN
INV. NO. XX-X-XX
PLATE 7
VALUE ENGINEERING PAYS
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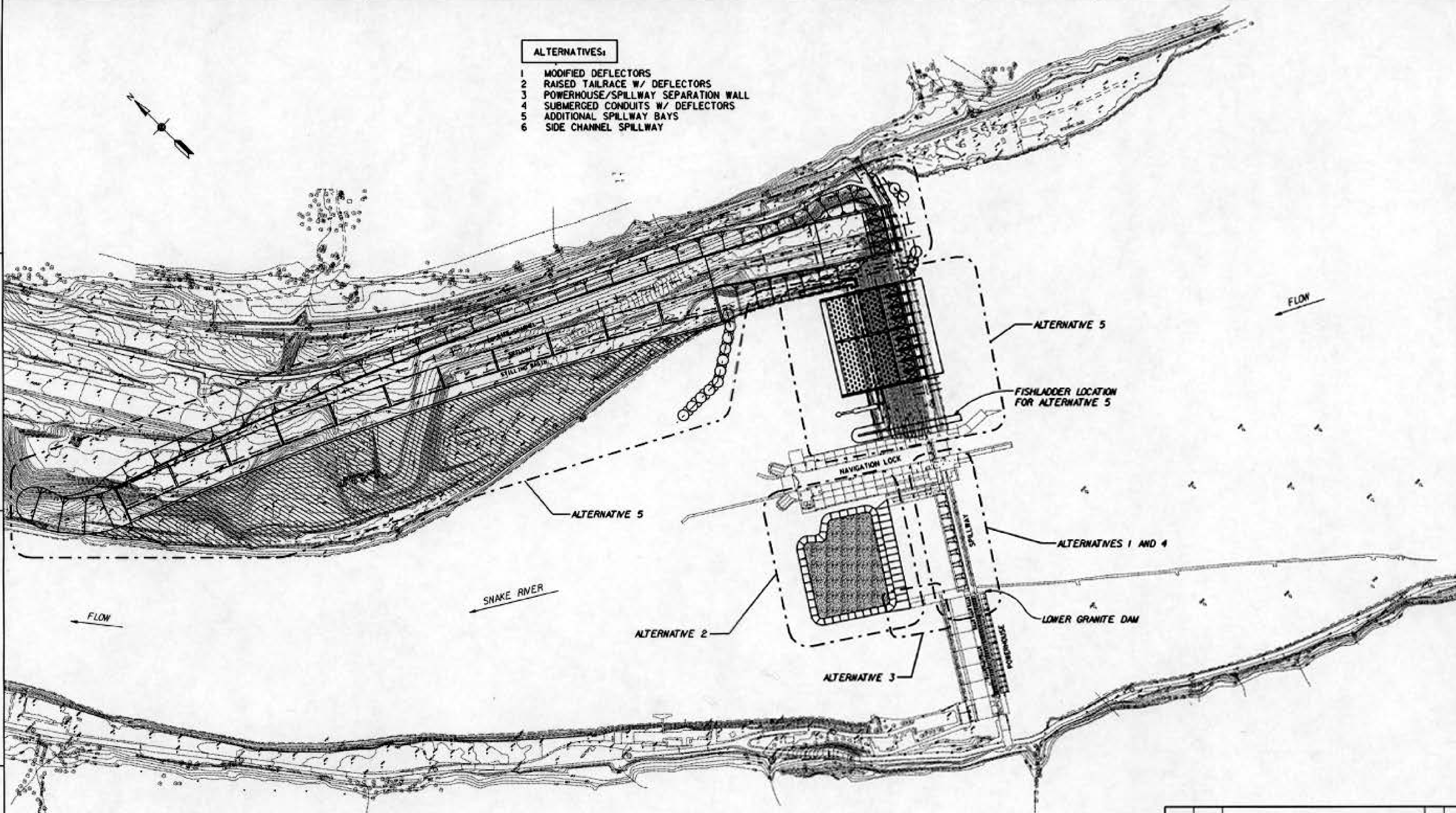

LOWER GRANITE DAM SITE PLAN

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COMPUTER AIDED DESIGN & DRAFTING

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON

DISSOLVED GAS ABATEMENT STUDY
COLUMBIA RIVER - SNAKE RIVER — OREGON AND WASHINGTON

LOWER GRANITE DAM
GENERAL SITE PLAN
ALTERNATIVES

SCALE AS SHOWN | INV. NO. XX-X-XX

PLATE 8

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ANNEX D

TURBINE PASSAGE SURVIVAL PROGRAM

[This annex contains a report prepared for other purposes and includes word tenses that are outdated for this FR/EIS. This report is incorporated into Appendix E simply because of its applicability.]

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FIGURES

1. Introduction

1.1 Background

Under present conditions, direct fish survival through a Columbia and Snake river turbine ranges from approximately 89 to 94 percent. The primary focus of this study is to gather information that will allow an accurate evaluation of fish passage benefits associated with turbine operational changes and changes resulting from the incorporation of improved fish passage turbine design concepts. Information gained from this study, therefore, may be incorporated into existing turbine systems in two ways: through operational changes and/or future turbine rehabilitation programs.

In response to the Northwest Power Planning Council's (NPPC) request to enhance the survival of migrating adult and juvenile salmonids passing the Columbia and Snake river projects, as well as the National Marine Fisheries Service (NMFS) 1995 Biological Opinion for system operations as Conservation Measure No. 5 (develop a program to study/improve fish passage through turbines); Reasonable and Prudent Alternative No. 6 (operation of turbines within 1 percent peak efficiency); and Reasonable and Prudent Alternative No. 15 (improving fish passage with a goal of 95 percent survival through each project), studies for various improvements to these projects were undertaken. In 1994, the Corps completed the System Configuration Study (SCS) to investigate various improvements to the Columbia and Snake river hydrosystems. The two major items corresponding to turbine passage survival resulting from the SCS were the Turbine Passage Survival Workshop and the Turbine Basecase Report.

The Turbine Passage Survival Workshop was held in Portland, Oregon on May 31 through June 1, 1995. The workshop was comprised of a 20-member panel of engineering and biological experts from government, industry, and universities, along with over 50 non-panel participants. The major goals of this workshop were to: 1) determine how to deliver fish from the turbine to the tailrace environment that are ready to cope with the river environment, 2) focus on those uncertainties that prevent closure on developing biological turbine design criteria, and 3) identify and prioritize the causal agents of turbine mortality. The general conclusion from the workshop was that there are physical and operational modifications to the turbines that have already been identified that could possibly increase the survival of fish passing through the turbine environment.

The base case report, entitled "Turbine Passage Survival Baseline Turbine Report," was completed on January 19, 1996. The purpose of the base case report was to gather data on physical attributes of turbines and the ability to perform prototype tests for eight prospective base case sites. Data from the report were used to select a site to perform engineering and biological prototype tests to be conducted under the Turbine Survival Program (TSP). A number of factors were evaluated in determining which site would be selected, including powerhouse capacity and the ability to use the selected unit without largely interfering with hydrosystem operations. McNary Unit 5 was selected by the Corps as the base case prototype test site. This decision was made in coordination with regional fishery agencies, tribes, and the Bonneville Power Administration (BPA).

1.2 Turbine Passage Survival Program

The TSP has been organized along two time frames, short-term (Phase I) and long-term (Phase II). The goal of Phase I is to explore methodologies for evaluating and understanding fishery impacts caused by turbine operation, develop turbine operational changes to improve fish passage through turbines, identify biological criteria for use in turbine re-design, and develop recommendations for future turbine studies. Phase II will implement the recommendations described in the TSP Phase I Final Report. Two options for Phase II implementation will be considered. The first option consists of conducting prototype tests on a modified turbine at the base case site, McNary Dam. The second option consists of incorporating results directly into an ongoing rehabilitation program.

To develop biological turbine design criteria, operational and physical modifications, and to provide a study of cost effective alternatives, Phase I of the TSP has been divided into three distinct yet integrated tasks: biological studies, engineering studies, and hydraulic modeling. This report presents a summary of efforts and results achieved on each of the tasks, as well as a discussion of future activities planned for the turbine program.

2. Phase I Project Study Plan

2.1 Program Philosophy

The region is currently evaluating a wide range of significantly different strategies for restoring the anadromous fish runs on the Snake and Columbia rivers to acceptable levels. Portland and Walla Walla Districts have developed the TSP to investigate improving juvenile fish passage through the turbine environment for the Corps projects located on the Snake and Columbia rivers. The basis for this program is reported in the Columbia River Salmon Mitigation Analysis System Configuration Study Phase I, Appendix F, dated April, 1994. This report was prepared in response to the NPPC's Columbia Fish and Wildlife Program. Section 6, titled "Turbine Passage Survival," describes the mechanisms that are the possible causes of fish injury and mortality by passage through turbines. These mechanisms include abrasion, strike or physical impact, shear, rapid pressure changes, and cavitation. The report identified that further investigation is necessary to quantify the parameters and also indicated that survival through the hydrosystem for many Columbia River salmon stocks could be increased with improved turbine passage conditions.

The Project Study Plan (PSP) was developed for the TSP to outline the activities which will be undertaken to conduct the investigation of short-term and possible long-term solutions to improve turbine passage. The investigation will conclude with implementation recommendations, after which a decision will be made to determine if turbine studies will continue into Phase II. The follow up work will refine and verify the best alternative through prototype testing to ensure it meets defined biological performance criteria.

The findings from this study will be incorporated into improved turbine operations as soon as possible and, if feasible, recommendations for future turbine rehabilitation programs will be made. The benefits to salmon stocks are potentially significant and cannot be ignored, since they would accrue over the life of a rehabilitated turbine, which is estimated to be 35 to 50 years. Since there are a large number of turbines that will eventually be rehabilitated, the development of new turbine designs that increase fish survival over existing conditions should occur as soon as possible to ensure the new designs can be incorporated into scheduled turbine rehabilitation programs.

The PSP was developed in coordination with activities being conducted by other organizations, such as Public Utility Districts (PUDs), U.S. Department of Energy (DOE), Electric Power Research Institute of Energy (EPRI), and BPA. This coordination was done to eliminate duplication, reduce cost, and to enhance the effectiveness of the Corps' turbine program (results from these related programs are discussed in Section 4). The Corps' study is intended to provide a comprehensive evaluation of the effects of the turbine environment on fish survival, first by physical modeling and then prototype testing on a base case unit. The difference between this program and the other related activities is that by integrating biological, engineering, and hydraulic modeling disciplines and conducting all tests on a single unit configuration, definite conclusions can be drawn regarding tracing the route of fish through the turbine, collection of data on the pressures and velocities along that route and the effect of those conditions on the fish. None of the related activities have a comprehensive plan such as this. The information obtained from this program will be incorporated with information obtained from other programs, allowing for comprehensive recommendations to be provided on which strategies or a combination of strategies should be implemented or investigated further.

2.2 Program Overview

The TSP has been divided into three distinct yet integrated tasks: biological studies, engineering studies, and hydraulic modeling. These three tasks are linked functionally and across fiscal years; each year builds on the results from the previous year. The scope of work for the project consists, in part, of using a base case turbine and site dedicated for engineering and biological prototype testing. The prototype tests will be performed on the selected unit for existing conditions and modifications to existing operations to obtain baseline information. Hydraulic modeling of existing conditions will provide additional information that cannot be collected from the prototype studies. Engineering testing consists of index testing, flow measurement, imaging investigations, and pressure distribution testing.

2.2.1 Biological Studies

The biological prototype testing consists of fish survival and condition studies, and fish route/distribution studies. The purpose of the fish survival and condition studies is to determine mortality and injury rates due to turbine passage under current conditions and operations. The assessments will be made using the balloon tag methodology. This will allow fish that have passed through a turbine to be recaptured in the immediate tailrace. Fish will be released at various points in the turbine intake. These release points will be selected based on hydraulic model studies of the turbine passage environment. Fish will be passed through areas where injury and mortality are suspected to occur, and cause and effect relationships will be developed between the area of concern and fish condition. For the first test year, these studies will be conducted at McNary Dam Unit 9.

A study of fish distribution with turbines will be conducted. The primary purpose of this component of the TSP is to compare fish trajectories to results from physical hydraulic model studies to determine if we can rely on the physical models in the future to evaluate various turbine design improvements or alternatives. The fish distribution study is comprised of three phases: 1) coordinate and develop a methodology, along with associated equipment, for use within the turbine environment to determine within turbine fish distribution; 2) prototype test the selected equipment and methodology; and 3) determine/map fish distribution within the turbine environment under a range of operations.

In addition to the studies at McNary Dam, biological testing of a new Minimum Gap Runner (MGR) will also be conducted under the TSP. MGRs are being installed at Bonneville First Powerhouse as part of an ongoing rehabilitation program. Fish will be released at various locations and turbine loadings to provide an overall assessment of MGR performance. Results from this study will determine whether MGR designs should be considered for installation at other Snake and Columbia river powerhouses through upcoming rehabilitation programs.

2.2.2 Engineering Studies

Initial prototype testing will “tune” the McNary and Bonneville First Powerhouse turbines for optimal performance with and without fish diversion devices. Operational modifications testing consists of testing the base case unit under various operating points to investigate the wicket gate/blade angle combination that optimizes fish passage conditions. Initial index testing will be performed to assure turbine operating conditions are consistent with the design and present operating parameters. After establishment of "on-cam" performance with and without fish screens, abbreviated field-testing will be performed to assure "on-cam" operation of the prototype prior to biological testing. In the second and third years of the program, operational modifications will be considered and biological tests will evaluate biological benefits of the operational modifications, if needed. Long-term installation of instrumentation and data acquisition equipment for monitoring turbine operation will be required to maintain definable turbine operating conditions during subsequent biological and turbine modification field testing. It is expected that an index test will be performed annually for at least 3 years to confirm correct operation of the turbine during biological testing.

Index measurement equipment consists of a set of transducers (pressure, differential pressure, linear, rotational, water level and power measurement), data acquisition and recording equipment, reporting and data reduction equipment, and computer monitoring. This equipment will be dedicated for field testing on the baseline unit, McNary Unit 5. Due to unexpected problems with Unit 5, the first year of field testing will be conducted on Unit 9. Once the Unit 5 problem is corrected, the testing will be returned to Unit 5.

The turbine intake will initially be instrumented with sonic measurement equipment suitable for estimation of the quantity of flow and water velocity profiles.

2.2.3 Hydraulic Modeling

Physical hydraulic models will be used to evaluate the hydraulic conditions within the turbine passage way. Sectional models of the powerhouse intakes will be used to define both turbine performance characteristics as well as fish related hydraulic conditions. A performance model for the McNary Turbine unit was built by a private turbine contractor. Sectional models designed specifically to examine hydraulic conditions within the intake and turbine areas were built at the Corps WES, located in Vicksburg, Mississippi, for both the McNary and Bonneville projects. The McNary model will include a model turbine, the downstream draft tube, and the exit to tailrace, which will allow for detailed examination of the complete passage route of water through the turbine environment. The Bonneville model will only be modeled through the wicket gates and stay vanes. These models are made of clear plexi-glass which allows for high visibility and easy data collection. A non-intrusive laser Doppler velocimeter, neutrally-buoyant beads, dye, videotape, and photography are being utilized to collect data and visualize flow patterns and fish passage routes.

Initial testing of baseline conditions is being performed on the McNary model, which will aid in identifying possible problem areas within the turbine environment. Areas to be studied include the flow patterns at the intake, wicket gates and stay vanes, the turbine runner, the length of the draft tube, and draft tube discharge. Flow patterns to be evaluated include water velocity, flow direction, formation of vortices, rapid decelerations and accelerations, and turbulence. Information from this testing will provide input on key locations for instrumentation of prototype engineering and fish release locations for the biological testing, in addition to providing critical data necessary to determine direction and set priorities for future efforts.

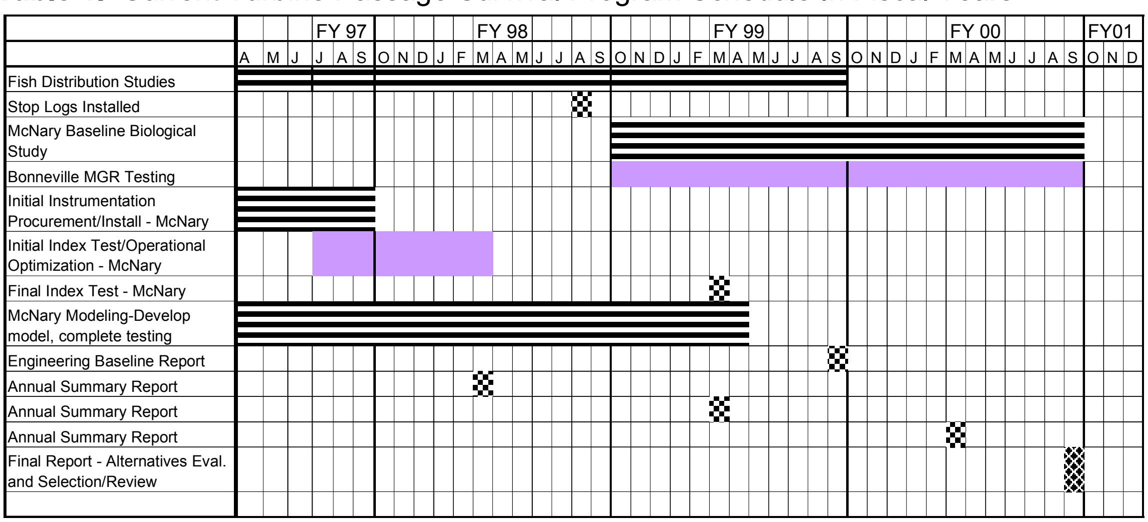
2.3 Schedule

The PSP was designed and approved as a 3 year program, beginning October 1, 1996. Since the inception of the program and the approval of the PSP, several unexpected events have occurred which have impacted initial program schedules, including:

- Program funding and therefore initiation of work did not occur until the middle of FY97 (April, 1997). This resulted in effectively shifting schedules back by approximately 6 months from those originally approved.
- Funding for FY98 was reduced by Congress for the entire Columbia River Fish Mitigation Program, of which the Turbine Passage Survival Program is a component. This has resulted in the extension of the program for an additional year, since some portions of the program scheduled for FY98 have been delayed due to funding cuts.
- Due to unsuspected damage to the generator of Unit 6 at Bonneville, which must be repaired prior to installation of the MGR, the MGR biological testing did not take place until FY99, instead of FY98 as originally scheduled and approved.
- A critical path item that was not anticipated prior to October, 1997 is the requirement for the building and installation of a set of stop logs, needed in order for dewatering to take place prior to completion of the MGR biological studies. Bonneville First Powerhouse has two sets of stop logs already constructed, but both will be in use by the turbine rehabilitation contractor during the period that dewatering for the MGR biological studies needs to occur. This component was added to the FY98 program.
- The baseline Test Unit at McNary (Unit 5) has been taken down for repairs. This required moving the first year of testing to Unit 9.

A current multi-year schedule is shown in Table 1.

Table 1. Current Turbine Passage Survival Program Schedule In Fiscal Years



2.4 Budget

The current budget is significantly different than that originally conceived in the PSP, for the reasons described in paragraph 2.3. The Turbine Passage Survival Program was designed and approved as a 3-year, $7.6-million dollar project. It has now been modified to a 4-year, $6.6-million dollar project. The current multi-year budget is shown in Table 2.

Table 2. Current Turbine Passage Survival Program Cost Estimate

Activity	FY 97	FY 98	FY 99	FY 00
Fish Distribution Studies - MIPR	$262,000	$65,000	$300,000	
McNary Baseline Biological Contract			$600,000	$600,000
Stop Log Contract		$346,000		
Bonneville MGR - Contract		$34,000	$800,000	
Initial Instrumentation Procure/Install - McNary - Contract	$495,000			
Initial Index Testing/Operational Optimization - McNary	$110,000	$110,000	$145,000	
Final Index Test - McNary	$50,000	$85,000	$145,000	
McNary Model - Design Model, Develop Techniques - MIPR	$235,000	$440,000	$120,000	
McNary Model - in-house labor	$88,000	$120,000	$75,000	
Engineering Baseline Testing Report			$154,500	
Annual Report		$50,000	$50,000	$50,000
Final Report				$191,000
Support Activities	$55,000	$150,000	$275,200	$97,300
Yearly Totals	**$1,295,000**	**$1,400,000**	**$2,664,700**	**$938,300**

Multi-year Total = $6,298,000
Contingency = $314,900
Project Total = $6,612,900

3. FY97 Task Summaries

3.1 Biological Studies

The biological studies portion of the TSP in 1997 focused on study design development, planning, and equipment procurement and commissioning. Progress made to date is summarized below for each study.

3.1.1 Minimum Gap Runner Testing at Bonneville First Powerhouse

3.1.1.1 General

Post construction biological evaluation and MGR testing was originally scheduled for the fall of 1998 after completion/installation of the MGR at Bonneville Unit 6. The installation of the MGR was delayed, however, which delayed the fish condition and survival tests until the spring of 1999. Following is a summary of the work completed in 1997 towards development of a study plan, including equipment and an engineering review to develop and design test fish release apparatus.

3.1.1.2 Study Objectives

The goals of the MGR test at Bonneville First Powerhouse are to:

- Monitor the newly installed MGR and estimate survival and condition of fish passing the unit.
- Determine whether installation of additional MGR units will help achieve the recovery goals outlined in the NMFS 1995 Biological Opinion.
- Gain information regarding fish condition and mortality that will be used in the TSP to develop more "fish-friendly" turbines.

The objectives required to fulfill the study goals are:

- Objective 1: Obtain overall survival/fish condition estimates with a precision of +/-3 percent, 90 percent of the time for an existing unit and an MGR unit operating at peak efficiency. Monitor fish injury types and condition to ensure that the MGR unit provides a fish passage environment at least as safe as the existing units. The overall survival/fish condition estimates will be pooled estimates for fish released at three locations that carry them near the blade tip, near the hub, and a "MIP" or Minimum Injury Path release for both turbines. Also, test to determine if the overall survival rate for the MGR unit is statistically higher than the existing unit at a power of 1-b=0.80 and a significance of a=0.10.
- Objective 2: Obtain survival estimates with a precision of +/-3 percent, 90 percent of the time for fish passing the blade, hub, and MIP in the MGR unit and existing unit operating at peak efficiency. Also, test to determine if the survival estimates for the three routes of passage through the MGR and existing units are different statistically at power of 1-b=0.80 and a significance of a=0.10. These tests will be conducted at peak efficiency.

- Objective 3: Increase the precision of the comparison between the MGR unit and existing unit to +/-2 percent, 90 percent of the time for both units.

- Objective 4: Obtain survival/injury estimates with a precision of +/-3 percent, 90 percent of the time from an existing and MGR unit for fish passed through each unit, with both units operating outside the one percent operating range.

3.1.1.3 Study Design

This study will involve releasing balloon tagged juvenile salmonids through various routes in a turbine unit. This involved using a 1:25 scale hydraulic model of the Bonneville First Powerhouse, located at WES, to identify release points in the turbine intake that will allow fish to pass the turbine runner in areas that are suspected of causing injury (i.e., near the hub and the blade tip). These are the areas of concern that have been addressed by the MGR.

Soon after the fish are released (and after they pass the turbine), the balloon tag will inflate, forcing the fish to the surface where they can be recovered in the tailrace. Each fish will also be tagged with an external radio tag to aid in recovery. Immediately upon recovery, tags will be removed and the fish will be examined for external injury. The fish will then be transported to a holding pond and will be held for 48 hours and then be examined again to determine delayed effects and mortality.

3.1.1.4 Release Points

Members of the TSP team met at WES for the purpose of discussing the use of the hydraulic models to assist in the development of release points within the turbine for the study. While the main focus of the discussions on fish release points was McNary, the same information will be applied to Bonneville for the MGR studies.

The release points will be based on the anticipated fish path as it passes the turbine unit. The idea behind these releases is to attempt to isolate areas of fish injury within the turbine. Fish releases were developed using neutrally buoyant beads in the physical model to direct fish/beads to pass in a specific area where it was thought injury may occur and where specific improvement in the turbine has occurred (MGR unit). The release points were chosen to allow a fish to pass through an area of concern and then have the rest of the passage be along what has been identified as the MIP. At Bonneville, three release "paths" were identified in FY97. In addition to a tailrace release, the release points were selected to have fish pass the blade tip, the hub, and the MIP. These releases will be made in both the MGR and an existing unit.

3.1.1.5 Estimated Fish Numbers and Precision of Estimates

The number of fish required for this study are dependant on several factors. The recovery rate of treatment and control fish, the survival of treatment and control fish, and the expected survival/injury rates of treatment fish, as well as the expected precision all play a factor in determining the number of fish used. For this study design, some assumptions were made for calculation of expected fish numbers. A 98 percent recovery of control fish, 98 percent survival of control fish, and a 92 to 98 percent survival of treatment fish (dependant on release) was assumed. The expected level of precision was +/-2 percent or 3 percent, depending on the objective.

Based on these assumptions, the following is an estimate of the number of fish required for each release point and expected level of precision. It should be noted that due to the nature of the test and the almost immediate results, fish numbers can be modified daily, if required, to achieve the desired precision of the estimate.

Option 1:	Blade tip	= 240 fish (for each unit)
	Hub	= 240 fish (for each unit)
	MIP	= 240 fish (for each unit)
	Control	= 720 fish total
	SUB TOTAL	*= 2,160 fish*

Option 2: *Note: fish needed for Option 2 are ADDED to fish needed for Option 1.*

	Blade tip	= 160 fish (for each unit)
	Hub	= 160 fish (for each unit)
	MIP	= 160 fish (for each unit)
	Control	= 160 fish total
	SUB TOTAL	*= 1,120 additional fish*

Option 3: *Note: fish needed for Option 3 are ADDED to fish needed for Options 1 and 2.*

	Blade tip	= 200 fish (for each unit)
	Hub	= 0 fish (for each unit)
	MIP	= 0 fish (for each unit)
	Control	= 200 fish total
	SUB TOTAL	*= 600 additional fish*

Total fish required to complete all objectives is 3,880.

3.1.1.6 Schedule

This study is scheduled to be completed in the fall of 1999. It is, however, dependent upon the scheduled installation of the MGR unit and the availability of funding in FY99.

3.1.2 Fish Condition/Survival Testing at McNary Dam

The objective of this study is to determine causal mechanisms or areas of injury to juvenile salmonids within the turbine environment through multiple releases of fish into the turbine intake.

The study will use the "balloon tag" or "Turbn' Tag" methodology to measure direct mortality and injury of juvenile fish passing through the turbine environment from multiple release sites in the turbine intake. The fish release points, which will be made in specific locations to identify the effects of passage through specific areas in the turbine, were determined using a 1:25 sectional turbine model at WES. Release points will be selected to place fish in an anticipated "path" through the turbine passage in an attempt to isolate areas of potential injury (i.e., near the hub, at the blade tip, near the intake roof, wicket gates, etc.). The number of release points is expected to be approximately four, plus tailrace releases.

The baseline test unit for this study is Unit 5 at McNary Dam. This unit unexpectedly went down for repairs, which resulted in the first year test program being switched to Unit 9. The turbine will be tested under one flow condition.

Fish will be released immediately upstream of the turbine distributor and recaptured in the tailrace below the project. Tailrace releases will be made downstream of the turbine boil. Fish will then be inspected for injury and mortality. Fish that are recaptured alive will then be held in circular tanks for 48 hours to determine any delayed mortality.

The use of Passive Integrated Transponder (PIT) tags was considered for the first year of study to help understand some of the indirect effects of turbine passage. Since the main objective of the first year of study, however, is to identify areas within the turbine that cause direct injury to juvenile salmonids, it was decided that the balloon tag methodology was best suited for collection of direct injury information. The use of PIT tags in the second year of study will be considered to assess both the direct and indirect components of turbine mortality.

3.1.2.1 Release Points

The release points will be based on the anticipated fish paths as they pass the turbine unit. The idea behind these releases is to attempt to isolate areas of fish injury within the turbine passage. Fish releases were developed using physical models at WES to direct fish to pass through a specific area where it is thought injury may occur. For example, the potential for injury when a fish strikes a wicket gate will be studied by releasing a fish such that it has a high potential of striking the wicket gate (based on particle modeling) and then follow the MIP the rest of the way through the turbine. This will allow the isolation of areas of concern within the turbine passage. Through physical modeling and use of neutrally buoyant beads placed in the model, the team developed several areas of concern. It appears injury may be occurring (based on studies with neutrally buoyant beads) when fish strike the wicket gates and stay vanes, fish pass the blade tip, fish pass the hub, and fish strike the draft tube pier. Priority will likely be placed on the wicket gate/stay vanes, blade tip, and the hub for the first year of study. After viewing the model, it was determined that blade strike did not occur at any definable point and that it would be difficult to set up fish releases with a high probability of strike on the blade, although it is noted that blade strike has been mentioned by other authors as an area of concern.

3.1.2.2 Estimated Fish Numbers and Precision of Estimates

The number of fish used will be approximately 250 per release (test and control). This release size will allow detection of approximately +/-3 percent differences between the control releases and test releases. This precision should be sufficient to determine if and where, relative to targeted areas of concern within the turbine environment, the injuries are caused and to statistically determine whether there is a difference in survival between release groups.

3.1.2.3 Schedule

This study was completed during the spring of 1999. Results are currently being analyzed.

3.1.3 Fish Distribution through Turbine Passage

An important component of prototype test results is fish distribution through the turbine passage. After biological results from prototype tests are available, the number of fish that would be passing through injury areas needs to be quantified in order to evaluate their impact on species survival. An area that causes high damage to a small number of fish may be of less concern than an area with more moderate fish damage, but with larger numbers of fish passing through.

In order to estimate fish distribution, existing distribution information will be used to set up a computer model. This information will be used to evaluate the likelihood that fish will enter anticipated injury areas identified in the fish passage model and prototype.

3.1.4 Fish Trajectory Mapping

The in-turbine fish trajectory-mapping task requires the use of ultrasonic and imaging technology. The data acquisition portion of an ultrasonic fish tracking system was designed. Three additional elements are also under development: an ultrasonic transmitter, a neutrally buoyant package for the ultrasonic transmitter, light emitting tag, and software to process data and to assist with deployment of the tracking system.

Three different contractors are pursuing the ultrasonic transmitter, ultrasonic tracking system and processing of tracking system output, and the tracking system data analysis software. WES is pursuing development of the neutrally buoyant package for the ultrasonic transmitter and light emitting tags.

3.1.5 Statistical Model for Estimation of Overall Turbine Survival Rates

Limited work was completed in the development of a model that would incorporate data from the survival/injury studies and fish trajectory mapping study, as well as past vertical distribution data, and develop an overall survival estimate that could be mapped back to the population at large. It is expected that this work will be completed by Dr. John Skalski of the University of Washington. The model will use a series of conditional probabilities to develop overall fish survival estimates and will be based on straightforward principles of probability theory.

3.2 Engineering Studies

3.2.1 General

Engineering investigations identified in the PSP consisted of turbine operational optimization studies, turbine environment studies, and turbine design studies. Each of these areas would be examined with both turbine model and prototype testing and evaluation. Two prototype sites for biological and engineering testing work have been identified as:

- McNary Unit 5, selected by the Corps and approved by the Region for evaluation of existing Kaplan turbines. The program calls for examining and evaluating fish mortality in an existing Kaplan turbine and evaluating the effects on fish mortality of operational and design changes to an existing turbine. The work is to include investigations into the possible mechanisms within the turbine which affect fish survival and develop and investigate design solutions which reduce (or eliminate) juvenile fish injury or mortality. Recommendations for design improvements developed in Phase I would, if funded, be evaluated in Phase II of the TSP.

- Bonneville First Powerhouse rehabilitated turbine. Additional engineering and economic evaluations of the replacement turbine runners for the Bonneville First Powerhouse were added to the TSP during the approval process of the PSP. Features which improved turbine efficiency and should reduce likely sources of turbine juvenile fish injury or mortality were included in the design and procurement of a replacement Kaplan turbine identified as a MGR has been undertaken. In order to evaluate the effects of the MGR on juvenile fish passage and to determine whether MGR's should be considered in future turbine rehabilitation programs, engineering and biological tests comparing an existing Bonneville Kaplan turbine to the MGR were added to the TSP program.

3.2.2 Operational Optimization

The operational optimization of McNary Unit 5 included the performance of a turbine Index test, which identified operating conditions that are consistent with the design and present operating parameters. This testing assures that the turbine will be operating as efficiently as possible prior to actual biological testing. This field Index test was performed with and without fish diversion devices in place.

3.2.3 Turbine Environment Studies

3.2.3.1 General

The purpose of these studies is to better define, in engineering terms, existing conditions within the turbine water passage environment. The studies consist of quantifying conditions within a turbine during operation. Both laboratory and prototype work will be performed to attempt to identify hydraulic and engineering design criteria limits. These limits can then be biologically evaluated to determine if a causal effect between the turbine environment and fish mortality exists. Three areas to be investigated under this program include: 1) turbine environmental imaging, 2) prototype pressure distribution, and 3) coordination with WES hydraulic studies. These tasks were identified by the TSP team as a lower priority or incidental work; accomplishments are identified elsewhere in this report.

3.2.3.2 Turbine Environmental Imaging

The purpose of turbine environmental imaging is to investigate the interior of a turbine water passage and how juvenile fish may respond to the turbine environment.

3.2.3.3 Prototype Pressure Distribution

Two existing piezometric taps in the turbine intake were selected for recording gauge pressure during the McNary Unit 5 field test. Measurement of six water passage sections in a model turbine test, being performed on a Lower Granite Kaplan turbine, was also added to the required model measurements.

3.2.3.4 Coordination with WES Hydraulic Studies

Basic observational testing was also done utilizing the assistance and experience of WES to determine what, where, and how to measure various water passage parameters of engineering and biological interest. This is described in detail in Section 3.3.

3.2.4 Turbine Design Studies

3.2.4.1 General

The proposed investigations are to incorporate numerical modeling, hydraulic modeling, and turbine performance model testing with prototype field measurements to better define, in engineering terms, the physical conditions within a turbine water passage. After initial definition of turbine water passage conditions, application of turbine environmental, and juvenile biological limits to the predicted turbine water passage conditions will be made. Results will indicate potentially dangerous or unsatisfactory areas or mortality mechanisms within an existing turbine water passage. These areas will then be examined in the WES models to assess biological impacts and to determine if design modifications can be made to these areas to improve fish passage conditions. In the future, these modifications may be turbine performance modeled and, if results are successful, the design changes may be incorporated into an existing prototype design and field tested to determine improvements in juvenile fish passage survival. The existing PSP calls for initial investigative work by three modeling methods: 1) computer numerical modeling, 2) WES hydraulic modeling, and 3) turbine performance model testing. These three investigative techniques are to be coordinated with other on-going turbine environmental studies, modeling, and prototype field testing efforts.

3.2.4.2 Computer Numerical Modeling

Computer numerical modeling, called computational fluid dynamics (CFD), has been used by industry for some years to develop preliminary turbine designs for actual hydraulic turbine performance model testing. The DOE, through the Advanced Hydropower Turbine System Program (AHTS), utilized the CFD analysis beyond the design of Kaplan turbine runner blades. The initial work, outlined in the PSP for FY97, was to develop plans and specifications for procurement of services to develop the McNary Unit 5 CFD model. The CFD model would be calibrated and tested using model and prototype measurements to assure reasonable results were obtainable. After development of an acceptable CFD model, design modifications to the existing turbine model could be made to assess the resulting hydraulic and turbine performance impacts. Currently, legal concerns regarding Intellectual Property Rights, poor results from other on-going CFD work, and lack of necessary detail have limited the effective work in this area.

3.2.4.3 WES Hydraulic Modeling

Information on hydraulic modeling at WES is provided in Section 3.3.

3.2.4.4 Turbine Performance Model Testing

During FY97, results of various turbine performance model tests which were funded outside of the scope of the TSP were incorporated into the hydraulic modeling at WES. Data obtained from these tests were also used in the development of prototype test plans for the FY98-99 engineering and biological field tests at McNary and Bonneville. See Section 4.6 for additional information.

3.3 Hydraulic Modeling

3.3.1 General

The PSP defines the need to understand the hydraulic conditions within the turbine environment in order to develop reasonable solutions to the problem of fish passing through turbines. However, trying to understand what is happening within a prototype turbine on the Snake and Columbia river is extremely complicated. The conditions are very harsh, with velocities as high as 50 ft/s, rapid pressure changes, rapid flow de-accelerations, high levels of shear, and constantly changing relationships between water flow and rotating parts. Other complications include the large size of the turbine passage area, the difficult access due to the depth of the intake, and the limited visibility due to high turbidity. Cameras can only capture a few feet of the water column that may be 20 feet wide, over 45 feet high, and 100 feet long.

The use of hydraulic scale models offer solutions to many of the difficulties associated with turbine study. Two types of hydraulic models are being used in this study: performance models (typically used by turbine manufactures to determine expected turbine performance) and fish passage models (used to examine flow characteristics through the turbine passage. See Section 3.3.2.1 for more information on these two types of models. Due to the smaller scale, the improved access, and better visibility, options can be built and tested faster in a model than in the prototype, at a much lower cost. Studies are not linked to the fish window, allowing year-round testing. These models can also be used to develop prototype tests and provide information for input into numerical models (important for study of the turbine area).

While hydraulic models enhance the ability to understand what is physically happening within the turbine environment, information on how these conditions actually affect fish passage is still required. In addition, it is important to verify that the models are accurately representing prototype conditions. Therefore, it is critical that the model test program be closely tied to a prototype test program (including both physical and biological testing) to verify conditions identified in the models.

3.3.2 Hydraulic Models

3.3.2.1 Turbine Performance Model and WES Sectional Model Testing

Two types of hydraulic models were used to evaluate turbine passage: performance models and fish passage models. Results of various turbine performance model tests, funded outside of the scope of the TSP, have been incorporated into the hydraulic modeling at WES, as well as in developing the prototype test plans for the FY98 to FY99 engineering and biological field tests at McNary and Bonneville. The focus of these models is to determine power and turbine performance issues. Curves and turbine settings related to turbine performance were developed using these models. Since the model is made of steel, limited visual access is available.

Specifically for the McNary effort, different modeling techniques and the effects of fish diversion devices are being investigated by performance models to determine which best represents prototype turbine performance with fish screens installed in the intakes. Turbine performance modeling is being used to identify the predicted prototype performance response and has been selected over comprehensive prototype field testing because of cost, accuracy, and flexibility.

The sectional models built at WES for this study are made of Plexiglas, which allows visual access to nearly the entire turbine passage. Beads and dye were used in combination with high speed photography and velocity laser readings to locate likely fish injury areas (associated with turbulence, bead strikes, etc.). The turbine blade angles, wicket gate angles, and turbine speeds for a given flow condition which were developed in the performance models were used in these models to simulate the prototype.

3.3.2.2 Model Description

The McNary 1:25 scale turbine model is the main model studied for this project. See Plate A for more information. It represents an entire turbine unit from the entrance through the draft tube outlet into the tailrace. Included are three intake bays, trashracks, intake gate slots, bulkhead slots, fish screens, a scroll case, stay vanes, wicket gates, a turbine, and a draft tube. The model turbine was built by an independent contractor. This contractor also developed performance curves for the 1:25 scale turbine unit with and without extended submersible bar screens (ESBSs). Contractor information, along with previous WES model information, were used to calibrate the WES model and ensure representation of the prototype.

A Bonneville Dam 1:25 scale fish passage model is also being used in this study. This model represents the intake down to the turbine scroll case (it does not contain an operational turbine, or any components downstream of the turbine) and will be used to help determine fish release locations for biological testing of the MGR turbine scheduled for 1999 installation.

3.3.3 McNary Model Test Set-Up

3.3.3.1 Testing Goals

Model testing goals for the turbine survival program included the following:

- Obtain a qualitative overview of zones through the intake, turbine, draft tube, and tailrace (with and without ESBSs)
- Perfect data collection techniques in model
- Locate and understand possible areas of fish injury (strike, pressure changes, velocity, shear, etc.)
- Determine equipment placement for fish imaging and pressure measurements in prototype
- Develop a plan for testing critical passage zones in the prototype (including both physical and biological testing)

Future goals for the turbine survival program include the following:

- Perfect data collection techniques in prototype
- Develop prototype tests to examine biological impacts of current operation and any proposed improvements
- Identify operational improvements to existing system
- Identify physical improvements to existing system
- Collect information for input into a numerical model of the turbine area

3.3.3.2 Data Collection Techniques

Techniques used to collect data in the model include:

- Neutrally buoyant beads—These were used to identify flow lines and determine possible fish hazards (such as "strike") downstream of the intake gate slots.
- Dye tracings—Dye was used to confirm bead paths.
- High-speed video—Three different video speeds were used to record bead paths. Video was shot at 500 frames per second near the wicket gates, 1,000 frames per second in the turbine area and 240 frames per second in the draft tube.
- Digital photography—Digital cameras (shooting at speeds up to 100 million frames per second) were used to provide stop action photos of bead passage, turbine, etc..
- Two dimensional laser—Two dimensional laser measurements were used to calibrate the WES model. Velocity measurements between previous WES data, independent contractor data, and current model operation were compared.
- Three dimensional laser—This laser will be used to obtain three dimensional flow information in the turbine and wicket gate areas.
- Pressure readings—Pressure readings will be used to double check prototype and numerical model information.

More information on data collection techniques can be found in Appendix A.

3.3.3.3 Zone Definition

The turbine passageway was divided into eight zones for study (see Figure 1). Zone numbers on Figure 1 correspond with those on the following list. Zones will be looked at one at a time and combined for a complete evaluation of the flow lines and patterns from the entrance to the tailrace exit. The following zones are presented in their order of study:

1. Intake gate slot through start of scroll case
2. Scroll case
3. Stay vanes, wicket gates, and turn into turbine area
4. Turbine runner and hub
5. Draft tube expansion and elbow to pier nose
6. Draft tube pier nose to exit
7. Draft tube exit into tailrace
8. Intake entrance to intake gate slot.

The intake entrance to intake the gate slot section will be evaluated last to simplify flow line analysis with ESBSs installed. Since ESBSs cause major flow disturbances (such as turbulence and redistribution of flow), it was determined that the best way to analyze turbine passage was to concentrate on conditions downstream of the ESBSs. The area upstream of the ESBSs will be studied to determine the extent of flow disturbances and to determine the probable flow re-distribution, as well as to estimate potential impacts on non-guided fish.

3.3.3.4 Model Set-up

Model turbine speed was set at 428.5 revolutions per minute (rpm). This is comparable to the prototype turbine speed of 85.7 rpm. Stay vanes were numbered and grids were added (dividing vanes vertically into four equal sections) to aid in identifying bead passage through the vanes. Turbine blades were also numbered. While grids were originally tried on the blades, this was abandoned in favor of a two camera system, which shows three dimensional bead location through the turbine.

The following conditions were used during model testing unless otherwise indicated:

- Turbine flow 12,400 cfs
- Turbine blade angle 25.75 degrees
- Wicket gate angle 39 degrees
- Forebay elevation 340 feet National Geodetic Vertical Datum (NGVD)
- Tailwater elevation 265 feet NGVD

3.3.4 McNary Model Test Results

3.3.4.1 Flow Lines and Fish Paths

General

Testing in the WES Plexiglas models evaluated flow lines downstream of the intake gate slots to determine possible fish paths and injury areas through the turbine and draft tube. Since velocities in this area are near or above capture velocities (7 ft/s for 6-inch fish), flow lines are assumed to approximate fish paths. This assumption will be verified through turbine fish distribution testing, described in section 3.1.3. Flow lines were studied with and without fish guidance screens installed.

Each intake bay was divided into five sections, vertically. For initial measurements, beads were released in the center of each of these sections just downstream of the intake gate slots in each bay (15 releases in all). Wicket gates were numbered and divided into four sections vertically. Video cameras were set up to record flow lines of the beads and bead distribution from the intake gate slots through the stay vanes and wicket gates. These films were later analyzed and the bead path and distribution information recorded on plots such as those seen in Appendix B. Bead paths were verified using dye tracings.

This method was used to identify bead paths, areas of turbulence, and dead zones through the turbine. In FY97, flow lines from the intake gate slot through the wicket gates were completely mapped. Flow lines through the turbine and draft tube were analyzed in FY98. Preliminary releases indicated that considerable turbulence existed downstream of the turbine. This turbulence made it difficult to trace the flow path from the entrance to the intake through the zone downstream of the turbine. It appears that tight control on bead release at stay vanes will be necessary to evaluate passage through the lower portion of the turbine.

Impact of Fish Guidance Screens on Flow Lines

ESBSs are 40-foot-long screens set at a 55 degree angle from vertical. They are installed in the McNary intake to increase fish guidance away from turbine passage. Due to guidance benefits and potential hazards of turbine passage, McNary is required to operate with ESBSs installed in all operating turbine units throughout the fish passage season.

Several dams on the Snake and Columbia rivers are fitted with fish guidance screens (some with ESBSs, some with 20-foot-long standard-length traveling screens). Not all intakes, however are screened. Therefore, an important part of this study is to look at conditions through the turbine passage with and without fish guidance screens installed. It is also important to understand the impacts guidance screens have on turbine passage conditions for those fish not guided by the screens.

In general, the ESBSs typically cause beads to spread more vertically and, often, more horizontally as they pass through the wicket gates. Since ESBSs change the distribution of flow, they also affect which wicket gate openings beads are most likely to pass through. This is particularly apparent in the bay A releases and least pronounced in bay B releases. See Appendix B for graphic representations of these results.

The bottom two releases in each bay represent the majority of the flow that passes under the ESBSs. Where ESBSs have increased the vertical spread of the beads, beads passing lower through the wicket gates would have a greater chance of passing near the outer gap of the turbine blades. Those passing higher may have less of a chance of being impacted by the outer gap. Understanding the zone of influence of the outer gap would help in evaluating the overall expected impact of the ESBSs on fish passage.

Where ESBSs increase the horizontal spread of beads entering the wicket gate and stay vane area, beads often pass through several more wicket gate openings than without ESBSs in place. It is possible that this spread could increase the incidence of strikes on stay vanes and wicket gates by exposing fish to more of these during their passage.

3.3.4.2 Anticipated Impact of Zones on Fish Passage Based on Model Observations

The following describes the anticipated impact of various zones on fish condition through turbine passage based on model studies performed in FY97 (see Figure 1 for a zone overview). The portion of the model that is difficult to get detailed measurements is the zone impacted by the rotating runner. This area will be evaluated using more general information such as bead paths, dye, and high-speed photography. Another possible method would be the use of a numerical model to analyze this particular area.

Intake Gate Slot Through Start of Scroll Case

The turbine intake bay is split into three intake sections. Each section is individually screened by a 40-foot ESBS. All three intake sections merge into the scroll case (see Figure 1).

Irregular flow patterns through the intake sections caused by flow redistribution associated with ESBSs result in dead spots (where beads collect) and flow disturbances (with no clear direction of flow). Since velocities in these areas are low, it is unlikely fish injury is occurring due to these flow patterns (though some abrasion injuries may be possible). These patterns could, however, affect fish distribution and orientation.

Scroll Case, Stay Vanes, and Wicket Gates

Flow from the intake section enters the scroll case and begins a clockwise flow around the scroll case, past stay vanes, through wicket gates, and down through the turbine (see Figure 1). Flow along the bottom of the scroll case rises up and then bends sharply down into the turbine. Flow from the top of the scroll case bends sharply down as it enters the turbine. With velocities increasing to about 27 ft/s as flows pass the wicket gates (for turbine flows of 12,400 cfs), abrasion injuries are possible along the surface of the scroll case.

Stay vanes and wicket gates offer a variety of hazards. As stationary objects in the flow, bead strikes indicate there may be a high incidence of fish strike on the vanes and gates. The gap between the vanes and gates seem to influence the flow patterns. Some beads become lodged between the two, and beads strike the stay vanes and then the wicket gates. Once past the vanes and gates, the turbine pulls flow sharply down. Abrasion injuries along the vanes and the gates are likely, along with strike injuries and velocity shear injuries. With these high velocities, there may be an area of influence around each surface that poses a hazard to fish passage. Based on our judgement and observations, we assume that within 6 inches of these surfaces may be a high hazard zone for fish. Fish in this area may have a higher likelihood of strike or abrasion injury. If they should change their course slightly, it could take them directly into a hazard area.

The approach to the stay vanes and wicket gates appeared to be a significant factor in determining the likelihood of impacting the stay vane or wicket gate surface. The flow with several stay vanes aligned very well, while at other locations the flow aligned very poorly, causing a rapid change in direction with considerably higher probability of bead impact. Possible future improvements include streamlining or reshaping the stay vane and wicket gate combination, reducing the number of vanes and gates, coating vanes and gates, or constructing them from a different material. Lab tests may indicate whether possible abrasion injuries are flow caused or behavior caused.

As a result of the higher velocities through the stay vane and wicket gate zone and the relatively poor alignment that occurred for a significant portion of the flow, this is considered an area with a high potential for fish injury.

Runner Region

This region covers all areas in the immediate vicinity of the rotating blades. This includes possible strike on the leading edge of the blades; both inside and outside gaps; high velocity passage next to the hub, the blade surface, and the outside ring; and the turbulent region associated with the trailing edge of the turbine blade.

Outside Gap

The outside of the turbine blades spin past the outer ring. The range of the gap between the blades and the outer ring varies as the angle of the blade is changed. In addition, water is passing vertically through the turbine. Pressure changes across the outside gap at the turbine blade are expected to be high. Fish in this area risk being sucked up to the blade, pulled through the gap, or crushed between the blade and the outer ring. It may be difficult to separate injuries caused by this gap from those caused by abrasion along the blades and outer ring. Gaps take up a fairly small part of the outer ring circumference. Therefore, the zone of impact of these gaps may be an important aspect in estimating injury to fish population. Reducing the gap size is currently being studied in turbine design, with a MGR turbine scheduled for installation in 1999 at the Bonneville First Powerhouse.

The outside edge of the turbine blade is an area with a high likelihood of fish injury. Abrasion caused by high velocities in the area, as well as rapid pressure changes at the gaps between the turbine blade and the outer ring, could contribute to fish injury.

Inside Gap at Hub

A gap exists between the turbine blades and the hub of the turbine. The range of the gap changes as the angle of the blades change. Injuries in this area could be caused by pressure changes across the gap, and abrasion as high velocity flows cross the blades and the hub. Injuries due to the gap near the hub should be similar to those seen along the outside gap (with the exception of being crushed between a moving blade and a fixed ring). The MGR design (mentioned above) also reduces the gap in this area..

General Runner Zone

The general runner zone of the turbine is the area in the vicinity of the rotating blades (see Figure 1). High velocities (up to about 40 fps for turbine flows of 12,400 cfs), pressure changes, and cavitation occur in this area. Fish face risks of injury associated with these plus the possibility of impact with the front edge of the turbine blade and abrasion along the blades, outer ring, or hub.

Trailing Edge of Turbine Blade

The trailing edge of the turbine blade is an area of high shear and pressure changes. Sudden changes in velocity and direction occur as the different pressures from both sides of the blade come together. This is a very difficult zone to analyze using the model due to the rapidly moving parts. Numerical model information may be the best tool for analyzing this region. The actual portion of the flow effected by this phenomenon is relatively small (see Figure 1). This is a relatively small area with a high probability of injuring fish that pass through it, due primarily to high shear and pressure changes.

Lower Turbine Hub and Draft Tube Elbow

Water exits the turbine with a slight clockwise rotation. The velocity as it exits the turbine runner area is very high. The flow is then rapidly de-accelerated and turned 90 degrees to align with the draft tube. This creates very turbulent flow with high shear. All fish passing through the turbine would experience these conditions. If shear is a major mechanism for fish injury, this should be considered a major area of concern.

Pier and Draft Tube

After the flow is turned at the elbow, it continues to expand through the draft tube. The pier (located just upstream of the outlet) divides the flow into two paths (see Figure 1). Impact and abrasion injuries are possible in this area. Turbulence at the pier nose could cause disorientation and additional abrasion injuries from the unsteady flow characteristics.

There appears to be more flow separation at the pier nose in the draft tube at low flows (around 10,500 cfs) than at high flows (around 16,000 cfs). It appears the draft tube design may have been optimized for the higher flow level. Average velocities at the upstream end of the pier range from 12 ft/s to 18 ft/s for the above flows (10,500 cfs to 16,000 cfs). Average velocities at the downstream end of the pier range from 6 ft/s to 9 ft/s.

Draft Tube Exit and Backroll

Flow exits the draft tube in a swirl pattern that seems to indicate higher velocities along the bottom of the draft tube than the top. The flow boils to the surface and splits into a front roller that travels quickly downstream and a backroller which generates a vertical eddy against the dam. This backroll of the flow is a good habitat for predator fish which could easily feed on disoriented juveniles caught in this portion of the flow. The velocities in this region are low enough that injury from shear is less likely. Predation associated with the backroller may be quite significant. Fish passing through the turbine experience high velocities, rapid pressure changes, high shear, and rapid de-acceleration. Though each of these may not cause direct fish injury, the combination is likely to leave a large number of fish very disoriented and in a very confused state. If half of these fish then pass into the backroller, significant predation losses may occur.

The TSP team, following observations described above, developed a list which identified the priority of study for each zone. Zones were evaluated based upon possible fish injury, fish mortality, and the potential for physical modifications to improve conditions in the area. The following table shows the results of this evaluation and the priority given to various areas for study.

Table 3. Priorities for Zones of Study.

Zone	Possibility of Fish Mortality	Possibility of Fish Injury	Priority for Study	Possibility of Physical Mods
Upstream of stay vanes	No	No	Low	Uncertain
Stay vanes/ wicket gates	Yes	Yes	High	Yes
Outside gap	Yes	Yes	High	Yes
General runner zone	Yes	Yes	Moderate to High	Yes
Trailing edge of blade	Yes	Yes	Moderate	Yes
Lower hub and elbow	Yes	Yes	Moderate	Uncertain
Pier and draft tube	Yes	Yes	Moderate	Uncertain
Draft tube exit and roller	Yes	Yes	High	Uncertain

3.3.5 Bonneville Model Test Results

Preliminary fish release locations were determined based on the Bonneville and McNary fish passage models, (see Section 3.3.6.3 for more information on release sites). These sites were chosen to optimize biological information from the MGR. Prototype tests were originally scheduled for FY98, but, due to delays, were scheduled for FY99.

3.3.6 Prototype Tests

3.3.6.1 Testing Overview

Hydraulic models will be used to develop and improve McNary prototype tests. It is assumed that beads released in high velocity areas (above 7 ft/s, capture velocity for 6-inch long juvenile chinook and steelhead) will approximate fish paths through the same areas. Bead flow paths will be studied to determine potential danger zones and "fish" paths through these zones. Release sites will be selected to place fish in the desired areas for prototype testing. Injury and survival information from prototype tests will be used (along with fish distribution information) to estimate the impact potential of each zone on fish injury and survival. Prototype tests were originally scheduled for FY98, but, due to delays, were postponed until FY99.

Hydraulic models will also be used to develop and improve prototype tests to evaluate changes in fish injury and survival with a MGR at Bonneville Dam First Powerhouse. Flow paths through the McNary turbine model will be used to estimate fish paths from the Bonneville scroll case through the turbine (the Bonneville model does not have a turbine). Similar prototype release sites will be used for the minimum gap turbine and a typical turbine to compare fish injury. Fish distribution information will also be analyzed to estimate impact on survival. Prototype tests were originally scheduled for FY98, but were postponed until FY99.

3.3.6.2 McNary Prototype Test Development

Model Release Sites

Initial release sites were selected based on model information (identification of potential injury areas and flow lines through these areas). Five sites were chosen. Areas targeted for study include the following:

- Minimum impact passage (a route through the turbine that is anticipated to have minimum fish injury)
- Stay vanes and wicket gates
- Hub gap at turbine
- Outer gap at turbine
- Center pier of draft tube outlet.

These sites were selected to provide a better understanding of where injuries are occurring in the turbine passage and what areas would benefit most from modifications. Injuries from the last four passage routes will be compared to injuries from the minimum impact passage to determine biological impacts of potential injury areas.

Release sites will be verified before being finalized for prototype testing. Approximately 500 beads will be released at each initial site and their paths studied to evaluate if the site will provide adequate biological information. Information from studying bead paths may also roughly indicate what portion of fish may be injured from each release site. New release sites will be selected if necessary.

Prototype Release Sites

In an attempt to confirm that bead paths in the model can represent fish paths in the prototype, verification studies will also be conducted (see Section 3.1). Currently, technology to track fish to the wicket gate area is being researched. It is important to confirm the fish path through the turbine passage for two reasons: 1) if fish paths are confirmed, the strength of the biological tests results increase, and 2) a higher confidence in the use of hydraulic models to evaluate fish passage conditions and possible improvements would provided.

3.3.6.3 Bonneville Prototype Test Development

Initial release sites were selected based on model information. The following three sites are targeted for study:

1. MIP (a route through the turbine that is anticipated to have minimum fish injury)
2. Hub gap at turbine
3. Outer gap at turbine.

These sites were selected specifically to evaluate potential benefits of a MGR turbine design.

4. Economic Data

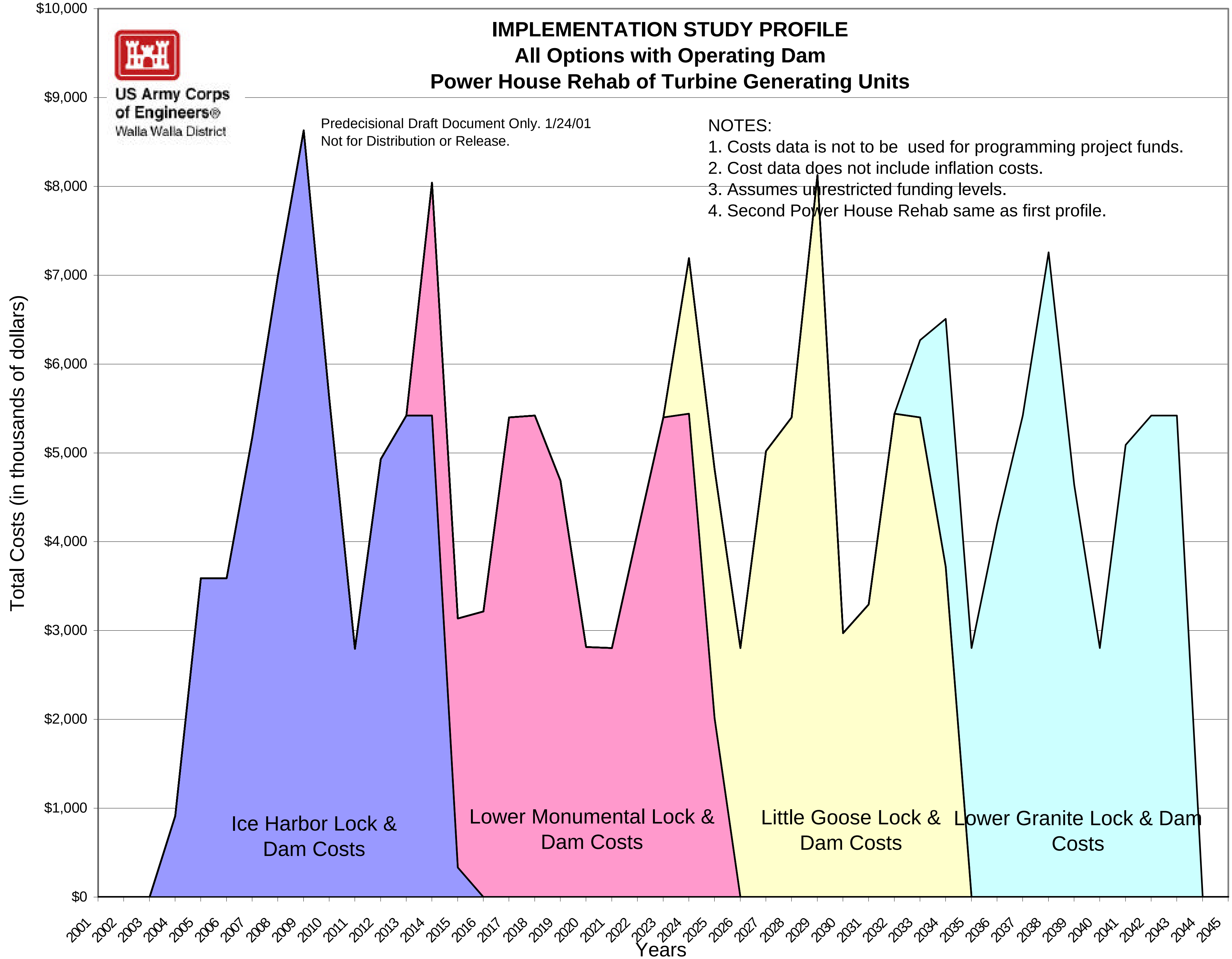

IMPLEMENTATION STUDY PROFILE
All Options with Operating Dam
Power House Rehab of Turbine Generating Units
US Army Corps
of Engineers®
Walla Walla District
Predecisional Draft Document Only. 1/24/01
Not for Distribution or Release.
NOTES:
1. Costs data is not to be used for programming project funds.
2. Cost data does not include inflation costs.
3. Assumes unrestricted funding levels.
4. Second Power House Rehab same as first profile.
Total Costs (in thousands of dollars)
$10,000
$9,000
$8,000
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Ice Harbor Lock & Dam Costs
Lower Monumental Lock & Dam Costs
Little Goose Lock & Dam Costs
Lower Granite Lock & Dam Costs
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045
Years

Figure 1. Zones of Concern

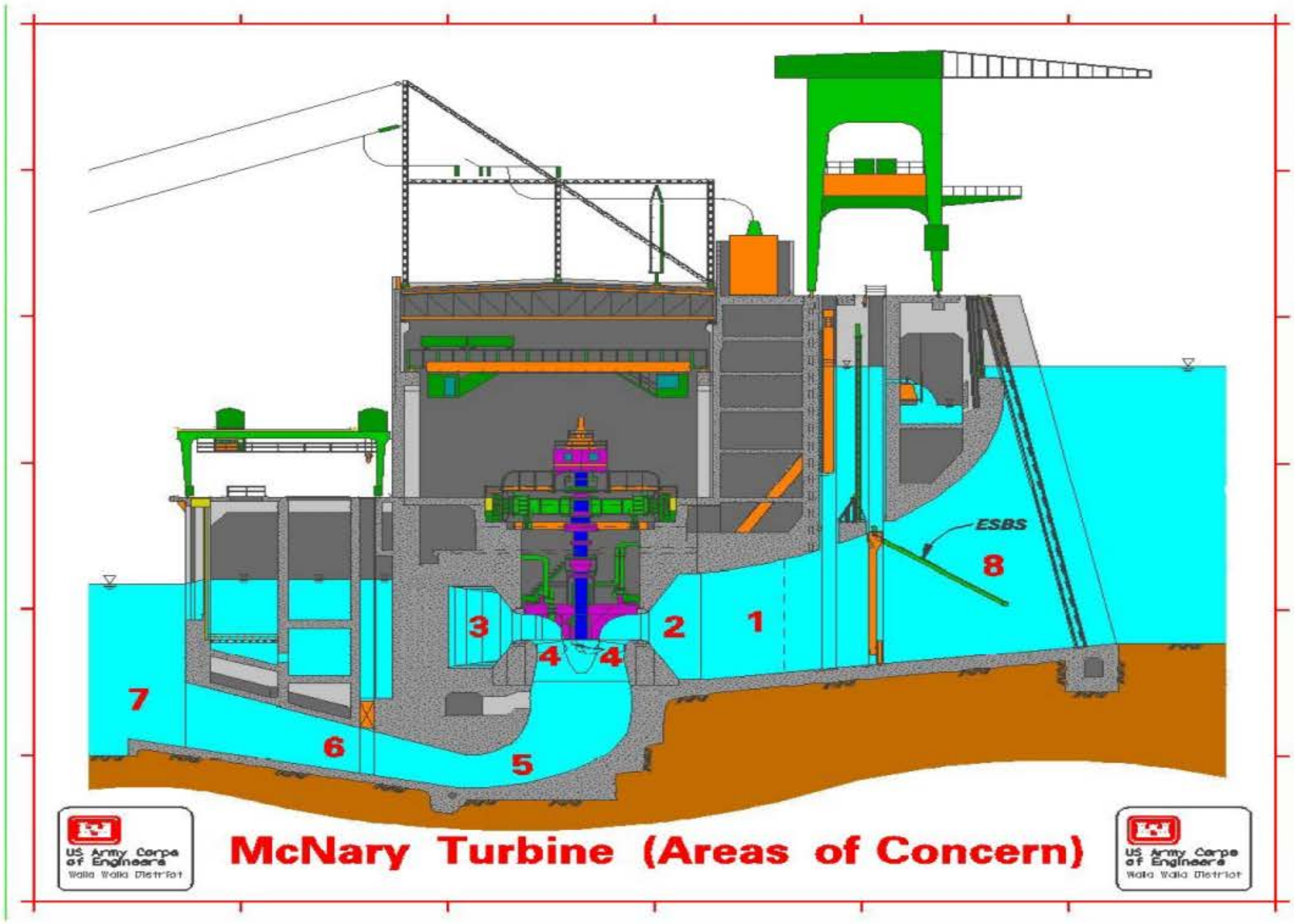
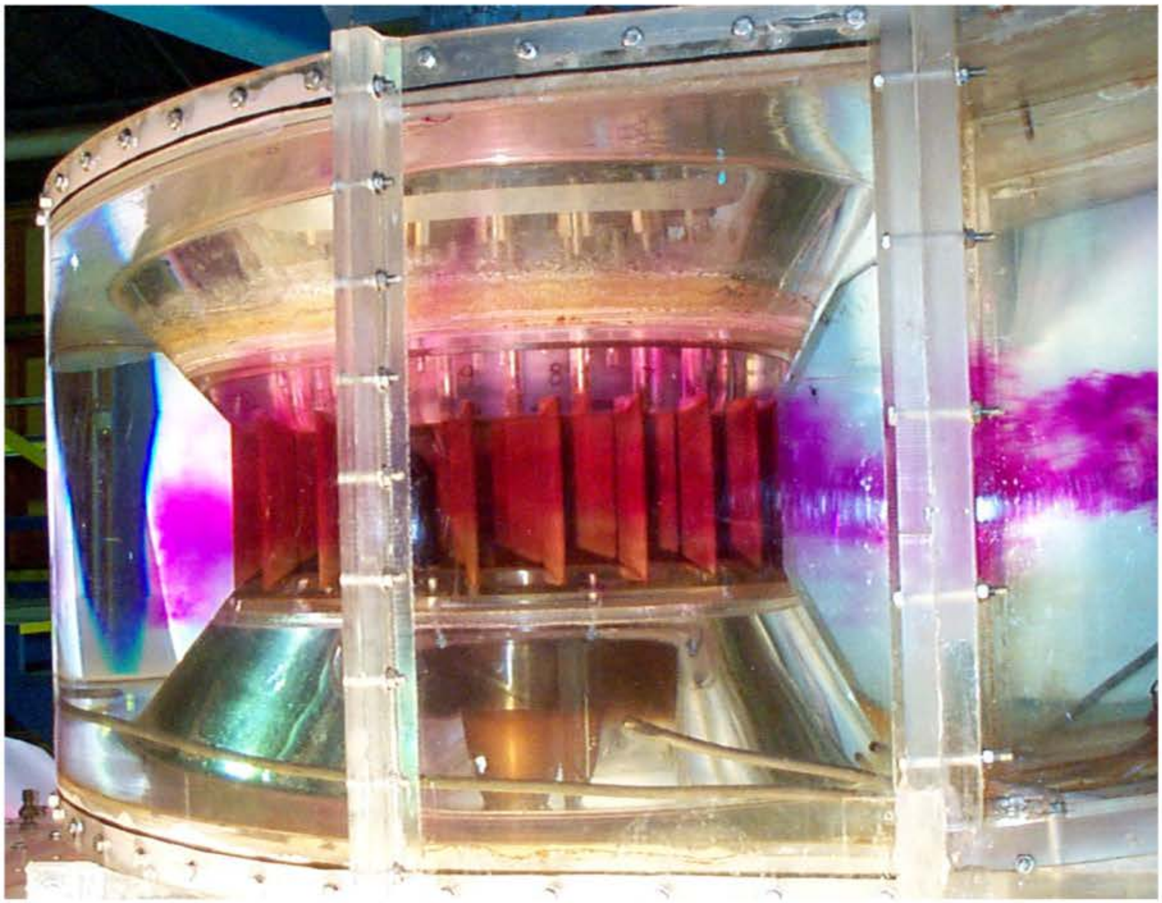
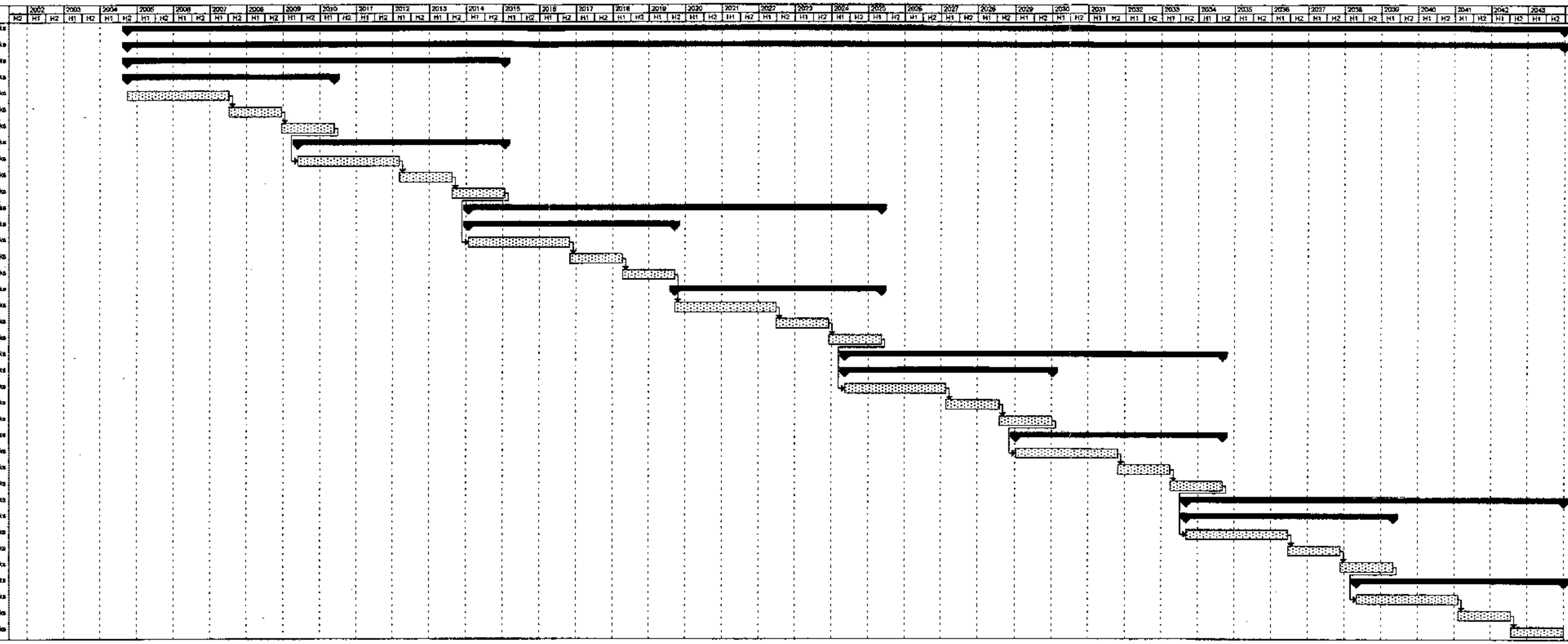


Plate A. McNary 1:25 Turbine Model.



ID	Task Name	Cost	Start	Duration
1	FUTURE COSTS, MAJOR REPAIR & REHAB COSTS	$193,555.00	10/1/04	2048 wks
2	TURBINES & POWER HOUSE REHAB	$193,544.00	10/1/04	2048 wks
3	ICE HARBOR LOCK & DAM	$53,389.00	10/1/04	636 wks
4	Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *	$30,028.00	10/1/04	295 wks
5	Turbine Unit #3 - Startup date 02/27/62 - Recieves a 11% Gen. Upgr.	$10,010.00	10/1/04	145 ewks
6	Turbine Unit #2 - Startup date 02/08/62	$10,009.00	7/13/07	75 ewks
7	Turbine Unit #1 - Startup date 12/08/61	$10,009.00	12/19/08	75 ewks
8	Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *	$23,361.00	5/28/09	295 wks
9	Turbine Unit #4 - Startup date 10/28/75	$7,787.00	5/29/09	145 ewks
10	Turbine Unit #5 - Startup date 10/18/75	$7,787.00	3/9/12	75 ewks
11	Turbine Unit #6 - Startup date 01/07/76	$7,787.00	8/16/13	75 ewks
12	LOWER MONUMENTAL LOCK & DAM	$46,722.00	1/24/14	590 wks
13	Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *	$23,361.00	1/24/14	295 wks
14	Turbine Unit #3 - Startup date 01/08/70	$7,787.00	1/24/14	145 ewks
15	Turbine Unit #2 - Startup date 09/08/69	$7,787.00	11/4/16	75 ewks
16	Turbine Unit #1 - Startup date 05/28/69	$7,787.00	4/13/18	75 ewks
17	Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *	$23,361.00	9/20/19	295 wks
18	Turbine Unit #4 - Startup date 02/01/78	$7,787.00	9/20/19	145 ewks
19	Turbine Unit #5 - Startup date 03/23/79	$7,787.00	7/1/22	75 ewks
20	Turbine Unit #6 - Startup date 06/01/79	$7,787.00	12/8/23	75 ewks
21	LITTLE GOOSE LOCK & DAM	$46,722.00	5/17/24	638 wks
22	Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *	$23,361.00	5/17/24	295 wks
23	Turbine Unit #3 - Startup date 12/08/70	$7,787.00	5/17/24	145 ewks
24	Turbine Unit #2 - Startup date 10/30/70	$7,787.00	2/26/27	75 ewks
25	Turbine Unit #1 - Startup date 03/26/70	$7,787.00	8/4/28	75 ewks
26	Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *	$23,361.00	1/12/29	295 wks
27	Turbine Unit #4 - Startup date 02/01/79	$7,787.00	1/12/29	145 ewks
28	Turbine Unit #5 - Startup date 03/23/79	$7,787.00	10/24/31	75 ewks
29	Turbine Unit #6 - Startup date 06/01/79	$7,787.00	4/1/33	75 ewks
30	LOWER GRANITE LOCK & DAM	$46,722.00	9/9/33	631 wks
31	Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *	$23,361.00	9/9/33	295 wks
32	Turbine Unit #3 - Startup date 12/08/70	$7,787.00	9/9/33	145 ewks
33	Turbine Unit #2 - Startup date 10/30/70	$7,787.00	6/20/36	75 ewks
34	Turbine Unit #1 - Startup date 03/26/70	$7,787.00	11/27/37	75 ewks
35	Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *	$23,361.00	8/7/38	295 wks
36	Turbine Unit #4 - Startup date 02/01/79	$7,787.00	5/7/38	145 ewks
37	Turbine Unit #5 - Startup date 03/23/79	$7,787.00	2/15/41	75 ewks
38	Turbine Unit #6 - Startup date 06/01/79	$7,787.00	7/25/42	75 ewks



Years	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22
FUTURE COSTS, MAJOR REPAIR & REHAB COSTS																						
TURBINES & POWER HOUSE REHAB																						
ICE HARBOR LOCK & DAM																						
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *																						
Turbine Unit #3 - Startup date 02/27/62																						
Costs				$911	$3,590	$3,590	$1,919															
Turbine Unit #2 - Startup date 02/08/62																						
Costs							$3,256	$6,753														
Turbine Unit #1 - Startup date 12/08/61																						
Costs								$240	$6,966	$2,803												
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *																						
Turbine Unit #4 - Startup date 10/28/75																						
Costs									$1,665	$2,803	$2,793	$526										
Turbine Unit #5 - Startup date 10/18/75																						
Costs												$4,402	$3,385									
Turbine Unit #6 - Startup date 01/07/76																						
Costs													$2,035	$5,420	$332							
LOWER MONUMENTAL LOCK & DAM																						
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *																						
Turbine Unit #3 - Startup date 01/06/70																						
Costs														$2,621	$2,803	$2,363						
Turbine Unit #2 - Startup date 09/08/69																						
Costs																$851	,399	$1,537				
Turbine Unit #1 - Startup date 05/28/69																						
Costs																		$3,883	$3,904			
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *																						
Turbine Unit #4 - Startup date 02/01/79																						
Costs																			$784	$2,814	$2,803	$1,386
Turbine Unit #5 - Startup date 03/23/79																						
Costs																						$2,720
Turbine Unit #6 - Startup date 06/01/79																						
Costs																						
LITTLE GOOSE LOCK & DAM																						
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *																						
Turbine Unit #3 - Startup date 12/08/70																						
Costs																						
Turbine Unit #2 - Startup date 10/30/70																						
Costs																						
Turbine Unit #1 - Startup date 03/26/70																						
Costs																						
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *																						
Turbine Unit #4 - Startup date 02/01/79																						
Costs																						
Turbine Unit #5 - Startup date 03/23/79																						
Costs																						
Turbine Unit #6 - Startup date 06/01/79																						
Costs																						
LOWER GRANITE LOCK & DAM																						
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *																						
Turbine Unit #3 - Startup date 12/08/70																						
Costs																						
Turbine Unit #2 - Startup date 10/30/70																						
Costs																						
Turbine Unit #1 - Startup date 03/26/70																						
Costs																						
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *																						
Turbine Unit #4 - Startup date 02/01/79																						
Costs																						
Turbine Unit #5 - Startup date 03/23/79																						
Costs																						

E-D-33

'PRORATING OF OPTION COSTS - All Options with operating Dams - Power House Rehab of Turbine Generating Units

Years	*FY01*	*FY02*	*FY03*	*FY04*	*FY05*	*FY06*	*FY07*	*FY08*	*FY09*	*FY10*	*FY11*	*FY12*	*FY13*	*FY14*	*FY15*	*FY16*	*FY17*	*FY18*	*FY19*	*FY20*	*FY21*	*FY22*
Turbine Unit #6 - Startup date 06/01/79																						
Costs																						
Subtotals																						
Ice Harbor Lock & Dam																						
Costs				$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$5,420	$332							
Lower Monumental Lock & Dam																						
Costs														$2,621	$2,803	$3,214	$5,399	$5,420	$4,688	$2,814	$2,803	$4,106
Little Goose Lock & Dam																						
Costs																						
Lower Granite Lock & Dam																						
Costs																						
TOTALS																						
Costs				$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814	$2,803	$4,106

1

FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38	FY39	FY40	FY41	FY42	FY43	FY44	FY45
$5,067																						
$332	$5,441	$2,014																				
	$1,751	$2,803	$2,803	$430																		
				$4,589	$3,198																	
					$2,201	$5,420	$166															
						$2,707	$2,803	$2,277														
								$1,018	$5,441	$1,329												
										$4,070	$3,717											
										$870	$2,793	$2,803	$1,321									
													$2,866	$4,901								
														$519	$5,420	$1,848						
															$1,837	$2,793	$2,803	$354				
																		$4,735	$3,053			

E-D-35

FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38	FY39	FY40	FY41	FY42	FY43	FY44	FY45
																			$2,367	$5,420		
$5,399	$5,441	$2,014																				
	$1,751	$2,803	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$5,399	$3,717											
										$870	$2,793	$2,803	$4,207	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420		
$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420		

Draft 3/30/99

PRORATING OF OPTION COSTS - Estimated Project Costs, Options All with operating Dams - Power House Rehab of Turbines

FUTURE COSTS, MAJOR REPAIR & REHAB COSTS

TURBINES & POWER HOUSE REHAB

Years	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23
ICE HARBOR LOCK & DAM																							
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *																							
Turbine Unit #3 - Startup date 02/27/62																							
Costs				$911	$3,590	$3,590	$1,919																
Turbine Unit #2 - Startup date 02/08/62																							
Costs							$3,256	$6,753															
Turbine Unit #1 - Startup date 12/08/61																							
Costs								$240	$6,966	$2,803													
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *																							
Turbine Unit #4 - Startup date 10/26/75																							
Costs									$1,665	$2,803	$2,793	$526											
Turbine Unit #5 - Startup date 10/16/75																							
Costs												$4,402	$3,385										
Turbine Unit #6 - Startup date 01/07/76																							
Costs													$2,035	$5,420	$332								
LOWER MONUMENTAL LOCK & DAM																							
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *																							
Turbine Unit #3 - Startup date 01/06/70																							
Costs														$2,621	$2,803	$2,363							
Turbine Unit #2 - Startup date 09/08/69																							
Costs																$851	$5,399	$1,537					
Turbine Unit #1 - Startup date 05/28/69																							
Costs																		$3,883	$3,904				
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *																							
Turbine Unit #4 - Startup date 02/01/78																							
Costs																			$784	$2,814	$2,803	$1,386	
Turbine Unit #5 - Startup date 03/23/79																							
Costs																						$2,720	$5,067
Turbine Unit #6 - Startup date 06/01/79																							
Costs																							$332
LITTLE GOOSE LOCK & DAM																							
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *																							
Turbine Unit #3 - Startup date 12/08/70																							
Costs																							
Turbine Unit #2 - Startup date 10/30/70																							
Costs																							
Turbine Unit #1 - Startup date 03/26/70																							
Costs																							
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *																							
Turbine Unit #4 - Startup date 02/01/78																							
Costs																							
Turbine Unit #5 - Startup date 03/23/79																							
Costs																							
Turbine Unit #6 - Startup date 06/01/79																							
Costs																							
LOWER GRANITE LOCK & DAM																							
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *																							
Turbine Unit #3 - Startup date 12/08/70																							
Costs																							
Turbine Unit #2 - Startup date 10/30/70																							
Costs																							
Turbine Unit #1 - Startup date 03/26/70																							
Costs																							
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *																							
Turbine Unit #4 - Startup date 02/01/79																							
Costs																							
Turbine Unit #5 - Startup date 03/23/79																							
Costs																							
Turbine Unit #6 - Startup date 06/01/79																							
Costs																							
Subtotals																							
Ice Harbor Lock & Dam																							
Costs				$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$5,420	$332								
Lower Monumental Lock & Dam																							
Costs														$2,621	$2,803	$3,214	$5,399	$5,420	$4,688	$2,814	$2,803	$4,106	$5,399
Little Goose Lock & Dam																							
Costs																							
Lower Granite Lock & Dam																							
Costs																							
TOTALS																							
Costs				$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814	$2,803	$4,106	$5,399

Years	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38	FY39	FY40	FY41	FY42	FY43	FY44	FY45
ICE HARBOR LOCK & DAM																						
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *																						
Turbine Unit #3 - Startup date 02/27/62																						
Costs																						
Turbine Unit #2 - Startup date 02/08/62																						
Costs																						
Turbine Unit #1 - Startup date 12/08/61																						
Costs																						
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *																						
Turbine Unit #4 - Startup date 10/26/75																						
Costs																						
Turbine Unit #5 - Startup date 10/16/75																						
Costs																						
Turbine Unit #6 - Startup date 01/07/76																						
Costs																						
LOWER MONUMENTAL LOCK & DAM																						
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *																						
Turbine Unit #3 - Startup date 01/06/70																						
Costs																						
Turbine Unit #2 - Startup date 09/08/69																						
Costs																						
Turbine Unit #1 - Startup date 05/28/69																						
Costs																						
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *																						
Turbine Unit #4 - Startup date 02/01/78																						
Costs																						
Turbine Unit #5 - Startup date 03/23/79																						
Costs																						
Turbine Unit #6 - Startup date 06/01/79																						
Costs	$5,441	$2,014																				
LITTLE GOOSE LOCK & DAM																						
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *																						
Turbine Unit #3 - Startup date 12/08/70																						
Costs	$1,751	$2,803	$2,803	$430																		
Turbine Unit #2 - Startup date 10/30/70																						
Costs				$4,589	$3,198																	
Turbine Unit #1 - Startup date 03/26/70																						
Costs					$2,201	$5,420	$166															
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *																						
Turbine Unit #4 - Startup date 02/01/78																						
Costs						$2,707	$2,803	$2,277														
Turbine Unit #5 - Startup date 03/23/79																						
Costs								$1,018	$5,441	$1,329												
Turbine Unit #6 - Startup date 06/01/79																						
Costs										$4,070	$3,717											
LOWER GRANITE LOCK & DAM																						
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *																						
Turbine Unit #3 - Startup date 12/08/70																						
Costs										$870	$2,793	$2,803	$1,321									
Turbine Unit #2 - Startup date 10/30/70																						
Costs													$2,886	$4,901								
Turbine Unit #1 - Startup date 03/26/70																						
Costs														$519	$5,420	$1,848						
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *																						
Turbine Unit #4 - Startup date 02/01/79																						
Costs															$1,837	$2,793	$2,803	$354				
Turbine Unit #5 - Startup date 03/23/79																						
Costs																		$4,735	$3,053			
Turbine Unit #6 - Startup date 06/01/79																						
Costs																			$2,367	$5,420		
Subtotals																						
Ice Harbor Lock & Dam																						
Costs																						
Lower Monumental Lock & Dam																						
Costs	$5,441	$2,014																				
Little Goose Lock & Dam																						
Costs	$1,751	$2,803	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$5,399	$3,717											
Lower Granite Lock & Dam																						
Costs										$870	$2,793	$2,803	$4,207	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420		
TOTALS																						
Costs	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420		

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE CONCEPTUAL REPORT, DATED: MARCH 97

PROJECT: ICE HARBOR, LOWER MONUMENTAL, LITTLE GOOSE, LOWER GRANITE LOCKS & DAMS
DISTRICT: Walla Walla
LOCATION: SNAKE RIVER, WASHINGTON
P.O.C.: KIM CALLAN, CHIEF, COST ENGINEERING

		CURRENT MCACES ESTIMATE PREPARED: 10 MAR 97 EFFECTIVE PRICING LEVEL: 1 OCT 96				AUTHORIZ./BUDGET YEAR: 1999 EFFECT. PRICING LEVEL: 1 OCT 98			.........FULLY FUNDED ESTIMATE.........			
ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	COST ($K)	CNTG ($K)	TOTAL ($K)	SPENT THRU FY 97 ($K)	COST ($K)	CNTG ($K)	FULL ($K)
07.--	POWER PLANTS - (MIN GAP)	125,607	25,125	20%	150,732	128,872	25,781	154,653		128,872	25,781	154,653
	Advances in Turbine Technology **(ATT)**	4,320	864	20%	5,184	4,432	888	5,320		4,432	888	5,320
	Cam Field Index Testing	181	36	20%	217	186	37	223		186	37	223
	3-D Cam Improvements	599	120	20%	719	615	123	738		615	123	738
	GOVERNMENT FURNISH SERVICES	100	20	20%	120	103	21	124		103	21	124
	TOTAL CONSTRUCTION COSTS ====>	130,807	26,165	20%	156,972	134,208	26,850	161,058		134,208	26,850	161,058
30---	PLANNING, ENGINEERING & DESIGN	17,680	3,534	20%	21,214	18,137	3,629	21,766		18,137	3,629	21,766
30---	Planning, Engineering & Design **(ATT)**	440	88	20%	528	448	88	536		448	88	536
31---	CONSTRUCTION MANAGEMENT	10,970	2,200	20%	13,170	11,251	2,259	13,510		11,251	2,259	13,510
31---	Construction Management **(ATT)**											
	TOTAL PROJECT COSTS =========>	159,898	31,987	20%	191,884	164,044	32,826	196,870		164,044	32,826	196,870

THIS TICS REFLECTS A PROJECT COST CHANGE OF $

TOTAL FEDERAL COSTS ===============> 196,870
TOTAL NON-FEDERAL COSTS ==========>

DISTRICT APPROVED: DISTRICT APPROVED DATE: ______________

THE MAXIMUM PROJECT COST IS =======> $

______________ CHIEF, COST ENGINEERING, Kim Callan

______________ CHIEF, REAL ESTATE, Richard Carlton

______________ CHIEF, PLANNING, Dennis Cannon

______________ CHIEF, ENGINEERING, Surya Bhamidipaty

______________ CHIEF, OPERATIONS, Wayne John

______________ CHIEF, CONSTRUCTION, John Treadwell

______________ CHIEF, CONTRACTING, Jackie Anderson

______________ PROJECT MANAGER, Greg Graham
______________ CHIEF, PM-PB, George Veighey
______________ DDE (PM), Mark Charlton

DIVISION APPROVED:

______________ CHIEF, COST ENGINEERING, Wally Brassfield

______________ DIRECTOR, REAL ESTATE, Cynthia Brown

______________ CHIEF, PROGRAMS & PROJECT MANAGEMENT, John Velehradsky

______________ DIRECTOR OF PPMD, Acting, Clyde Barnhill

DIVISION APPROVED DATE: ______________

NOTE: Valid when only when completely signed.

Walla Walla District

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE CONCEPTUAL REPORT, DATED: MARCH 97

PROJECT: ICE HARBOR, LOCK & DAM — DISTRICT: Walla Walla

LOCATION: SNAKE RIVER, WASHINGTON — P.O.C.: KIM CALLAN, CHIEF, COST ENGINEERING

	CURRENT MCACES ESTIMATE PREPARED: 10 MAR 97 EFFECTIVE PRICING LEVEL: 1 OCT 96					AUTHORIZ./BUDGET YEAR: 1999 EFFECT. PRICING LEVEL: 1 OCT 98				........FULLY FUNDED ESTIMATE.........				
ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
	CONTRACT FOR 1/2 THE POWER HOUSE #1, #2, AND #3 OF ICE HARBOR LOCK & DAM													
07.--	POWER PLANTS (MIN GAP)	**3 Units Each**												
07.02.--	**TURBINES AND GENERATORS**													
07.02.00.--	GENERAL (MOB. & DEMOB.)	239	48	20%	287	2.6%	245	49	294	FY00		245	49	294
07.02.76.--	TURBINE WORK, 3 each	6,307	1,261	20%	7,568	2.6%	6,471	1,294	7,765	FY00		6,471	1,294	7,765
07.02.77.--	GOVERNORS, 3 each, (included in O&M costs)													
07.02.78.--	GENERATOR WORK, 3 each	8,255	1,651	20%	9,906	2.6%	8,469	1,694	10,163	FY00		8,469	1,694	10,163
07.02.79.--	ELECTRONIC EXCITERS, 3 each, (included in O&M costs)													
07.02.85.--	STATN. SERVICE & UNIT PROT. 1 each , (included in O&M costs)													
07.02.90.--	MISCELLANEOUS HIRE, 3 each	339	68	20%	406	2.6%	348	70	418	FY00		348	70	418
07.03.--	**ACCESSORY ELECTRICAL EQUIPMENT** (Required for a 11% generator rewind)													
07.03.00.--	GENERAL (MOB. & DEMOB.)	64	13	20%	76	2.6%	65	13	78	FY00		65	13	78
07.03.87.--	POWER TRANSFORMER 3 each	4,401	882	20%	5,283	2.6%	4,515	905	5,420	FY00		4,515	905	5,420
	SUBTOTAL CONSTRUCTION COSTS ====>	19,604	3,923	20%	23,526		20,113	4,025	24,138			20,113	4,025	24,138
07.02.--	**IMPROVED TURBINE COSTS**													
07.02.76.--	Advances in Turbine Technology **(ATT)**	540	108	20%	648	2.6%	554	111	665	FY00		554	111	665
	TOTAL CONSTRUCTION COSTS(1 Contract)=>	20,144	4,031	20%	24,174		20,667	4,136	24,803			20,667	4,136	24,803
30---	PLANNING, ENGINEERING & DESIGN													
1.08%	Project Management	212	43	20%	255	2.6%	217	44	261	FY00		217	44	261
0.14%	Planning & Environmental Compliance	26	6	20%	32	2.6%	27	6	33	FY00		27	6	33
2.14%	Engineering & Design	421	84	20%	505	2.6%	432	86	518	FY00		432	86	518
3.27%	Engineering & Design (HDC)	640	129	20%	769	2.6%	657	132	789	FY00		657	132	789
0.91%	Engineering Tech Review & VE	177	35	20%	212	2.6%	182	36	218	FY00		182	36	218
0.46%	Contracting & Reprographics	91	19	20%	110	2.6%	93	19	112	FY00		93	19	112
1.36%	Engineering During Construction	265	54	20%	319	2.6%	272	55	327	FY00		272	55	327
3.39%	Engineering During Construction (HDC)	664	133	20%	797	2.6%	681	136	817	FY00		681	136	817
10.00%	Planning, Engineering & Design **(ATT)**	55	11	20%	66	2.6%	56	11	67	FY00		56	11	67
	Total 30 Account (One Contract)======>	2,551	514	20%	3,065		2,617	525	3,142			2,617	525	3,142
31---	CONSTRUCTION MANAGEMENT													
1.08%	Project Management	212	43	20%	255	2.6%	217	44	261	FY00		217	44	261
7.55%	Construction Management	1,480	296	20%	1,776	2.6%	1,518	304	1,822	FY00		1,518	304	1,822
	Construction Management **(ATT)**			20%		2.6%				FY00				
	TOTAL COSTS (One Contract)====>	24,387	4,884	20%	29,270		25,019	5,009	30,028			25,019	5,009	30,028
1	**CONTRACTS (REQUIRED) COST ===>**	24,387	4,884	20%	29,270		25,019	5,009	30,028			25,019	5,009	30,028
1	Contracts (times the number of units/contract)	3 Units per Contract			3	= Total Units for this part of lower Snake River Dams				30,028				

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE CONCEPTUAL REPORT, DATED: MARCH 97

PROJECT: ICE HARBOR, LOWER MONUMENTAL, LITTLE GOOSE, LOWER GRANITE LOCKS & DAMS — DISTRICT: Walla Walla

LOCATION: SNAKE RIVER, WASHINGTON — P.O.C.: KIM CALLAN, CHIEF, COST ENGINEERING

ACCOUNT NUMBER	FEATURE DESCRIPTION	CURRENT MCACES ESTIMATE PREPARED: 10 MAR 97 / EFFECTIVE PRICING LEVEL: 1 OCT 96 COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	AUTHORIZ./BUDGET YEAR: 1999 / EFFECT. PRICING LEVEL: 1 OCT 98 OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	........FULLY FUNDED ESTIMATE........ FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
	TYPICAL CONTRACT FOR 1/2 THE POWER HOUSE OF EACH SNAKE RIVER DAM (except Ice Harbor Unit #1, #2 & #3)													
07.--	POWER PLANTS (MIN GAP) **3 Units Each**													
07.02.--	**TURBINES AND GENERATORS**													
07.02.00.--	GENERAL (MOB. & DEMOB.)	239	48	20%	287	2.6%	245	49	294	FY00		245	49	294
07.02.76.--	TURBINE WORK, 3 each	6,309	1,262	20%	7,571	2.6%	6,473	1,295	7,768	FY00		6,473	1,295	7,768
07.02.77.--	GOVERNORS, 3 each, (Included in O&M costs)													
07.02.78.--	GENERATOR WORK, 3 each	8,257	1,651	20%	9,908	2.6%	8,471	1,694	10,165	FY00		8,471	1,694	10,165
07.02.79.--	ELECTRONIC EXCITERS, 3 each, (Included in O&M costs)													
07.02.85.--	STATN. SERVICE & UNIT PROT, 1 each , (Included in O&M costs)													
07.02.90.--	MISCELLANEOUS HIRE, 3 each	339	68	20%	407	2.6%	348	70	418	FY00		348	70	418
07.03.--	**ACCESSORY ELECTRICAL EQUIPMENT**- (Not required for only a 5% generator rewind)													
07.03.00.--	GENERAL (MOB. & DEMOB.)													
07.03.87.--	POWER TRANSFORMER 3 each													
	SUBTOTAL CONSTRUCTION COSTS ====>	15,143	3,029	20%	18,172		15,537	3,108	18,645			15,537	3,108	18,645
07.02.--	**IMPROVED TURBINE COSTS**													
07.02.76.--	Advances in Turbine Technology **(ATT)**	540	108	20%	648	2.6%	554	111	665	FY00		554	111	665
	TOTAL CONSTRUCTION COSTS(1 Contract)=>	15,683	3,137	20%	18,820		16,091	3,219	19,310			16,091	3,219	19,310
30---	PLANNING, ENGINEERING & DESIGN													
1.08%	Project Management	163	33	20%	196	2.6%	167	34	201	FY00		167	34	201
0.14%	Planning & Environmental Compliance	20	4	20%	24	2.6%	21	4	25	FY00		21	4	25
2.14%	Engineering & Design	325	65	20%	390	2.6%	333	67	400	FY00		333	67	400
3.27%	Engineering & Design (HDC)	495	99	20%	594	2.6%	508	102	610	FY00		508	102	610
0.91%	Engineering Tech Review & VE	137	27	20%	164	2.6%	141	28	169	FY00		141	28	169
0.46%	Contracting & Reprographics	70	14	20%	84	2.6%	72	14	86	FY00		72	14	86
1.36%	Engineering During Construction	206	41	20%	247	2.6%	211	42	253	FY00		211	42	253
3.39%	Engineering During Construction (HDC)	513	102	20%	615	2.6%	526	105	631	FY00		526	105	631
10.00%	Planning, Engineering & Design **(ATT)**	55	11	20%	66	2.6%	56	11	67	FY00		56	11	67
	Total 30 Account (One Contract)======>	1,984	396	20%	2,380		2,035	407	2,442			2,035	407	2,442
31---	CONSTRUCTION MANAGEMENT													
1.08%	Project Management	163	33	20%	196	2.6%	167	34	201	FY00		167	34	201
7.55%	Construction Management	1,143	229	20%	1,372	2.6%	1,173	235	1,408	FY00		1,173	235	1,408
	Construction Management **(ATT)**			20%		2.6%				FY00				
	TOTAL COSTS (One Contract)====>	18,973	3,795	20%	22,768		19,466	3,895	23,361			19,466	3,895	23,361
7	**CONTRACTS (REQUIRED) COST ===>**	132,813	26,564	20%	159,377		136,262	27,265	163,527			136,262	27,265	163,527
8	Contracts (times the number of units/contract)	3 Units per Contract			24	= Total Units for the lower Snake River Dams				193,555				

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE CONCEPTUAL REPORT, DATED: MARCH 97

PROJECT: ICE HARBOR, LOWER MONUMENTAL, LITTLE GOOSE, LOWER GRANITE LOCKS & DAMS — DISTRICT: Walla Walla

LOCATION: SNAKE RIVER, WASHINGTON — P.O.C.: KIM CALLAN, CHIEF, COST ENGINEERING

	CURRENT MCACES ESTIMATE PREPARED: 10 MAR 97 EFFECTIVE PRICING LEVEL: 1 OCT 96					AUTHORIZ./BUDGET YEAR: 1999 EFFECT. PRICING LEVEL: 1 OCT 98				........FULLY FUNDED ESTIMATE.........				
ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
	ICE HARBOR, LOWER MONUMENTAL, LITTLE GOOSE & LOWER GRANITE LOCKS &													
06.2--	GOVERNMENT FURNISH MATERIALS	100	20	20%	120	2.6%	103	21	124	FY00		103	21	124
	FABRICATE INDEX TEST FRAME 2 EACH													
30---	PLANNING, ENGINEERING & DESIGN													
15.00%	Engineering & Design	16	3	20%	19	2.6%	16	3	19	FY00		16	3	19
4.00%	Contracting & Reprographics	4	1	20%	5	2.6%	4	1	5	FY00		4	1	5
	TOTAL GFS COSTS =====>	120	24	20%	144		123	25	148			123	25	148
	ICE HARBOR, LOWER MONUMENTAL, LITTLE GOOSE & LOWER GRANITE LOCKS &													
07.--	3-D Cam - Index Testing	**181**	36	20%	217	2.6%	186	37	223	FY00		186	37	223
	for 24 Turbines - (6 Turbines on each of the 4 dams).													
	Call Rodney Wittinger for backup. (503) 808-4280													
	TOTAL CONSTRUCTION COSTS =====>	181	36	20%	217		186	37	223			186	37	223
30---	PLANNING, ENGINEERING & DESIGN													
27.65%	Project Management	50	10	20%	60	2.6%	51	10	61	FY00		51	10	61
	Planning & Environmental Compliance													
128.50%	Engineering & Design	232	46	20%	278	2.6%	238	48	286	FY00		238	48	286
186.55%	Engineering & Design (HDC)	337	67	20%	404	2.6%	346	69	415	FY00		346	69	415
	Engineering & Design (Project)													
	Engineering Tech Review & VE													
2.00%	Contracting & Reprographics	4	1	20%	5	2.6%	4	1	5	FY00		4	1	5
40.44%	Engineering During Testing	73	15	20%	88	2.6%	75	15	90	FY00		75	15	90
186.55%	Engineering During Testing (HDC)	337	67	20%	404	2.6%	346	69	415	FY00		346	69	415
124.20%	Engineering During Testing (Project))	225	45	20%	270	2.6%	230	46	276	FY00		230	46	276
	Total 30 Account ======>	1,259	251	20%	1,509		1,290	258	1,548			1,290	258	1,548
31---	CONSTRUCTION MANAGEMENT													
27.65%	Project Management	50	10	20%	60		50	10	60	FY00		50	10	60
10.00%	Construction Management	18	4	20%	22		18	4	22	FY00		18	4	22
	TOTAL COSTS ================>	1,507	301	20%	1,808		1,544	309	1,853			1,544	309	1,853

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE CONCEPTUAL REPORT, DATED: MARCH 97

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LOCATION: SNAKE RIVER, WASHINGTON — P.O.C.: KIM CALLAN, CHIEF, COST ENGINEERING

		CURRENT MCACES ESTIMATE PREPARED: 10 MAR 97 EFFECTIVE PRICING LEVEL: 1 OCT 96				AUTHORIZ./BUDGET YEAR: 1999 EFFECT. PRICING LEVEL: 1 OCT 98				........FULLY FUNDED ESTIMATE.........				
ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
	ICE HARBOR, LOWER MONUMENTAL, LITTLE GOOSE & LOWER GRANITE LOCKS &													
07.--	3-D Cam Improvements	**599**	120	20%	719	2.6%	615	123	738	FY00		615	123	738
	for 24 Turbines - (6 Turbines on each of the 4 dams).													
	Call Rodney Wittinger for backup. (503) 808-4280													
	TOTAL CONSTRUCTION COSTS =====>	599	120	20%	719		615	123	738			615	123	738
30---	PLANNING, ENGINEERING & DESIGN													
8.34%	Project Management	50	10	20%	60	2.6%	51	10	61	FY00		51	10	61
	Planning & Environmental Compliance													
10.90%	Engineering & Design	65	13	20%	78	2.6%	67	13	80	FY00		67	13	80
8.01%	Engineering & Design (HDC)	48	10	20%	58	2.6%	49	10	59	FY00		49	10	59
4.00%	Engineering & Design (Project)	24	5	20%	29	2.6%	25	5	30	FY00		25	5	30
	Engineering Tech Review & VE													
4.00%	Contracting & Reprographics	7	1	20%	8	2.6%	7	1	8	FY00		7	1	8
4.17%	Engineering During Construction	25	5	20%	30	2.6%	26	5	31	FY00		26	5	31
25.51%	Engineering During Construction (HDC)	153	31	20%	184	2.6%	157	31	188	FY00		157	31	188
5.07%	Engineering During Construction (Project))	30	6	20%	36	2.6%	31	6	37	FY00		31	6	37
	Total 30 Account ======>	403	81	20%	483		413	81	494			413	81	494
31---	CONSTRUCTION MANAGEMENT													
8.34%	Project Management	50	10	20%	60		50	10	60	FY00		50	10	60
10.00%	Construction Management	18	4	20%	22		18	4	22	FY00		18	4	22
	TOTAL COSTS =================>	1,070	214	20%	1,285		1,096	218	1,314			1,096	218	1,314

ANNEX E

IMPLEMENTATION COSTS AND SCHEDULES

TABLE OF CONTENTS

1. Implementation Costs and Schedules

1.1 General

The following cost graphs, tables, and schedules are developed by Cost Engineering Branch, Engineering Division. All Corps' Federal costs and the Bureau of Reclamation's (BOR) water acquisition costs are included in these documents. Cost information includes costs for construction, operating, and maintenance as well as other specific federal requirements. The costs were developed as comparison type costs for use in the economic studies and option selecting. Costs do not include escalation and are not intended to be used as program funding estimates. These costs are based on the scope of work, assumptions, and methodology presented in this report, "Detailed Project Schedule PB-2A" (PB-2A) and engineering annexes (Annexes A through D of this appendix). Final cost comparisons will take place in Appendix H, Economics. Graphs and schedules show costs out to year 2045.

Costs were gathered for the nine options for operating the four lower Snake River Dams

1. Option A-1, Existing System — Existing Conditions
2. Option A-1a, Existing System — In-River Conditions
3. Option A-2a, Existing System — Maximum Transport
4. Option A-2b, Major System Improvements — (SBC) with Maximum Transport (<u>high</u> cost)
5. Option A-2c, Major System Improvements — (SBC) with Maximum Transport (<u>low</u> cost)
6. Option A-2d, Major System Improvements — (SBC) Adaptive Migration Strategy
7. Option A-6a, Major System Improvements — (Maximum SBC) In-River Passage <u>without</u> BGS Extra BOR Water purchased
8. Option A-6b, Major System Improvements — (Maximum SBC) In-River Passage <u>without</u> BGS
9. Option A-6d, Major System Improvements — (SBC) In-River Passage <u>with</u> BSG

1.2 Methodology Used for Development of Implementation Costs

1.2.1 General

This report includes concept level cost estimates. Estimates and costs obtained were developed for each of the nine options. Costs were developed based on a 100-year life cycle analysis. All costs were at a price level for October 1, 1998 (start of the fiscal year). For economic comparison purposes, no allowance for inflation to cover construction time is included. A period was shown for year 2001 to year 2045. Costs will level out at year 2045. Second Power Rehab Costs are not shown in the graph because they occur after 2045, but are still used in the economic analysis.

1.2.2 Construction and Acquisition Costs

Construction and acquisition short point-in-time costs are based on PB-2A, conceptual design reports, and supporting documents. These budgetary costs include costs for contracts, construction, prototypes, testing and development, feasibility studies, real estate, cultural resources, engineering and design, construction management, and project management. The major assumptions are that fish passage around the projects will be maintained during construction. In-water construction work will be allowed to occur during limited fish windows, which occur during non-fish migration periods. Other assumptions and costs are documented in the annex reports. The cost for construction and acquisition occur for a short duration period of these economic studies.

1.2.3 Anadromous Fish Evaluation Program Costs

Anadromous fish evaluation program (AFEP) annual costs are for testing, research, development, and evaluation on how the dam improvements are working. These study costs occur for the first 25 years (approximate) of the construction and rehab improvements.

1.2.4 Operations and Maintenance Costs

Operations and maintenance (O&M) annual costs are based on history records received from Programs Management Branch. They are tabulated and broken out per work breakdown structure and separated into O&M costs for each dam. Minor and major rehab repair costs such as costs for navigation locks, spillways, minor turbine repairs, dredging, fish transportation, and miscellaneous costs are included in the O&M cost data. Costs for major rehab of the powerhouse are not included. These costs are included below.

1.2.5 Minor Repairs Costs

Cost for minor repair is shown as a annual cost developed as a percentage based on annual O&M costs. An additional percentage was used to cover cost of aging equipment and increase dredging costs. When minor repairs and O&M costs are combined, they come up with the complete cost to operate and maintain the four Snake River dams except for major rehab of the dam turbine and generator units. These operating, maintaining, and minor repair costs occur for the full duration of the economic studies.

1.2.6 Major Repair and Rehab Costs

Major present short point-in-time costs are for completely rehabbing all 24 turbine and generator units. This rehab includes the turbines, the turbine blades (six blades per turbine), rewinding generators, and miscellaneous work. Because of the time spanned by economic study, more than one rehab cost will be required. The second turbine rehabs are not shown in the table or on the graphs because they are so far into the future. The second rehab costs are included in the economic studies report. These major repair and rehab costs occur for the defined many short duration periods of the economic studies.

1.2.7 Fish Hatcheries

Fish hatcheries annual costs are for operating, repair, and rehab of the fish hatcheries. The costs for operating and maintaining the fish hatcheries occur for the full duration of the economic studies.

1.2.8 Bureau of Reclamation Water Acquisition and Transaction

BOR water acquisition annual costs are for extra water and flow needed to pass more water flow over the dams during critical flow times. Average costs were used in the developing of these costs. The water is purchased from natural (irrigator) flow rights, changes in Snake River reservoirs operations, and additional water from BOR storage reservoirs. These water purchase costs occur for the full duration of the economic studies.

1.3 Backup of the Implementation Costs

1.3.1 General

The costs were gathered from the sources listed below. Further descriptions of these items can be found in Annexes A through D of this appendix. If the below tasks do not have funds currently appropriated, funding documents may be developed, submitted, and approved before work can start on those items.

1.3.2 Fish Improvement I (Construction General Funds)

All listed budget costs for Fish Improvements were obtained the from the program manager's PB-2A program cost printout dated October 1, 1998, except for the following items:

- DGAS 1 – 2 End Bay Deflectors
- DGAS 2 – Modified Existing 8 or 10 Deflectors (lower the elevation of the deflectors)
- Cam Field Test Improvement Studies on eight different types of turbines
- 3-D Cam Improvements for 24 each turbines.

October 1, 1998 PB-2A costs are currently in the construction general (CG) budget. These costs come from Programs Management Branch and the program managers have backups to these costs. These PB-2A costs were developed in Programs Management Branch and supplied by CENWW-PM-PB. Funding is currently appropriated in the existing CG budget. The costs backup for the above item 1 through 4 can be found the appropriate annex.

The DGAS 1 and 2 listed budget costs came from the "Dissolved Gas Abatement Study of Investigations of Additional Spillways and Side Channel Gas Abatement Alternatives," final report dated June 1998, Contract No. DACW57-96-D-0001, and Assessment of Gas Abatement Alternatives, final report dated August 1998, Contract No. DACW57-96-D-00016. Funding is not currently appropriated in the existing CG budget.

The Cam Field Test improvement studies and 3-D Cam Improvements were developed from a presentation by CENWW-EN-DB-HY and CENWP-HDC-P. Funding is not currently appropriated in the existing CG budget.

1.3.3 Fish Improvement II (Construction General Funds)

All listed budget costs came from the Lower Snake River Surface Bypass and Collection System Combinations Conceptual Design Report, Contract No. DACW68-97-D-0002. Funding is not currently appropriated in the existing CG budget.

1.3.4 Anadromous Fish Program (Construction General Funds)

The Anadromous Fish Evaluation Program studies (AFEP) costs were developed in Planning by CENWW-PL-EP. Some of this funding is currently appropriated in the existing CG budget.

1.3.5 Annual Routine Maintenance & Repair Costs (O&M funds)

Annual routine maintenance and repair costs were developed from five years of accumulated total O&M costs. These costs were developed from actual cost supplied from CENWW-PM-PB. The listed costs are an average value of those five-year actual costs. No escalation was used in the development of these figures. Actual costs accumulated did not show any escalation tendencies. Also, congress' budget tendencies seem to prevent escalation or increases in budget. Funding is currently appropriated in the existing O&M budget.

When five extra barges were required, the extra barging costs were developed with the help of CENWW-OP-T. Funding is not currently appropriated in the existing O&M budget.

The extra listed Surface Bypass and Collection system budget costs came from the Lower Snake River Surface Bypass and Collection System Combinations Conceptual Design Report, Contract No. DACW68-97-D-0002. Funding is not currently appropriated in the existing O&M budget.

1.3.6 Minor Repair Costs (O&M funds)

The minor repair costs were assumed to be 5 percent of all annual routine maintenance and repair costs. This information was supplied by Operations Branch. The source of funding for these extra costs will need to be procured. Current funding is only found and may be available only if the item has broken down. Funding is not currently appropriated in the existing O&M budget.

1.3.7 Major Repair and Rehab Costs (O&M funds)

Budget costs were from the Turbine Annex. These costs were derived from the Ice Harbor Lock and Dam Power House Major Rehabilitation (Rehab) Program in-house work report dated March 1997. The source of funding for these extra costs is unknown. Current funding is available only if the item has broken down. At this time, funds can be found to fix the item. Funding is not currently appropriated in the existing O&M budget.

1.3.8 Costs for Others, Fish Hatcheries (O&M funds)

These costs were developed from actual cost supplied from CENWW-PM-PB with the help of CENWW-OP-T. Funding is currently appropriated in the existing O&M budget.

1.3.9 Bureau of Reclamation – Water Acquisition and Transaction Costs

BOR supplied these costs from the "Snake River Flow Augmentation Impact Analysis Appendix" dated February 1999. Funding is currently appropriated in their existing O&M budget for the lower flows.

1.4 Implementation Schedules

1.4.1 General

Schedules do not reflect potential problems associated with political restraints such as limited funding per year. The yearly costs funding profile graphs show the funds required to accomplish the work on schedule (without inflation). Final schedules and project costs are dependent on funding limitations and will be adjusted accordingly.

The schedule assumes that a decision will be made and the work will start in the FY 2001 (October 1, 2000).

Research is being conducted on the fish program. As new data are analyzed, certain requirements may change and costs may vary. There were no additional costs included with future improvements to existing fish facilities that may occur upon completion of research.

The 24 lower Snake River dam turbine units have an approximate life span of 25 to 50 years. It takes approximately 10 years to rehab six turbine units at each dam. Only *one* turbine unit can be rehabbed at a time for several reasons including power maintenance and funding limitations. When the final of turbine units is rehabbed, the final turbine unit rehab may be completed +10 years after its estimated fifty years life span (see schedule). This method is a conservative approach to rehab of the turbine units.

Note: Only the 24 turbine unit's initial rehabs are shown on these spreadsheets and graphs. Due to the economic studies duration of a 100 years, the second turbine units rehabs costs are not shown in the graph but will be included in the decision economic analysis.

Schedules, concept costs, and this program are under development and are subject to change as direction and funding are made available. All annual costs are an approximation of fluctuating costs and funding, and subject to changes over time.

1.4.2 Summary of Completion Dates

The following are Construction and Acquisition Costs activities' approximate start and finish dates:

For more informative schedules see option schedules printouts.

Option A-1, Existing System Existing Conditions	Starts 10/1/2000 (Voluntary spill operating conditions)	Finishes 1/1/2005
Option A-1a, Existing System In-River (Logic Option)	Starts 10/1/2000 (Voluntary spill operating conditions)	Finishes 1/1/2005
Option A-2a, Existing System Maximum Transport	Starts 10/1/2000 (No voluntary spill operating except at Ice Harbor Dam)	Finishes 1/1/2005
Option A-2b, Major System Improvements with Maximum Transport (High Costs)	Starts 10/1/2000 (No voluntary spill operating except at Ice Harbor Dam)	Finishes 1/1/2011
OptionA-2c, Major System Improvements with Maximum Transport (Low Costs)	Starts 10/1/2000 (No voluntary spill operating except at Ice Harbor Dam)	Finishes 1/1/2007
Option A-2d, Major System Improvements Adaptive Migration Strategy	Starts 10/1/2000 (Voluntary spill operating conditions)	Finishes 1/1/2010
Option A-6a & b Major System Improvements In-River Passage without BGS str	Starts 10/1/2000 (Voluntary spill operating conditions)	Finishes 1/1/2010
Option A-6d, Major System Improvements In-River Passage with BGS str	Starts 10/1/2000 (No voluntary spill operating except at Little Goose Dam)	Finishes 1/1/2009

The two following activity items have approximate start and finish dates and are completed before the end of economic study period:

All Options First Turbine Major Rehab — Starts 10/1/2004 — Finishes 1/1/2044
(Initial Rehab only, under Operation and Maintenance Costs Grouping) (Second Rehab included in Economic Study)

Anadromous Fish Evaluation Program — Starts 10/1/2000 — Finishes 1/1/2027
(Extra work due to the Turbine Major Rehab Program)

O&M costs, BOR water purchases costs, and fish hatcheries costs are average costs and the duration is the length of the economic study period.

2. Implementation Costs - Graphs, Spreadsheets, and Schedules

2.1 Implementation Study, Summary Costs Profile Graphs

The following are summary-timed graphs showing when total yearly option costs will occur for a group of options.

Note: Summary Implementation Study Profiles were developed from each option's prorated cost spreadsheets in backup.

Graph Listings

Grouping of Items	Type of Graph	Location
Summary (of all)	Summary Implementation Study Profile	1 Page
Major System Improvements	Summary Implementation Study Profile	1 Page
Existing System	Summary Implementation Study Profile	1 Page

2.2 Implementation Study, Options Costs Profile Graphs

The following are timed graphs of when grouped yearly costs will occur for each option.

Note: Implementation Study Funding Profiles were developed from each option's prorated cost spreadsheets in backup.

Graph Listings

Options	Type of Graph	Location	Alternatives
Option A-1	Implementation Study Profile	1 Page	Alternative #1
Option A-1a	Implementation Study Profile	1 Page	
Option A-2a	Implementation Study Profile	1 Page	Alternative #2
Option A-2b	Implementation Study Profile	1 Page	
Option A-2c	Implementation Study Profile	1 Page	
Option A-2d	Implementation Study Profile	1 Page	Alternative #3
Option A-6a	Implementation Study Profile	1 Page	
Option A-6b	Implementation Study Profile	1 Page	
Option A-6d	Implementation Study Profile	1 Page	

2.3 Implementation Study, Summary Costs Spreadsheets

The following are summary cost spreadsheets for each of the options.

The total costs summary spreadsheet was developed from the Contract Detail Summary spreadsheets.

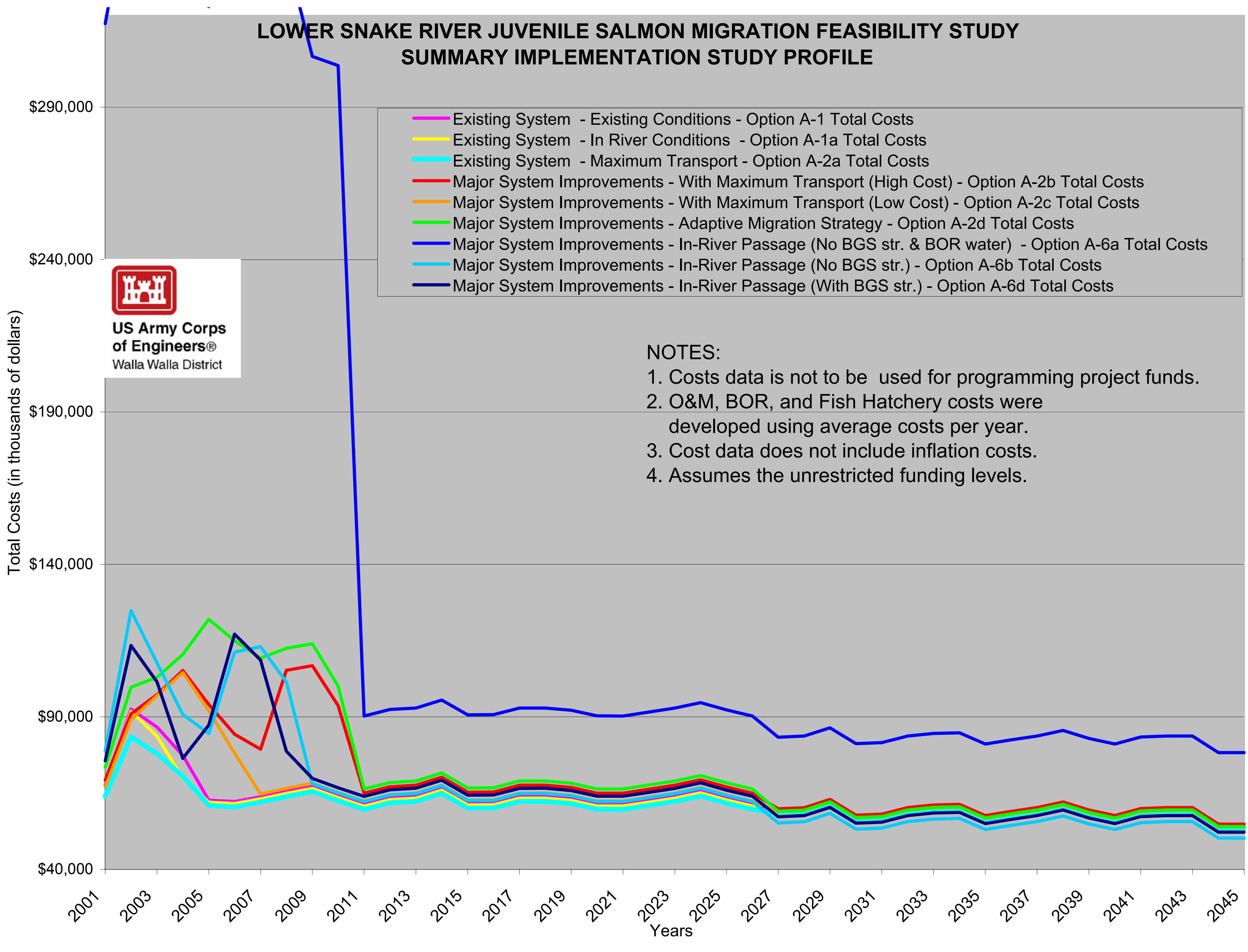
For how the Contract Detail Summary spreadsheets were developed, see paragraph 1.3 Backup of Costs.

Implementation Costs, Summary Spreadsheet	1 Page
Implementation Costs, Contract Detail Summary Spreadsheet (Expanded)	4 Pages

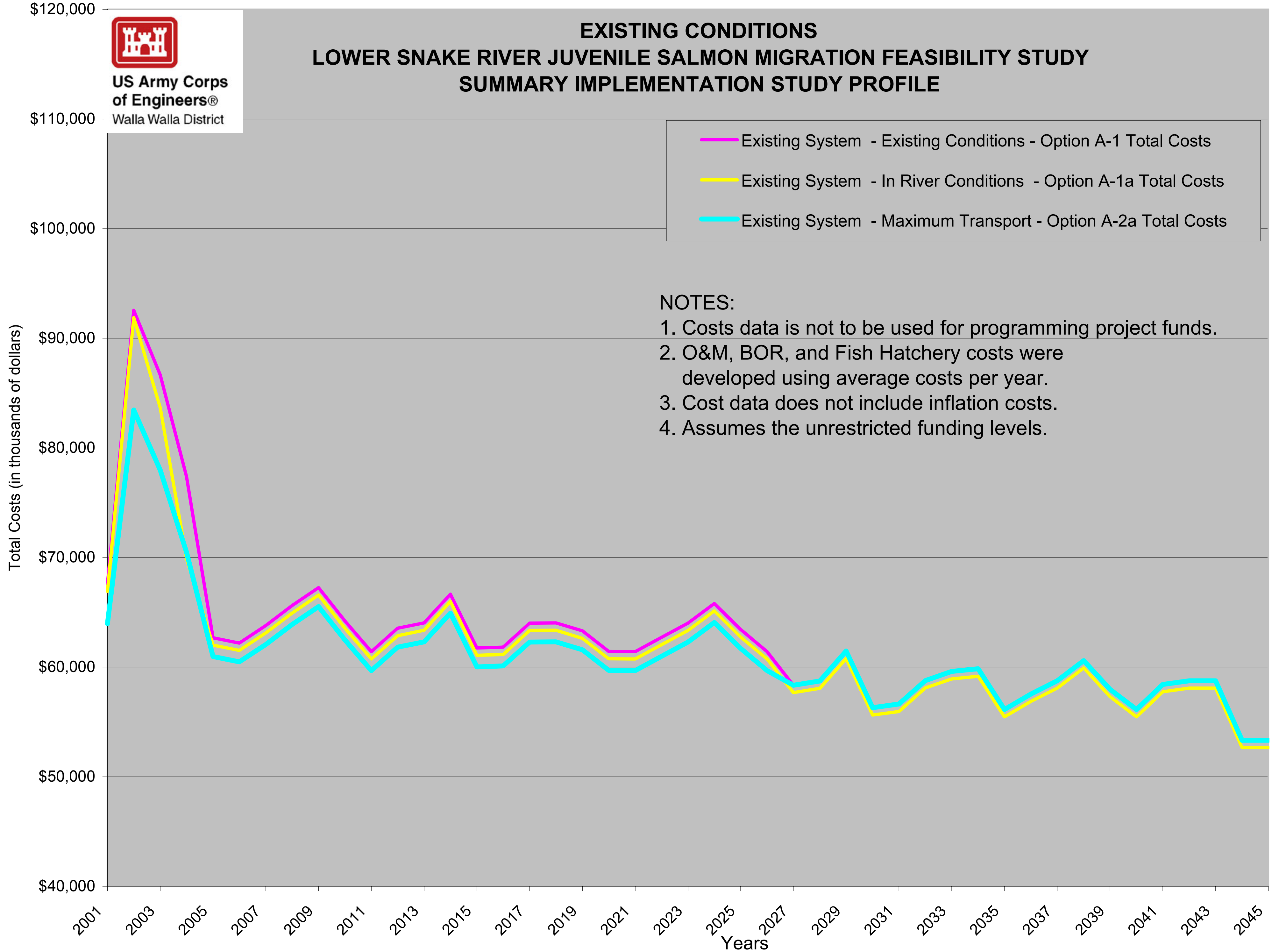
2.4 Prorating of All Option Costs Spreadsheets

The following are yearly timed cost spreadsheets of when work item costs are planned to occur for each option.

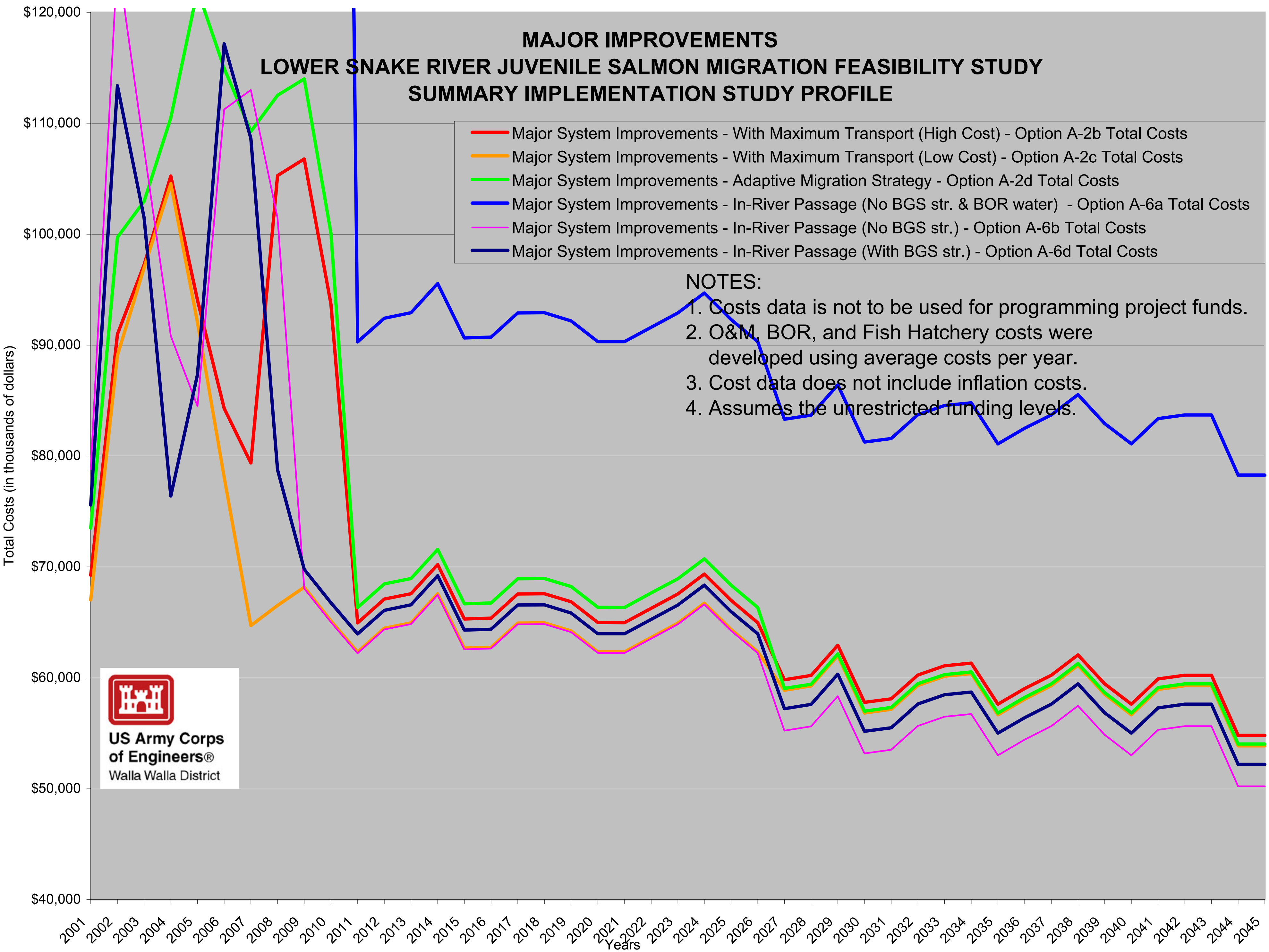
Note: The yearly work item costs were developed from each option's schedules in backup.



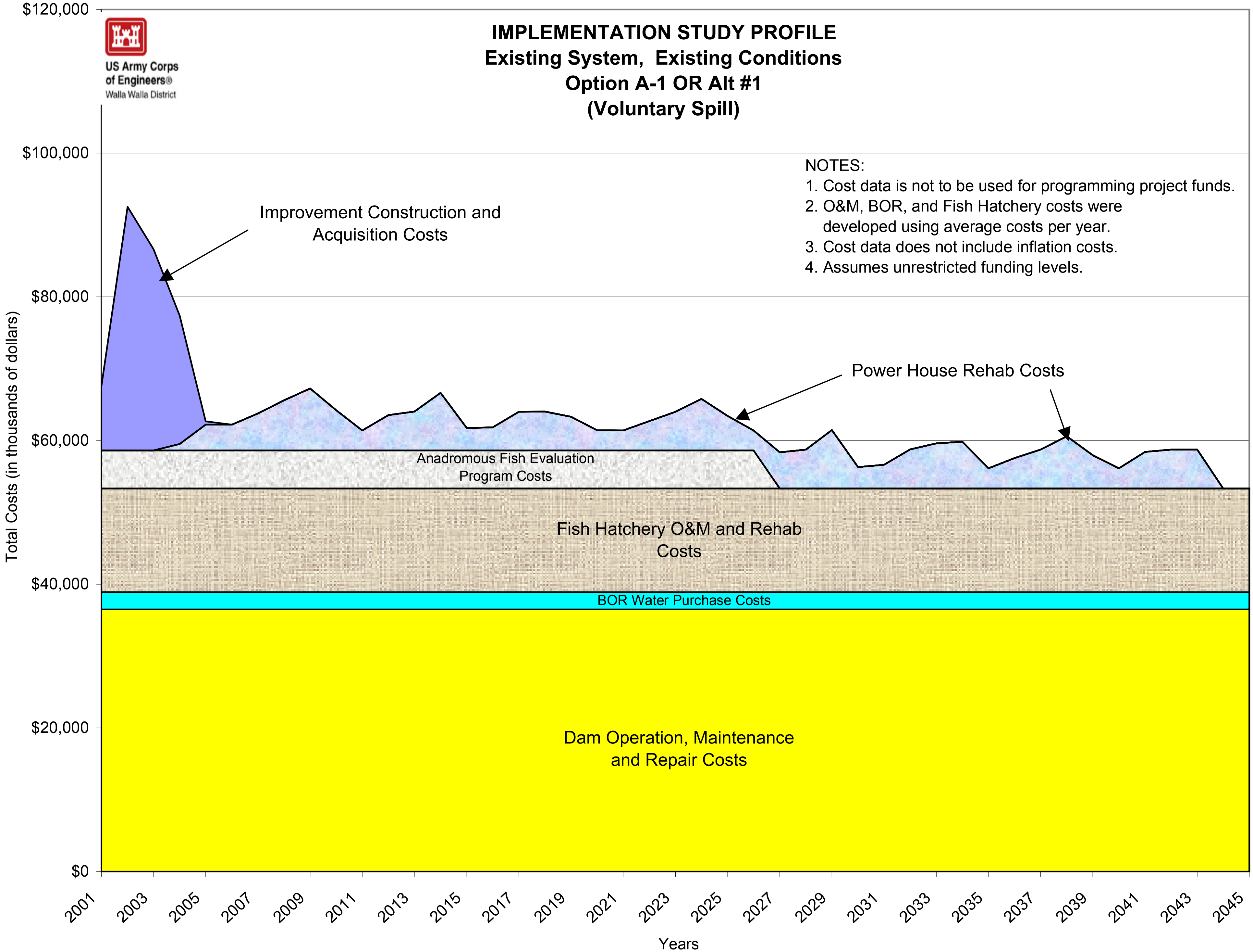
App E/Annex E/ProrationSect24rev.xls/Timescaled Data Graph All



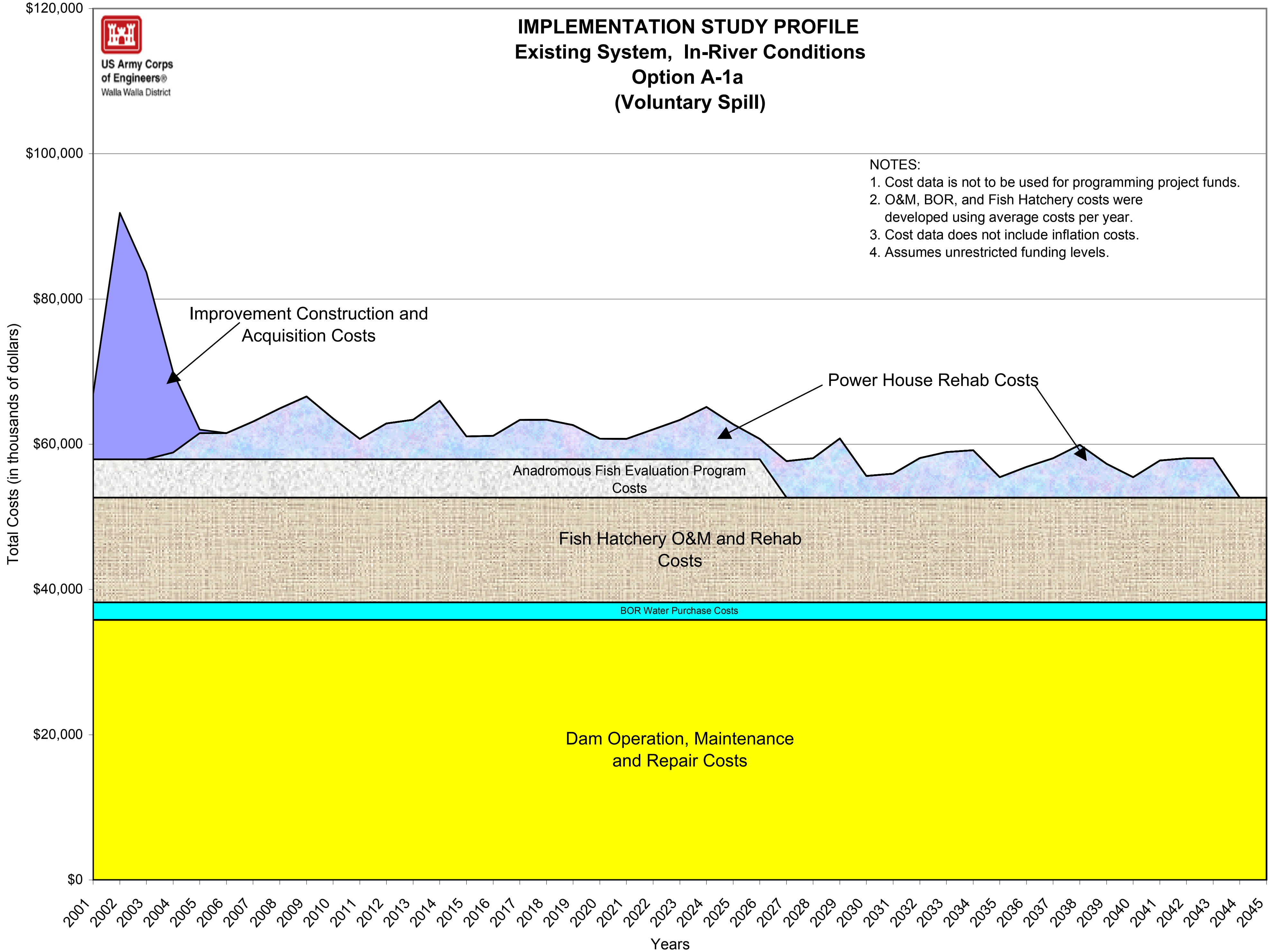
App E/Annex E/ProrationSect24rev.xls/Timescaled Data Graph ECond



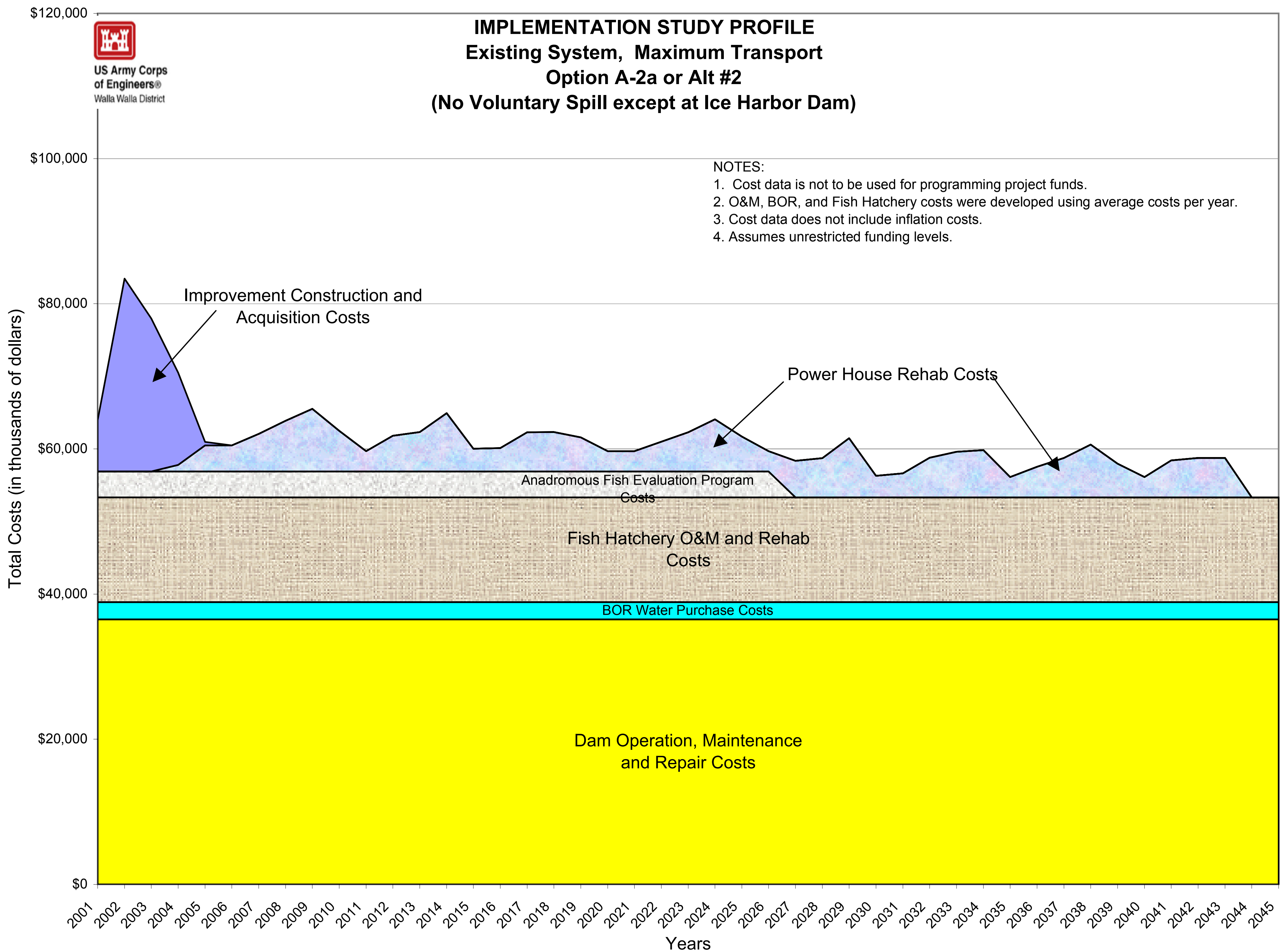
App E/Annex E/ProrationSect24rev.xls/Timescaled Data Graph Major I



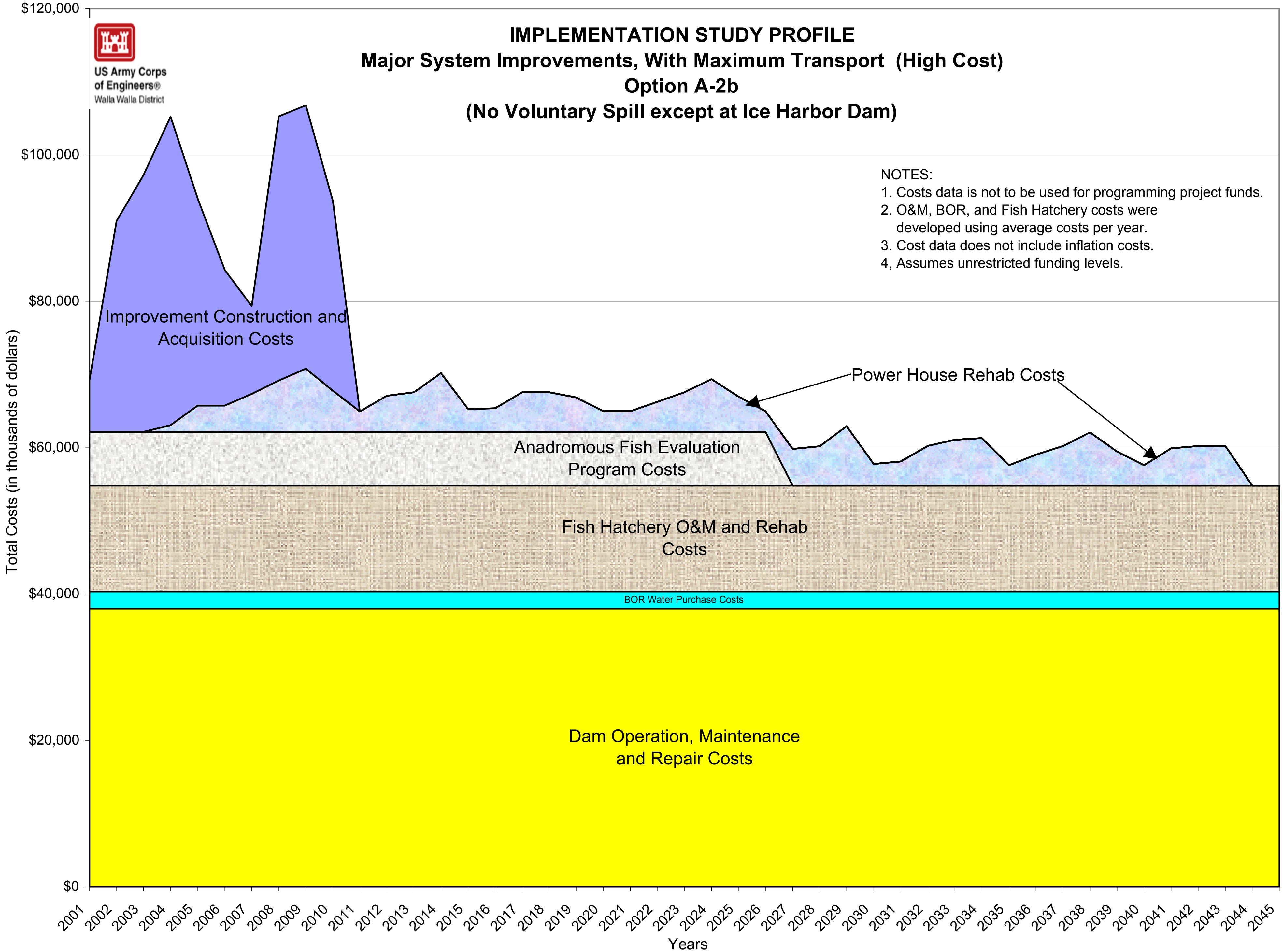
App E/Annex E/Option A-1 rev.xls



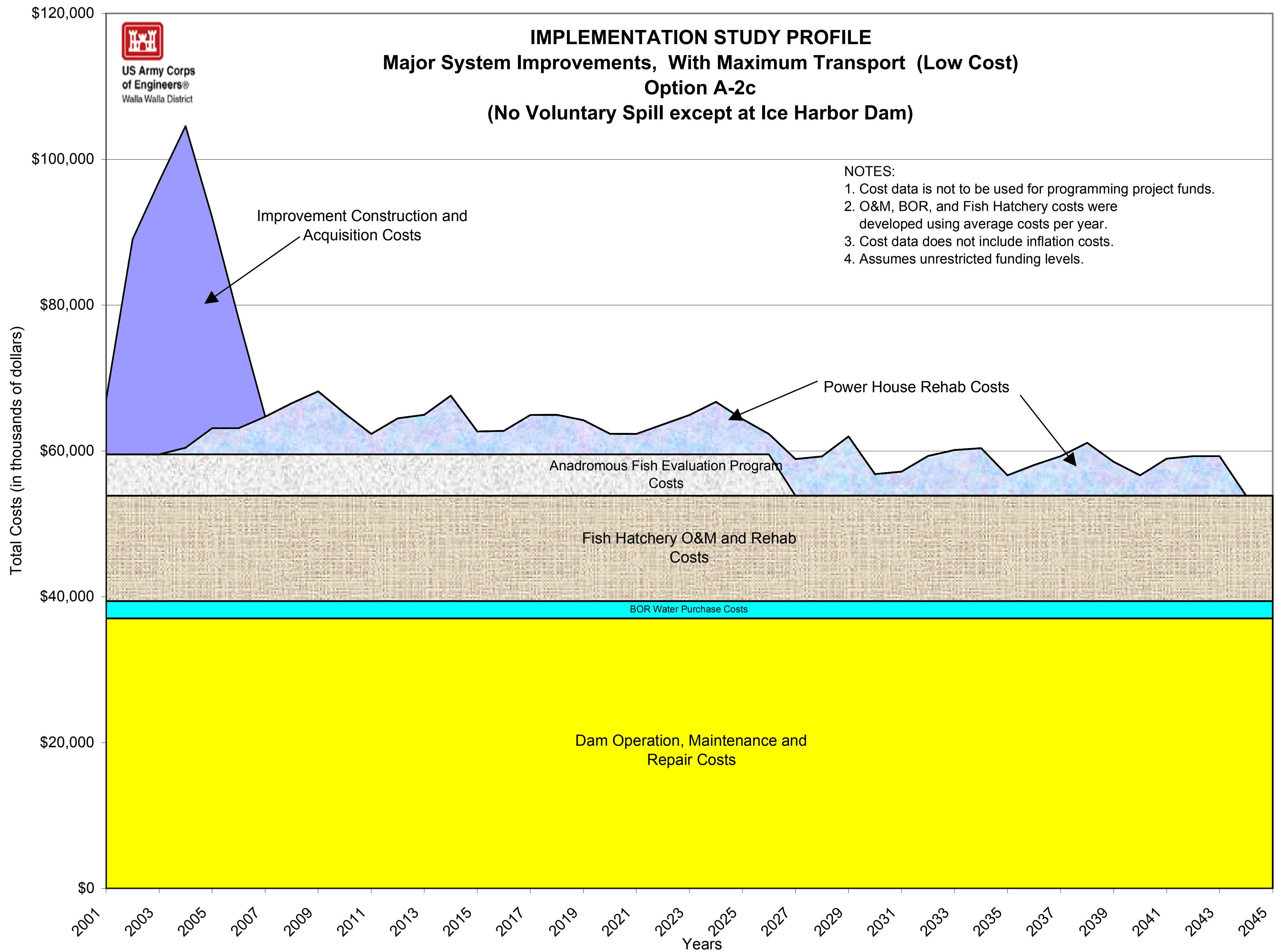
App E/Annex E/Option A-1a rev.xls



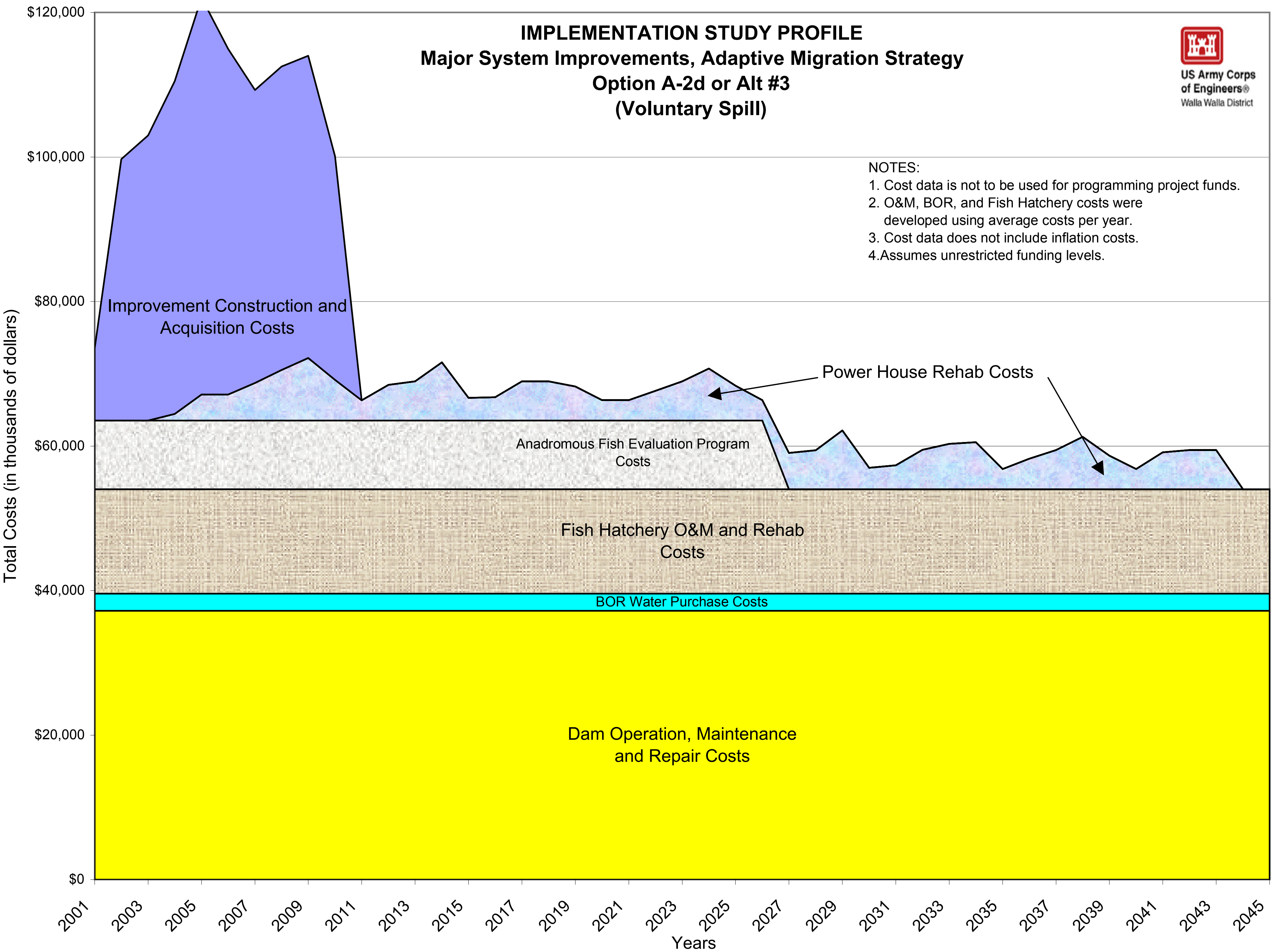
App E/Annex E/Option A-2a rev.xls



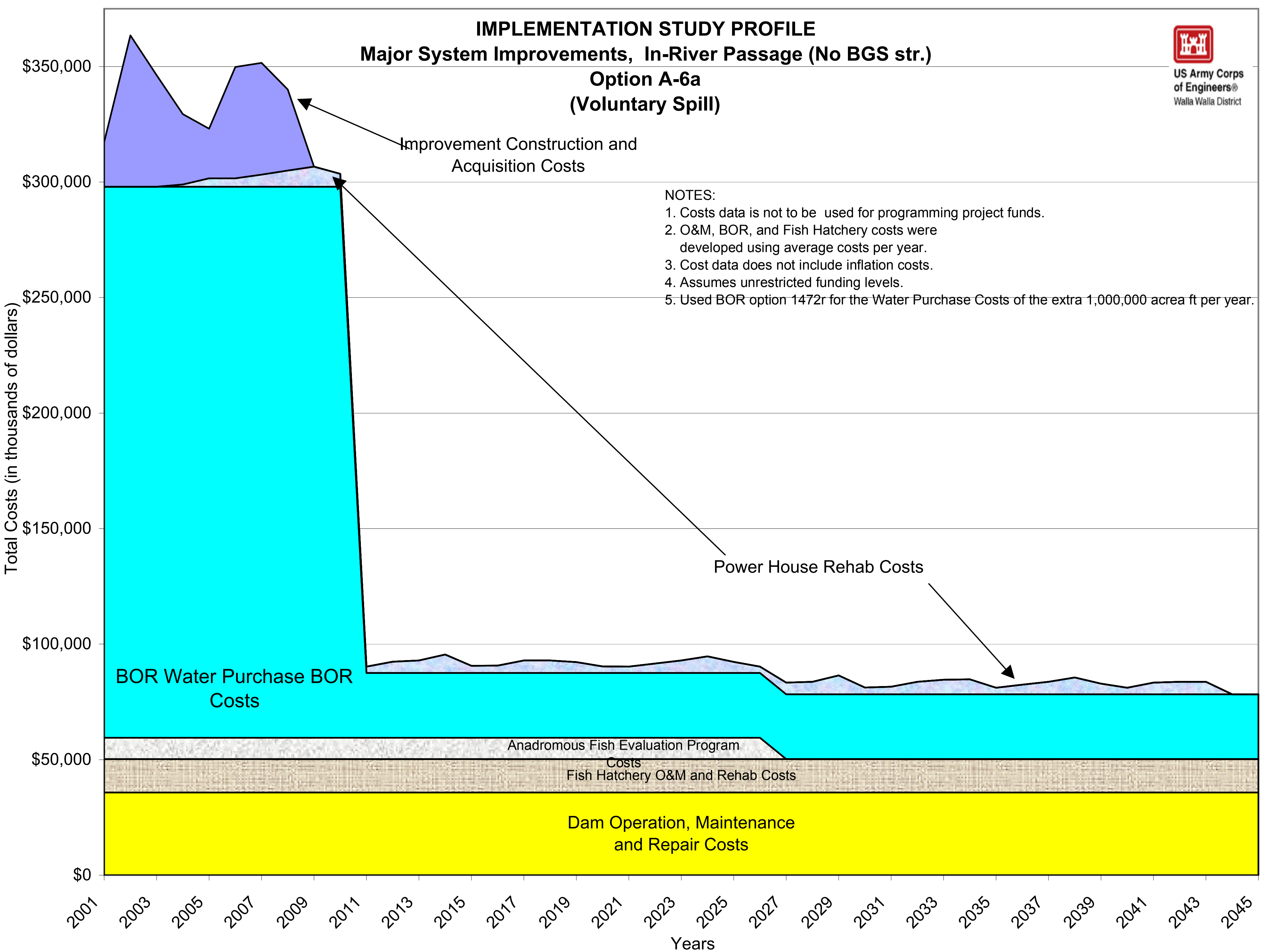
App E/Annex E/Option A-2b rev.xls



App E/Annex E/Option A-2c rev.xls

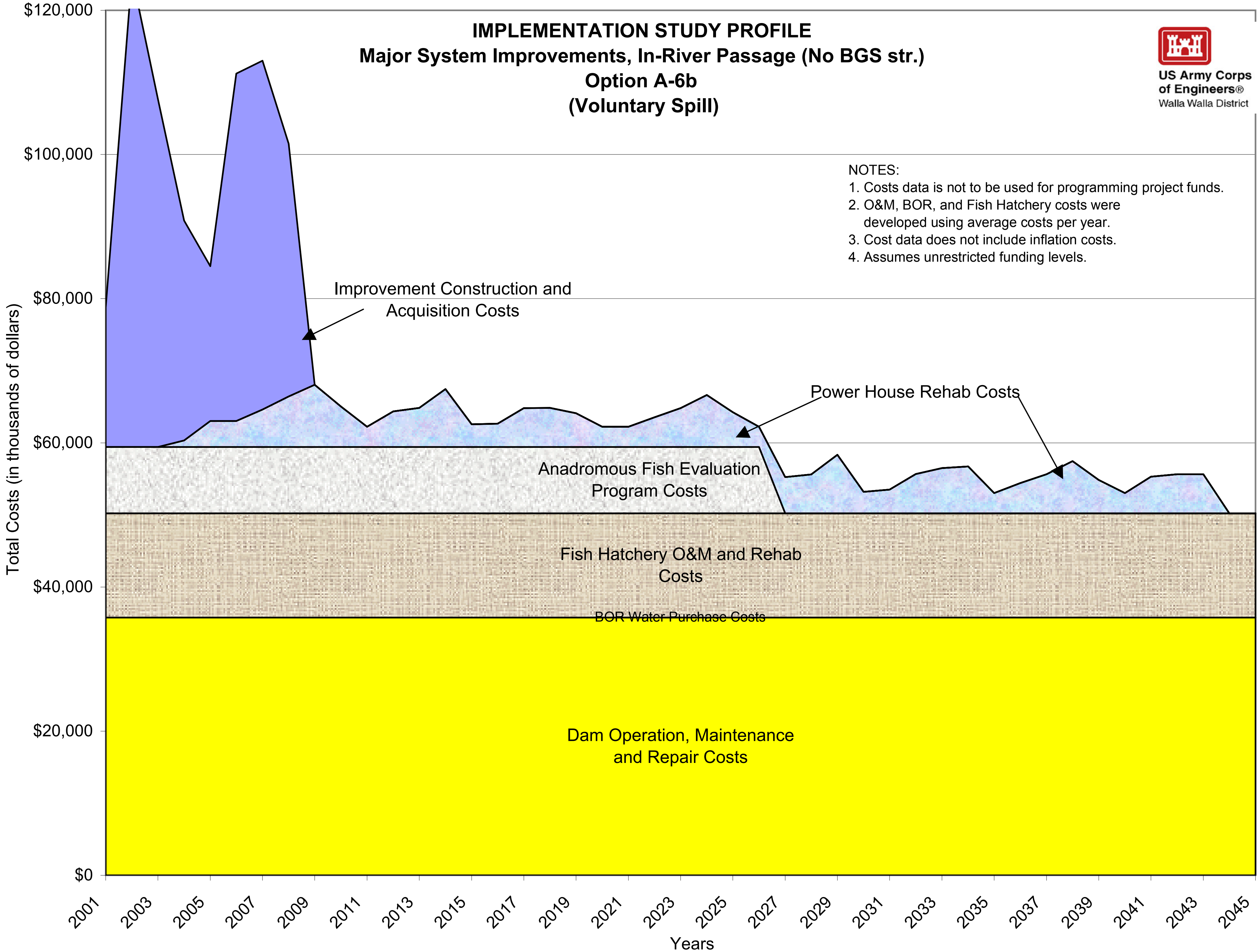


App E/Annex E/Option A-2d rev.xls

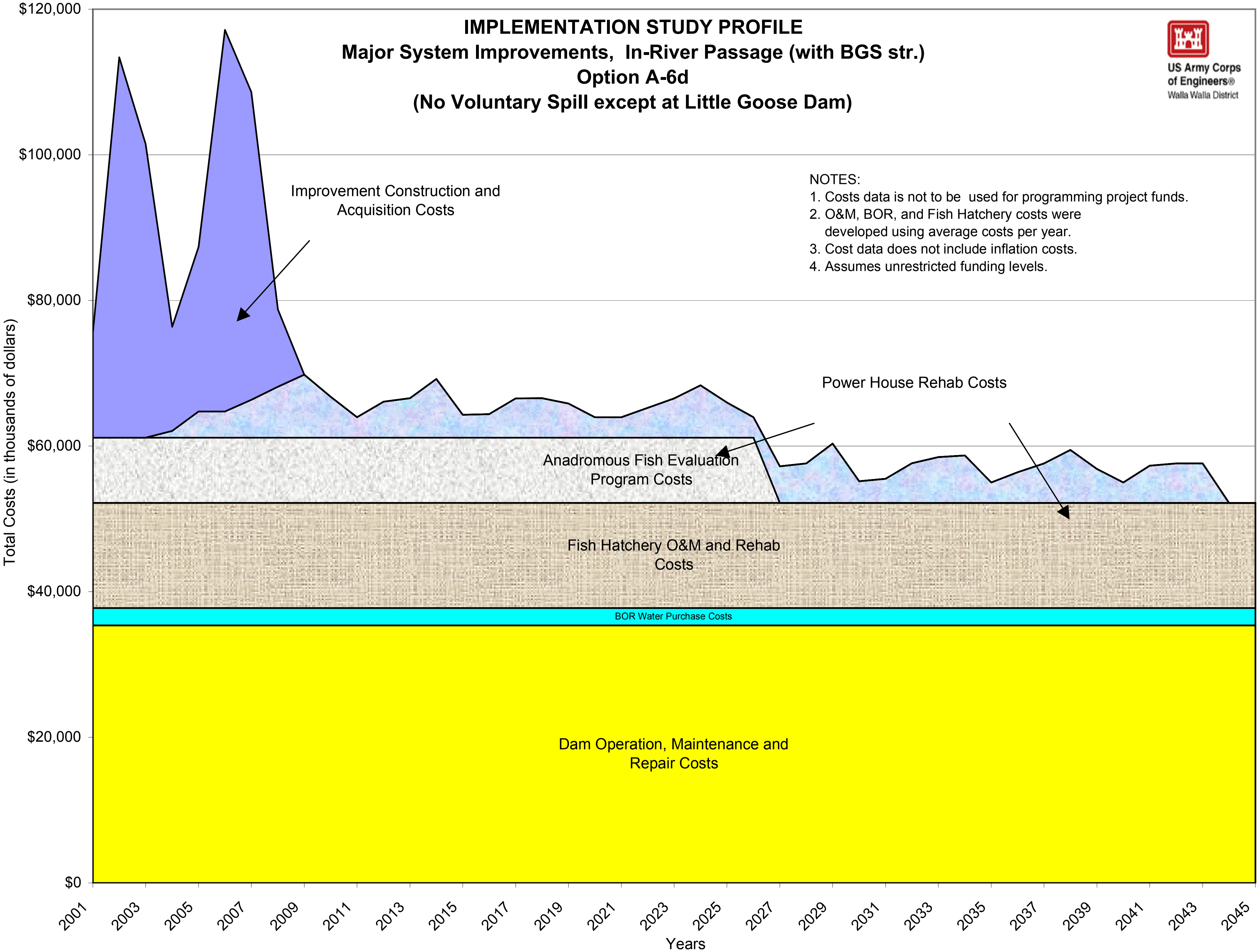


App E/Annex E/Option A-6a rev.xls

IMPLEMENTATION STUDY PROFILE
Major System Improvements, In-River Passage (No BGS str.)
Option A-6b
(Voluntary Spill)



App E/Annex E/Option A-6b rev.xls



App E/Annex E/Option A-6d rev.xls

IMPLEMENTATION SUMMARY OF PRORATING ALL OPTIONS SPREADSHEETS - LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

All Dollars in K-Dollars

YEARLY FUNDING PROFILE, *Prorating of Option Costs*		*Years*	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36
Existing System - Existing Conditions	**- Option A-1**	*Total Costs*	$67,579	$92,543	$86,648	$77,370	$62,683	$62,203	$63,788	$65,606	$67,244	$64,219	$61,405	$63,541	$64,033	$66,653	$61,748	$61,827	$64,012	$64,033	$63,301	$61,427	$61,416	$62,719	$64,012	$65,804	$63,430	$61,416	$58,352	$58,732	$61,459	$56,302	$56,628	$58,774	$59,602	$59,843	$56,136	$57,540
Existing System - In River Conditions	**- Option A-1a**	*Total Costs*	$66,908	$91,872	$83,665	$69,902	$62,012	$61,532	$63,117	$64,935	$66,573	$63,548	$60,734	$62,870	$63,362	$65,982	$61,077	$61,156	$63,341	$63,362	$62,630	$60,756	$60,745	$62,048	$63,341	$65,133	$62,759	$60,745	$57,681	$58,061	$60,788	$55,631	$55,957	$58,103	$58,931	$59,172	$55,465	$56,869
Existing System - Maximum Transport	**- Option A-2a**	*Total Costs*	$63,958	$83,455	$77,982	$70,492	$60,958	$60,478	$62,063	$63,881	$65,519	$62,494	$59,681	$61,817	$62,308	$64,928	$60,024	$60,102	$62,287	$62,308	$61,576	$59,702	$59,691	$60,994	$62,287	$64,079	$61,706	$59,691	$58,352	$58,732	$61,459	$56,302	$56,628	$58,774	$59,602	$59,843	$56,136	$57,540
Major System Improvements - With Maximum Transport (High Cost)	**- Option A-2b**	*Total Costs*	$69,238	$90,979	$97,259	$105,245	$94,044	$84,295	$79,363	$105,282	$106,783	$93,693	$64,961	$67,097	$67,588	$70,208	$65,304	$65,382	$67,567	$67,588	$66,856	$64,982	$64,971	$66,274	$67,567	$69,359	$66,986	$64,971	$59,833	$60,213	$62,940	$57,783	$58,109	$60,255	$61,083	$61,324	$57,617	$59,021
Major System Improvements - With Maximum Transport (Low Cost)	**- Option A-2c**	*Total Costs*	$67,023	$89,071	$96,980	$104,568	$92,035	$78,093	$64,710	$66,528	$68,166	$65,141	$62,328	$64,464	$64,955	$67,575	$62,671	$62,749	$64,934	$64,955	$64,223	$62,349	$62,338	$63,641	$64,934	$66,726	$64,353	$62,338	$58,883	$59,263	$61,990	$56,833	$57,159	$59,305	$60,133	$60,374	$56,667	$58,071
Major System Improvements - Adaptive Migration Strategy	**- Option A-2d**	*Total Costs*	$73,505	$99,714	$102,972	$110,485	$122,019	$114,951	$109,271	$112,523	$114,001	$100,092	$66,332	$68,468	$68,959	$71,579	$66,675	$66,753	$68,938	$68,959	$68,227	$66,353	$66,342	$67,645	$68,938	$70,730	$68,357	$66,342	$59,045	$59,425	$62,152	$56,995	$57,321	$59,467	$60,295	$60,536	$56,829	$58,233
Major System Improvements - In-River Passage (No BGS str. & BOR water	**- Option A-6a**	*Total Costs*	$317,351	$363,441	$346,245	$329,377	$323,045	$349,792	$351,563	$340,027	$306,613	$303,588	$90,292	$92,428	$92,920	$95,540	$90,635	$90,714	$92,899	$92,920	$92,188	$90,314	$90,303	$91,606	$92,899	$94,691	$92,317	$90,303	$83,306	$83,686	$86,413	$81,256	$81,582	$83,728	$84,556	$84,797	$81,090	$82,494
Major System Improvements - In-River Passage (No BGS str.)	**- Option A-6b**	*Total Costs*	$78,796	$124,887	$107,690	$90,822	$84,490	$111,237	$113,008	$101,473	$68,059	$65,034	$62,220	$64,356	$64,848	$67,468	$62,563	$62,642	$64,827	$64,848	$64,116	$62,242	$62,231	$63,534	$64,827	$66,619	$64,245	$62,231	$55,234	$55,614	$58,341	$53,184	$53,510	$55,656	$56,484	$56,725	$53,018	$54,422
Major System Improvements - In-River Passage (With BGS str.)	**- Option A-6d**	*Total Costs*	$75,576	$113,399	$101,477	$76,382	$87,353	$117,172	$108,631	$78,764	$69,790	$66,765	$63,952	$66,088	$66,579	$69,199	$64,295	$64,373	$66,558	$66,579	$65,847	$63,973	$63,962	$65,265	$66,558	$68,350	$65,977	$63,962	$57,220	$57,600	$60,327	$55,170	$55,496	$57,642	$58,470	$58,711	$55,004	$56,408

ACCUMULATED YEARLY FUNDING PROFILE, of Prorating of Option Costs			FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36
Existing System - Existing Conditions	**- Option A-1**	*Accumulative Costs*	$67,579	$160,122	$246,770	$324,140	$386,823	$449,026	$512,814	$578,420	$645,663	$709,882	$771,288	$834,829	$898,861	$965,515	$1,027,263	$1,089,090	$1,153,102	$1,217,135	$1,280,435	$1,341,862	$1,403,278	$1,465,997	$1,530,009	$1,595,813	$1,659,243	$1,720,659	$1,779,011	$1,837,743	$1,899,202	$1,955,505	$2,012,132	$2,070,906	$2,130,508	$2,190,350	$2,246,487	$2,304,027
Existing System - In River Conditions	**- Option A-1a**	*Accumulative Costs*	$66,908	$158,780	$242,445	$312,347	$374,359	$435,891	$499,008	$563,943	$630,515	$694,063	$754,798	$817,668	$881,029	$947,012	$1,008,089	$1,069,245	$1,132,586	$1,195,948	$1,258,577	$1,319,333	$1,380,078	$1,442,126	$1,505,467	$1,570,600	$1,633,359	$1,694,104	$1,751,785	$1,809,846	$1,870,634	$1,926,266	$1,982,222	$2,040,325	$2,099,256	$2,158,427	$2,213,893	$2,270,762
Existing System - Maximum Transport	**- Option A-2a**	*Accumulative Costs*	$63,958	$147,412	$225,394	$295,886	$356,844	$417,322	$479,385	$543,266	$608,785	$671,279	$730,960	$792,776	$855,084	$920,012	$980,036	$1,040,138	$1,102,425	$1,164,733	$1,226,309	$1,286,011	$1,345,702	$1,406,696	$1,468,983	$1,533,062	$1,594,768	$1,654,459	$1,712,811	$1,771,543	$1,833,003	$1,889,305	$1,945,933	$2,004,706	$2,064,308	$2,124,151	$2,180,287	$2,237,827
Major System Improvements - With Maximum Transport (High Cost)	**- Option A-2b**	*Accumulative Costs*	$69,238	$160,217	$257,476	$362,720	$456,765	$541,060	$620,423	$725,705	$832,488	$926,181	$991,142	$1,058,238	$1,125,826	$1,196,034	$1,261,338	$1,326,720	$1,394,287	$1,461,875	$1,528,731	$1,593,713	$1,658,684	$1,724,958	$1,792,525	$1,861,884	$1,928,870	$1,993,841	$2,053,674	$2,113,887	$2,176,828	$2,234,611	$2,292,720	$2,352,974	$2,414,057	$2,475,381	$2,532,998	$2,592,019
Major System Improvements - With Maximum Transport (Low Cost)	**- Option A-2c**	*Accumulative Costs*	$67,023	$156,094	$253,074	$357,641	$449,676	$527,769	$592,479	$659,007	$727,173	$792,314	$854,642	$919,105	$984,060	$1,051,635	$1,114,306	$1,177,055	$1,241,989	$1,306,944	$1,371,167	$1,433,516	$1,495,854	$1,559,495	$1,624,429	$1,691,155	$1,755,508	$1,817,846	$1,876,729	$1,935,992	$1,997,983	$2,054,816	$2,111,975	$2,171,279	$2,231,412	$2,291,786	$2,348,453	$2,406,524
Major System Improvements - Adaptive Migration Strategy	**- Option A-2d**	*Accumulative Costs*	$73,505	$173,219	$276,191	$386,676	$508,695	$623,646	$732,917	$845,440	$959,440	$1,059,532	$1,125,864	$1,194,331	$1,263,290	$1,334,869	$1,401,544	$1,468,297	$1,537,235	$1,606,194	$1,674,421	$1,740,774	$1,807,116	$1,874,761	$1,943,699	$2,014,429	$2,082,786	$2,149,128	$2,208,173	$2,267,598	$2,329,751	$2,386,746	$2,444,066	$2,503,533	$2,563,828	$2,624,364	$2,681,193	$2,739,426
Major System Improvements - In-River Passage (No BGS str. & BOR wate	**- Option A-6a**	*Accumulative Costs*	$317,351	$680,792	########	$1,356,413	$1,679,458	$2,029,250	$2,380,812	$2,720,840	$3,027,453	$3,331,041	$3,421,334	$3,513,762	$3,606,681	$3,702,222	$3,792,857	$3,883,571	$3,976,470	$4,069,390	$4,161,577	$4,251,891	$4,342,194	$4,433,800	$4,526,699	$4,621,390	$4,713,707	$4,804,010	$4,887,316	$4,971,002	$5,057,415	$5,138,672	$5,220,253	$5,303,981	$5,388,537	$5,473,333	$5,554,424	$5,636,918
Major System Improvements - In-River Passage (No BGS str.)	**- Option A-6b**	*Accumulative Costs*	$78,796	$203,683	$311,373	$402,195	$486,685	$597,923	$710,931	$812,404	$880,462	$945,496	$1,007,717	$1,072,073	$1,136,920	$1,204,389	$1,266,952	$1,329,594	$1,394,421	$1,459,269	$1,523,384	$1,585,626	$1,647,857	$1,711,391	$1,776,218	$1,842,837	$1,907,082	$1,969,313	$2,024,547	$2,080,161	$2,138,502	$2,191,687	$2,245,196	$2,300,852	$2,357,336	$2,414,060	$2,467,079	$2,521,501
Major System Improvements - In-River Passage (With BGS str.)	**- Option A-6d**	*Accumulative Costs*	$75,576	$188,976	$290,452	$366,834	$454,187	$571,360	$679,990	$758,754	$828,544	$895,309	$959,261	$1,025,348	$1,091,927	$1,161,126	$1,225,421	$1,289,794	$1,356,352	$1,422,931	$1,488,778	$1,552,751	$1,616,713	$1,681,978	$1,748,536	$1,816,886	$1,882,863	$1,946,825	$2,004,045	$2,061,645	$2,121,973	$2,177,143	$2,232,638	$2,290,280	$2,348,750	$2,407,461	$2,462,465	$2,518,873

US Army Corps
of Engineers®
Walla Walla District

All Dollars in K-Dollars			FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36
Existing System - Existing Conditions	**- Option A-1**	**Alternative # 1**																																				
	Construction Subtotal	*Total Costs*	$8,966	$33,930	$28,036	$17,846	$480																															
	AFEP Subtotal	*Total Costs*	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280										
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
	BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386
	O,M,R,R,R Subtotal	*Total Costs*	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497
	Powerhouse MR Subtotal	*Total Costs*				$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207
Existing System - In River Conditions	**- Option A-1a**																																					
	Construction Subtotal	*Total Costs*	$8,966	$33,930	$25,723	$11,049	$480																															
	AFEP Subtotal	*Total Costs*	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280	$5,280										
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
	BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386
	O,M,R,R,R Subtotal	*Total Costs*	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826
	Powerhouse MR Subtotal	*Total Costs*				$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207
Existing System - Maximum Transport	**- Option A-2a**	**Alternative # 2**																																				
	Construction Subtotal	*Total Costs*	$7,070	$26,567	$21,094	$12,693	$480																															
	AFEP Subtotal	*Total Costs*	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555	$3,555										
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
	BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386
	O,M,R,R,R Subtotal	*Total Costs*	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497
	Powerhouse MR Subtotal	*Total Costs*				$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207
Major System Improvements - With Maximum Transport (High Cost)	**- Option A-2b**																																					
	Construction Subtotal	*Total Costs*	$7,070	$28,811	$35,091	$42,165	$28,286	$18,538	$12,020	$36,121	$35,984	$25,919																										
	AFEP Subtotal	*Total Costs*	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354	$7,354										
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
	BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386
	O,M,R,R,R Subtotal	*Total Costs*	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978
	Powerhouse MR Subtotal	*Total Costs*				$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207
Major System Improvements - With Maximum Transport (Low Cost)	**- Option A-2c**																																					
	Construction Subtotal	*Total Costs*	$7,488	$29,536	$37,445	$44,121	$28,910	$14,968																														
	AFEP Subtotal	*Total Costs*	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671	$5,671										
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
	BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386
	O,M,R,R,R Subtotal	*Total Costs*	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028
	Powerhouse MR Subtotal	*Total Costs*				$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207
Major System Improvements - Adaptive Migration Strategy	**- Option A-2d**	**Alternative # 3**																																				
	Construction Subtotal	*Total Costs*	$9,966	$36,175	$39,433	$46,035	$54,890	$47,823	$40,556	$41,991	$41,831	$30,947																										
	AFEP Subtotal	*Total Costs*	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513	$9,513										
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
	BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386
	O,M,R,R,R Subtotal	*Total Costs*	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190
	Powerhouse MR Subtotal	*Total Costs*				$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207
Major System Improvements - In-River Passage (No BGS str. & BOR wate	**- Option A-6a**																																					
	Construction Subtotal	*Total Costs*	$19,368	$65,459	$48,262	$30,483	$21,473	$48,220	$48,405	$35,052																												
	AFEP Subtotal	*Total Costs*	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213										
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
	BOR Water Purchase Subtotal	*Total Costs*	$238,555	$238,555	$238,555	$238,555	$238,555	$238,555	$238,555	$238,555	$238,555	$238,555	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072
	O,M,R,R,R Subtotal	*Total Costs*	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765
	Powerhouse MR Subtotal	*Total Costs*				$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207
Major System Improvements - In-River Passage (No BGS str.)	**- Option A-6b**																																					
	Construction Subtotal	*Total Costs*	$19,368	$65,459	$48,262	$30,483	$21,473	$48,220	$48,405	$35,052																												
	AFEP Subtotal	*Total Costs*	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213	$9,213										
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
	BOR Water Purchase Subtotal	*Total Costs*																																				
	O,M,R,R,R Subtotal	*Total Costs*	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765
	Powerhouse MR Subtotal	*Total Costs*				$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207
Major System Improvements - In-River Passage (With BGS str.)	**- Option A-6d**																																					
	Construction Subtotal	*Total Costs*	$14,417	$52,240	$40,318	$14,311	$22,605	$52,424	$42,296	$10,612																												
	AFEP Subtotal	*Total Costs*	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958										
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
	BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386
	O,M,R,R,R Subtotal	*Total Costs*	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365
	Powerhouse MR Subtotal	*Total Costs*				$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207
		Years	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36

Cost data does not include inflation costs.

IMPLEMENTATION SUMMARY OF PRORATING ALL OPTIONS SPREADSHEET

All Dollars in K-Dollars

YEARLY FUNDING PROFILE, *Prorating of Option Costs*		Years	FY37	FY38	FY39	FY40	FY41	FY42	FY43	FY44	FY45	FY46	FY47	FY48	FY49	FY50	FY51	FY52	FY53	FY54	FY55	FY56	FY57	FY58	FY59	FY60	FY61	FY62	FY63	FY64	FY65	FY66	FY67	FY68	FY69	FY70	FY71
Existing System - Existing Conditions	- Option A-1	Total Costs	$58,753	$60,589	$57,974	$56,136	$58,422	$58,753	$58,753	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$54,244	$56,923	$56,923	$58,508	$60,326	$61,964	$58,939	$56,126	$58,262	$58,753	$61,373	$56,469	$56,547	$58,732	$58,753	$58,021	$56,147
Existing System - In River Conditions	- Option A-1a	Total Costs	$58,082	$59,918	$57,303	$55,465	$57,751	$58,082	$58,082	$52,662	$52,662	$52,662	$52,662	$52,662	$52,662	$52,662	$52,662	$52,662	$52,662	$52,662	$53,573	$56,252	$56,252	$57,837	$59,655	$61,293	$58,268	$55,455	$57,591	$58,082	$60,702	$55,798	$55,876	$58,061	$58,082	$57,350	$55,476
Existing System - Maximum Transport	- Option A-2a	Total Costs	$58,753	$60,589	$57,974	$56,136	$58,422	$58,753	$58,753	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$54,244	$56,923	$56,923	$58,508	$60,326	$61,964	$58,939	$56,126	$58,262	$58,753	$61,373	$56,469	$56,547	$58,732	$58,753	$58,021	$56,147
Major System Improvements - With Maximum Transport (High Cost)	- Option A-2b	Total Costs	$60,234	$62,070	$59,455	$57,617	$59,903	$60,234	$60,234	$54,814	$54,814	$54,814	$54,814	$54,814	$54,814	$54,814	$54,814	$54,814	$54,814	$54,814	$55,725	$58,404	$58,404	$59,989	$61,807	$63,445	$60,420	$57,607	$59,743	$60,234	$62,854	$57,950	$58,028	$60,213	$60,234	$59,502	$57,628
Major System Improvements - With Maximum Transport (Low Cost)	- Option A-2c	Total Costs	$59,284	$61,120	$58,505	$56,667	$58,953	$59,284	$59,284	$53,864	$53,864	$53,864	$53,864	$53,864	$53,864	$53,864	$53,864	$53,864	$53,864	$53,864	$54,775	$57,454	$57,454	$59,039	$60,857	$62,495	$59,470	$56,657	$58,793	$59,284	$61,904	$57,000	$57,078	$59,263	$59,284	$58,552	$56,678
Major System Improvements - Adaptive Migration Strategy	- Option A-2d	Total Costs	$59,446	$61,282	$58,667	$56,829	$59,115	$59,446	$59,446	$54,026	$54,026	$54,026	$54,026	$54,026	$54,026	$54,026	$54,026	$54,026	$54,026	$54,026	$54,937	$57,616	$57,616	$59,201	$61,019	$62,657	$59,632	$56,819	$58,955	$59,446	$62,066	$57,162	$57,240	$59,425	$59,446	$58,714	$56,840
Major System Improvements - In-River Passage (No BGS str. & BOR water	- Option A-6a	Total Costs	$83,707	$85,543	$82,928	$81,090	$83,376	$83,707	$83,707	$78,287	$78,287	$78,287	$78,287	$78,287	$78,287	$78,287	$78,287	$78,287	$78,287	$78,287	$79,198	$81,877	$81,877	$83,462	$85,280	$86,918	$83,893	$81,080	$83,216	$83,707	$86,327	$81,423	$81,501	$83,686	$83,707	$82,975	$81,101
Major System Improvements - In-River Passage (No BGS str.)	- Option A-6b	Total Costs	$55,635	$57,471	$54,856	$53,018	$55,304	$55,635	$55,635	$50,215	$50,215	$50,215	$50,215	$50,215	$50,215	$50,215	$50,215	$50,215	$50,215	$50,215	$51,126	$53,805	$53,805	$55,390	$57,208	$58,846	$55,821	$53,008	$55,144	$55,635	$58,255	$53,351	$53,429	$55,614	$55,635	$54,903	$53,029
Major System Improvements - In-River Passage (With BGS str.)	- Option A-6d	Total Costs	$57,621	$59,457	$56,842	$55,004	$57,290	$57,621	$57,621	$52,201	$52,201	$52,201	$52,201	$52,201	$52,201	$52,201	$52,201	$52,201	$52,201	$52,201	$53,112	$55,791	$55,791	$57,376	$59,194	$60,832	$57,807	$54,994	$57,130	$57,621	$60,241	$55,337	$55,415	$57,600	$57,621	$56,889	$55,015

ACCUMULATED YEARLY FUNDING PROFILE, *of Prorating of Option Costs*			FY37	FY38	FY39	FY40	FY41	FY42	FY43	FY44	FY45	FY46	FY47	FY48	FY49	FY50	FY51	FY52	FY53	FY54	FY55	FY56	FY57	FY58	FY59	FY60	FY61	FY62	FY63	FY64	FY65	FY66	FY67	FY68	FY69	FY70	FY71
Existing System - Existing Conditions	- Option A-1	Accumulative Costs	$2,362,780	$2,423,369	$2,481,343	$2,537,479	$2,595,901	$2,654,654	$2,713,407	$2,766,740	$2,820,073	$2,873,406	$2,926,739	$2,980,072	$3,033,405	$3,086,738	$3,140,071	$3,193,404	$3,246,737	$3,300,070	$3,354,314	$3,411,237	$3,468,160	$3,526,668	$3,586,994	$3,648,958	$3,707,897	$3,764,023	$3,822,284	$3,881,037	$3,942,410	$3,998,879	$4,055,426	$4,114,158	$4,172,911	$4,230,932	$4,287,079
Existing System - In River Conditions	- Option A-1a	Accumulative Costs	$2,328,844	$2,388,762	$2,446,065	$2,501,530	$2,559,281	$2,617,363	$2,675,445	$2,728,107	$2,780,769	$2,833,431	$2,886,093	$2,938,755	$2,991,417	$3,044,079	$3,096,741	$3,149,403	$3,202,065	$3,254,727	$3,308,300	$3,364,552	$3,420,804	$3,478,641	$3,538,296	$3,599,589	$3,657,857	$3,713,312	$3,770,902	$3,828,984	$3,889,686	$3,945,484	$4,001,360	$4,059,421	$4,117,503	$4,174,853	$4,230,329
Existing System - Maximum Transport	- Option A-2a	Accumulative Costs	$2,296,580	$2,357,170	$2,415,143	$2,471,280	$2,529,701	$2,588,454	$2,647,207	$2,700,540	$2,753,873	$2,807,206	$2,860,539	$2,913,872	$2,967,205	$3,020,538	$3,073,871	$3,127,204	$3,180,537	$3,233,870	$3,288,114	$3,345,037	$3,401,960	$3,460,468	$3,520,794	$3,582,758	$3,641,697	$3,697,823	$3,756,084	$3,814,837	$3,876,210	$3,932,679	$3,989,226	$4,047,958	$4,106,711	$4,164,732	$4,220,879
Major System Improvements - With Maximum Transport (High Cost)	- Option A-2b	Accumulative Costs	$2,652,253	$2,714,324	$2,773,778	$2,831,396	$2,891,298	$2,951,532	$3,011,766	$3,066,580	$3,121,394	$3,176,208	$3,231,022	$3,285,836	$3,340,650	$3,395,464	$3,450,278	$3,505,092	$3,559,906	$3,614,720	$3,670,445	$3,728,849	$3,787,253	$3,847,242	$3,909,049	$3,972,494	$4,032,914	$4,090,521	$4,150,263	$4,210,497	$4,273,351	$4,331,301	$4,389,329	$4,449,542	$4,509,776	$4,569,278	$4,626,906
Major System Improvements - With Maximum Transport (Low Cost)	- Option A-2c	Accumulative Costs	$2,465,808	$2,526,929	$2,585,433	$2,642,101	$2,701,053	$2,760,337	$2,819,621	$2,873,485	$2,927,349	$2,981,213	$3,035,077	$3,088,941	$3,142,805	$3,196,669	$3,250,533	$3,304,397	$3,358,261	$3,412,125	$3,466,900	$3,524,354	$3,581,808	$3,640,847	$3,701,704	$3,764,199	$3,823,669	$3,880,326	$3,939,118	$3,998,402	$4,060,306	$4,117,306	$4,174,384	$4,233,647	$4,292,931	$4,351,483	$4,408,161
Major System Improvements - Adaptive Migration Strategy	- Option A-2d	Accumulative Costs	$2,798,872	$2,860,155	$2,918,821	$2,975,651	$3,034,765	$3,094,211	$3,153,657	$3,207,683	$3,261,709	$3,315,735	$3,369,761	$3,423,787	$3,477,813	$3,531,839	$3,585,865	$3,639,891	$3,693,917	$3,747,943	$3,802,880	$3,860,496	$3,918,112	$3,977,313	$4,038,332	$4,100,989	$4,160,621	$4,217,440	$4,276,394	$4,335,840	$4,397,906	$4,455,068	$4,512,308	$4,571,733	$4,631,179	$4,689,893	$4,746,733
Major System Improvements - In-River Passage (No BGS str. & BOR wate	- Option A-6a	Accumulative Costs	$5,720,625	$5,806,168	$5,889,096	$5,970,186	$6,053,562	$6,137,269	$6,220,976	$6,299,263	$6,377,550	$6,455,837	$6,534,124	$6,612,411	$6,690,698	$6,768,985	$6,847,272	$6,925,559	$7,003,846	$7,082,133	$7,161,331	$7,243,208	$7,325,085	$7,408,547	$7,493,827	$7,580,745	$7,664,638	$7,745,718	$7,828,933	$7,912,640	$7,998,967	$8,080,390	$8,161,891	$8,245,577	$8,329,284	$8,412,259	$8,493,360
Major System Improvements - In-River Passage (No BGS str.)	- Option A-6b	Accumulative Costs	$2,577,136	$2,634,607	$2,689,463	$2,742,481	$2,797,785	$2,853,420	$2,909,055	$2,959,270	$3,009,485	$3,059,700	$3,109,915	$3,160,130	$3,210,345	$3,260,560	$3,310,775	$3,360,990	$3,411,205	$3,461,420	$3,512,546	$3,566,351	$3,620,156	$3,675,546	$3,732,754	$3,791,600	$3,847,421	$3,900,429	$3,955,572	$4,011,207	$4,069,462	$4,122,813	$4,176,242	$4,231,856	$4,287,491	$4,342,394	$4,395,423
Major System Improvements - In-River Passage (With BGS str.)	- Option A-6d	Accumulative Costs	$2,576,494	$2,635,952	$2,692,793	$2,747,798	$2,805,087	$2,862,708	$2,920,329	$2,972,530	$3,024,731	$3,076,932	$3,129,133	$3,181,334	$3,233,535	$3,285,736	$3,337,937	$3,390,138	$3,442,339	$3,494,540	$3,547,652	$3,603,443	$3,659,234	$3,716,610	$3,775,804	$3,836,636	$3,894,443	$3,949,437	$4,006,566	$4,064,187	$4,124,428	$4,179,765	$4,235,180	$4,292,780	$4,350,401	$4,407,290	$4,462,305

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Walla Walla District

All Dollars in K-Dollars				FY37	FY38	FY39	FY40	FY41	FY42	FY43	FY44	FY45	FY46	FY47	FY48	FY49	FY50	FY51	FY52	FY53	FY54	FY55	FY56	FY57	FY58	FY59	FY60	FY61	FY62	FY63	FY64	FY65	FY66	FY67	FY68	FY69	FY70	FY71
Existing System - Existing Conditions	**- Option A-1**	**Alternative # 1**																																				
		Construction Subtotal	*Total Costs*																																			
		AFEP Subtotal	*Total Costs*																																			
		Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
		BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386
		O,M,R,R,R Subtotal	*Total Costs*	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497
		Powerhouse MR Subtotal	*Total Costs*	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814
Existing System - In River Conditions	**- Option A-1a**																																					
		Construction Subtotal	*Total Costs*																																			
		AFEP Subtotal	*Total Costs*																																			
		Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
		BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386
		O,M,R,R,R Subtotal	*Total Costs*	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826
		Powerhouse MR Subtotal	*Total Costs*	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814
Existing System - Maximum Transport	**- Option A-2a**	**Alternative # 2**																																				
		Construction Subtotal	*Total Costs*																																			
		AFEP Subtotal	*Total Costs*																																			
		Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
		BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386
		O,M,R,R,R Subtotal	*Total Costs*	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497
		Powerhouse MR Subtotal	*Total Costs*	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814
Major System Improvements - With Maximum Transport (High Cost)	**- Option A-2b**																																					
		Construction Subtotal	*Total Costs*																																			
		AFEP Subtotal	*Total Costs*																																			
		Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
		BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386
		O,M,R,R,R Subtotal	*Total Costs*	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978
		Powerhouse MR Subtotal	*Total Costs*	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814
Major System Improvements - With Maximum Transport (Low Cost)	**- Option A-2c**																																					
		Construction Subtotal	*Total Costs*																																			
		AFEP Subtotal	*Total Costs*																																			
		Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
		BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386
		O,M,R,R,R Subtotal	*Total Costs*	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028
		Powerhouse MR Subtotal	*Total Costs*	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814
Major System Improvements - Adaptive Migration Strategy	**- Option A-2d**	**Alternative # 3**																																				
		Construction Subtotal	*Total Costs*																																			
		AFEP Subtotal	*Total Costs*																																			
		Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
		BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386
		O,M,R,R,R Subtotal	*Total Costs*	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190
		Powerhouse MR Subtotal	*Total Costs*	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814
Major System Improvements - In-River Passage (No BGS str. & BOR wate	**- Option A-6a**																																					
		Construction Subtotal	*Total Costs*																																			
		AFEP Subtotal	*Total Costs*																																			
		Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
		BOR Water Purchase Subtotal	*Total Costs*	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072
		O,M,R,R,R Subtotal	*Total Costs*	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765
		Powerhouse MR Subtotal	*Total Costs*	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814
Major System Improvements - In-River Passage (No BGS str.)	**- Option A-6b**																																					
		Construction Subtotal	*Total Costs*																																			
		AFEP Subtotal	*Total Costs*																																			
		Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
		BOR Water Purchase Subtotal	*Total Costs*																																			
		O,M,R,R,R Subtotal	*Total Costs*	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765
		Powerhouse MR Subtotal	*Total Costs*	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814
Major System Improvements - In-River Passage (With BGS str.)	**- Option A-6d**																																					
		Construction Subtotal	*Total Costs*																																			
		AFEP Subtotal	*Total Costs*																																			
		Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
		BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386
		O,M,R,R,R Subtotal	*Total Costs*	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365
		Powerhouse MR Subtotal	*Total Costs*	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$911	$3,590	$3,590	$5,175	$6,993	$8,631	$5,606	$2,793	$4,929	$5,420	$8,040	$3,136	$3,214	$5,399	$5,420	$4,688	$2,814
			Years	FY37	FY38	FY39	FY40	FY41	FY42	FY43	FY44	FY45	FY46	FY47	FY48	FY49	FY50	FY51	FY52	FY53	FY54	FY55	FY56	FY57	FY58	FY59	FY60	FY61	FY62	FY63	FY64	FY65	FY66	FY67	FY68	FY69	FY70	FY71

Cost data does not include inflation costs.

IMPLEMENTATION SUMMARY OF PRORATING ALL OPTIONS SPREADSHEET

All Dollars in K-Dollars

YEARLY FUNDING PROFILE, ***Prorating of Option Costs***		*Years*	*FY72*	*FY73*	*FY74*	*FY75*	*FY76*	*FY77*	*FY78*	*FY79*	*FY80*	*FY81*	*FY82*	*FY83*	*FY84*	*FY85*	*FY86*	*FY87*	*FY88*	*FY89*	*FY90*	*FY91*	*FY92*	*FY93*	*FY94*	*FY95*	*FY96*	*FY97*	*FY98*	*FY99*	*FY00*	*FY01*	*FY02*	*FY03*	*FY04*	*FY05*	**Total Costs** *for 105 years*
Existing System - Existing Conditions	- Option A-1	Total Costs	$56,136	$57,439	$58,732	$60,524	$58,151	$56,136	$58,352	$58,732	$61,459	$56,302	$56,628	$58,774	$59,602	$59,843	$56,136	$57,540	$58,753	$60,589	$57,974	$56,136	$58,422	$58,753	$58,753	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$6,213,608
Existing System - In River Conditions	- Option A-1a	Total Costs	$55,465	$56,768	$58,061	$59,853	$57,480	$55,465	$57,681	$58,061	$60,788	$55,631	$55,957	$58,103	$58,931	$59,172	$55,465	$56,869	$58,082	$59,918	$57,303	$55,465	$57,751	$58,082	$58,082	$52,662	$52,662	$52,662	$52,662	$52,662	$52,662	$52,662	$52,662	$52,662	$52,662	$52,662	$6,134,044
Existing System - Maximum Transport	- Option A-2a	Total Costs	$56,136	$57,439	$58,732	$60,524	$58,151	$56,136	$58,352	$58,732	$61,459	$56,302	$56,628	$58,774	$59,602	$59,843	$56,136	$57,540	$58,753	$60,589	$57,974	$56,136	$58,422	$58,753	$58,753	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$53,333	$6,147,408
Major System Improvements - With Maximum Transport (High Cost)	- Option A-2b	Total Costs	$57,617	$58,920	$60,213	$62,005	$59,632	$57,617	$59,833	$60,213	$62,940	$57,783	$58,109	$60,255	$61,083	$61,324	$57,617	$59,021	$60,234	$62,070	$59,455	$57,617	$59,903	$60,234	$60,234	$54,814	$54,814	$54,814	$54,814	$54,814	$54,814	$54,814	$54,814	$54,814	$54,814	$54,814	$6,603,789
Major System Improvements - With Maximum Transport (Low Cost)	- Option A-2c	Total Costs	$56,667	$57,970	$59,263	$61,055	$58,682	$56,667	$58,883	$59,263	$61,990	$56,833	$57,159	$59,305	$60,133	$60,374	$56,667	$58,071	$59,284	$61,120	$58,505	$56,667	$58,953	$59,284	$59,284	$53,864	$53,864	$53,864	$53,864	$53,864	$53,864	$53,864	$53,864	$53,864	$53,864	$53,864	$6,352,744
Major System Improvements - Adaptive Migration Strategy	- Option A-2d	Total Costs	$56,829	$58,132	$59,425	$61,217	$58,844	$56,829	$59,045	$59,425	$62,152	$56,995	$57,321	$59,467	$60,295	$60,536	$56,829	$58,233	$59,446	$61,282	$58,667	$56,829	$59,115	$59,446	$59,446	$54,026	$54,026	$54,026	$54,026	$54,026	$54,026	$54,026	$54,026	$54,026	$54,026	$54,026	$6,696,824
Major System Improvements - In-River Passage (No BGS str. & BOR water	- Option A-6a	Total Costs	$81,090	$82,393	$83,686	$85,478	$83,105	$81,090	$83,306	$83,686	$86,413	$81,256	$81,582	$83,728	$84,556	$84,797	$81,090	$82,494	$83,707	$85,543	$82,928	$81,090	$83,376	$83,707	$83,707	$78,287	$78,287	$78,287	$78,287	$78,287	$78,287	$78,287	$78,287	$78,287	$78,287	$78,287	$11,268,325
Major System Improvements - In-River Passage (No BGS str.)	- Option A-6b	Total Costs	$53,018	$54,321	$55,614	$57,406	$55,033	$53,018	$55,234	$55,614	$58,341	$53,184	$53,510	$55,656	$56,484	$56,725	$53,018	$54,422	$55,635	$57,471	$54,856	$53,018	$55,304	$55,635	$55,635	$50,215	$50,215	$50,215	$50,215	$50,215	$50,215	$50,215	$50,215	$50,215	$50,215	$50,215	$6,215,940
Major System Improvements - In-River Passage (With BGS str.)	- Option A-6d	Total Costs	$55,004	$56,307	$57,600	$59,392	$57,019	$55,004	$57,220	$57,600	$60,327	$55,170	$55,496	$57,642	$58,470	$58,711	$55,004	$56,408	$57,621	$59,457	$56,842	$55,004	$57,290	$57,621	$57,621	$52,201	$52,201	$52,201	$52,201	$52,201	$52,201	$52,201	$52,201	$52,201	$52,201	$52,201	$6,350,346

ACCUMULATED YEARLY FUNDING PROFILE, of Prorating of Option Costs			*FY72*	*FY73*	*FY74*	*FY75*	*FY76*	*FY77*	*FY78*	*FY79*	*FY80*	*FY81*	*FY82*	*FY83*	*FY84*	*FY85*	*FY86*	*FY87*	*FY88*	*FY89*	*FY90*	*FY91*	*FY92*	*FY93*	*FY94*	*FY95*	*FY96*	*FY97*	*FY98*	*FY99*	*FY00*	*FY01*	*FY02*	*FY03*	*FY04*	*FY05*	**Total Costs** *for 105 years*
Existing System - Existing Conditions	- Option A-1	Accumulative Costs	$4,343,215	$4,400,654	$4,459,386	$4,519,910	$4,578,061	$4,634,197	$4,692,549	$4,751,281	$4,812,740	$4,869,043	$4,925,670	$4,984,444	$5,044,046	$5,103,888	$5,160,025	$5,217,565	$5,276,318	$5,336,907	$5,394,881	$5,451,017	$5,509,439	$5,568,192	$5,626,945	$5,680,278	$5,733,611	$5,786,944	$5,840,277	$5,893,610	$5,946,943	$6,000,276	$6,053,609	$6,106,942	$6,160,275	$6,213,608	$6,213,608
Existing System - In River Conditions	- Option A-1a	Accumulative Costs	$4,285,794	$4,342,562	$4,400,623	$4,460,476	$4,517,956	$4,573,421	$4,631,102	$4,689,163	$4,749,951	$4,805,583	$4,861,539	$4,919,642	$4,978,573	$5,037,744	$5,093,210	$5,150,079	$5,208,161	$5,268,079	$5,325,382	$5,380,847	$5,438,598	$5,496,680	$5,554,762	$5,607,424	$5,660,086	$5,712,748	$5,765,410	$5,818,072	$5,870,734	$5,923,396	$5,976,058	$6,028,720	$6,081,382	$6,134,044	$6,134,044
Existing System - Maximum Transport	- Option A-2a	Accumulative Costs	$4,277,015	$4,334,454	$4,393,186	$4,453,710	$4,511,861	$4,567,997	$4,626,349	$4,685,081	$4,746,541	$4,802,843	$4,859,471	$4,918,244	$4,977,846	$5,037,689	$5,093,825	$5,151,365	$5,210,118	$5,270,708	$5,328,681	$5,384,818	$5,443,239	$5,501,992	$5,560,745	$5,614,078	$5,667,411	$5,720,744	$5,774,077	$5,827,410	$5,880,743	$5,934,076	$5,987,409	$6,040,742	$6,094,075	$6,147,408	$6,147,408
Major System Improvements - With Maximum Transport (High Cost)	- Option A-2b	Accumulative Costs	$4,684,523	$4,743,443	$4,803,656	$4,865,661	$4,925,293	$4,982,910	$5,042,743	$5,102,956	$5,165,897	$5,223,680	$5,281,789	$5,342,043	$5,403,126	$5,464,450	$5,522,067	$5,581,088	$5,641,322	$5,703,393	$5,762,847	$5,820,465	$5,880,367	$5,940,601	$6,000,835	$6,055,649	$6,110,463	$6,165,277	$6,220,091	$6,274,905	$6,329,719	$6,384,533	$6,439,347	$6,494,161	$6,548,975	$6,603,789	$6,603,789
Major System Improvements - With Maximum Transport (Low Cost)	- Option A-2c	Accumulative Costs	$4,464,828	$4,522,798	$4,582,061	$4,643,116	$4,701,798	$4,758,465	$4,817,348	$4,876,611	$4,938,602	$4,995,435	$5,052,594	$5,111,898	$5,172,031	$5,232,405	$5,289,072	$5,347,143	$5,406,427	$5,467,548	$5,526,052	$5,582,720	$5,641,672	$5,700,956	$5,760,240	$5,814,104	$5,867,968	$5,921,832	$5,975,696	$6,029,560	$6,083,424	$6,137,288	$6,191,152	$6,245,016	$6,298,880	$6,352,744	$6,352,744
Major System Improvements - Adaptive Migration Strategy	- Option A-2d	Accumulative Costs	$4,803,562	$4,861,694	$4,921,119	$4,982,336	$5,041,180	$5,098,009	$5,157,054	$5,216,479	$5,278,632	$5,335,627	$5,392,947	$5,452,414	$5,512,709	$5,573,245	$5,630,074	$5,688,307	$5,747,753	$5,809,036	$5,867,702	$5,924,532	$5,983,646	$6,043,092	$6,102,538	$6,156,564	$6,210,590	$6,264,616	$6,318,642	$6,372,668	$6,426,694	$6,480,720	$6,534,746	$6,588,772	$6,642,798	$6,696,824	$6,696,824
Major System Improvements - In-River Passage (No BGS str. & BOR wate	- Option A-6a	Accumulative Costs	$8,574,450	$8,656,843	$8,740,529	$8,826,007	$8,909,112	$8,990,202	$9,073,508	$9,157,194	$9,243,607	$9,324,864	$9,406,445	$9,490,173	$9,574,729	$9,659,525	$9,740,616	$9,823,110	$9,906,817	$9,992,360	#########	#########	#########	#########	#########	#########	#########	#########	#########	#########	#########	#########	#########	#########	#########	#########	$11,268,325
Major System Improvements - In-River Passage (No BGS str.)	- Option A-6b	Accumulative Costs	$4,448,441	$4,502,762	$4,558,376	$4,615,782	$4,670,815	$4,723,833	$4,779,067	$4,834,681	$4,893,022	$4,946,207	$4,999,716	$5,055,372	$5,111,856	$5,168,580	$5,221,599	$5,276,021	$5,331,656	$5,389,127	$5,443,983	$5,497,001	$5,552,305	$5,607,940	$5,663,575	$5,713,790	$5,764,005	$5,814,220	$5,864,435	$5,914,650	$5,964,865	$6,015,080	$6,065,295	$6,115,510	$6,165,725	$6,215,940	$6,215,940
Major System Improvements - In-River Passage (With BGS str.)	- Option A-6d	Accumulative Costs	$4,517,309	$4,573,616	$4,631,216	$4,690,608	$4,747,627	$4,802,631	$4,859,851	$4,917,451	$4,977,779	$5,032,949	$5,088,444	$5,146,086	$5,204,556	$5,263,267	$5,318,271	$5,374,679	$5,432,300	$5,491,758	$5,548,599	$5,603,604	$5,660,893	$5,718,514	$5,776,135	$5,828,336	$5,880,537	$5,932,738	$5,984,939	$6,037,140	$6,089,341	$6,141,542	$6,193,743	$6,245,944	$6,298,145	$6,350,346	$6,350,346

US Army Corps of Engineers
Walla Walla District

All Dollars in K-Dollars			*FY72*	*FY73*	*FY74*	*FY75*	*FY76*	*FY77*	*FY78*	*FY79*	*FY80*	*FY81*	*FY82*	*FY83*	*FY84*	*FY85*	*FY86*	*FY87*	*FY88*	*FY89*	*FY90*	*FY91*	*FY92*	*FY93*	*FY94*	*FY95*	*FY96*	*FY97*	*FY98*	*FY99*	*FY00*	*FY01*	*FY02*	*FY03*	*FY04*	*FY05*	**Total Costs** *for 105 years*
Existing System - Existing Conditions	**- Option A-1**	**Alternative # 1**																																			$6,213,608
	Construction Subtotal	*Total Costs*																																			$89,258
	AFEP Subtotal	*Total Costs*																																			$137,275
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$1,517,250
	BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$250,530
	O,M,R,R,R Subtotal	*Total Costs*	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$3,832,185
	Powerhouse MR Subtotal	*Total Costs*	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$387,110
Existing System - In River Conditions	**- Option A-1a**																																				$6,134,044
	Construction Subtotal	*Total Costs*																																			$80,149
	AFEP Subtotal	*Total Costs*																																			$137,275
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$1,517,250
	BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$250,530
	O,M,R,R,R Subtotal	*Total Costs*	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$35,826	$3,761,730
	Powerhouse MR Subtotal	*Total Costs*	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$387,110
Existing System - Maximum Transport	**- Option A-2a**	**Alternative # 2**																																			$6,147,408
	Construction Subtotal	*Total Costs*																																			$67,903
	AFEP Subtotal	*Total Costs*																																			$92,430
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$1,517,250
	BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$250,530
	O,M,R,R,R Subtotal	*Total Costs*	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$36,497	$3,832,185
	Powerhouse MR Subtotal	*Total Costs*	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$387,110
Major System Improvements - With Maximum Transport (High Cost)	**- Option A-2b**																																				$6,603,789
	Construction Subtotal	*Total Costs*																																			$270,005
	AFEP Subtotal	*Total Costs*																																			$191,204
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$1,517,250
	BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$250,530
	O,M,R,R,R Subtotal	*Total Costs*	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$37,978	$3,987,690
	Powerhouse MR Subtotal	*Total Costs*	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$387,110
Major System Improvements - With Maximum Transport (Low Cost)	**- Option A-2c**																																				$6,352,744
	Construction Subtotal	*Total Costs*																																			$162,468
	AFEP Subtotal	*Total Costs*																																			$147,446
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$1,517,250
	BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$250,530
	O,M,R,R,R Subtotal	*Total Costs*	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$37,028	$3,887,940
	Powerhouse MR Subtotal	*Total Costs*	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$387,110
Major System Improvements - Adaptive Migration Strategy	**- Option A-2d**	**Alternative # 3**																																			$6,696,824
	Construction Subtotal	*Total Costs*																																			$389,646
	AFEP Subtotal	*Total Costs*																																			$247,338
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$1,517,250
	BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$250,530
	O,M,R,R,R Subtotal	*Total Costs*	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$37,190	$3,904,950
	Powerhouse MR Subtotal	*Total Costs*	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$387,110
Major System Improvements - In-River Passage (No BGS str. & BOR wate	**- Option A-6a**																																				$11,268,325
	Construction Subtotal	*Total Costs*																																			$316,722
	AFEP Subtotal	*Total Costs*																																			$239,533
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$1,517,250
	BOR Water Purchase Subtotal	*Total Costs*	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$28,072	$5,052,385
	O,M,R,R,R Subtotal	*Total Costs*	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$3,755,325
	Powerhouse MR Subtotal	*Total Costs*	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$387,110
Major System Improvements - In-River Passage (No BGS str.)	**- Option A-6b**																																				$6,215,940
	Construction Subtotal	*Total Costs*																																			$316,722
	AFEP Subtotal	*Total Costs*																																			$239,533
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$1,517,250
	BOR Water Purchase Subtotal	*Total Costs*																																			
	O,M,R,R,R Subtotal	*Total Costs*	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$35,765	$3,755,325
	Powerhouse MR Subtotal	*Total Costs*	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$387,110
Major System Improvements - In-River Passage (With BGS str.)	**- Option A-6d**																																				$6,350,346
	Construction Subtotal	*Total Costs*																																			$249,223
	AFEP Subtotal	*Total Costs*																																			$232,908
	Fish Hatchery O,M,R Subtotal	*Total Costs*	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$1,517,250
	BOR Water Purchase Subtotal	*Total Costs*	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$250,530
	O,M,R,R,R Subtotal	*Total Costs*	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$35,365	$3,713,325
	Powerhouse MR Subtotal	*Total Costs*	$2,803	$4,106	$5,399	$7,191	$4,818	$2,803	$5,019	$5,399	$8,126	$2,969	$3,295	$5,441	$6,269	$6,510	$2,803	$4,207	$5,420	$7,256	$4,641	$2,803	$5,089	$5,420	$5,420												$387,110
		Years	*FY72*	*FY73*	*FY74*	*FY75*	*FY76*	*FY77*	*FY78*	*FY79*	*FY80*	*FY81*	*FY82*	*FY83*	*FY84*	*FY85*	*FY86*	*FY87*	*FY88*	*FY89*	*FY90*	*FY91*	*FY92*	*FY93*	*FY94*	*FY95*	*FY96*	*FY97*	*FY98*	*FY99*	*FY00*	*FY01*	*FY02*	*FY03*	*FY04*	*FY05*	*for 105 years*

Cost data does not include inflation costs.

	LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY					<------- OPERATING DAM OPTIONS ------->									
						EXISTING SYSTEM				MAJOR SYSTEM IMPROVEMENTS					
	US Army Corps of Engineers® Walla Walla District — *Cost Numbers are for Economic Study Purposes Only* — *Not Intended for Program Funding*	TYPE OF COST	DESIGN & CONSTRUCTION DURATION	MID POINT OF CONSTR.		EXISTING CONDITIONS	IN RIVER CONDITIONS (Logic Option)	MAXIMUM TRANSPORT		WITH MAXIMUM TRANSPORT (High Cost)	WITH MAXIMUM TRANSPORT (Low Cost)	ADAPTIVE MIGRATION STRATEGY	IN-RIVER PASSAGE (No BGS Str.)	IN-RIVER PASSAGE (W/ BGS Str.)	
			FEASIBILITY ALTERNATIVES ====>			ALT # 1		ALT # 2				ALT # 3			
	Assumes Unrestricted Funds, No Escalation					(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @ICE H)		(NO V. SPILL EX @ICE H)	(NO V. SPILL EX @ICE H)	(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @L Go)	
			ENGINEERING APPENDIXES & PATH OPTIONS ====>			*OPTION A-1*	*OPTION A-1a*	*OPTION A-2a*		*OPTION A-2b*	*OPTION A-2c*	*OPTION A-2d*	*OPTION A-6a&b*	*OPTION A-6d*	
	DESCRIPTIONS - for Ice Harbor, Lower Monumental, Little Goose & Lower Granite Locks & Dams -> Mc Nary Dam not included.					Thousand Dollars	Thousand Dollars	Thousand Dollars		Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	
	CONSTRUCTION AND ACQUISITION COSTS		Summary of Fish Improvements I & II			$89,258	$80,149	$67,903		$270,005	$162,468	$389,646	$316,722	$249,223	=
	FISH IMPROVEMENTS I, - MOD. FOR EXISTING FISH FAC.		Summary of the Dam Cost Below			$89,258	$80,149	$67,903		$67,903	$67,903	$89,258	$73,249	$58,836	
	ALL FOUR DAMS	Oct 98 Price Level	Summary		=	$3,315	$3,315	$3,315	=	$3,315	$3,315	$3,315	$3,315	$3,315	=
	Project Management - (Cost Holder that is spread into the other costs)		115.00%			$846	$846	$846		$846	$846	$846	$846	$846	
	Field Cam Tests Improvement Studies (8 Types of Turbines)		2 Years	FY 2002	^	$2,001	$2,001	$2,001	^	$2,001	$2,001	$2,001	$2,001	$2,001	^
	3-D Cam Improvements (24 Each Turbines)		2 Years	FY 2004	^	$1,314	$1,314	$1,314	^	$1,314	$1,314	$1,314	$1,314	$1,314	^
	ICE HARBOR LOCK & DAM	Oct 98 Price Level	Summary		=	$2,645	$2,645	$2,645	=	$2,645	$2,645	$2,645	$2,645	$2,645	=
	Aux. Water Supply Fish Ladder		1 Years	FY 2002	^	$2,185	$2,185	$2,185	^	$2,185	$2,185	$2,185	$2,185	$2,185	^
	Fish Fac. Cylindrical Dewater System		1 Years	FY 2004	^	$460	$460	$460	^	$460	$460	$460	$460	$460	^
	LOWER MONUMENTAL LOCK & DAM	Oct 98 Price Level	Summary		=	$18,294	$18,294	$11,352	=	$11,352	$11,352	$18,294	$14,844	$7,902	=
	Gantry Crane Mod		1 Years	FY 2002	^	$542	$542	$542	^	$542	$542	$542	$542	$542	^
	Aux. Water Supply Fish Ladder		1 Years	FY 2003	^	$2,300	$2,300	$2,300	^	$2,300	$2,300	$2,300	$2,300	$2,300	^
	Fish Fac. Cylindrical Dewater System		1 Years	FY 2004	^	$460	$460	$460	^	$460	$460	$460	$460	$460	^
	Separator Improvements		1 Years	FY 2004	^	$3,450	$3,450	$3,450	^	$3,450	$3,450	$3,450	NOT REQ'D	NOT REQ'D	^
	DGAS 1 -> 2 End Bay Deflectors		3 Years	FY 2003	^	$4,600	$4,600	$4,600	^	$4,600	$4,600	$4,600	$4,600	$4,600	^
	DGAS 2 -> Modified Existing 8 Deflectors & Pier Extensions		5 Years	FY 2004	^	$6,942	$6,942	NOT REQ'D	^	NOT REQ'D	NOT REQ'D	$6,942	$6,942	NOT REQ'D	^
	LITTLE GOOSE LOCK & DAM	Oct 98 Price Level	Summary		=	$24,170	$24,170	$17,228	=	$17,228	$17,228	$24,170	$20,720	$20,720	=
	Aux. Water Supply Fish Ladder		1 Years	FY 2004	^	$2,645	$2,645	$2,645	^	$2,645	$2,645	$2,645	$2,645	$2,645	^
	ESBS Mods		1 Years	FY 2002	^	$1,530	$1,530	$1,530	^	$1,530	$1,530	$1,530	$1,530	$1,530	^
	Trash Boom		1 Years	FY 2001	^	$4,543	$4,543	$4,543	^	$4,543	$4,543	$4,543	$4,543	$4,543	^
	Fish Fac. Cylindrical Dewater System		1 Years	FY 2003	^	$460	$460	$460	^	$460	$460	$460	$460	$460	^
	Separator Improvements		1 Years	FY 2003	^	$3,450	$3,450	$3,450	^	$3,450	$3,450	$3,450	NOT REQ'D	NOT REQ'D	^
	DGAS 1 -> 2 End Bay Deflectors		3 Years	FY 2003	^	$4,600	$4,600	$4,600	^	$4,600	$4,600	$4,600	$4,600	$4,600	^
	DGAS 2 -> Modified Existing 8 Deflectors & Pier Extensions		4 Years	FY 2005	^	$6,942	$6,942	NOT REQ'D	^	NOT REQ'D	NOT REQ'D	$6,942	$6,942	$6,942	^
	LOWER GRANITE LOCK & DAM	Oct 98 Price Level	Summary		=	$40,834	$31,725	$33,363	=	$33,363	$33,363	$40,834	$31,725	$24,254	=
	Juvenile Fish Fac. Improvements		2 Years	FY 2003	^	$21,609	$21,609	$21,609	^	$21,609	$21,609	$21,609	$21,609	$21,609	^
	5 Each Additional Barges Phase II - (Does not include 2 McNary Barges)		1 Years	FY 2004	^	$6,636	NOT REQ'D	$6,636	^	$6,636	$6,636	$6,636	NOT REQ'D	NOT REQ'D	^
	Aux. Water Supply Fish Ladder		1 Years	FY 2002	^	$2,645	$2,645	$2,645	^	$2,645	$2,645	$2,645	$2,645	$2,645	^
	Barge Moorage Cells		1 Years	FY 2004	^	$2,473	NOT REQ'D	$2,473	^	$2,473	$2,473	$2,473	NOT REQ'D	NOT REQ'D	^
	DGAS 2 -> Modified Existing 10 Deflectors & Pier Extensions		4 Years	FY 2005	^	$7,471	$7,471	NOT REQ'D	^	NOT REQ'D	NOT REQ'D	$7,471	$7,471	NOT REQ'D	^
	FISH IMPROVEMENTS II, MAJOR SYSTEM IMPROVEMENTS		Summary of the Dam Cost Below			N/A	N/A	N/A		$202,102	$94,565	$300,388	$243,473	$190,387	
	ALL FOUR DAMS	Oct 98 Price Level	Summary		=	N/A	N/A	N/A	=	$1,000	$1,000	$1,000	$1,000	$1,000	=
	Prototypes, Tests & Feature Design Memorandum		7 Years	FY 2006	^				^	$1,000	$1,000	$1,000	$1,000	$1,000	^
	ICE HARBOR LOCK & DAM	Oct 98 Price Level	Summary		=	N/A	N/A	N/A	=	$16,058	$16,058	$85,407	$56,837	$53,883	=
Std	New 19 ESB Screens		5 Years	FY 2005	^				^	$16,058	$16,058	$16,058	$16,058	$16,058	^
TYPE 2	Full Flow Bypass SBC w/ Modified Spillbay - 6 Units, Bypass Channel		7 Years	FY 2006	^				^				$40,779		^
TYPE 4	BGS to a Modified Spillbay - 0 Units, Removable Spillway Weir w/BGS		2 Years	FY 2005	^				^					$37,825	^
TYPE 7	BGS to Spillway, FLE, & (2 Each) RSW		3 Years	FY 2005								$69,349			
	LOWER MONUMENTAL LOCK & DAM	Oct 98 Price Level	Summary		=	N/A	N/A	N/A	=	$69,808	$16,058	$95,610	$76,142	$53,883	=
Std	New 19 ESB Screens		5 Years	FY 2005	^				^	$16,058	$16,058	$16,058	$16,058	$16,058	^
TYPE 1	Full powerhouse SBC for Transportation - 6 Units, Screen Channel		3 Years	FY 2009	^				^	$53,750					^
TYPE 2	Full Flow Bypass SBC w/ Modified Spillbay - 6 Units, Bypass Channel		7 Years	FY 2006	^				^				$60,084		^
TYPE 3	Adaptive Migration SBC w/BGS - 2 Units, Dual Bypass/Screen Channel W/BGS		3 Years	FY 2007	^				^						^
TYPE 4	BGS to a Modified Spillbay - 0 Units, Removable Spillway Weir w/BGS		2 Years	FY 2005	^				^					$37,825	^

Cost data does not include inflation costs.

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY						**<------- OPERATING DAM OPTIONS ------->**									
US Army Corps of Engineers® Walla Walla District						**EXISTING SYSTEM**				**MAJOR SYSTEM IMPROVEMENTS**					
	Cost Numbers are for Economic Study Purposes Only	**TYPE OF COST**	**DESIGN & CONSTRUCTION DURATION**	**MID POINT OF CONSTR.**		**EXISTING CONDITIONS**	**IN RIVER CONDITIONS** (Logic Option)	**MAXIMUM TRANSPORT**		**WITH MAXIMUM TRANSPORT (High Cost)**	**WITH MAXIMUM TRANSPORT (Low Cost)**	**ADAPTIVE MIGRATION STRATEGY**	**IN-RIVER PASSAGE (No BGS Str.)**	**IN-RIVER PASSAGE (W/ BGS Str.)**	
	Not Intended for Program Funding		*FEASIBILITY ALTERNATIVES ====>*			ALT # 1		ALT # 2				ALT # 3			
	Assumes Unrestricted Funds, No Escalation					(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @ICE H)		(NO V. SPILL EX @ICE H)	(NO V. SPILL EX @ICE H)	(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @L Go)	
			ENGINEERING APPENDIXES & PATH OPTIONS ====>			*OPTION A-1*	*OPTION A-1a*	*OPTION A-2a*		*OPTION A-2b*	*OPTION A-2c*	*OPTION A-2d*	*OPTION A-6a&b*	*OPTION A-6d*	
DESCRIPTIONS - for Ice Harbor, Lower Monumental, Little Goose & Lower Granite Locks & Dams -> Mc Nary Dam not included.						Thousand Dollars	Thousand Dollars	Thousand Dollars		Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	
TYPE 5	Partial Powerhouse SBC, BGS, FLE, & (2 Each) RSW		3 Years	FY 2005	^				^			$79,552			^
LITTLE GOOSE LOCK & DAM		Oct 98 Price Level	Summary		=	N/A	N/A	N/A	=	**$53,787**	**$0**	**$42,093**	**$43,796**	**$43,796**	=
TYPE 1	Full powerhouse SBC for Transportation - 6 Units, Screen Channel		3 Years	FY 2009	^				^	$53,787					^
TYPE 2	Full Flow Bypass SBC w/ Modified Spillbay - 6 Units, Bypass Channel		3 Years	FY 2007	^				^		$0		$43,796	$43,796	^
TYPE 6	Partial Powerhouse OCCLUSION Structure & (2 Each) RSW		3 Years	FY 2005	^				^			$42,093			^
LOWER GRANITE LOCK & DAM		Oct 98 Price Level	Summary		=	N/A	N/A	N/A	=	**$61,449**	**$61,449**	**$76,278**	**$65,698**	**$37,825**	=
TYPE 1	Full powerhouse SBC for Transportation - 6 Units, Screen Channel		6 Years	FY 2005	^				^	$61,449	$61,449				^
TYPE 2	Full Flow Bypass SBC w/ Modified Spillbay - 6 Units, Bypass Channel		4 Years	FY 2002	^				^				$65,698		^
TYPE 3	Adaptive Migration SBC w/BGS - 2 Units, Dual Bypass/Screen Channel W/BGS		3 Years	FY 2003	^				^						^
TYPE 4	BGS to a Modified Spillbay - 0 Units, Removable Spillway Weir w/BGS		2 Years	FY 2005	^				^					$37,825	^
	Testing - BGS Gap											$1,000			
TYPE 5, P	Prototype - Partial Powerhouse SBC		3 Years	FY 2004	^				^			$29,819			^
TYPE 5, F	Final - Partial Powerhouse SBC, BGS, FLE, & (1 moved & 1 new) RSW		3 Years	FY 2009	^				^			$45,459			^
ANADROMOUS FISH EVALUATION PROGRAM		Annual Costs for 27 Years		Each Year	=	$5,280	$5,280	$3,555	=	$7,354	$5,671	$9,513	$9,213	$8,958	=
ALL FOUR DAMS (Monitoring & Mitigation)					^				^						^
	Anadromous Fish Evaluation Program Studies (AFEP)		27 Years	Each Year	^	$5,280	$5,280	$3,555	^	$7,354	$5,671	$9,513	$9,213	$8,958	^
BREACHING DAMS		Summary of all the Breach Constr. Dams Costs Below													
ICE HARBOR LOCK & DAM		Oct 98 Price Level	Summary		=	N/A	N/A	N/A	=	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	=
	Power House Turbine Modifications		2 Years	FY 2005	^				^						^
	Dam Embankment Removal		2 Years	FY 2005	^				^						^
	River Channelization		1 Years	FY 2006	^				^						^
	Full Concrete Structure Removal		2 Years	FY 2007	^				^						^
	Temporary Fish Handling Facilities		2 Years	FY 2005	^				^						^
	Project Dam Decommissioning		1 Years	FY 2006	^				^						^
	Railroad Relocations		2 Years	FY 2004	^				^						^
	Bridge Pier & Abutment Protection		3 Years	FY 2005	^				^						^
	Reservoir Embankment Protection		3 Years	FY 2004	^				^						^
	Drainage Structures Protection		3 Years	FY 2004	^				^						^
	Railroad and Roadway Damage Repair		3 Years	FY 2007	^				^						^
	Recreation Access Modification		2 Years	FY 2007	^				^						^
	HMU Modification		2 Years	FY 2006	^				^						^
	Reservoir Revegetation (For Air & Water Quality)		4 Years	FY 2007	^				^						^
	Cultural Resources Protection		2 Years	FY 2006	^				^						^
	Cattle Watering Facilities		2 Years	FY 2006	^				^						^
	Real Estate (Excessing Property)		4 Years	FY 2007	^				^						^
LOWER MONUMENTAL LOCK & DAM		Oct 98 Price Level	Summary		=	N/A	N/A	N/A	=	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	=
	Power House Turbine Modifications		2 Years	FY 2005	^				^						^
	Dam Embankment Removal		2 Years	FY 2005	^				^						^
	River Channelization		1 Years	FY 2006	^				^						^
	Full Concrete Structure Removal		2 Years	FY 2007	^				^						^
	Temporary Fish Handling Facilities		2 Years	FY 2005	^				^						^
	Project Dam Decommissioning		1 Years	FY 2006	^				^						^
	Railroad Relocations		2 Years	FY 2004	^				^						^
	Bridge Pier & Abutment Protection		3 Years	FY 2005	^				^						^
	Reservoir Embankment Protection		3 Years	FY 2004	^				^						^

Cost data does not include inflation costs.

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY					<------- OPERATING DAM OPTIONS ------->										
US Army Corps of Engineers® Walla Walla District					EXISTING SYSTEM				MAJOR SYSTEM IMPROVEMENTS					
Cost Numbers are for Economic Study Purposes Only *Not Intended for Program Funding*	TYPE OF COST	DESIGN & CONSTRUCTION DURATION	MID POINT OF CONSTR.		EXISTING CONDITIONS	IN RIVER CONDITIONS (Logic Option)	MAXIMUM TRANSPORT		WITH MAXIMUM TRANSPORT (High Cost)	WITH MAXIMUM TRANSPORT (Low Cost)	ADAPTIVE MIGRATION STRATEGY	IN-RIVER PASSAGE (No BGS Str.)	IN-RIVER PASSAGE (W/ BGS Str.)	
		FEASIBILITY ALTERNATIVES ====>			ALT # 1		ALT # 2				ALT # 3			
Assumes Unrestricted Funds, No Escalation					(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @ICE H)		(NO V. SPILL EX @ICE H)	(NO V. SPILL EX @ICE H)	(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @L Go)	
		ENGINEERING APPENDIXES & PATH OPTIONS ====>			*OPTION A-1*	*OPTION A-1a*	*OPTION A-2a*		*OPTION A-2b*	*OPTION A-2c*	*OPTION A-2d*	*OPTION A-6a&b*	*OPTION A-6d*	
DESCRIPTIONS - for Ice Harbor, Lower Monumental, Little Goose & Lower Granite Locks & Dams -> Mc Nary Dam not included.					Thousand Dollars	Thousand Dollars	Thousand Dollars		Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	
Drainage Structures Protection		3 Years	FY 2004	^				^						^
Railroad and Roadway Damage Repair		3 Years	FY 2007	^				^						^
Recreation Access Modification		2 Years	FY 2007	^				^						^
HMU Modification		2 Years	FY 2006	^				^						^
Reservoir Revegetation (For Air & Water Quality)		4 Years	FY 2007	^				^						^
Cultural Resources Protection		2 Years	FY 2006	^				^						^
Cattle Watering Facilities		2 Years	FY 2006	^				^						^
Lyons Ferry Hatchery Modifications		3 Years	FY 2005	^				^						^
Real Estate (Excessing Property)		4 Years	FY 2007	^				^						^
LITTLE GOOSE LOCK & DAM	Oct 98 Price Level	Summary		=	N/A	N/A	N/A	=	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	=
Power House Turbine Modifications		2 Years	FY 2005	^				^						^
Dam Embankment Removal		2 Years	FY 2005	^				^						^
River Channelization		1 Years	FY 2006	^				^						^
Full Concrete Structure Removal		2 Years	FY 2007	^				^						^
Temporary Fish Handling Facilities		2 Years	FY 2005	^				^						^
Project Dam Decommissioning		1 Years	FY 2006	^				^						^
Railroad Relocations		2 Years	FY 2004	^				^						^
Bridge Pier & Abutment Protection		3 Years	FY 2005	^				^						^
Reservoir Embankment Protection		3 Years	FY 2004	^				^						^
Drainage Structures Protection		3 Years	FY 2004	^				^						^
Railroad and Roadway Damage Repair		3 Years	FY 2007	^				^						^
Recreation Access Modification		2 Years	FY 2007	^				^						^
HMU Modification		2 Years	FY 2006	^				^						^
Reservoir Revegetation (For Air & Water Quality)		4 Years	FY 2007	^				^						^
Cultural Resources Protection		2 Years	FY 2006	^				^						^
Cattle Watering Facilities		2 Years	FY 2006	^				^						^
Real Estate (Excessing Property)		4 Years	FY 2007	^				^						^
LOWER GRANITE LOCK & DAM	Oct 98 Price Level	Summary		=	N/A	N/A	N/A	=	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	=
Power House Turbine Modifications		2 Years	FY 2005	^				^						^
Dam Embankment Removal		2 Years	FY 2005	^				^						^
River Channelization		1 Years	FY 2006	^				^						^
Full Concrete Structure Removal		2 Years	FY 2007	^				^						^
Temporary Fish Handling Facilities		2 Years	FY 2005	^				^						^
Project Dam Decommissioning		1 Years	FY 2006	^				^						^
Railroad Relocations		2 Years	FY 2004	^				^						^
Bridge Pier & Abutment Protection		3 Years	FY 2005	^				^						^
Reservoir Embankment Protection		3 Years	FY 2004	^				^						^
Drainage Structures Protection		3 Years	FY 2004	^				^						^
Railroad and Roadway Damage Repair		3 Years	FY 2007	^				^						^
Recreation Access Modification		2 Years	FY 2007	^				^						^
HMU Modification		2 Years	FY 2006	^				^						^
Reservoir Revegetation (For Air & Water Quality)		4 Years	FY 2007	^				^						^
Cultural Resources Protection		2 Years	FY 2006	^				^						^
Cattle Watering Facilities		2 Years	FY 2006	^				^						^
Real Estate (Excessing Property)		4 Years	FY 2007	^				^						^

Cost data does not include inflation costs.

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY				<------- OPERATING DAM OPTIONS ------->							
US Army Corps of Engineers® Walla Walla District				EXISTING SYSTEM			MAJOR SYSTEM IMPROVEMENTS				
Cost Numbers are for Economic Study Purposes Only / *Not Intended for Program Funding*	TYPE OF COST	DESIGN & CONSTRUCTION DURATION	MID POINT OF CONSTR.	EXISTING CONDITIONS	IN RIVER CONDITIONS (Logic Option)	MAXIMUM TRANSPORT	WITH MAXIMUM TRANSPORT (High Cost)	WITH MAXIMUM TRANSPORT (Low Cost)	ADAPTIVE MIGRATION STRATEGY	IN-RIVER PASSAGE (No BGS Str.)	IN-RIVER PASSAGE (W/ BGS Str.)
		FEASIBILITY ALTERNATIVES ====>		ALT # 1		ALT # 2			ALT # 3		
Assumes Unrestricted Funds, No Escalation				(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @ICE H)	(NO V. SPILL EX @ICE H)	(NO V. SPILL EX @ICE H)	(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @L Go)
		ENGINEERING APPENDIXES & PATH OPTIONS ====>		*OPTION A-1*	*OPTION A-1a*	*OPTION A-2a*	*OPTION A-2b*	*OPTION A-2c*	*OPTION A-2d*	*OPTION A-6a&b*	*OPTION A-6d*
DESCRIPTIONS - for Ice Harbor, Lower Monumental, Little Goose & Lower Granite Locks & Dams -> Mc Nary Dam not included.				Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars
OPERATION & MAINTENANCE COSTS	Summary of Dam Routine & Minor Repair Costs, Each Year			$36,497	$35,826	$36,497	$37,978	$37,028	$37,190	$35,765	$35,365
ALL FOUR DAMS (Monitoring & Mitigation)	Oct 98 Price Level	Summary		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wildlife Monitoring Costs		25 Years	FY 2019								
Vegetation Monitoring Costs		25 Years	FY 2019								
Fish Monitoring Costs		25 Years	FY 2019								
Water Quantity Monitoring Costs		12 Years	FY 2012								
Air Quality Monitoring Costs		10 Years	FY 2011								
Sedimentation Monitoring Costs		10 Years	FY 2011								
Fish & Wildlife Mitigation Costs		25 Years	FY 2019								
Culture Resources Mitigation Costs		10 Years	FY 2011								
ANNUAL ROUTINE OPERATIONS, MAINTENANCE & REPAIR COSTS			Each Year	$29,281	$29,129	$29,281	$30,762	$29,812	$29,974	$28,892	$28,492
ICE HARBOR LOCK & DAM	Annual Costs, Summary of Oper & Main Cost In the Detail Below,		Each Year	**$9,457**	**$9,420**	**$9,457**	**$9,457**	**$9,457**	**$9,596**	**$9,265**	**$9,268**
NOTE: For the Drawdown Options, Ice Harbor Lock & Dam will Operate another 6 Years after start of project work.											
Operation Costs											
Sub Total Operations	Annual Costs	Summary	Each Year	$4,339	$4,303	$4,339	$4,339	$4,339	$4,339	$4,009	$4,009
Navigation - (Locks Work)				$209	$209	$209	$209	$209	$209	$209	$209
Power - (Turbines, Generators, & Power Lines Work)				$623	$623	$623	$623	$623	$623	$623	$623
Recreation - (Parks Work)				$764	$764	$764	$764	$764	$764	$764	$764
Fish - (Barging, Ladders, Screens Work & AFEP)				$641	$641	$641	$641	$641	$641	$348	$348
Fish - (5 Each Extra Barges)				$37	$0	$37	$37	$37	$37	$0	$0
Wildlife - (Managing Lands Work)				$279	$279	$279	$279	$279	$279	$279	$279
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				$1,785	$1,785	$1,785	$1,785	$1,785	$1,785	$1,785	$1,785
SBC System - Extra Costs due to Options							$0	$0	$0	$0	$0
Maintenance Costs											
Sub Total Maintenance	Annual Costs	Summary	Each Year	$5,117	$5,117	$5,117	$5,117	$5,117	$5,256	$5,256	$5,259
Navigation - (Locks Work)				$1,899	$1,899	$1,899	$1,899	$1,899	$1,899	$1,899	$1,899
Power - (Turbines, Generators, & Power Lines Work)				$1,452	$1,452	$1,452	$1,452	$1,452	$1,452	$1,452	$1,452
Recreation - (Parks Work)				$163	$163	$163	$163	$163	$163	$163	$163
Fish - (Barging, Ladders, Screens Work & AFEP)				$288	$288	$288	$288	$288	$288	$288	$288
Fish - (5 Each Extra Barges)				$0	$0	$0	$0	$0	$0	$0	$0
Wildlife - (Managing Lands Work)				$33	$33	$33	$33	$33	$33	$33	$33
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				$1,282	$1,282	$1,282	$1,282	$1,282	$1,282	$1,282	$1,282
SBC System - Extra Costs due to Options							$0	$0	$139	$139	$142
LOWER MONUMENTAL LOCK & DAM	Annual Costs, Summary of Oper & Main Cost In the Detail Below,		Each Year	**$6,234**	**$6,196**	**$6,234**	**$6,709**	**$6,234**	**$6,494**	**$6,226**	**$6,031**
NOTE: For the Drawdown Options, Lower Monumental Lock & Dam will Operate another 6 Years after start of project work.											
Operation Costs											
Sub Total Operations	Annual Costs	Summary	Each Year	$2,866	$2,828	$2,866	$2,866	$2,866	$2,866	$2,522	$2,522
Navigation - (Locks Work)				$67	$67	$67	$67	$67	$67	$67	$67
Power - (Turbines, Generators, & Power Lines Work)				$442	$442	$442	$442	$442	$442	$442	$442
Recreation - (Parks Work)				$146	$146	$146	$146	$146	$146	$146	$146
Fish - (Barging, Ladders, Screens Work & AFEP)				$791	$791	$791	$791	$791	$791	$485	$485
Fish - (5 Each Extra Barges)				$38	$0	$38	$38	$38	$38	$0	$0
Wildlife - (Managing Lands Work)				$171	$171	$171	$171	$171	$171	$171	$171
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				$1,212	$1,212	$1,212	$1,212	$1,212	$1,212	$1,212	$1,212
SBC System - Extra Costs due to Options							$0	$0	$0	$0	$0
Maintenance Costs											

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY					<------- OPERATING DAM OPTIONS ------->									
US Army Corps of Engineers® Walla Walla District					EXISTING SYSTEM				MAJOR SYSTEM IMPROVEMENTS					
Cost Numbers are for Economic Study Purposes Only *Not Intended for Program Funding*	TYPE OF COST	DESIGN & CONSTRUCTION DURATION	MID POINT OF CONSTR.		EXISTING CONDITIONS	IN RIVER CONDITIONS (Logic Option)	MAXIMUM TRANSPORT		WITH MAXIMUM TRANSPORT (High Cost)	WITH MAXIMUM TRANSPORT (Low Cost)	ADAPTIVE MIGRATION STRATEGY	IN-RIVER PASSAGE (No BGS Str.)	IN-RIVER PASSAGE (W/ BGS Str.)	
		FEASIBILITY ALTERNATIVES ====>			ALT # 1		ALT # 2				ALT # 3			
Assumes Unrestricted Funds, No Escalation					(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @ICE H)		(NO V. SPILL EX @ICE H)	(NO V. SPILL EX @ICE H)	(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @L Go)	
		ENGINEERING APPENDIXES & PATH OPTIONS ====>			*OPTION A-1*	*OPTION A-1a*	*OPTION A-2a*		*OPTION A-2b*	*OPTION A-2c*	*OPTION A-2d*	*OPTION A-6a&b*	*OPTION A-6d*	
DESCRIPTIONS - for Ice Harbor, Lower Monumental, Little Goose & Lower Granite Locks & Dams -> Mc Nary Dam not included.					Thousand Dollars	Thousand Dollars	Thousand Dollars		Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	
Sub Total Maintenance	Annual Costs	Summary	Each Year	=	$3,368	$3,368	$3,368	=	$3,843	$3,368	$3,628	$3,705	$3,510	=
Navigation - (Locks Work)				^	$142	$142	$142	^	$142	$142	$142	$142	$142	^
Power - (Turbines, Generators, & Power Lines Work)				^	$1,975	$1,975	$1,975	^	$1,975	$1,975	$1,975	$1,975	$1,975	^
Recreation - (Parks Work)				^	$77	$77	$77	^	$77	$77	$77	$77	$77	^
Fish - (Barging, Ladders, Screens Work & AFEP)				^	$365	$365	$365	^	$365	$365	$365	$365	$365	^
Fish - (5 Each Extra Barges)				^	$0	$0	$0	^	$0	$0	$0	$0	$0	^
Wildlife - (Managing Lands Work)				^	$123	$123	$123	^	$123	$123	$123	$123	$123	^
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				^	$686	$686	$686	^	$686	$686	$686	$686	$686	^
SBC System - Extra Costs due to Options				^				^	$475	$0	$260	$337	$142	^
LITTLE GOOSE LOCK & DAM Annual Costs, Summary of Oper & Main Cost In the Detail Below, Each Year					**$5,790**	**$5,750**	**$5,790**		**$6,265**	**$5,790**	**$5,824**	**$5,584**	**$5,584**	
Operation Costs														
NOTE: For the Drawdown Options, Little Goose Lock & Dam will Operate another 5 Years after start of project work.														
Sub Total Operations	Annual Costs	Summary	Each Year	=	$2,797	$2,756	$2,797	=	$2,797	$2,797	$2,797	$2,434	$2,434	=
Navigation - (Locks Work)				^	$87	$87	$87	^	$87	$87	$87	$87	$87	^
Power - (Turbines, Generators, & Power Lines Work)				^	$387	$387	$387	^	$387	$387	$387	$387	$387	^
Recreation - (Parks Work)				^	$167	$167	$167	^	$167	$167	$167	$167	$167	^
Fish - (Barging, Ladders, Screens Work & AFEP)				^	$804	$804	$804	^	$804	$804	$804	$482	$482	^
Fish - (5 Each Extra Barges)				^	$40	$0	$40	^	$40	$40	$40	$0	$0	^
Wildlife - (Managing Lands Work)				^	$228	$228	$228	^	$228	$228	$228	$228	$228	^
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				^	$1,083	$1,083	$1,083	^	$1,083	$1,083	$1,083	$1,083	$1,083	^
SBC System - Extra Costs due to Options				^				^	$0	$0	$0	$0	$0	^
Maintenance Costs														
Sub Total Maintenance	Annual Costs	Summary	Each Year	=	$2,994	$2,994	$2,994	=	$3,469	$2,994	$3,028	$3,150	$3,150	=
Navigation - (Locks Work)				^	$153	$153	$153	^	$153	$153	$153	$153	$153	^
Power - (Turbines, Generators, & Power Lines Work)				^	$1,647	$1,647	$1,647	^	$1,647	$1,647	$1,647	$1,647	$1,647	^
Recreation - (Parks Work)				^	$28	$28	$28	^	$28	$28	$28	$28	$28	^
Fish - (Barging, Ladders, Screens Work & AFEP)				^	$476	$476	$476	^	$476	$476	$476	$476	$476	^
Fish - (5 Each Extra Barges)				^	$0	$0	$0	^	$0	$0	$0	$0	$0	^
Wildlife - (Managing Lands Work)				^	$8	$8	$8	^	$8	$8	$8	$8	$8	^
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				^	$681	$681	$681	^	$681	$681	$681	$681	$681	^
SBC System - Extra Costs due to Options				^				^	$475	$0	$34	$156	$156	^
LOWER GRANITE LOCK & DAM Annual Costs, Summary of Oper & Main Cost In the Detail Below, Each Year					**$7,800**	**$7,763**	**$7,800**		**$8,331**	**$8,331**	**$8,060**	**$7,816**	**$7,608**	
NOTE: For the Drawdown Option, Lower Granite Lock & Dam will Operate another 5 Years after start of project work.														
Operation Costs														
Sub Total Operations	Annual Costs	Summary	Each Year	=	$4,584	$4,547	$4,584	=	$4,584	$4,584	$4,584	$4,250	$4,250	=
Navigation - (Locks Work)				^	$65	$65	$65	^	$65	$65	$65	$65	$65	^
Power - (Turbines, Generators, & Power Lines Work)				^	$525	$525	$525	^	$525	$525	$525	$525	$525	^
Recreation - (Parks Work)				^	$447	$447	$447	^	$447	$447	$447	$447	$447	^
Fish - (Barging, Ladders, Screens Work & AFEP)				^	$1,275	$1,275	$1,275	^	$1,275	$1,275	$1,275	$979	$979	^
Fish - (5 Each Extra Barges)				^	$37	$0	$37	^	$37	$37	$37	$0	$0	^
Wildlife - (Managing Lands Work)				^	$217	$217	$217	^	$217	$217	$217	$217	$217	^
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				^	$2,018	$2,018	$2,018	^	$2,018	$2,018	$2,018	$2,018	$2,018	^
SBC System - Extra Costs due to Options				^				^	$0	$0	$0	$0	$0	^
Maintenance Costs														
Sub Total Maintenance	Annual Costs	Summary	Each Year	=	$3,216	$3,216	$3,216	=	$3,747	$3,747	$3,476	$3,566	$3,358	=
Navigation - (Locks Work)				^	$120	$120	$120	^	$120	$120	$120	$120	$120	^
Power - (Turbines, Generators, & Power Lines Work)				^	$638	$638	$638	^	$638	$638	$638	$638	$638	^

Cost data does not include inflation costs.

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY				<------- OPERATING DAM OPTIONS ------->							
US Army Corps of Engineers® Walla Walla District				EXISTING SYSTEM			MAJOR SYSTEM IMPROVEMENTS				
Cost Numbers are for Economic Study Purposes Only	TYPE OF	DESIGN & CONSTRUCTION	MID POINT OF	EXISTING CONDITIONS	IN RIVER CONDITIONS	MAXIMUM TRANSPORT	WITH MAXIMUM TRANSPORT	WITH MAXIMUM TRANSPORT	ADAPTIVE MIGRATION	IN-RIVER PASSAGE	IN-RIVER PASSAGE
Not Intended for Program Funding	COST	DURATION	CONSTR.		(Logic Option)		(High Cost)	(Low Cost)	STRATEGY	(No BGS Str.)	(W/ BGS Str.)
		FEASIBILITY ALTERNATIVES ====>		ALT # 1		ALT # 2			ALT # 3		
Assumes Unrestricted Funds, No Escalation				(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @ICE H)	(NO V. SPILL EX @ICE H)	(NO V. SPILL EX @ICE H)	(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @L Go)
		ENGINEERING APPENDIXES & PATH OPTIONS ====>		*OPTION A-1*	*OPTION A-1a*	*OPTION A-2a*	*OPTION A-2b*	*OPTION A-2c*	*OPTION A-2d*	*OPTION A-6a&b*	*OPTION A-6d*
DESCRIPTIONS - for Ice Harbor, Lower Monumental, Little Goose & Lower Granite Locks & Dams -> Mc Nary Dam not included.				Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars
Recreation - (Parks Work)				$169	$169	$169	$169	$169	$169	$169	$169
Fish - (Barging, Ladders, Screens Work & AFEP)				$329	$329	$329	$329	$329	$329	$329	$329
Fish - (5 Each Extra Barges)				$0	$0	$0	$0	$0	$0	$0	$0
Wildlife - (Managing Lands Work)				$36	$36	$36	$36	$36	$36	$36	$36
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				$1,925	$1,925	$1,925	$1,925	$1,925	$1,925	$1,925	$1,925
SBC System - Extra Costs due to Options							$531	$531	$260	$350	$142
MINOR - REPAIR COSTS	Annual Costs	Summary of the Dams	Each Year	$7,216	$6,697	$7,216	$7,216	$7,216	$7,216	$6,874	$6,874
ICE HARBOR LOCK & DAM	Annual Costs, Summary of Oper & Main Cost In the Detail Below,		Each Year	**$2,364**	**$2,355**	**$2,364**	**$2,364**	**$2,364**	**$2,364**	**$2,282**	**$2,282**
NOTE: For the Drawdown Ice Harbor Lock & Dam will Operate Until another 6 Years											
Operation Costs											
Sub Total Operations	Annual Costs	Summary	Each Year	$1,085	$1,076	$1,085	$1,085	$1,085	$1,085	$1,002	$1,002
Navigation - (Locks Work)		25.0%		$52	$52	$52	$52	$52	$52	$52	$52
Power - (Turbines, Generators, & Power Lines Work)	of Operation & Maintenance Costs			$156	$156	$156	$156	$156	$156	$156	$156
Recreation - (Parks Work)				$191	$191	$191	$191	$191	$191	$191	$191
Fish - (Barging, Ladders, Screens Work & AFEP)				$160	$160	$160	$160	$160	$160	$87	$87
Fish - (5 Each Extra Barges)				$9	$0	$9	$9	$9	$9	$0	$0
Wildlife - (Managing Lands Work)				$70	$70	$70	$70	$70	$70	$70	$70
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				$446	$446	$446	$446	$446	$446	$446	$446
Maintenance Costs											
Sub Total Maintenance	Annual Costs	Summary	Each Year	$1,279	$1,279	$1,279	$1,279	$1,279	$1,279	$1,279	$1,279
Navigation - (Locks Work)		25.0%		$475	$475	$475	$475	$475	$475	$475	$475
Power - (Turbines, Generators, & Power Lines Work)	of Operation & Maintenance Costs			$363	$363	$363	$363	$363	$363	$363	$363
Recreation - (Parks Work)				$41	$41	$41	$41	$41	$41	$41	$41
Fish - (Barging, Ladders, Screens Work & AFEP)				$72	$72	$72	$72	$72	$72	$72	$72
Fish - (5 Each Extra Barges)				$0	$0	$0	$0	$0	$0	$0	$0
Wildlife - (Managing Lands Work)				$8	$8	$8	$8	$8	$8	$8	$8
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				$320	$320	$320	$320	$320	$320	$320	$320
LOWER MONUMENTAL LOCK & DAM	Annual Costs, Summary of Oper & Main Cost In the Detail Below,		Each Year	**$1,523**	**$1,513**	**$1,523**	**$1,523**	**$1,523**	**$1,523**	**$1,437**	**$1,437**
NOTE: For the Drawdown Lower Monumental Lock & Dam will Operate Until another 6 Years											
Operation Costs											
Sub Total Operations	Annual Costs	Summary	Each Year	$717	$707	$717	$717	$717	$717	$630	$630
Navigation - (Locks Work)		25.0%		$17	$17	$17	$17	$17	$17	$17	$17
Power - (Turbines, Generators, & Power Lines Work)	of Operation & Maintenance Costs			$111	$111	$111	$111	$111	$111	$111	$111
Recreation - (Parks Work)				$36	$36	$36	$36	$36	$36	$36	$36
Fish - (Barging, Ladders, Screens Work & AFEP)				$198	$198	$198	$198	$198	$198	$121	$121
Fish - (5 Each Extra Barges)				$10	$0	$10	$10	$10	$10	$0	$0
Wildlife - (Managing Lands Work)				$43	$43	$43	$43	$43	$43	$43	$43
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				$303	$303	$303	$303	$303	$303	$303	$303
Maintenance Costs											
Sub Total Maintenance	Annual Costs	Summary	Each Year	$806	$806	$806	$806	$806	$806	$806	$806
Navigation - (Locks Work)		25.0%		$36	$36	$36	$36	$36	$36	$36	$36
Power - (Turbines, Generators, & Power Lines Work)	of Operation & Maintenance Costs			$494	$494	$494	$494	$494	$494	$494	$494
Recreation - (Parks Work)				$19	$19	$19	$19	$19	$19	$19	$19
Fish - (Barging, Ladders, Screens Work & AFEP)				$91	$91	$91	$91	$91	$91	$91	$91
Fish - (5 Each Extra Barges)				$0	$0	$0	$0	$0	$0	$0	$0
Wildlife - (Managing Lands Work)				$31	$31	$31	$31	$31	$31	$31	$31
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				$172	$172	$172	$172	$172	$172	$172	$172

Cost data does not include inflation costs.

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY					<------- OPERATING DAM OPTIONS ------->									
US Army Corps of Engineers® Walla Walla District					EXISTING SYSTEM				MAJOR SYSTEM IMPROVEMENTS					
Cost Numbers are for Economic Study Purposes Only	TYPE OF	DESIGN & CONSTRUCTION	MID POINT OF		EXISTING CONDITIONS	IN RIVER CONDITIONS	MAXIMUM TRANSPORT		WITH MAXIMUM TRANSPORT	WITH MAXIMUM TRANSPORT	ADAPTIVE MIGRATION	IN-RIVER PASSAGE	IN-RIVER PASSAGE	
Not Intended for Program Funding	COST	DURATION	CONSTR.			(Logic Option)			(High Cost)	(Low Cost)	STRATEGY	(No BGS Str.)	(W/ BGS Str.)	
		FEASIBILITY ALTERNATIVES ====>			ALT # 1		ALT # 2				ALT # 3			
Assumes Unrestricted Funds, No Escalation					(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @ICE H)		(NO V. SPILL EX @ICE H)	(NO V. SPILL EX @ICE H)	(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @L Go)	
		ENGINEERING APPENDIXES & PATH OPTIONS ====>			*OPTION A-1*	*OPTION A-1a*	*OPTION A-2a*		*OPTION A-2b*	*OPTION A-2c*	*OPTION A-2d*	*OPTION A-6a&b*	*OPTION A-6d*	
DESCRIPTIONS - for Ice Harbor, Lower Monumental, Little Goose & Lower Granite Locks & Dams -> Mc Nary Dam not included.					Thousand Dollars	Thousand Dollars	Thousand Dollars		Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	
LITTLE GOOSE LOCK & DAM Annual Costs, Summary of Oper & Main Cost In the Detail Below, Each Year					**$1,409**	**$1,399**	**$1,409**		**$1,409**	**$1,409**	**$1,409**	**$1,319**	**$1,319**	
NOTE: For the Drawdown, Little Goose Lock & Dam will Operate Until another 5 Years														
Operation Costs														
Sub Total Operations	Annual Costs	Summary	Each Year	=	$699	$689	$699	=	$699	$699	$699	$609	$609	=
Navigation - (Locks Work)		25.0%		^	$22	$22	$22	^	$22	$22	$22	$22	$22	^
Power - (Turbines, Generators, & Power Lines Work)		of Operation & Maintenance Costs		^	$97	$97	$97	^	$97	$97	$97	$97	$97	^
Recreation - (Parks Work)				^	$42	$42	$42	^	$42	$42	$42	$42	$42	^
Fish - (Barging, Ladders, Screens Work & AFEP)				^	$201	$201	$201	^	$201	$201	$201	$120	$120	^
Fish - (5 Each Extra Barges)				^	$10	$0	$10	^	$10	$10	$10	$0	$0	^
Wildlife - (Managing Lands Work)				^	$57	$57	$57	^	$57	$57	$57	$57	$57	^
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				^	$271	$271	$271	^	$271	$271	$271	$271	$271	^
Maintenance Costs														
Sub Total Maintenance	Annual Costs	Summary	Each Year	=	$710	$710	$710	=	$710	$710	$710	$710	$710	=
Navigation - (Locks Work)		25.0%		^	$38	$38	$38	^	$38	$38	$38	$38	$38	^
Power - (Turbines, Generators, & Power Lines Work)		of Operation & Maintenance Costs		^	$412	$412	$412	^	$412	$412	$412	$412	$412	^
Recreation - (Parks Work)				^	$7	$7	$7	^	$7	$7	$7	$7	$7	^
Fish - (Barging, Ladders, Screens Work & AFEP)				^	$119	$119	$119	^	$119	$119	$119	$119	$119	^
Fish - (5 Each Extra Barges)				^	$0	$0	$0	^	$0	$0	$0	$0	$0	^
Wildlife - (Managing Lands Work)				^	$2	$2	$2	^	$2	$2	$2	$2	$2	^
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				^	$170	$170	$170	^	$170	$170	$170	$170	$170	^
LOWER GRANITE LOCK & DAM Annual Costs, Summary of Oper & Main Cost In the Detail Below, Each Year					**$1,920**	**$1,429**	**$1,920**		**$1,920**	**$1,920**	**$1,920**	**$1,837**	**$1,837**	
NOTE: For the Drawdown, Lower Granite Lock & Dam will Operate Until another 5 Years														
Operation Costs														
Sub Total Operations	Annual Costs	Summary	Each Year	=	$1,146	$1,137	$1,146	=	$1,146	$1,146	$1,146	$1,063	$1,063	=
Navigation - (Locks Work)		25.0%		^	$16	$16	$16	^	$16	$16	$16	$16	$16	^
Power - (Turbines, Generators, & Power Lines Work)		of Operation & Maintenance Costs		^	$131	$131	$131	^	$131	$131	$131	$131	$131	^
Recreation - (Parks Work)				^	$112	$112	$112	^	$112	$112	$112	$112	$112	^
Fish - (Barging, Ladders, Screens Work & AFEP)				^	$319	$319	$319	^	$319	$319	$319	$245	$245	^
Fish - (5 Each Extra Barges)				^	$9	$0	$9	^	$9	$9	$9	$0	$0	^
Wildlife - (Managing Lands Work)				^	$54	$54	$54	^	$54	$54	$54	$54	$54	^
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				^	$505	$505	$505	^	$505	$505	$505	$505	$505	^
Maintenance Costs														
Sub Total Maintenance	Annual Costs	Summary	Each Year	=	$774	$293	$774	=	$774	$774	$774	$774	$774	=
Navigation - (Locks Work)		25.0%		^	$30	$30	$30	^	$30	$30	$30	$30	$30	^
Power - (Turbines, Generators, & Power Lines Work)		of Operation & Maintenance Costs		^	$159	$159	$159	^	$159	$159	$159	$159	$159	^
Recreation - (Parks Work)				^	$42	$42	$42	^	$42	$42	$42	$42	$42	^
Fish - (Barging, Ladders, Screens Work & AFEP)				^	$82	$82	$82	^	$82	$82	$82	$82	$82	^
Fish - (5 Each Extra Barges)				^	$0	$0	$0	^	$0	$0	$0	$0	$0	^
Wildlife - (Managing Lands Work)				^	$9	$9	$9	^	$9	$9	$9	$9	$9	^
Other - (Operations, Dredging, Pumping Plants, Bldgs, Plant Eq. all the rest Work except for above items)				^	$481	^	$481	^	$481	$481	$481	$481	$481	^
THE ITEMS ARE INCLUDED IN MINOR REPAIR COSTS AND ARE ASSUMED TO BE 5% OF TOTAL 0 & M COSTS.														
RE-ROOFING POWER HOUSES & VISITOR CENTERS														
POWER HOUSE HVAC UPGRADE														
REPLACEMENT OF NAV LOCK TIMBER BUMPERS														
REPLACEMENT OF FISH LADDER PUMPS														

Cost data does not include inflation costs.

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

US Army Corps of Engineers® Walla Walla District

				<------- OPERATING DAM OPTIONS ------->							
				EXISTING SYSTEM			MAJOR SYSTEM IMPROVEMENTS				
Cost Numbers are for Economic Study Purposes Only	TYPE OF	DESIGN & CONSTRUCTION	MID POINT OF	EXISTING CONDITIONS	IN RIVER CONDITIONS	MAXIMUM TRANSPORT	WITH MAXIMUM TRANSPORT	WITH MAXIMUM TRANSPORT	ADAPTIVE MIGRATION	IN-RIVER PASSAGE	IN-RIVER PASSAGE
Not Intended for Program Funding	COST	DURATION	CONSTR.		(Logic Option)		(High Cost)	(Low Cost)	STRATEGY	(No BGS Str.)	(W/ BGS Str.)
		FEASIBILITY ALTERNATIVES ====>		ALT # 1		ALT # 2			ALT # 3		
Assumes Unrestricted Funds, No Escalation				(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @ICE H)	(NO V. SPILL EX @ICE H)	(NO V. SPILL EX @ICE H)	(VOLUNTARY SPILL)	(VOLUNTARY SPILL)	(NO V. SPILL EX @L Go)
		ENGINEERING APPENDIXES & PATH OPTIONS ====>		*OPTION A-1*	*OPTION A-1a*	*OPTION A-2a*	*OPTION A-2b*	*OPTION A-2c*	*OPTION A-2d*	*OPTION A-6a&b*	*OPTION A-6d*
DESCRIPTIONS - for Ice Harbor, Lower Monumental, Little Goose & Lower Granite Locks & Dams -> Mc Nary Dam not included.				Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars	Thousand Dollars
REHABILITATION OF ROADS											
SPILLWAY GATE											
NAVIGATION GATES											
NAVIGATION VALVES											
WELDING, SANDBLASTING AND STORAGE FACILITY											
MAJOR - REPAIR & REHAB COSTS											
TURBINE UNITS & POWER HOUSE REHAB	Oct 98 Price Level - Summary,	One Total Rehab Shown only		**$193,555**	**$193,555**	**$193,555**	**$193,555**	**$193,555**	**$193,555**	**$193,555**	**$193,555**
ICE HARBOR LOCK & DAM	Second Costs included in Prorating Spreadsheets										
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *	45 Year Life Span	5 Years		$30,028	$30,028	$30,028	$30,028	$30,028	$30,028	$30,028	$30,028
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *	35 Year Life Span	5 Years		$23,361	$23,361	$23,361	$23,361	$23,361	$23,361	$23,361	$23,361
LOWER MONUMENTAL LOCK & DAM											
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *	45 Year Life Span	5 Years		$23,361	$23,361	$23,361	$23,361	$23,361	$23,361	$23,361	$23,361
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *	35 Year Life Span	5 Years		$23,361	$23,361	$23,361	$23,361	$23,361	$23,361	$23,361	$23,361
LITTLE GOOSE LOCK & DAM											
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *	45 Year Life Span	5 Years		$23,361	$23,361	$23,361	$23,361	$23,361	$23,361	$23,361	$23,361
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *	35 Year Life Span	5 Years		$23,361	$23,361	$23,361	$23,361	$23,361	$23,361	$23,361	$23,361
LOWER GRANITE LOCK & DAM											
Rehab. & Upgrade Turbine & Gen. Units (#1, #2, & #3) *	45 Year Life Span	5 Years		$23,361	$23,361	$23,361	$23,361	$23,361	$23,361	$23,361	$23,361
Rehab. & Upgrade Turbine & Gen. Units (#4, #5, & #6) *	35 Year Life Span	5 Years		$23,361	$23,361	$23,361	$23,361	$23,361	$23,361	$23,361	$23,361
** Minimum Gap - Fish Friendly Turbines (6 turbines per dam) as part of the Rehab.*											
COSTS FOR OTHERS											
FISH HATCHERIES Summary of Fish Hatcheries Operations, Minor & Rehab Costs			Each Year	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450	$14,450
FISH HATCHERIES OPERATIONS	Annual Costs	Summary	Each Year	$13,762	$13,762	$13,762	$13,762	$13,762	$13,762	$13,762	$13,762
DWORSHAK FISH HATCHERY				$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250
LOWER SNAKE RIVER FISH COMP PLAN				$11,512	$11,512	$11,512	$11,512	$11,512	$11,512	$11,512	$11,512
INCLUDING WASHINGTON, OREGON, & IDAHO STATE ALSO NEX PERCE & CONFEDERATED TRIBES OF THE UMATILLLA											
FISH HATCHERIES MINOR & REHAB COSTS	Annual Costs	Summary	Each Year	$688	$688	$688	$688	$688	$688	$688	$688
An assume costs that goes across the board.		5.0%									
BREACHING DAM, - NON-IMPLEMENTATION COSTS- option 2, - with 960 Acres Settling Reservoir for Pumping Plants								N/A	N/A	N/A	N/A
PRIVATE WATER USERS	Oct 98 Price Level										
WITH RESERVOIR - OPTION 2											
ICE HARBOR LOCK & DAM - ALL 6	Oct 98 Price Level	10 Years	FY 2005								
Pumping Plants											
Modification to Water Wells											
LOWER MONUMENTAL LOCK & DAM - ALL 6	Oct 98 Price Level	10 Years	FY 2005								
Modification to Water Wells											
Modification to Gas Line Crossing											
LITTLE GOOSE LOCK & DAM - ALL 6	Oct 98 Price Level	10 Years	FY 2005								
Modification to Water Wells											
LOWER GRANITE LOCK & DAM - ALL 6	Oct 98 Price Level	10 Years	FY 2005								
Modification to Water Wells											
Clarkston Golf Course + Atlas Sand & Rock + Lewiston Golf Course											
Potlatch Modification to Water Intake & Outlet											
BOR - WATER ACQUISITION AND TRANSACTION COSTS		Summary	Each Year	$2,386	$2,386	$2,386	$2,386	$2,386	$2,386	$28,072	$2,386

Cost data does not include inflation costs.

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY US Army Corps of Engineers® Walla Walla District *Cost Numbers are for Economic Study Purposes Only* *Not Intended for Program Funding* *Assumes Unrestricted Funds, No Escalation* **DESCRIPTIONS** - for Ice Harbor, Lower Monumental, Little Goose & Lower Granite Locks & Dams -> Mc Nary Dam not included.	TYPE OF COST	DESIGN & CONSTRUCTION DURATION	MID POINT OF CONSTR.	<------- OPERATING DAM OPTIONS -------> EXISTING SYSTEM EXISTING CONDITIONS ALT # 1 (VOLUNTARY SPILL) *OPTION A-1* Thousand Dollars	IN RIVER CONDITIONS (Logic Option) (VOLUNTARY SPILL) *OPTION A-1a* Thousand Dollars	MAXIMUM TRANSPORT ALT # 2 (NO V. SPILL EX @ICE H) *OPTION A-2a* Thousand Dollars	MAJOR SYSTEM IMPROVEMENTS WITH MAXIMUM TRANSPORT (High Cost) (NO V. SPILL EX @ICE H) *OPTION A-2b* Thousand Dollars	WITH MAXIMUM TRANSPORT (Low Cost) (NO V. SPILL EX @ICE H) *OPTION A-2c* Thousand Dollars	ADAPTIVE MIGRATION STRATEGY ALT # 3 (VOLUNTARY SPILL) *OPTION A-2d* Thousand Dollars	IN-RIVER PASSAGE (No BGS Str.) (VOLUNTARY SPILL) *OPTION A-6a&b* Thousand Dollars	IN-RIVER PASSAGE (W/ BGS Str.) (NO V. SPILL EX @L Go) *OPTION A-6d* Thousand Dollars	
FEASIBILITY ALTERNATIVES ====>												
ENGINEERING APPENDIXES & PATH OPTIONS ====>												
AMOUNT OF THE WATER PURCHASED				*427,000 Acre-Ft*	*427,000 Acre-Ft*	*427,000 Acre-Ft*	*427,000 Acre-Ft*	*427,000 Acre-Ft*	*427,000 Acre-Ft*	*1,427,000 Acre-Ft*	*427,000 Acre-Ft*	
PURCHASING WATER RIGHTS										*0 Acre-Ft (b)*	<- Option B	
ALL FOUR DAMS	Annual Costs		Each Year	--> See BOR Report, Paragraph 4.1.2 - Page 4-6(Allen Reiners)								
Annual Acquisition Costs (Spill effect the amount of water purchases for 427,000 Acre-Ft)			$5.35/Acre-foot	$2,286	$2,286	$2,286	$2,286	$2,286	$2,286	$2,286	$2,286	
Annual Transaction Costs (Spill effect the amount of water purchases for 427,000 Acre-Ft)			4.45%	$100	$100	$100	$100	$100	$100	$100	$100	
Annual Transaction Costs (Spill effect the amount of water purchases for 1,000,000 Acre-Ft)			$18.0/Acre-foot	--> See BOR Report , Paragraph 6.2.2.7.3 - Page 6-28 - $14 to $22 per acre foot (Assume the average)						$25,686	<- Option A extra H2O	
BOR - PURCHASING WATER RIGHTS for an extra 1,000,000 Acre-Ft		10 Years	Each Year			=				$210,483	<- Option A extra H2O	
			$147.5/Acre-foot	--> See BOR Report , Paragraph 6.2.2.7.3 - Page 6-28 - $130 to $165 per acre foot (Assume the average)								