Annex D

River Channelization Plan

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D.1 General

This river channelization plan is based on a separate report prepared for the Corps by Raytheon Infrastructure, Inc., titled *Embankment Excavation, River Channelization, and Removal of Concrete Structures* (Raytheon, 1998).

This study team proposed construction of diversion levees at each project to smoothly direct the river flow into and through the new channels and around the abandoned concrete structures. The levees would be constructed of crushed rock with riprap faces placed during the period following removal and breaching of the embankment dams. The levee configurations for each of the dam sites are shown in Figures D1 through D4. A major premise in implementing a natural river state is to do so at minimal, reasonable cost. The full removal of the concrete structures would add significant cost to the project. The levees provide a hydraulic bypass around the abandoned structures in a manner that allows the hydraulic performance to be analyzed and properly designed. The goal is to construct a channel that will provide acceptable fish passage for a broad range of flows and will not be damaged during high flows through the unnatural transistion section. The goal is not to protect and preserve the abandoned structures. Figures D1 through D4 illustrate the proposed channelization of river.

D.2 Hydraulic Considerations

Hydraulic issues are a critical factor in establishing the need for diversion levees. The primary function of the levees is to provide predictability of flow velocities and flow distribution. Without the diversion levees, flow patterns could not be predicted by analytical methods. Reverse eddies would form both upstream and downstream of the concrete structures, which would influence velocities and water surface elevations in the new channels. Predictability is necessary in the design process to guarantee performance for the range of possible conditions.

The diversion levees would be designed to be porous and to support a maximum, unbalanced head of 3 meters (10 feet). The lower portion of the diversion levees would be constructed in the wet by end dumping rockfill into the river from the shore or the levee crest. The diversion levees are sized to divert a 100-year flood of 9,060 cubic meters per second (m^3/s) (320,000 cubic feet per second [cfs]) without being overtopped. The levees would also be capable of remaining in place for a flood of 11,890 m^3/s (420,000 cfs). If the 11,890-m^3/s (420,000-cfs) flood overtopped the levees, there should be no appreciable damage because the levees would be essentially under balanced head. The levees would still divert most of the flow through the new channels. The diversion levees would have a crest width of 6.1 meters (20 feet), and crest heights would be set 1.5 meters (5 feet) above average river levels for a flow of 9,060 m^3/s (320,000 cfs). The riverside and damside slopes of both levees would be 3 horizontal (h):1 vertical (v). These slopes are very conservative. Steeper slopes may be possible after evaluation of available materials and the design of the levee section. The riverside face of both upstream and downstream levees would have approximately 0.8 meter (2.5 feet) of riprap measured normal to the slope.

Should design progress to the next stage, detailed model studies would be performed to ascertain actual flow conditions. Model studies may redefine the configuration of these levees. Studies into the performance and economics of available materials for levee construction may allow less conservative section design than proposed at this concept development stage.

D.3 Levee Design

The operational function of the diversion levees controls their design. Diversion levees would consist of rockfill overlain by a layer of riprap and would be used both upstream and downstream of the remaining concrete structures. Rockfill levees are proposed for the entire length of levee. Sheetpile cells were considered for portions of the levee that tie to the concrete structures. The sheetpile was not utilized because rockfill levees are significantly less expensive and faster to construct than the steel sheetpile levees. A typical section of the pervious diversion levee is shown on Figure D5.

The rockfill diversion levee would be constructed of porous rockfill (7.5 centimeters [approximately 3 inches]) so that water levels inside the levees (damside) would be nearly the same as the river levels outside the levees (riverside). Because the levees would be porous, they would allow some flow, but not fish, to pass through the levees and thus reduce the chance of stagnant water developing behind them. An option using a levee arrangement with a non-continuous centerline, (that is, with two parallel segments overlapping to provide a gap between them) was abandoned. While such an arrangement would be helpful in passing water to prevent stagnant conditions from developing behind the levees, it would provide a blind path or dead end that would confuse fish during migration. Since blind paths are unacceptable for fish migration, the levees alignment is continuous.

The submerged portions of the levees would be placed in the wet and, therefore, would not be compacted. The material properties of levee fill are estimated as follows. It is assumed that any fines or sand in the embankment gravel would wash out in an underwater placement.

- Unit weight of gravel/rockfill (placed underwater): 1,922 kilograms per cubic meter (kg/m^3) (120 pounds per cubic foot [pcf])
- Friction angle of gravel fill: 35 degrees
- Unit weight of riprap: 2,083 kg/m^3 (130 pcf)
- Friction angle of riprap: 40 degrees

Where rockfill levees with 3h:1v slopes join with the existing vertical concrete structure walls, a portion of the slope would protrude into the flow. This area would be heavily armored with riprap to resist the high velocities and eddies likely to be encountered at this junction.

The arrangement of the diversion cofferdams used for the original Lower Granite Dam's construction created eddies along the sections of cofferdam parallel to the lock wall. The eddies were a result of the sharp corners at the entrance to the channel and produced areas of slower velocity. The cofferdam joined the channel at right angles, and rather than forming smooth, rounded entrances, they jutted into the flow. The study team recommends that this configuration be tested in a model study to try to reproduce the turbulence and resulting slower velocities along the sides of the new channels. These slower velocities would be desirable for fish to migrate upstream, provided model studies show they do not produce flow directions and patterns that would be confusing to migrating fish. The volume of fill required for the levee at each of the dams is shown in Table D1.

Table D1. Summary of Levee Fill Material

	Barged Shotrock (m^3)	Barged Riprap (m^3)
Lower Granite	310,000	16,000
Little Goose	656,000	33,000
Lower Monumental	380,000	15,000
Ice Harbor	398,630	16,678
Total	**1,743,665**	**66,293**

D.4 Levee Fill Material

Various issues were considered to determine the most appropriate source of material for the levees. For example, at each of the dam sites, the existing embankment is on the opposite side of the river from where levee construction would begin. Therefore, temporary haul bridges, stockpiling, and double handling of embankment material would be required. In addition, embankment materials obtained from upstream of the core would be saturated. Local borrow areas on the same side of the river as levee construction (south side for all sites except Lower Monumental Dam) may be available.

The study team determined that existing embankment material should not be used for levee fill because it would involve multi-step processing. Embankment material would need to have fines to 76 millimeter (+3 inch) removed to be suitable for underwater placement. In addition there is not enough riprap of adequate size in the existing embankments, so quarried rockfill would need to be supplemented and blended with the existing material to provide suitable gradation. Therefore, use of existing embankment material for levee rockfill and riprap berms would require stockpiling, screening, double handling, and transportation across the river either by barge or bridge. This is complicated, time consuming, and expensive compared with obtaining all rockfill and riprap from one source as part of a larger rock supply operation.

Consequently, the study team assumed that all levee material – both rockfill and riprap – would come from quarries proposed for riprap production for the railroad and highway embankment protection effort that is described further in Annex F. It is most economical to take advantage of the scale of that operation to obtain the rockfill and riprap required for the channelization levees. Riprap and rockfill for channelization levees would be barged to the four respective sites and stockpiled from quarries prior to the start of this project's construction.

Angular material is preferred for the underwater placement of the levee fill. Shot-rock is angular and, therefore, would be more stable for levee construction than processed embankment excavation. From a technical stability viewpoint, shotrock is preferred over alluvial embankment material because of the high angularity of the individual pieces and their ability to interlock more tightly in under water placement. Existing rock quarries near the Snake River are not as abundant as gravel pits. Haul distances for shotrock would make trucking uneconomical; therefore, barging and stockpiling shotrock is assumed for all levee fill.

Information from existing sources does not define the size of rockfill or riprap used in the existing embankment dams. However, direct observation of existing rockfill and riprap materials on the embankment dams indicates the following general dimensions:

- Rockfill: 0.3 to 0.6 meter (1 to 2 feet) in diameter
- Riprap: 0.6 to 0.9 meter (2 to 3 feet) in diameter

D.5 Channelization Levee Material Transportation

The transportation of levee materials to convenient stockpile locations is significantly impeded by removal of the embankment dam. Materials from the embankment that may be appropriate for levee construction are difficult to transport to the opposite banks because the access to the opposite shore crosses the embankment. Furthermore, access across the concrete structures cannot accommodate off-road haul vehicles or high frequency highway haul vehicle usage. Consequently, other material sources and alternate haul methods were determined to be more feasible.

Since all levee material – both rockfill and riprap – would be supplied as part of the contract for the Railroad and highway embankment protection effort, and the required loading and hauling operation would be in-place, the study team determined that transporting that material from upstream by barge would be the most cost efficient form of transportation. The study team also examined using existing bridges and local roads to transport the materials, but determined that this alternative was not feasible or cost effective.

The team determined that the closest existing bridges to each dam that would facilitate highway hauling of material were as follows:

- For Lower Granite: 38.6 kilometers (24 miles) downstream of the project at Central Ferry
- For Little Goose: 11.3 kilometers (6.9 miles) upstream of the project at Central Ferry
- For Lower Monumental: 26.6 kilometers (16.3 miles) upstream of the project at Lyons Ferry
- For Ice Harbor: 13.0 kilometers (8.1 miles) downstream of the project at State Route 12.

Using these bridges would require using the existing local roadway system that has lower load limits than for the equipment assumed. The 46-m^3 (60-cy) off-road trucks planned for embankment excavation could not be used on local roads. Truck size would be limited to approximately 15 m^3 (20 cy). Haul distances would be 32 kilometers to 80 kilometers (20 miles to 50 miles). The long-haul distances and reduced truck size would increase unit costs for material transported over existing bridges and would be more than the cost of the material from a quarry.

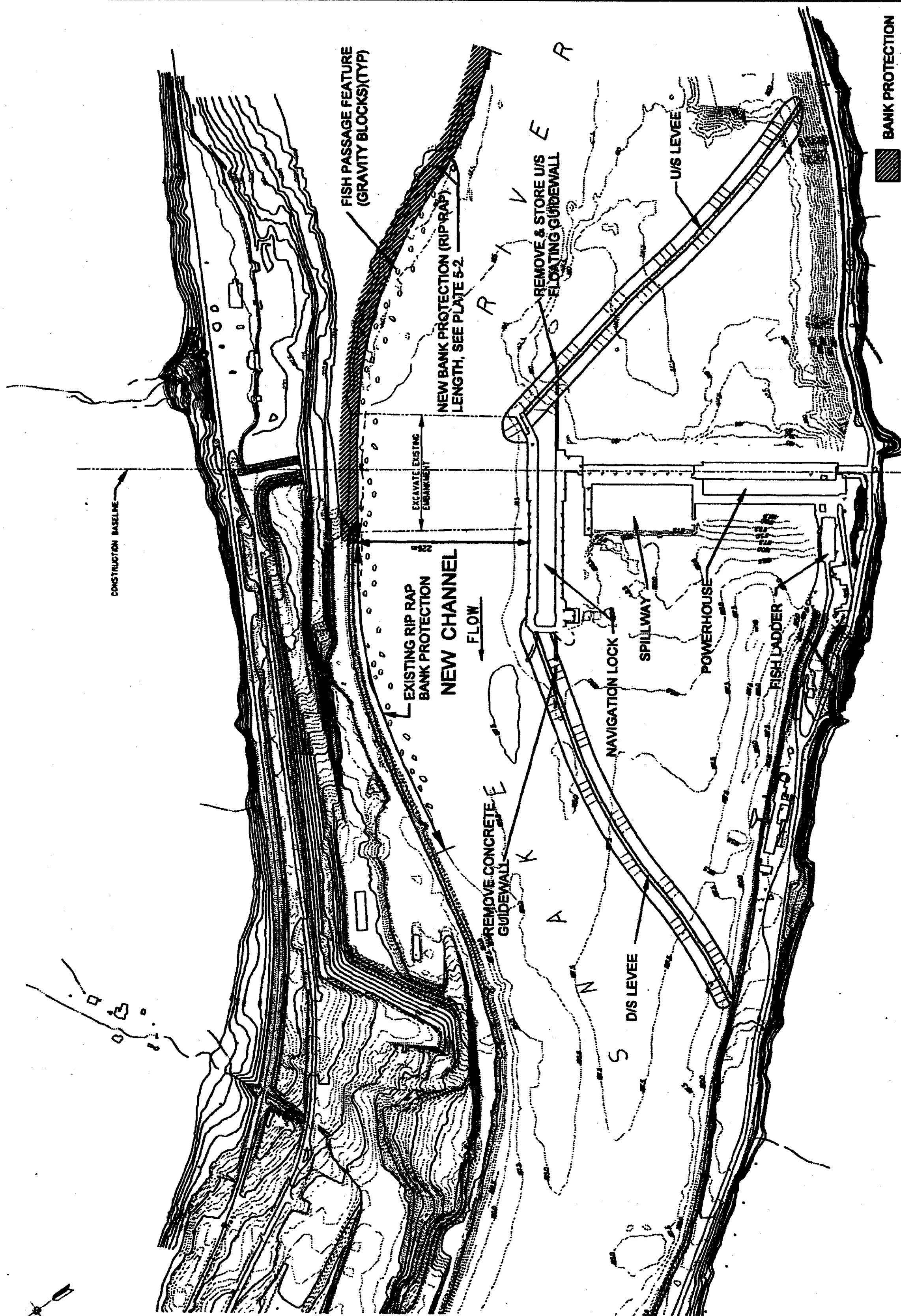
The use of temporary haul bridges or pile supported conveyor systems was determined to not be cost effective given the short duration of use, the wide range of potential river flows, and the required volume of levee materials to be transported.

D.6 Construction Sequence

Construction of the diversion levees requires controlled placement to achieve the appropriate cross section for river diversion and erosion prevention. Placement would require the use of end-dump trucks and dozers commencing construction from the shore opposite from the new channel.

Upstream diversion levee construction could begin only after the reservoir had been drawn down and the embankment had been excavated. This would be several weeks after cofferdam breaching is complete.

Construction of half of the downstream levee may begin coincident with the start of reservoir drawdown because downstream water levels stabilize at near natural levels within the first few days. However, the downstream levee cannot be closed or more than 50 percent completed until drawdown through the turbine passages is complete and the dam embankment cofferdams are breached.



NOTES:
1. UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

SHEET MAIN SCALE:

US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY
LOWER GRANITE
NEW CHANNEL PROJECT ARRANGEMENT - PLAN

Figure:
D1

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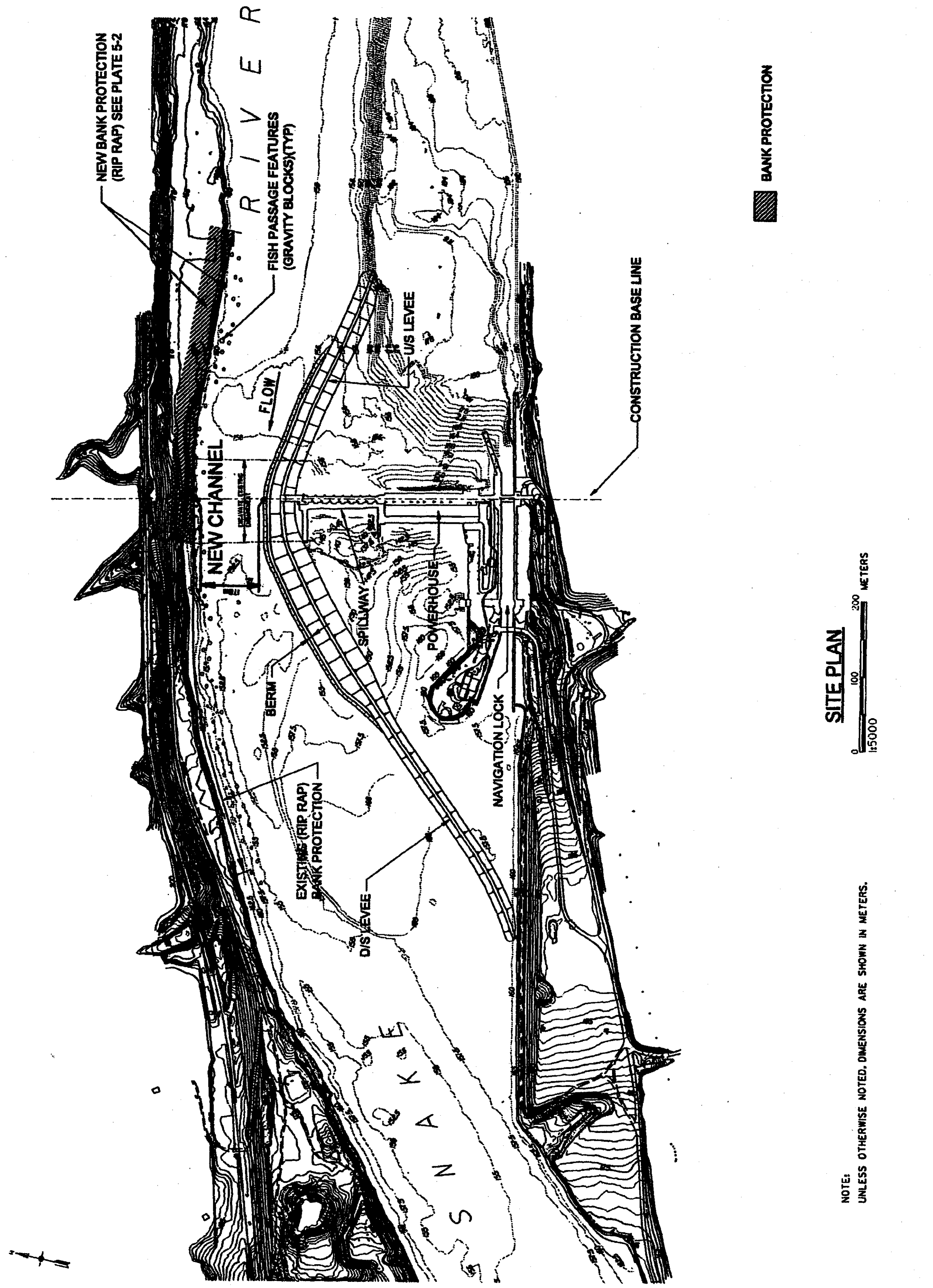

SHEET MAIN SCALE:

US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

LITTLE GOOSE

NEW CHANNEL PROJECT ARRANGEMENT - PLAN

Figure:
D2

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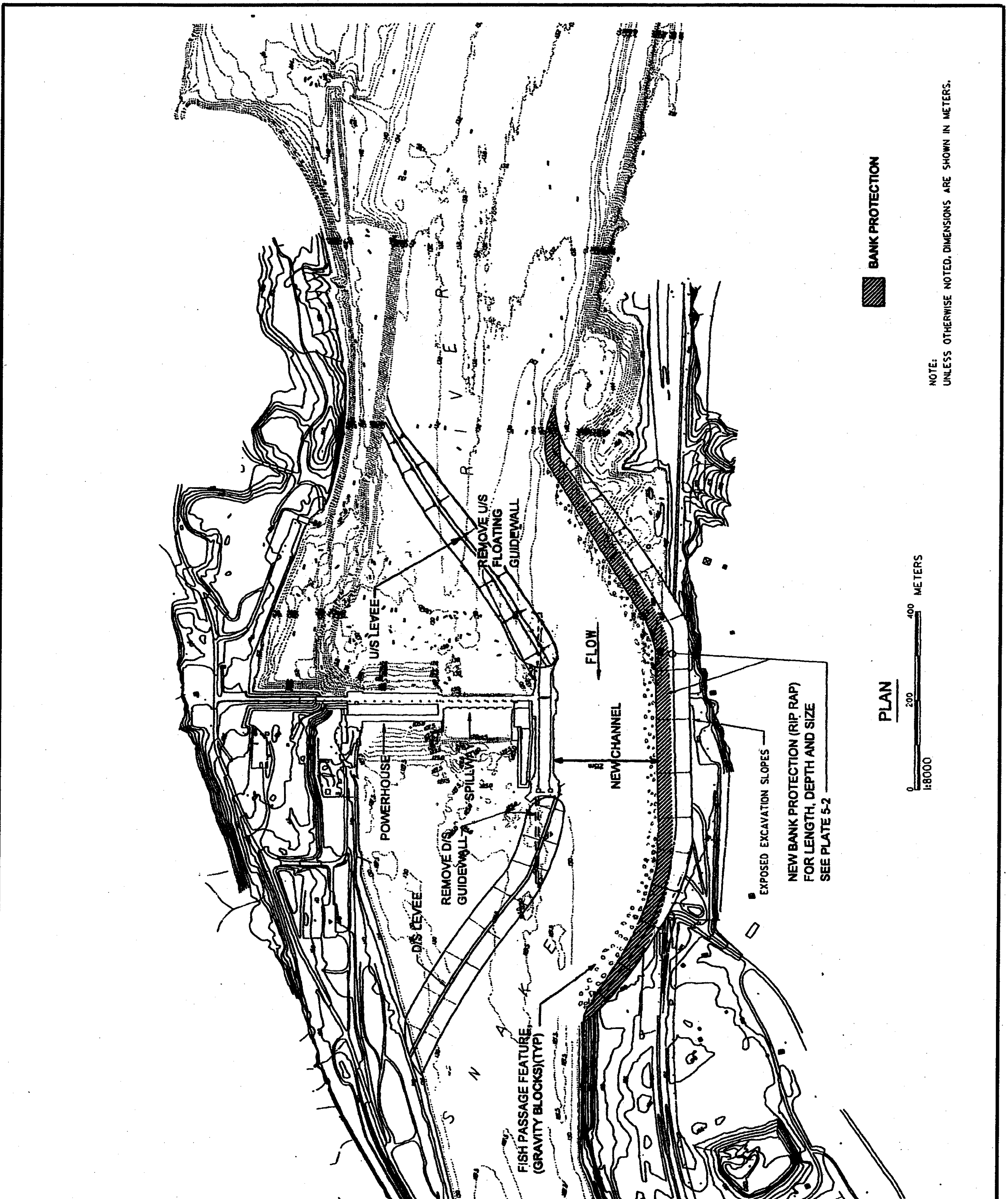

SHEET MAIN SCALE:

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LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY
LOWER MONUMENTAL
NEW CHANNEL PROJECT ARRANGEMENT - PLAN

Figure: D3

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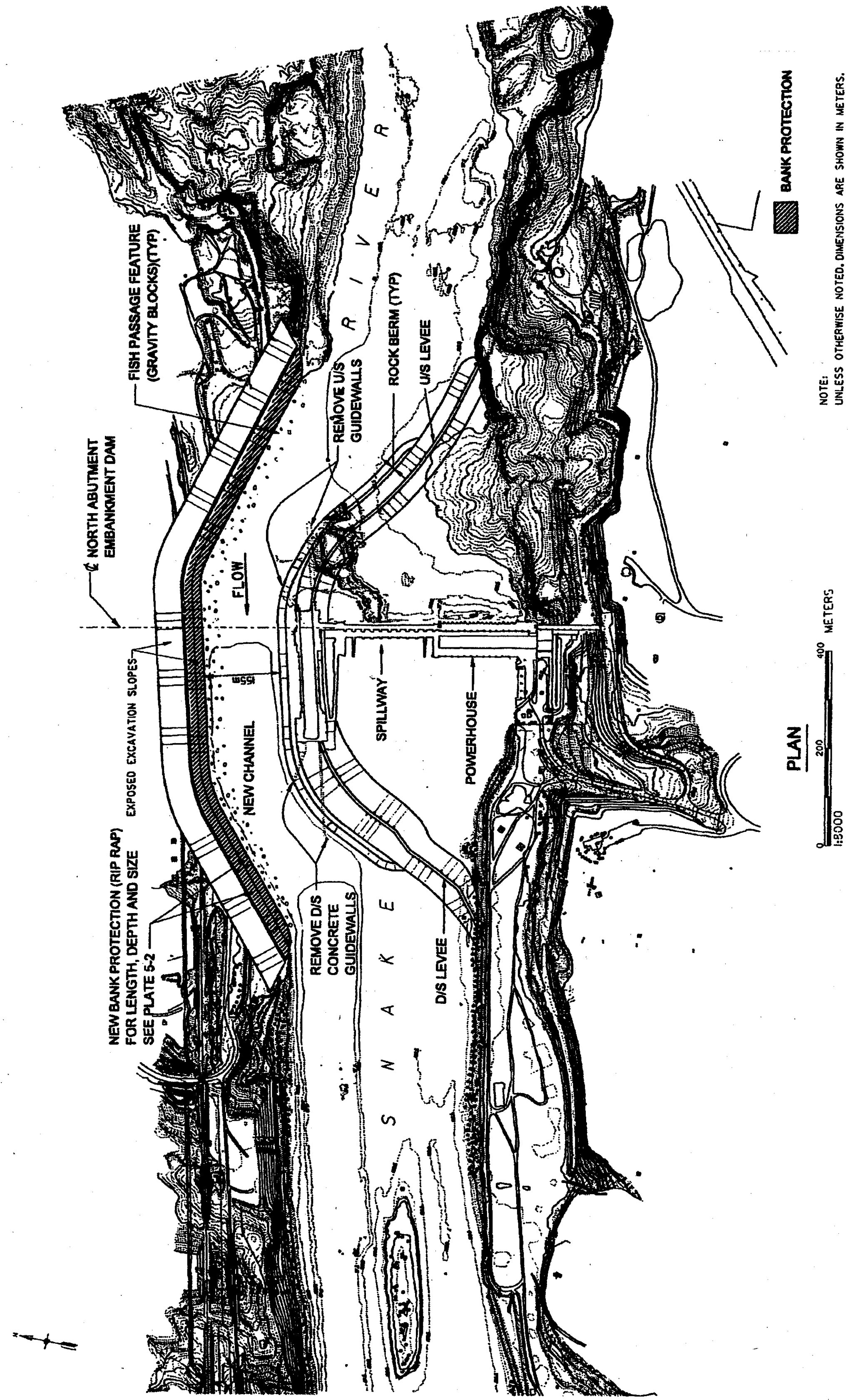

SHEET MAIN SCALE:

US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY
ICE HARBOR
NEW CHANNEL PROJECT ARRANGEMENT - PLAN

Figure:
D4

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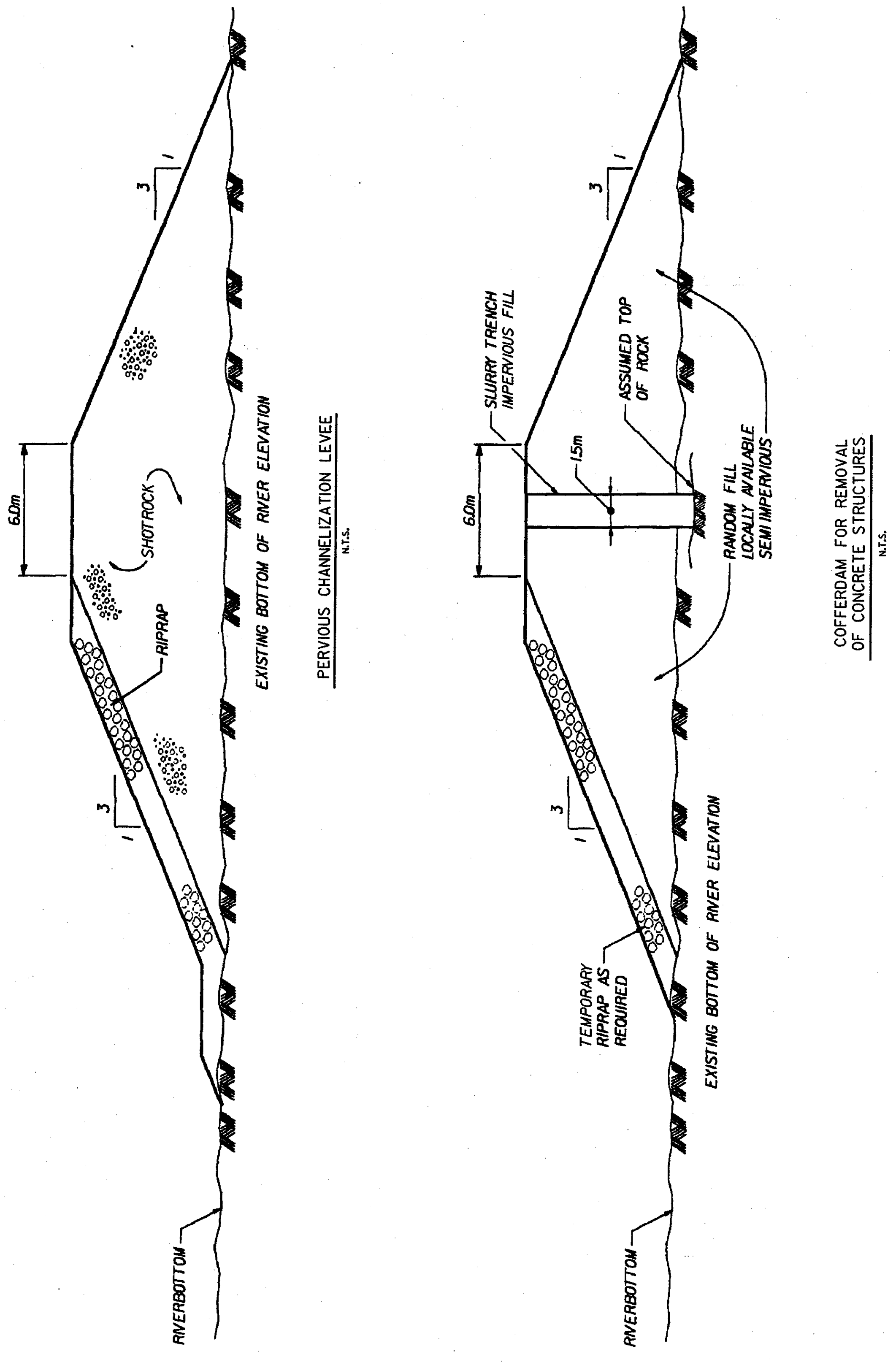

NOTES:
1. UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.

SHEET MAIN SCALE:

US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY
EMBANKMENT EXCAVATION AND RIVER CHANNELIZATION
TYPICAL LEVEE SECTIONS

Figure:
D5

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