Annex B

Dam Embankment Excavation Plan

Annex B: Dam Embankment Excavation Plan

B.1 General

This annex describes the new channels that would be excavated around each of the four lower Snake River dams to provide unimpounded yet controlled river conditions. The concepts for this dam excavation plan derive from a separate report prepared for the Corps by Raytheon Infrastructure, Inc., titled *Embankment Excavation, River Channelization, and Removal of Concrete Structures* (Raytheon, 1998). A general plan of the proposed new channel arrangements for each site is shown on Figures B1 through B4.

The new channels are formed by excavation of the dam embankments or the abutments and construction of levees to channelize the river. The extent of excavation is determined such that average velocities at the sides of the new channel would be well below the upper limit of acceptable fish migration velocities. Fish passage features, however, would be needed to provide resting places for fish during upstream migration because, at times, velocities are above the lower velocity limit against which fish can swim for long distances. The navigation locks and the spillways would not be used to supplement the hydraulic capacity of the new channels for two reasons: 1) they could not be modified within the eight-month construction window, and 2) modifications to these structures would be more costly than adding fish passage features to the new channels.

The total volume of excavation required for the new channels, comprised of embankment excavation and common excavation from the abutments, is shown in Table B1.

Table B1. Total Excavation Quantities for the New Channels (Embankment and Common)

	Quantity (m^3)				
Material	**Lower Granite**	**Little Goose**	**Lower Monumental**	**Ice Harbor**	**Total**
Embankments Only					
Core Material	240,200	138,300	78,300	7,500	464,300
Gravel Fill (shell), Including Rockfill and Riprap	1,101,700	978,000	675,200	59,500	2,814,400
Cofferdams (part of dam)	276,400	263,900			540,300
Embankment Subtotal	1,618,300	1,380,200	753,500	67,000	3,819,000
Common Excavation					
Abutments			4,395,000	3,971,000	8,366,000
Cofferdams (temporary)			172,340	228,480	400,820
Common Subtotal			4,567,340	4,199,480	8,766,820
Total Volumes	**1,618,300**	**1,380,200**	**5,320,840**	**4,266,480**	**12,585,820**

B.2 Conditions

All channel inverts under the footprint of the embankment dam would be excavated to form a uniform continuation of the natural river gradient from upstream to downstream. The plan avoids low areas or depressions in the channel floors because a depression would likely be filled in by deposition and, therefore, would change the channel sections and velocities.

At Ice Harbor, Lower Monumental, and Lower Granite dams, the new channels would be located adjacent to and confined by the navigation lock walls on one side, with hillside bordering the other. At Little Goose Dam, the channel would be bounded on one side by the remaining concrete dam structures, with the other side bounded by the hillside.

Except at Little Goose Dam, guide walls upstream and downstream of the navigation locks would be removed in order to eliminate flow obstructions into and out of the new channel. Guide walls upstream would be floating, and downstream would be concrete anchored into rock. A short portion of the downstream walls would be left in place, with the levee built around it. At Little Goose Dam, this wall would be a tie-in wall for the embankment dam.

At all four sites the new channel’s width would be bordered on the land side by the railroads. The top of the channel slope would be offset 12 meters (40 feet) toward the river from the centerline of the track. The excavated cut slopes of the new channels that are exposed to flows would be 2.5 horizontal (h):1 vertical (v), similar to excavated slopes of the existing channels, and would be 1.5 (h):1 (v) above the maximum water surface.

B.2.1 Lower Granite Dam

Removing the north shore embankment would form a free-flowing river channel at Lower Granite Dam. Flow would be diverted from its main course along the south shore to a new channel on the north side of the concrete structures through the area where the embankment is located. This same configuration was successfully used for diversion during the original project construction and, therefore, is expected to work satisfactorily.

At Lower Granite Dam, the natural river channel, which existed before structures were constructed, contained a large island that split the river into two flow channels. The proposed new channel would have a flow area approximately 65 percent of the original river's area; however, the majority of flow previously went through the south channel. Flow would now be diverted to the north of the structures. Since this is hydraulically inefficient, a diversion levee system would be constructed to guide flow smoothly into the new channel and around abandoned structures.

B.2.2 Little Goose Dam

The new channel at Little Goose Dam would be similar to, but narrower than, the channel at Lower Granite Dam. Removing the north abutment embankment dam would form the channel. At Little Goose, not only is the embankment dam shorter in length than at Lower Granite, but there also is a concrete tie-in wall extending 30 meters (98 feet) north of the spillway along the dam's axis. The tie-in wall would be left in place because acceptable river flow velocities would be achieved without removing it. The levee would be arranged to tie into this wall, and the levee’s north slope would extend into the new channel. Fish passage features would be required at Little Goose because average flow velocities in the overbank area are higher than 1.5 m/s (5 ft/s).

The main flow course prior to dam construction was on the north side where the new channel would be located.

B.2.3 Lower Monumental Dam

The new channel at Lower Monumental Dam would be on the south side of the river because it would require less excavation than a similar channel on the north side. Flow would be diverted from its original main course along the north shore prior to dam construction to the new channel on the south side of the concrete structures. There is a south embankment dam, but the engineered fill portion of it is only approximately 15 meters high (versus 40 meters for the total excavation). Therefore, embankment excavation would be only a small portion of the total excavation required for the new channel. The majority of excavation for the new channel would be from the natural soil of the abutment.

The Union Pacific Railroad line exists on the south shore. In order to configure the channel with sufficient width, the existing rail lines must be relocated to the south. The reach of double track has been identified and costs for significant excavation and relocation of rail beds and lines have been developed. It is assumed that funding would be appropriated for such modifications.

The study team planned to leave a temporary cofferdam of natural material along the shoreline to retain the river, thus enabling a significant amount of the excavation to be accomplished in the dry. The natural material of the abutment used for these cofferdams is predominantly sands and gravels. This material could be pervious and significant pumping may be required. An impervious layer of soil may be required on the water side for the cofferdams to function adequately. After excavation of the abutment material, temporary cofferdams along with any required river bed material would be removed by dragline.

B.2.4 Ice Harbor Dam

The new channel at Ice Harbor Dam would be excavated out of the north abutment because the top of the foundation rock on the north side is nearly horizontal and excavation in the abutment would be entirely in soil.

An abandoned rail line, previously owned by Burlington-Santa Fe Railroad exists on the north shore. The railroad right-of-way is currently being developed under the Rails to Trails program. The railroad maintains the right to re-establish the rail line should conditions change. In order to configure the channel with sufficient width, the existing rail lines must be relocated to the north. The reach track has been identified and costs for significant excavation and relocation of rail beds and lines have been developed. It is assumed that the railroad would exercise the option to re-establish the line and that funding would be appropriated for such modifications.

Flow would be diverted from its original main course along the south shore prior to dam construction to the new channel on the north side of the concrete structures.

The location of the new channel would require relocation of the railroad to allow sufficient channel width for acceptable velocities.

To minimize the quantity of "in wet" excavation, temporary cofferdams would remain in place at Ice Harbor, parallel to the shoreline on the river side of the excavation. Material between the cofferdam and the new channel bank would be excavated "in the dry."

B.3 Reservoir Drawdown Issues

All four reservoirs are approximately the same size. The turbines at all four sites have approximately the same hydraulic capacity so that drawdown at all four dams would not be limited by turbine capacity, but rather by the limiting drawdown rate of 0.6 meters (2 feet) per day. This rate was established based, in part, on the results of the *1992 Reservoir Drawdown Test, Lower Granite and Little Goose Dams* (Corps, 1993). At this rate, it would take approximately 40 days to lower the reservoirs from the top of normal pool to the top of the temporary cofferdams. Breaching and removal of the cofferdams must be done to establish a free flowing channel.

The two means of passing flow for reservoir drawdown are: 1) through the spillway, and 2) through the powerhouse turbines. Since turbine hydraulic capacity is much greater than average mean daily flow from August through January, it is likely that the turbines would be used for most of the drawdown unless an unusually high inflow occurs. For unusually high flows, the spillway bays would be used for drawdown until the water surface reaches the ogee crest. Thereafter, powerhouse turbines would be used to draw the reservoir down at 0.6 meters (2 feet) per day and to control flows. Figure B5 provides a summary hydrograph for the Snake River.

When the reservoir has been drawn down only 9.1 meters (30 feet), more than 60 percent of the upstream reservoir shore would be exposed or above water, thereby significantly reducing the amount of shore line susceptible to damage from a breach caused by overtopping.

B.3.1 Risk of Embankment Overtopping During Excavation

One way to reduce risk of embankment overtopping during construction is to schedule embankment removal during a low flow period. Scheduling construction in August to November period produces the least risk. January through March is the period most susceptible to higher flows and thus has the highest risk of embankment overtopping. Starting drawdown on August 1 is the most beneficial time to assure the embankments would not be overtopped due to sudden high flows during the construction period.

A freeboard of 3 meters (10 feet) has been assumed for this study. (Freeboard is the distance the water surface is maintained below the top of excavation.) Another way to reduce the risk of overtopping during excavation is to vary the freeboard during drawdown from 3 to 6 meters (10 to 20 feet), depending on whether excavation starts in August or December, respectively. A third way to reduce the risk of overtopping would be to increase freeboard proportionally from 3 to 6 meters as the top of excavation is lowered from the top of dam to the top of cofferdam.

The highest average mean daily flows from August through January are less than 1,700 m^3/s (60,000 cfs). The six turbines at any site can pass a combined flow of 2,230 m^3/s (78,700 cfs) with the minimum operating head of 6.1 meters (20 feet), except at Ice Harbor for which the combined flow is approximately 1,784 m^3/s (63,000 cfs). Thus, if excavation is completed before January, there should be little risk of overtopping the embankments or cofferdams.

If river flows exceed 1,700 m^3/s (60,000 cfs) when the embankment has been excavated to within 9.1 meters (30 feet) of tailwater, the embankment could overtop. This flow has a monthly frequency that exceeds the normal flow by approximately 30 percent in February and 40 percent in March. However, with average river inflow, the embankment excavations would not be overtopped during March, even at the lowest reservoir level.

To further reduce the risk of overtopping during excavation, the embankment could be removed in an asymmetrical pattern, so that the upstream face is left high while the downstream face is excavated at a faster rate. This sequence was used for the original embankment's construction. It keeps the crest high, but allows excavation to proceed faster than the reservoir drawdown rate. This excavation sequence would allow some protection against minor rises in river water due to inflows higher than 1,700 m^3/s (60,000 cfs). An estimate of the extent of damage that would be caused by rapid drawdown of the reservoir faster than the 0.6 meter (2 feet) per day rate is contained in Annex H.

If higher than expected flows were to occur, close monitoring of river flows would be required in order to provide contractors with sufficient lead time to pull out of the construction area and avoid loss of equipment or lives.

B.4 Bank Protection

The purpose of bank protection is to prevent scour of the new channel bank or shore when subjected to velocities resulting from flows up to 11,890 m^3/s (420,000 cfs) after the embankment dam has been excavated.

Allowing the banks to erode naturally, except for embankments that support structures, is generally considered favorable; therefore, riprap would be applied only to bank areas that support existing roads, railroads, or other essential structures.

Typical forms of bank protection are as follows:

- Riprap
- Jute matting
- Concrete filled fabri-form
- Hand-placed stone
- End-dumped stone
- Concrete paving.

For this study, riprap was chosen as the primary form of bank protection. Riprap would be sized according to standard riprap design procedures, with a minimum diameter of 0.3 meter (1.0 feet).

Material exposed by bank excavation would be sandy gravel, cobbles, and occasional boulders on the right bank, and rock that does not need protection in the main channel. Areas that are to receive bank protection are shown in Figures B2 through B4. Bank protection has been designed to remain functional for velocities resulting from flows of 11,890 m^3/s (420,000 cfs).

B.5 Navigation Lock and Spillway Modifications

Modifications to the navigation locks and spillways to provide additional channel width are not necessary to achieve acceptable fish migration velocities with the use of fish passage features at any of the four dams. All flows would pass around the remaining concrete structures and through the new channels.

Hydraulic studies have shown that even with the navigation locks used as a supplemental flow passage, fish passage features would still be needed because minimum velocities would exceed 1.5 mps (5 ft/s). Increasing the number of fish passage features is far less costly than physically modifying the navigation lock or spillway as a means of providing acceptable velocities.

In addition, modification of the spillway, specifically for cofferdams and construction sequencing, would take significantly longer than the 8-month construction window allocated for the embankment excavation and river channelization activities.

B.6 Construction Methodology

B.6.1 General

The construction methodology used for this study assumes average achievable excavation rates and reasonably common construction methods employing conventional construction equipment. The construction period is primarily limited by the drawdown rate of 0.6 meter (2 feet) per day and the sequencing of construction activities.

Other construction techniques could be employed to increase production rates, but the construction window and the drawdown rates would still govern.

B.6.2 Excavating Unit Systems

Excavation is assumed to be accomplished by various numbers of excavating unit systems, defined as a labor crew and equipment needed to excavate, transport, and stockpile materials.

Each excavating unit system consists of: a prime excavator; one or more dozers; a sufficient number of trucks to keep the excavator continuously productive; and other support equipment and labor to maintain haul roads, direct traffic, and handle material at stockpiles. The number of trucks required at each site is a function of the round trip haul time. At the stockpile area, two track dozers and compactors are used to spread the deposited material, and a grader and water truck are used for road maintenance.

B.6.3 Excavation Equipment

Excavation, loading, hauling, and stockpiling of the excavated embankment material requires very large units to perform efficient cycling times for handling materials. For the embankment excavation, scrapers cannot be used, but instead, large hydraulic excavators (with backhoe attachment) loading large-capacity; end-dump trucks on the excavated surface would be more efficient. This system could also be used for excavation of the dam foundation between the embankment cofferdams. An alternative approach would be to use large-capacity, dual engine, self-loading scrapers to load and haul and place soil materials, but this would require a larger working area and could be less effective if adequate turnaround areas are not available.

Typical excavating equipment and production rates are shown in Table B2.

All above water excavation is assumed to be performed by track mounted hydraulic excavators with 9.9-m^3 (13-cy) buckets and/or rubber-tired front-end loaders with 10.7-m^3 (14-cy) buckets. Trucks are assumed to be 81.6-metric-ton (90-ton), 46-m^3 (60-cy) end-dump, off-highway haul units. With advance notice of bidding, these types of equipment are commonly available in the Pacific Northwest and western United States, and in numbers that would permit removal of all four dams simultaneously. Uniform bucket fill factors and job efficiency factors were developed for establishing production rates.

Table B2. Typical Excavation Equipment and Production Rates

Name	Model	Capacity	Typical Rate
Large Hydraulic Excavator (general)	CAT 5130	9.9 m^3 (13 cy) bucket	1150 m^3/hr (1500 cy/hr)
Small Hydraulic Excavator (riprap)	CAT 235D	3.8 m^3 (5 cy) bucket	153 m^3 (200 cy/hr)
Front End Loader (general)	CAT 992D	10.7 m^3 (14 cy) bucket	917 m^3/hr (1200 cy/hr)
Hauling Trucks	CAT 777c	81.6 metric ton (90 ton)	46 m^3 (60 cy)/hr
Dozer	CAT D-9N or D-7H		
Grader	CAT 16-G		
Compactor	CS563		
Dragline	American 12220	7.6 m^3 (10 cy)	321 m^3/hr (420 cy/hr)

B.6.4 Excavation Procedures/Rates

The dam embankment excavation rate is a function of the following:

- The size and type of equipment
- The type of material
- The space available for turnaround of haul trucks.

Equipment cannot efficiently travel on the riprap and rockfill surface areas. The upstream and downstream width of rockfill and riprap is 1.5 meters and 1.8 meters (5 feet and 6 feet), respectively, for a total of 3.4 meters (11 feet); therefore, at any given embankment excavation surface level, 3.4 meters (11 feet) of width would be unusable as a roadway. Also the core material on the upstream side might be wet and would be more difficult to work on than the gravel fill zones and filters.

Front end loaders would be used in matching numbers to track-mounted hydraulic excavators because front end loaders are generally less expensive to transport and assemble, but less versatile in dealing with variable excavation conditions.

Until the working surface is 30.5 meters (100 feet) wide, there would be room for only one excavating unit. A single, track-mounted, hydraulic excavator would be used because it has greater flexibility in excavating all materials. Its initial production rate was assumed to be reduced to 765 m^3/hr (1,000 cy/hr) from a normal rate of 1,150 m^3/hr (1,500 cy/hr). Where multiple sets of excavating unit systems are to be used, each additional excavating unit was assumed to require an additional 15.2 meters (50 feet) of working surface width. Excavating units could be staggered along the embankment's length, and the study team assumed trucks would share a common turnaround area. A summary of excavation rates versus available surface width on the dam is shown in Table B3. Figures B6 through B9 graphically show the drawdown elevation and the corresponding embankment excavation during the period of embankment excavation.

Table B3. Number of Excavation Units Vs. Available Space

Depth Below Top of Dam (m)	(feet)	Surface Width (m)	(feet)	Number of Excavating Units	Anticipated Production Rate (m^3/hr)	(cy/hr)	Total (m^3/hr)	(cy/hr)
0 - 5.0	0 - 16.7	13.7 - 33.8	45 - 111	1 Hydraulic Excavator	764	1,000	764	1,000
5.0 - 8.7	16.5 - 28.5	33.8 - 48.5	111 - 159	1 Hydraulic Excavator	1,147	1,500	1,147	1,500
8.7 - 12.3	28.5 - 40.0	48.5 - 63.0	159 - 206	1 Hydraulic Excavator	1,147	1,500		
				1 Front End Loader	917	1,200	2,064	2,700
12.3 - 16.6	40.0 -54.4	63.0 - 80.0	206 - 263	2 Hydraulic Excavators	2,293	3,000		
				1 Front End Loader	917	1,200	3,211	4,200
Below 16.6	Below 54.4	80+	263+	2 Hydraulic Excavators	2,293	3,000		
				2 Front End Loaders	1,835	2,400	4,128	5,400

B.6.5 Embankment Material Stockpiling

The embankment material would be removed to stockpiles located on the same side of the river as the new channel and within 3.2 km (2 miles) of the embankments. The embankments consist of several zones of material, but separation of each type would severely increase costs and limit excavation rates because of the material zone configuration and the thin layers of filter and riprap material. Material would be removed in two classifications comprised of: 1) impervious core, and 2) all other materials, consisting primarily of gravel fill plus filter material. Riprap would be stockpiled to the extent segregation is possible. Obtaining new filter materials would be cheaper than separating and stockpiling it separately for future use. Stockpiling of impervious core material separately is important because it could be used for topsoil to landscape the channels for plantings of trees, shrubs, and grass. Figures B10 through B13 show anticipated material stockpile areas and potential hauls roads.

B.6.6 Embankment Excavation Operations

Excavation operations are assumed to involve two 10-hour shifts per day in a 5-day work week (Saturday and Sunday off). At the maximum embankment excavation rates and assuming 100 hours a week (20 hours a day over 5 days), the embankment and abutments at all dams could be removed at the schedule shown in Table B4. In order to provide additional time to deal with contingencies that may arise, an addition two shifts per week is added to the excavation schedule.

Since maximum production rates of excavation indicate that the top of the embankment dam could be lowered much faster than the reservoir drawdown rate of 0.6 meter (feet) per day, the drawdown rate is the governing factor in the construction schedule. For the contractor to maximize the efficiency of the excavating equipment, it is likely that the actual start of excavation would be delayed approximately 4 to 5 weeks after the beginning of the 1 August drawdown. This procedure will also provide greater freeboard for a longer period of time, thus reducing the risk of overtopping should problems develop during the early stages of drawdown.

The dates in Table B4 are for excavation of the embankment materials. Subsequent activities for breaching and removal of the cofferdams are not shown in Table B4.

Table B4. Embankment Excavation Time at Maximum Excavation Rate (Drawdown Begins 1 August)

Dam	Excavation Duration	Excavation Begins	Excavation Ends
Lower Granite	28	August 30	September 28
Little Goose	21	September 7	September 28
Lower Monumental	55	August 1	September 25
Ice Harbor	61	August 2	October 2

The most apparent problem may be from the presence of saturated materials in the embankment. Excavating, hauling, and stockpiling these materials may be problematic because of possible difficulties in handling the material and driving vehicles across existing and new fill sections. It is not possible to drain the reservoir the required time in advance of drawdown for the embankment materials to drain to a point where these problems are eliminated.

The outer shells of the embankments would remain in place while excavation below water surface elevation proceeded within the cofferdam area. Excavating this interior under relatively dry conditions would be done using the ongoing excavation processes. This procedure minimizes the volume of material that must be excavated “in the wet” using underwater methods such as crane-mounted draglines. In-water excavation requires draglines to operate at a much slower production rate. The area within the cofferdams would require two temporary pump stations – one upstream of the core and one downstream of the core – to allow dry excavation operation.

It is very likely that the downstream cofferdams at Lower Granite and Little Goose Dams and the abutment cofferdams at Lower Monumental and Ice Harbor Dams will not be sufficiently impervious to allow dry construction operations. Placement of silt core material on these water-side cofferdam surfaces is proposed to make these structures relatively impervious so excavation may proceed.

B.6.7 Embankment Removal Sequence for Lower Granite and Little Goose Dams

The embankment material could be removed to the top of the original embankment’s upstream and downstream cofferdams. The two cofferdams would remain in place while the saturated embankment material between them would be excavated to the foundation using surface excavation equipment. Figure B14 illustrates the embankment cross section and the phasing of excavation equipment for these dams.

The area between cofferdams should remain accessible as the upstream cofferdam has an impervious blanket on the upstream face. The impervious blanket was removed from the downstream face of the downstream cofferdam, but the cofferdam fill material should be sufficiently compacted from construction and the weight of the embankment fill above to minimize leakage. Pumps would handle leakage.

B.6.8 Embankment Removal Sequence for Lower Monumental and Ice Harbor:

The abutment material for the new channel downstream of the existing embankment could be excavated at an unrestrained rate. The embankment would be left in place while the reservoir is being drawn down. After material downstream of the existing embankment is excavated, equipment would move upstream to the embankment and abutment material would be excavated at an unrestrained rate down to the new channel's invert. Temporary cofferdams both upstream and downstream would be left in place parallel with the shore line at the outer edge of the required excavation, behind which excavation of abutment material could proceed to the channel invert using surface excavation equipment. Pumps would handle seepage. The remaining cofferdam and any river bottom material would then be excavated by dragline.

Embankment removal is limited by the reservoir drawdown rate of 0.6 meter (2 feet) per day. However, with proper sequencing, most excavation could be completed at an unrestrained rate. Proper sequencing would involve starting excavation several weeks after drawdown begins and leaving a natural cofferdam of existing earth in place between the river and the excavation area, behind which excavation could be made in the dry. Figure B15 illustrates the embankment in elevation view and shows where the temporary earth dike would be used for these dams. Note that the Ice Harbor configuration is opposite hand.

B.6.9 Cofferdam Breaching and Removal Sequence

The original embankments for Lower Granite and Little Goose dams were constructed between two parallel cofferdams that were incorporated into the heel and toe of the dam. While the embankment material is being removed from between these cofferdams, a vertical row of sheet piles would be driven in and perpendicular to the cofferdams about 30 meters (98 feet) from the navigation lock wall. A typical construction sequence for Lower Granite and Little Goose Dams is shown in Figure B16. The sequence of cofferdam breaching is illustrated in the photographs in Figures B18 and B19.

This construction sequence would allow the cofferdams to be breached while reducing the possibility of losing equipment. The cofferdams are primarily constructed of rockfill; however, very large rock next to the navigation lock wall was used in the upstream cofferdam for closure against the final flows. This material would be more difficult to remove than the cofferdam material and may require special handling. The downstream cofferdam had an impervious blanket on the downstream face. Some of it was removed prior to placing the remaining embankment fill between the cofferdams in order to allow a free flow path through the lower part of the embankment.

At Lower Monumental and Ice Harbor dams, temporary earth dikes would be left in place upstream and downstream. These temporary cofferdams would consist of unexcavated abutment material and would be located at the riverside limit of the abutment excavation. Sheetpiles would be placed 30 meters (98 feet) from the navigation-lock end, driven into and perpendicular to the temporary cofferdams. Sheetpiles would be used to control erosion during breaching. A typical construction sequence for Lower Monumental and Ice Harbor Dams is shown in Figure B17.

Cofferdam removal would be similar at all four dams. Material would be removed from the downstream cofferdam between the sheetpiles and the outer end, allowing water to flow into the area between the two cofferdams. The upstream cofferdam would be breached, allowing the water surfaces upstream and downstream to equalize. When the water surfaces equalize, the downstream cofferdam would be removed. If dams are not removed sequentially, then downstream reservoirs could be lowered to facilitate removal of the cofferdams. Once the water surface elevations on both sides of the upstream cofferdam are equalized, the removal of both cofferdams could begin. Excavation would commence at the cofferdam breach by removal of the sheet piles and proceed toward the shoreline. This is a controlled breach scenario and assumes river flows of 1,700 m^3/s (60,000 cfs) or less. Cofferdam material above water would be removed with a hydraulic excavator, while material below water would be removed by a dragline.

If higher river flows occurred, the head differential might result in velocities that preclude controlled breach and removal of the cofferdam. In this scenario, excavation of the cofferdams would commence from the shore, providing a water passage that would force an uncontrolled breach. In this case, the river flow would carry away the cofferdam material. The amount of material carried away would depend on flows. Subsequent high river flows through the new channel would continue to carry the material further downstream.

The total volume of material in the cofferdams at all four sites is 1,030,400 m^3. Less than 40 percent of this material consists of silt-sized particles. The bulk of the material is sand and gravel. Under expected conditions, less than 10 percent of the material in the cofferdams would not be recovered from the river by dragline excavation. However, extreme flow events could lead to a worst-case scenario where up to 90 percent of the silt is lost to the river. This range of silt addition to the river is considered a very small fraction of the volume of sediment that will be mobilized immediately following breaching the cofferdams. Specific information on sediment concentrations is not yet available.

There would be some additional sediment introduced into the river during removal of cofferdams and during levee construction. In addition, Lower Monumental and Ice Harbor dams together would require approximately 142,400 m^3 of local dredging of the riverbed material to produce acceptable velocities in the new channel.

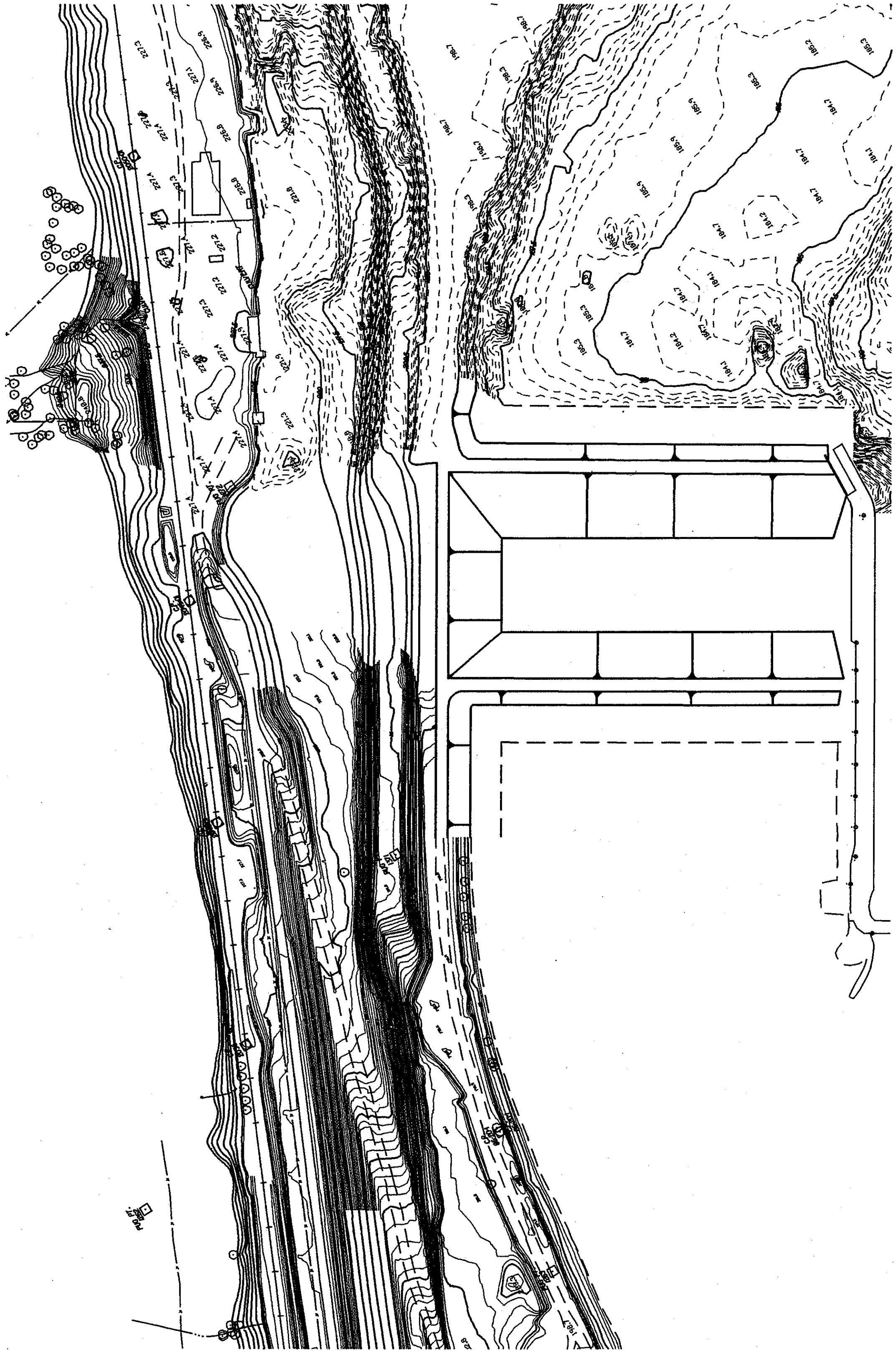
Extremely close coordination and cooperation would be required to ensure that controlled breaching can be achieved safely at all of the dams. Contracts would need to be structured such that constraints on the individual contractors prevent delays, contractual claims and increased costs.

B.6.10 Cofferdam Removal Equipment

Cofferdam removal would be accomplished by a hydraulic excavator for material above the water surface and by dragline for material below the water surface. Estimates for quantities of material to be removed above and below water were based on the water surface elevation for a flow of 1,700 m^3/sec (60,000 cfs) at each site. The hydraulic excavator is assumed to be a 7.6-m^3 (10-cy) CAT 5130 with a productivity rate 50 percent of normal for this equipment or approximately 573 m^3/hr (750 cy/hr). The dragline would have a 7.5-m^3 (10-cy) bucket and a productivity rate of 321 m^3/hr (420 cy/hr). End-dump trucks would need to back up along the cofferdam crest to receive material.

B.6.11 Sequenced Removal of the Four Lower Snake River Dams

Removal of all four lower Snake River dams can be sequenced in several ways. The proposed method selected as a result of this study is to sequence the work so that Lower Granite and Little Goose Dams are breached during the fifth year of the construction period. Lower Monumental and Ice Harbor Dams would be breached during the sixth year of the construction period. Several other variations are possible, however this method provides a realistic phasing of design and construction activities and is not overly optimistic for this level of feasibility. See Annex W for more detailed discussion of construction sequencing.



US Army Corps of Engineers
Walla Walla District

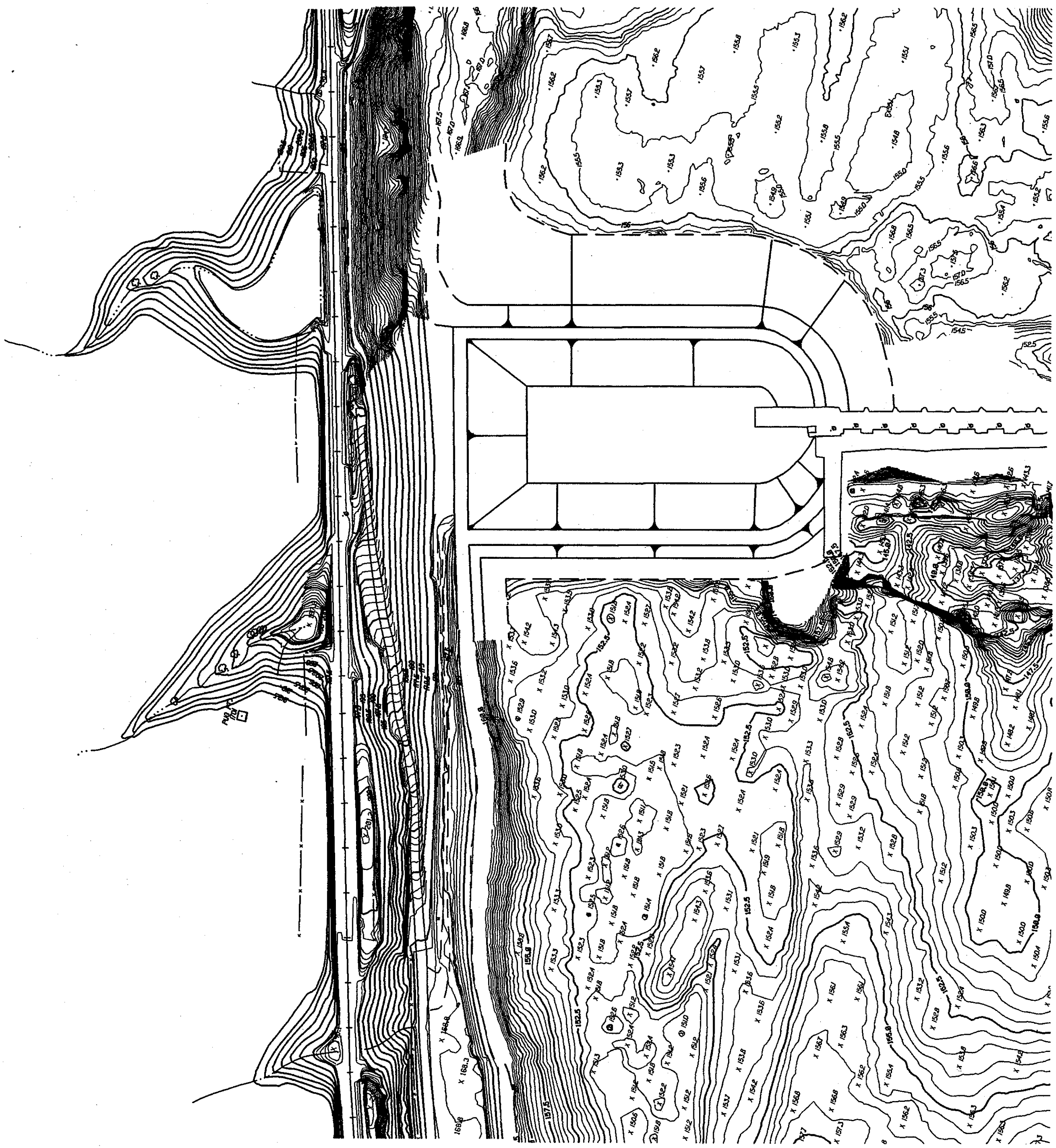
LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

LOWER GRANITE DAM - GENERAL EMBANKMENT REMOVAL CONFIGURATION

Figure: B1

CADD FILENAME: E:\drawdown\plates\b\pltb1.dgn PLOT TIME: 14-OCT-1999 13:54

SHEET MAIN SCALE:



US Army Corps of Engineers
Walla Walla District

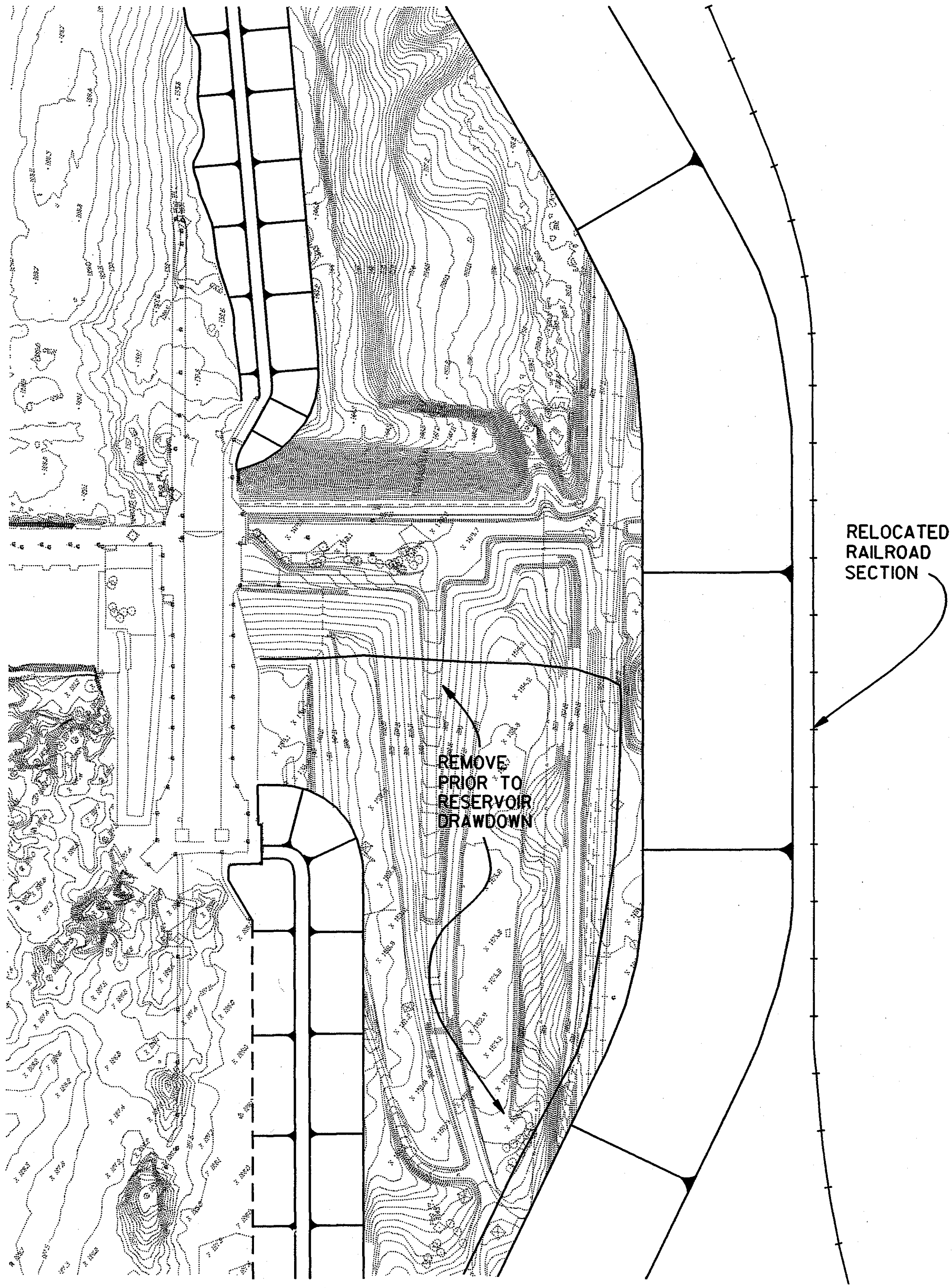
LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

LITTLE GOOSE DAM - GENERAL EMBANKMENT REMOVAL CONFIGURATION

Figure: B2

CADD FILENAME:E:\drawdown\plates\b\pltb2.dgn PLOT TIME: 25-OCT-1999 07:41

SHEET MAIN SCALE:



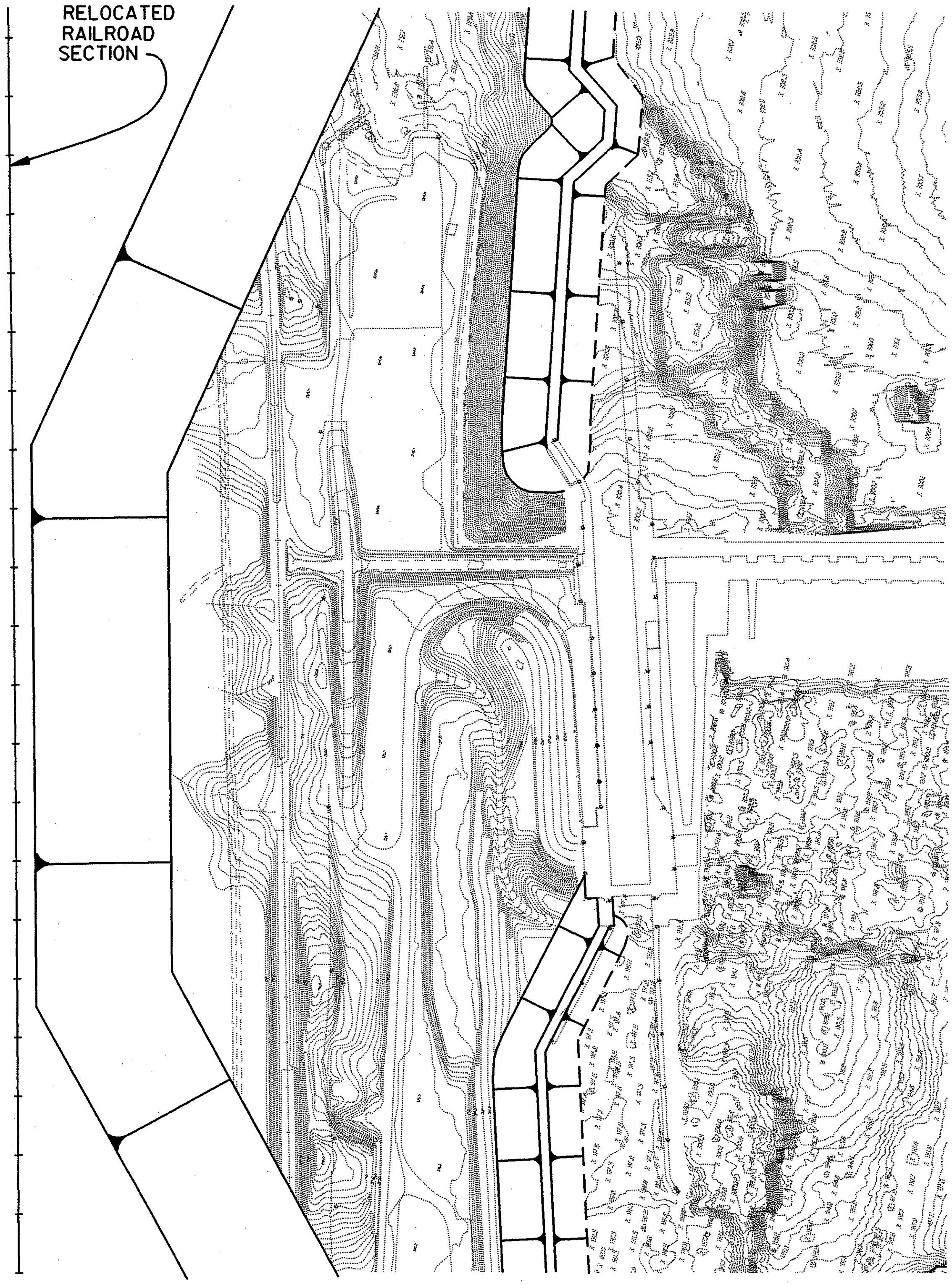
US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

LOWER MONUMENTAL DAM - GENERAL EMBANKMENT REMOVAL CONFIGURATION

Figure: B3

CADD FILENAME: E:\drawdown\plates\b\pltb3.dgn PLOT TIME: 25-OCT-1999 08:56



LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

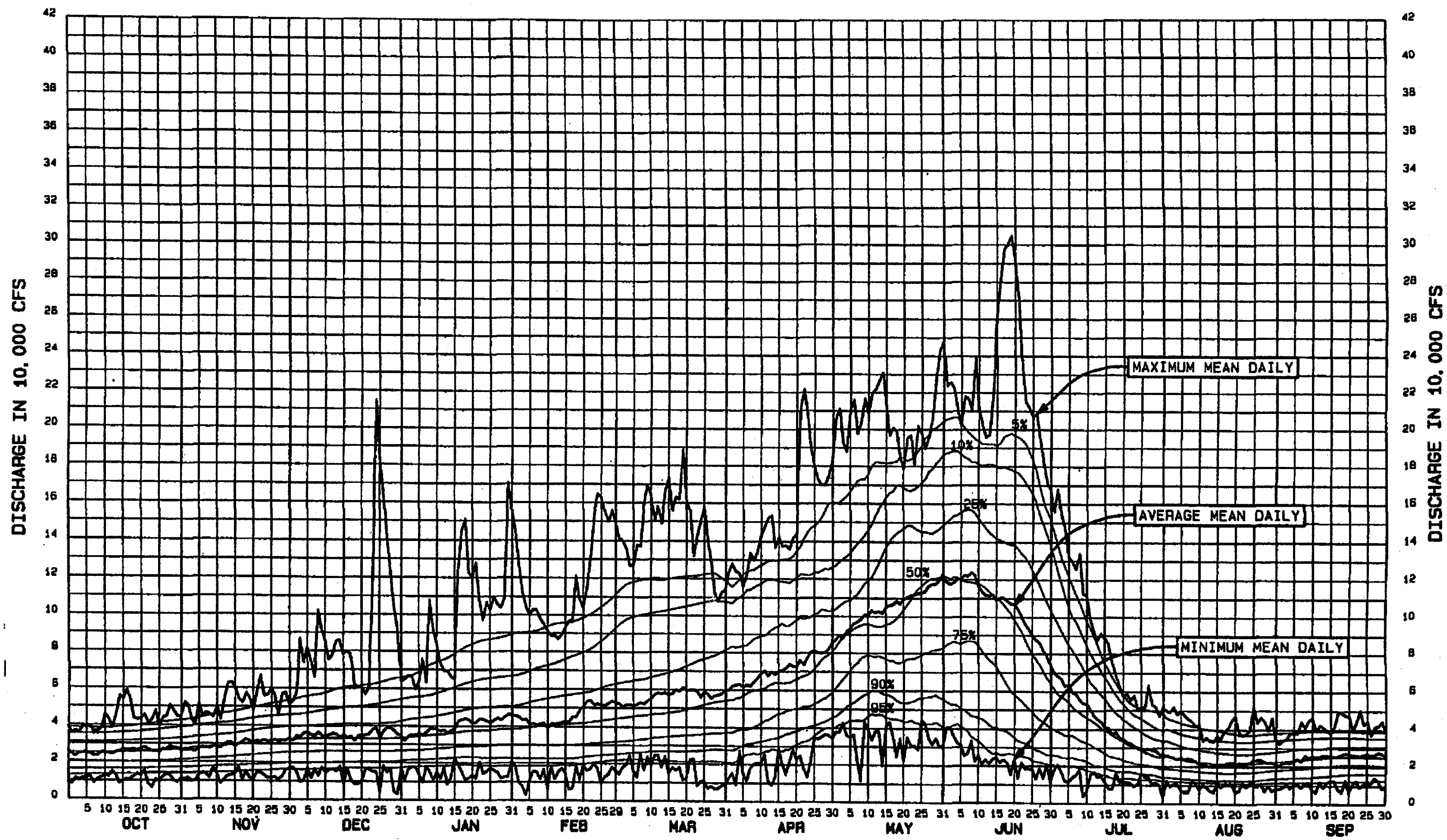
ICE HARBOR DAM - GENERAL EMBANKMENT REMOVAL CONFIGURATION

Figure: B4

US Army Corps of Engineers
Walla Walla District

SHEET MAIN SCALE:

CADD FILENAME: E:\drawdown\plates\b\pltb4.dgn PLOT TIME: 15-OCT-1999 13:11



NOTES:

1. SUMMARY HYDROGRAPHS PLOTTED FROM CORPS OF ENGINEERS MEAN DAILY OUTFLOW DATA FOR ICE HARBOR DAM.

2. PERIOD OF RECORD IS OCTOBER 1962 THROUGH SEPTEMBER 1995.

3. DRAINAGE AREA AT ICE HARBOR DAM IS 108,500 SQUARE MILES (APPROXIMATELY).

4. EXCEEDENCE LINES REPRESENT THE PERCENTAGE OF TIME THE FLOW IS EQUALLED OR EXCEEDED ON THAT PARTICULAR DAY.

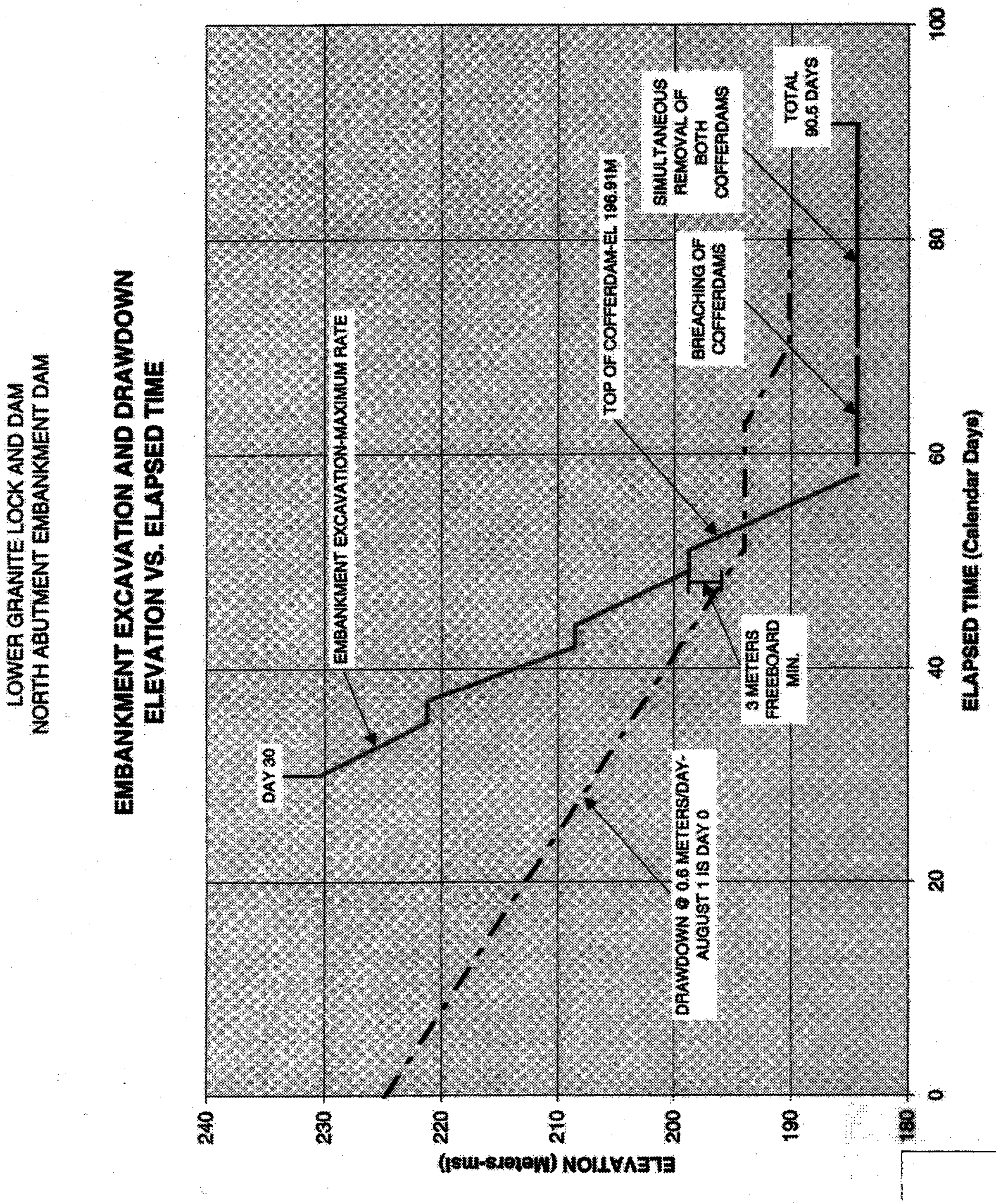
US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY
EMBANKMENT EXCAVATION AND RIVER CHANNELIZATION
SUMMARY HYDROGRAPH

Figure: B5

CADD FILENAME:E:\drawdown\plates\b\pltb5.dgn PLOT TIME:16-SEP-1999 15:19

SHEET MAIN SCALE:



US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

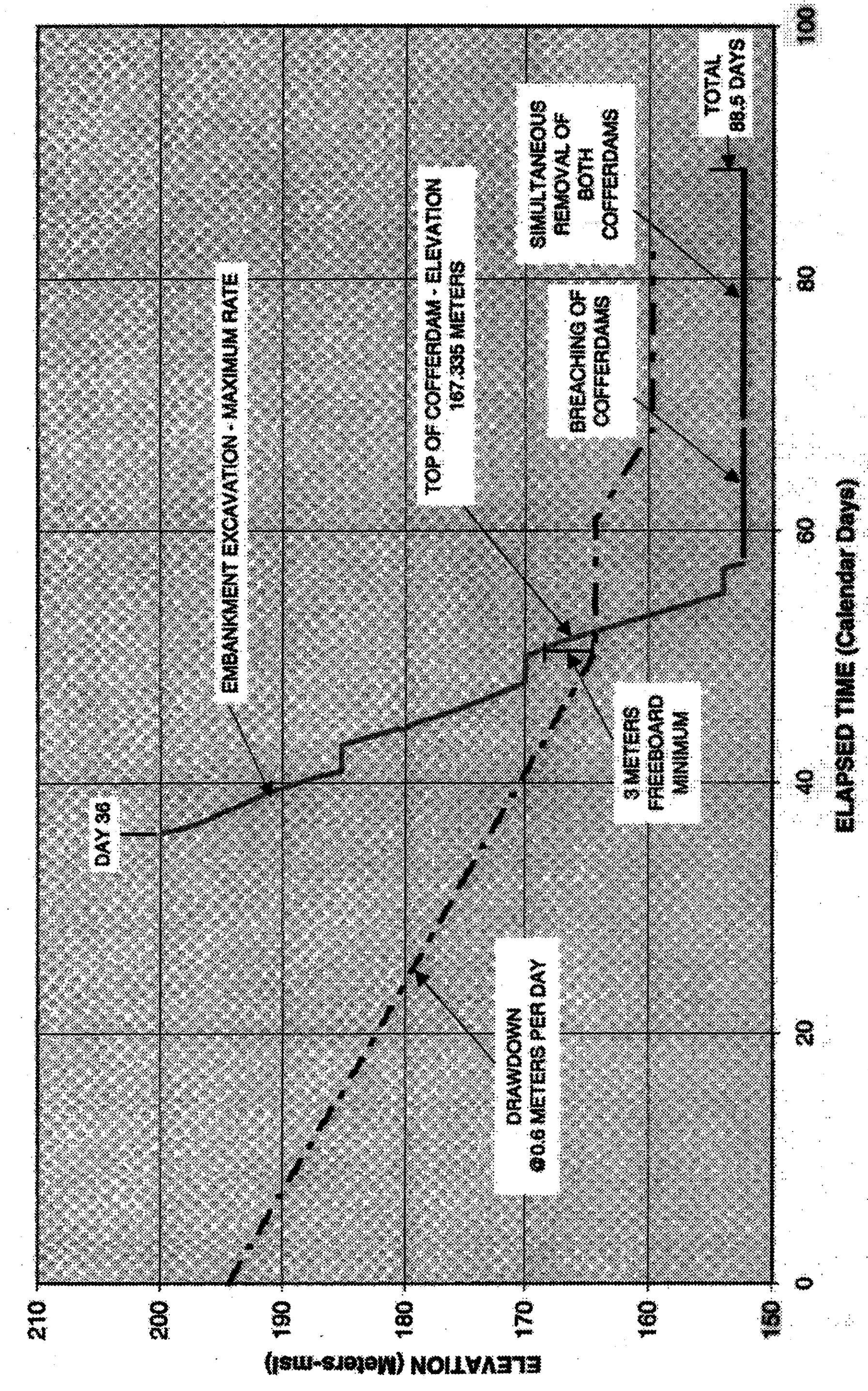
EMBANKMENT EXCAVATION AND DRAWDOWN ELEVATION VS. ELAPSED TIME

Figure: B6

CADD FILENAME:E:\drawdown\plates\b\pltb6.dgn PLOT TIME:17-SEP-1999 07:36

LITTLE GOOSE LOCK AND DAM
NORTH SHORE EMBANKMENT DAM

EMBANKMENT EXCAVATION AND DRAWDOWN ELEVATION VS. ELAPSED TIME



US Army Corps of Engineers
Walla Walla District

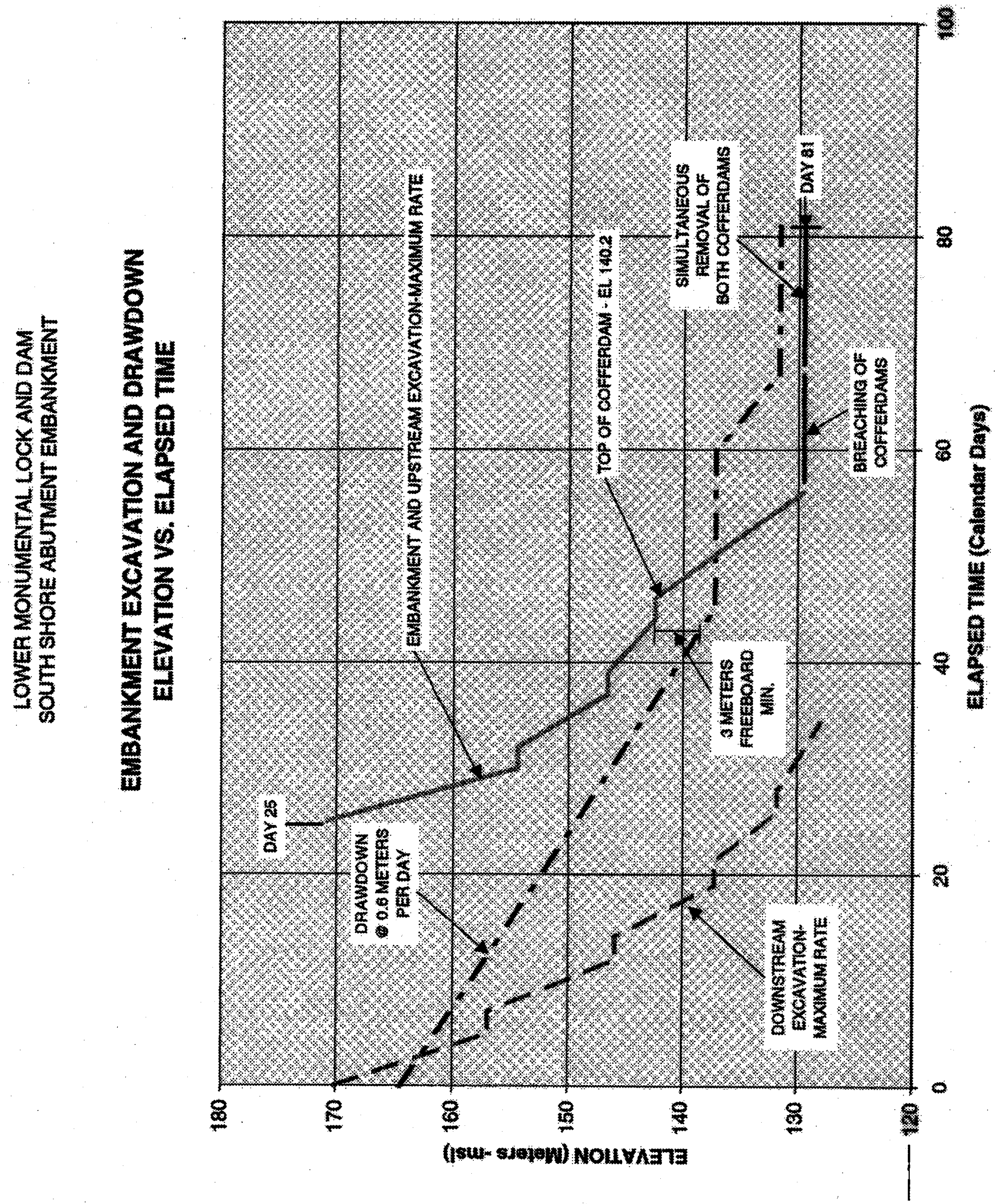
LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

EMBANKMENT EXCAVATION AND DRAWDOWN ELEVATION VS. ELAPSED TIME

Figure: B7

CADD FILENAME:E:\drawdown\plates\b\pltb7.dgn PLOT TIME:17-SEP-1999 07:40

SHEET MAIN SCALE:



SHEET MAIN SCALE:

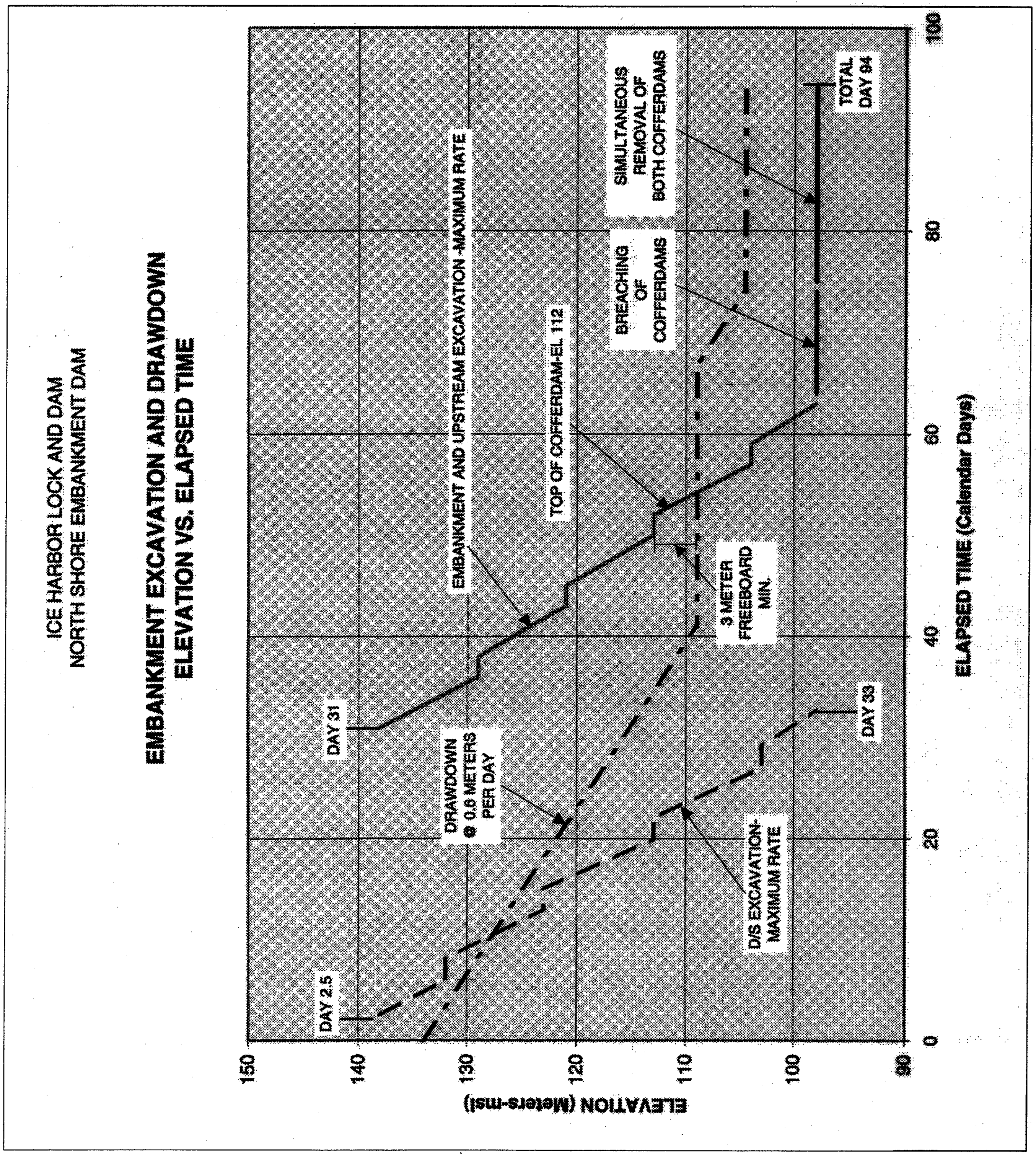
US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

EMBANKMENT EXCAVATION AND DRAWDOWN ELEVATION VS. ELAPSED TIME

Figure:
B8

CADD FILENAME: E:\drawdown\plates\b\pltb8.dgn   PLOT TIME: 17-SEP-1999 07:42



SHEET MAIN SCALE:

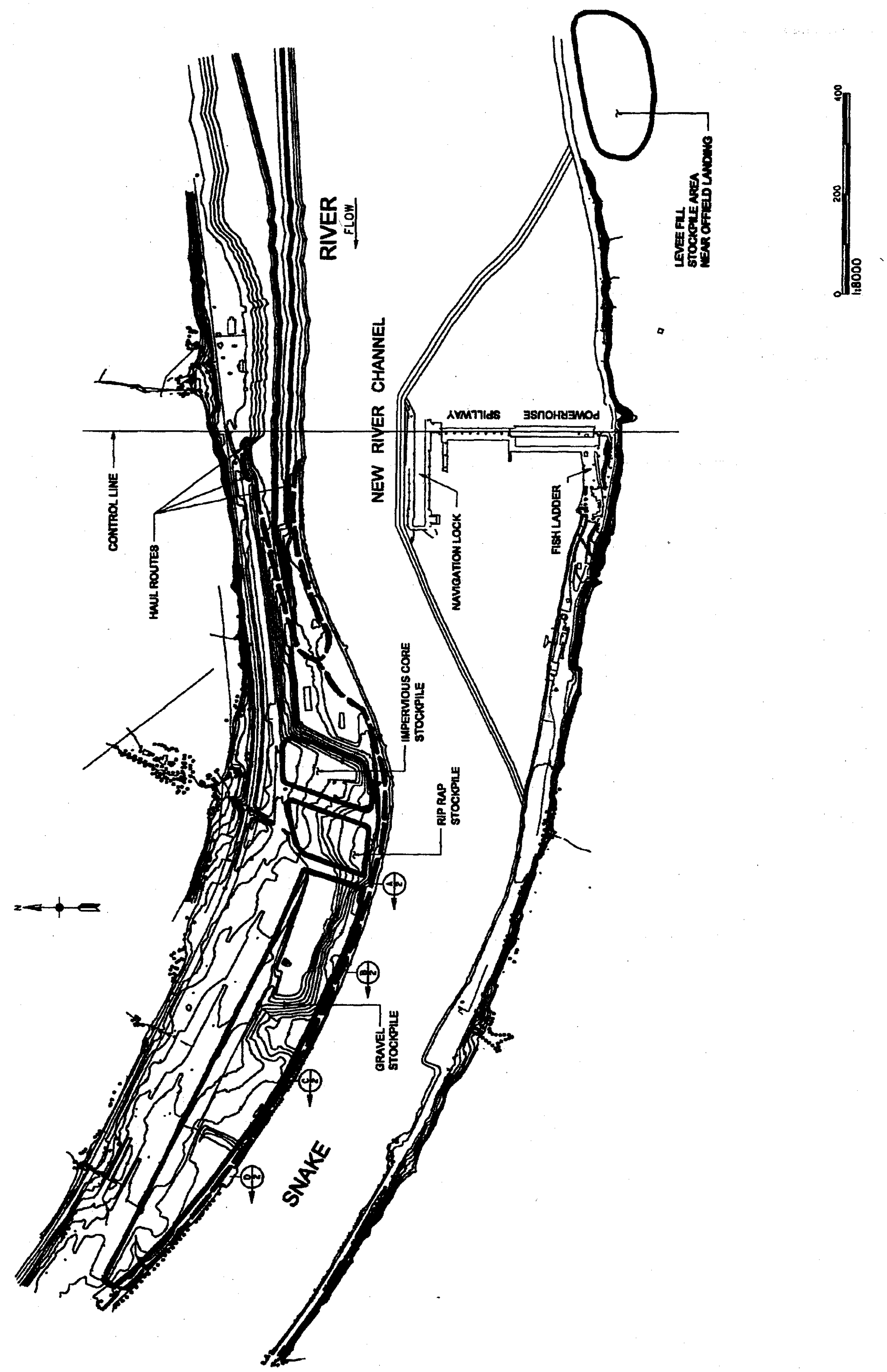
US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

EMBANKMENT EXCAVATION AND DRAWDOWN ELEVATION VS. ELAPSED TIME

Figure: B9

CADD FILENAME: E:\drawdown\plates\b\pltb9.dgn PLOT TIME: 17-SEP-1999 07:45



SHEET MAIN SCALE:

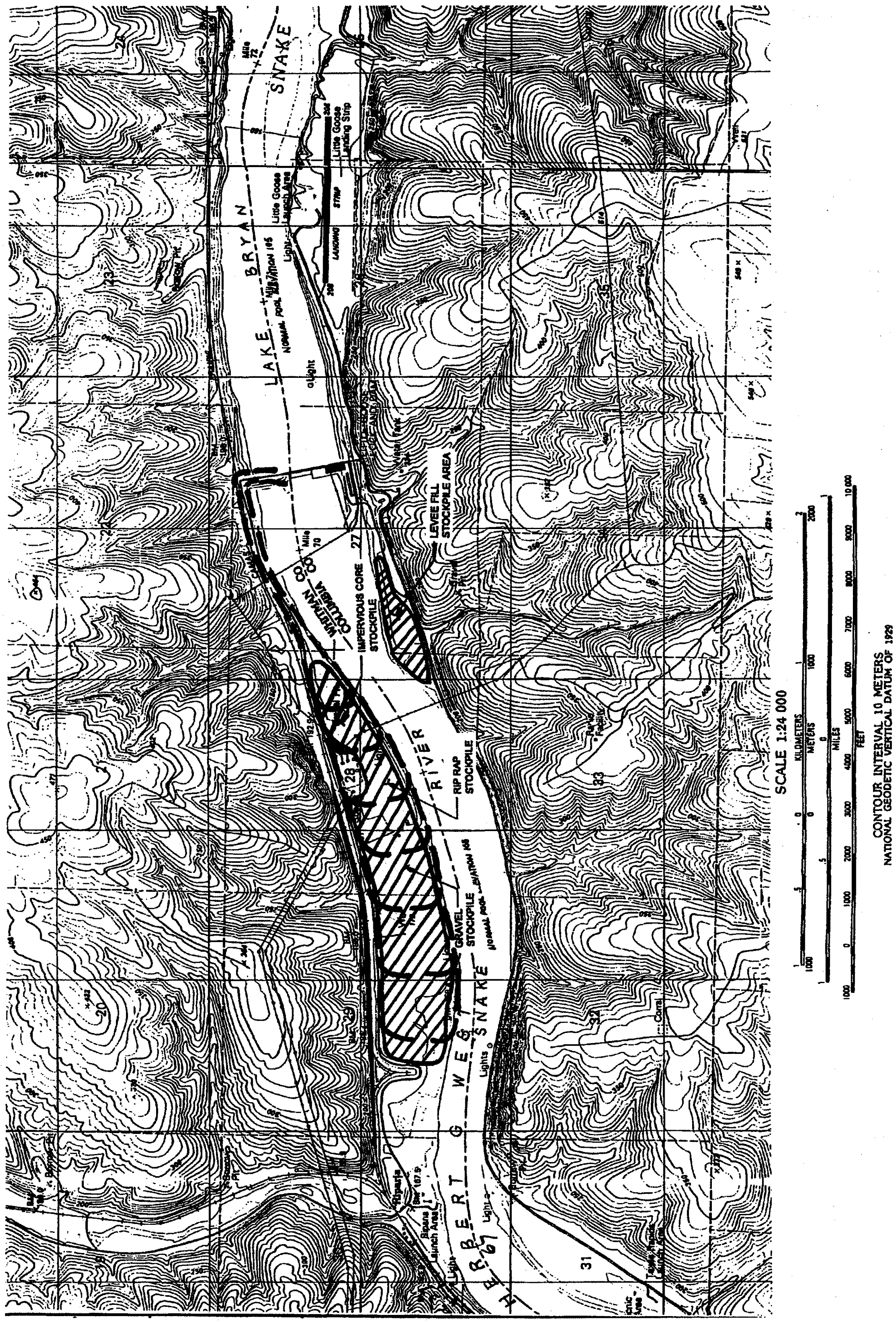
US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

LOWER GRANITE STOCKPILE AREAS AND HAUL ROADS - PLAN

Figure: B10

CADD FILENAME:E:\drawdown\plates\b\pltb10.dgn PLOT TIME:14-OCT-1999 10:57



SHEET MAIN SCALE:

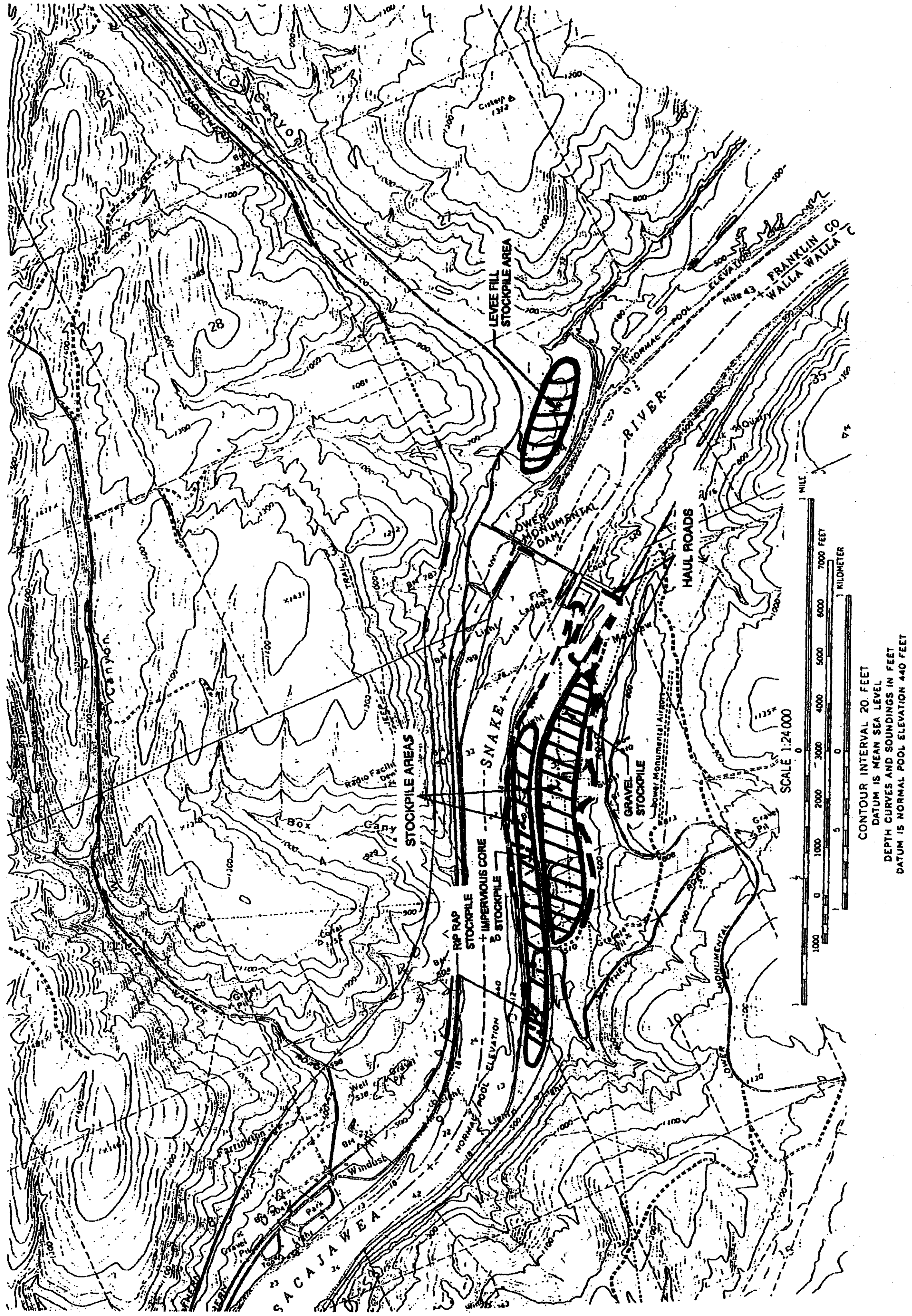
US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

LITTLE GOOSE STOCKPILE AREAS AND HAUL ROADS - PLAN

Figure:
B11

CADD FILENAME: E:\drawdown\plates\b\pltb11.dgn PLOT TIME: 17-SEP-1999 07:51



US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

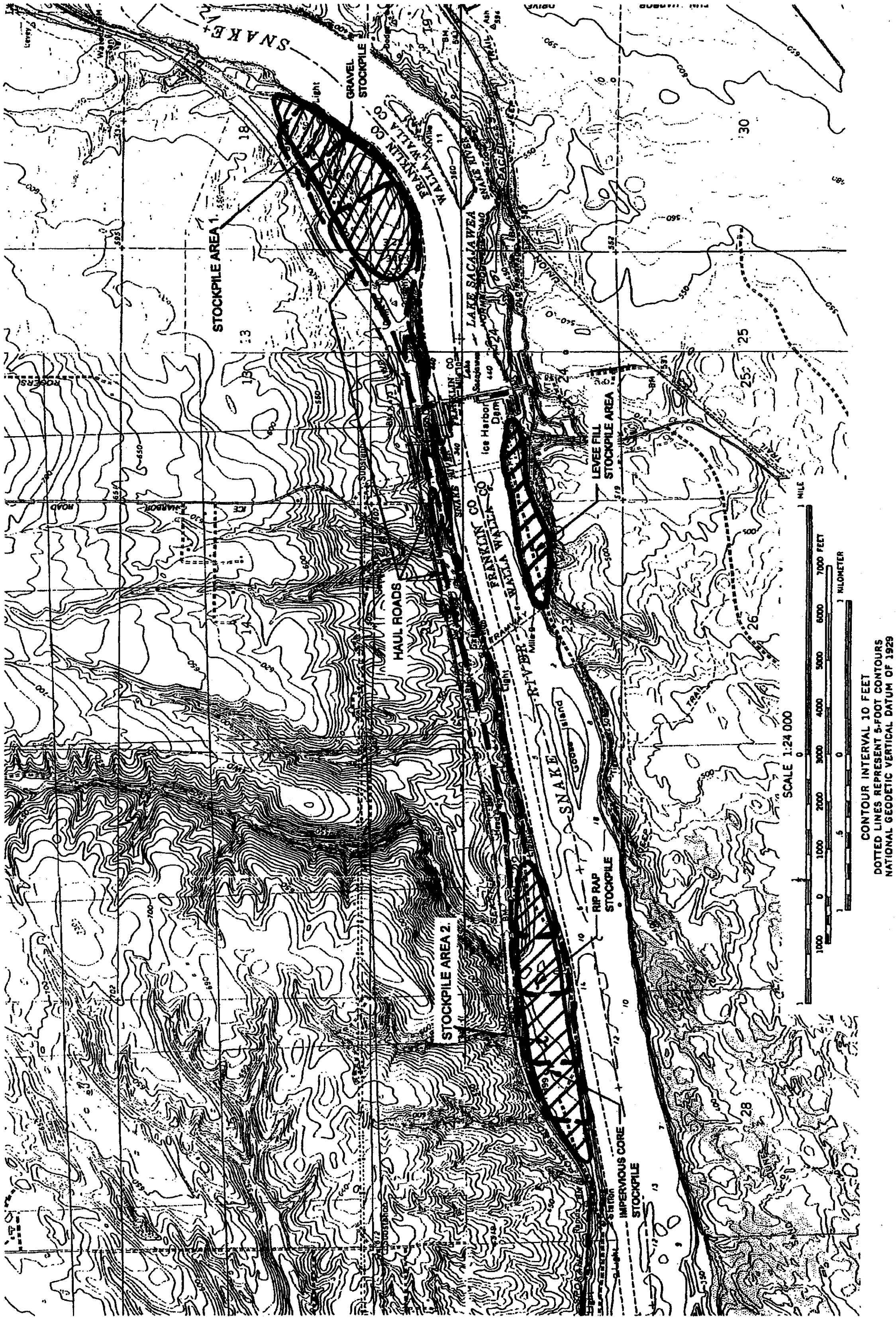
LOWER MONUMENTAL STOCKPILE AREAS AND HAUL ROADS - PLAN

Figure: B12

CADD FILENAME: E:\drawdown\plates\b\pltb12.dgn

PLOT TIME: 17-SEP-1999 07:52

SHEET MAIN SCALE:



SHEET MAIN SCALE:

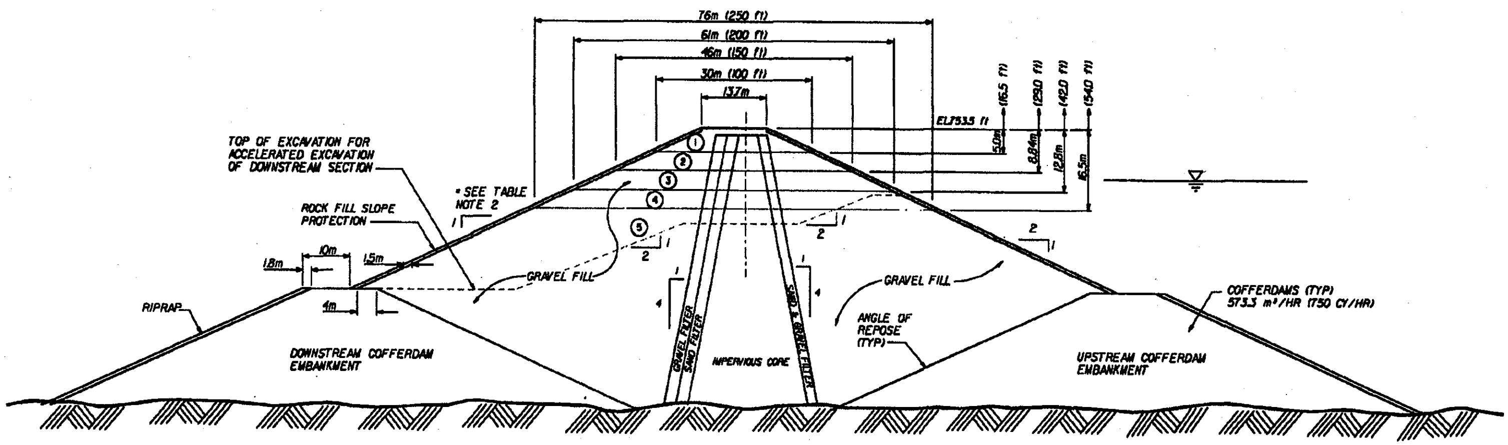
US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

ICE HARBOR STOCKPILE AREAS AND HAUL ROADS - PLAN

Figure:
B13

CADD FILENAME:E:\drawdown\plates\b\pltb13.dgn PLOT TIME:17-SEP-1999 07:54



EXCAVATING EQUIPMENT & RATES

1. 1 EXCAVATOR @ 765m³/HR (1000/CY/HR)
2. 1 EXCAVATOR @ 1150m³/HR (1500/CY/HR)
3. 1 EXCAVATOR @ 1150m³/HR (1000/CY/HR) PLUS 1 FRONT END LOADER @ 920m³/HR (1200/CY/HR) = 2070m³/HR (2700/CY/HR)
4. 2 EXCAVATOR @ 1150m³/HR (3000/CY/HR) PLUS 1 FRONT END LOADER @ 920m³/HR (1200/CY/HR) = 3220m³/HR (4200/CY/HR)
5. 2 EXCAVATOR @ 765m³/HR (3000/CY/HR) PLUS 2 FONT END LOADER @ 1830m³/HR (2400/CY/HR) = 4130m³/HR (5700/CY/HR)

TYPICAL EMBANKMENT SECTION

0 1 2 3 4
1:100

NOTE:
1. UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
2. EMBANKMENT SECTION SHOWN IS TYPICAL FOR EACH SITE WITH THE FOLLOWING EXCEPTIONS:

PROJECT SITE	FILL SLOPES UPSTREAM	FILL SLOPES DOWNSTREAM	CREST WIDTH meter	CREST WIDTH (ft)	CREST ELEVATION meter	CREST ELEVATION (ft)	AVERAGE HEIGHT meter	AVERAGE HEIGHT (ft)
Lower Granite	2H:1V	2H:1V	45	13.70	230.43	756	47.55	156.0
Little Goose	2.5H:1V	2H:1V	30	9.14	199.94	656	47.50	155.8
Lower Monumental	2H:1V	2H:1V	30	9.14	170.08	558	40.50	132.9
Ice Harbor	2H:1V	1.5H:1V	25	7.62	138.00	453	28.50	93.5

3. COFFERDAMS SHOWN ARE PRESENT AT LOWER GRANITE AND LITTLE GOOSE ONLY.
4. EMBANKMENTS FOR LOWER MONUMENTAL AND ICE HARBOR DO NOT HAVE COFFERDAMS.

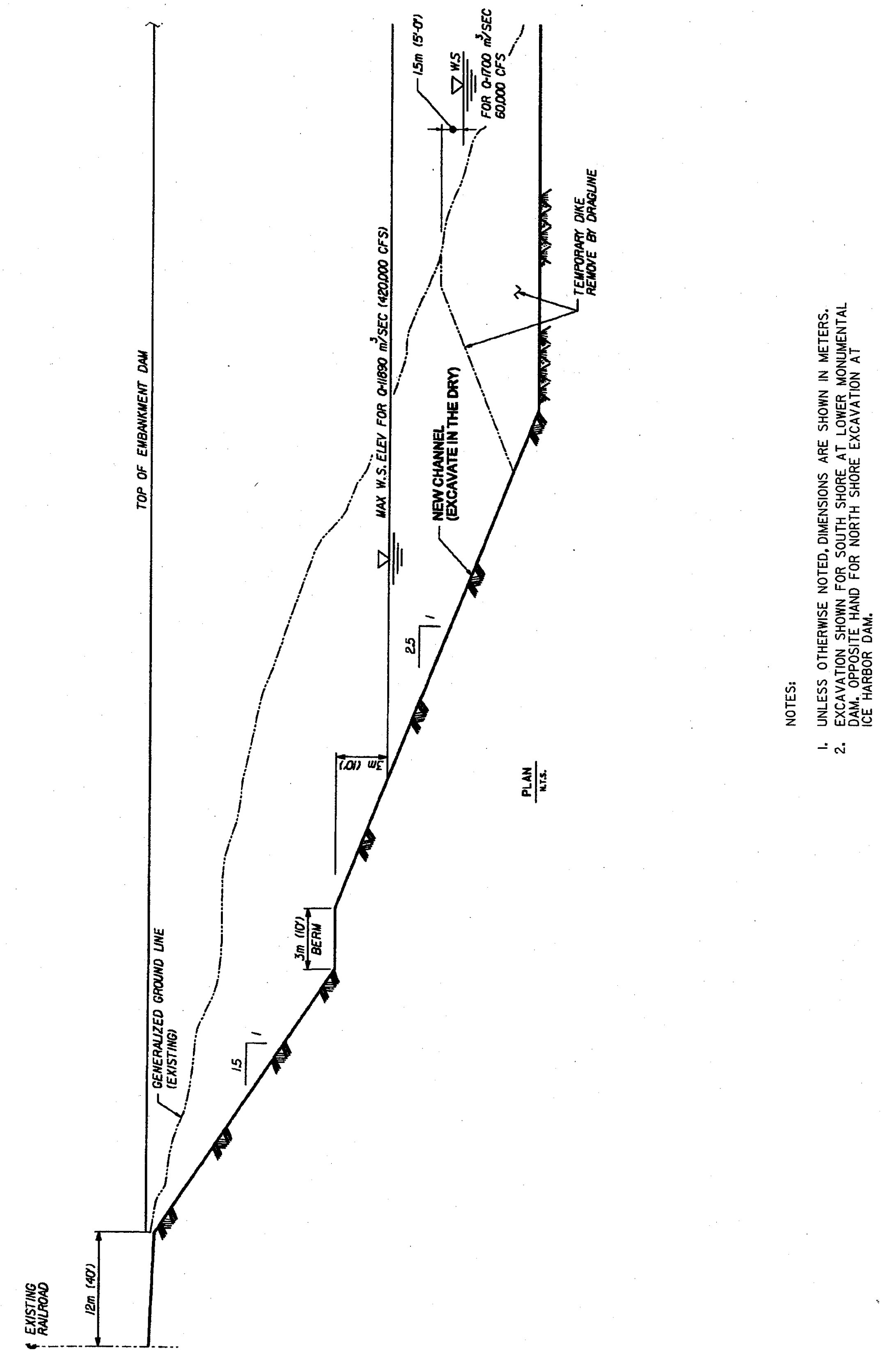
SHEET MAIN SCALE:

US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY
TYPICAL EMBANKMENT EXCAVATION AND TYPICAL CROSS SECTION AT LOWER GRANITE AND LITTLE GOOSE

Figure: B14

CADD FILENAME: E:\drawdown\plates\b\pltb14.dgn
PLOT TIME: 17-SEP-1999 07:56



NOTES:

1. UNLESS OTHERWISE NOTED, DIMENSIONS ARE SHOWN IN METERS.
2. EXCAVATION SHOWN FOR SOUTH SHORE AT LOWER MONUMENTAL DAM. OPPOSITE HAND FOR NORTH SHORE EXCAVATION AT ICE HARBOR DAM.

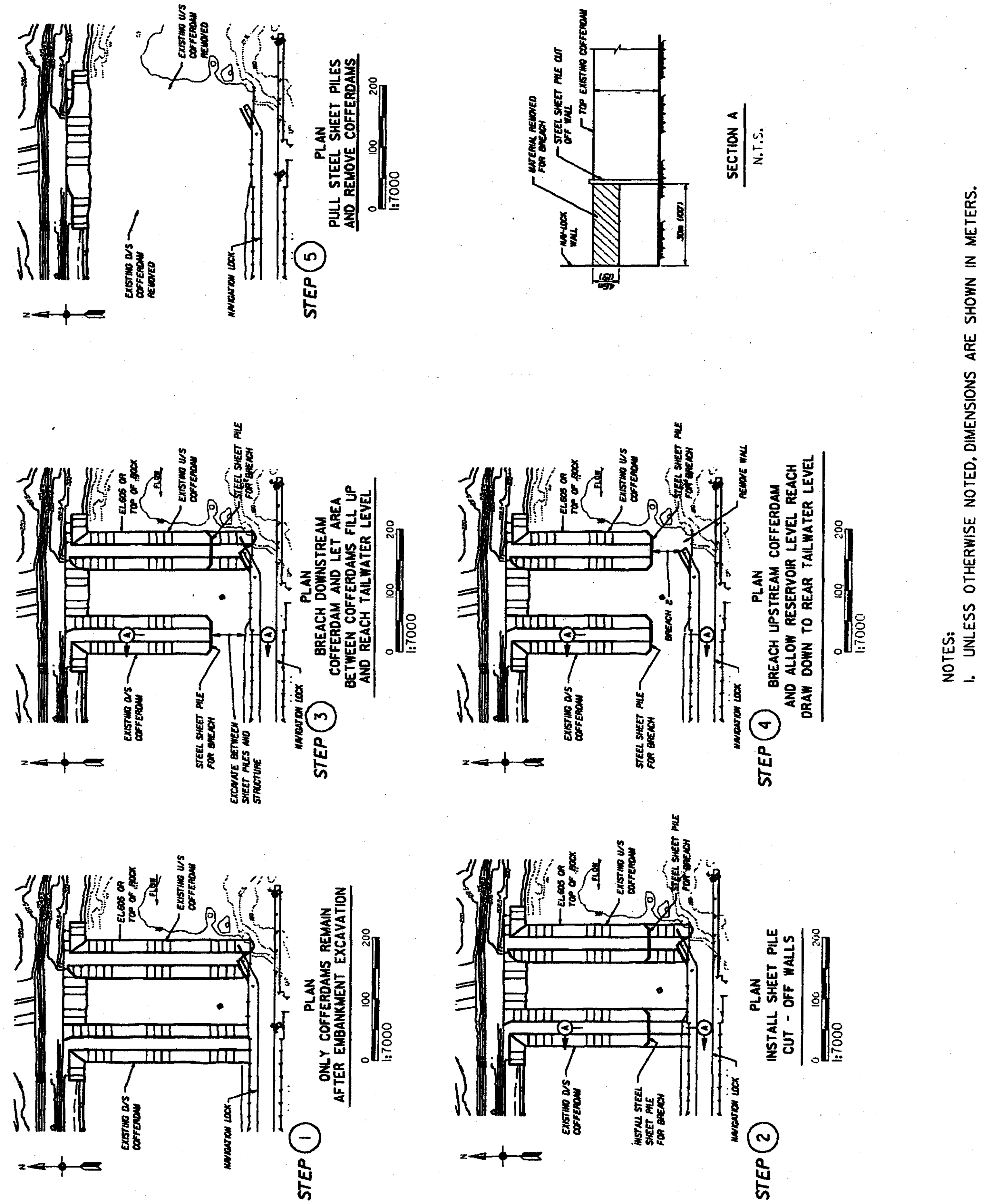
US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY
TYPICAL ABUTMENT EXCAVATION AT LOWER MONUMENTAL DAM
ICE HARBOR (OPP HAND)

Figure:
B15

CADD FILENAME: E:\drawdown\plates\b\pltb15.dgn PLOT TIME: 17-SEP-1999 07:57

SHEET MAIN SCALE:



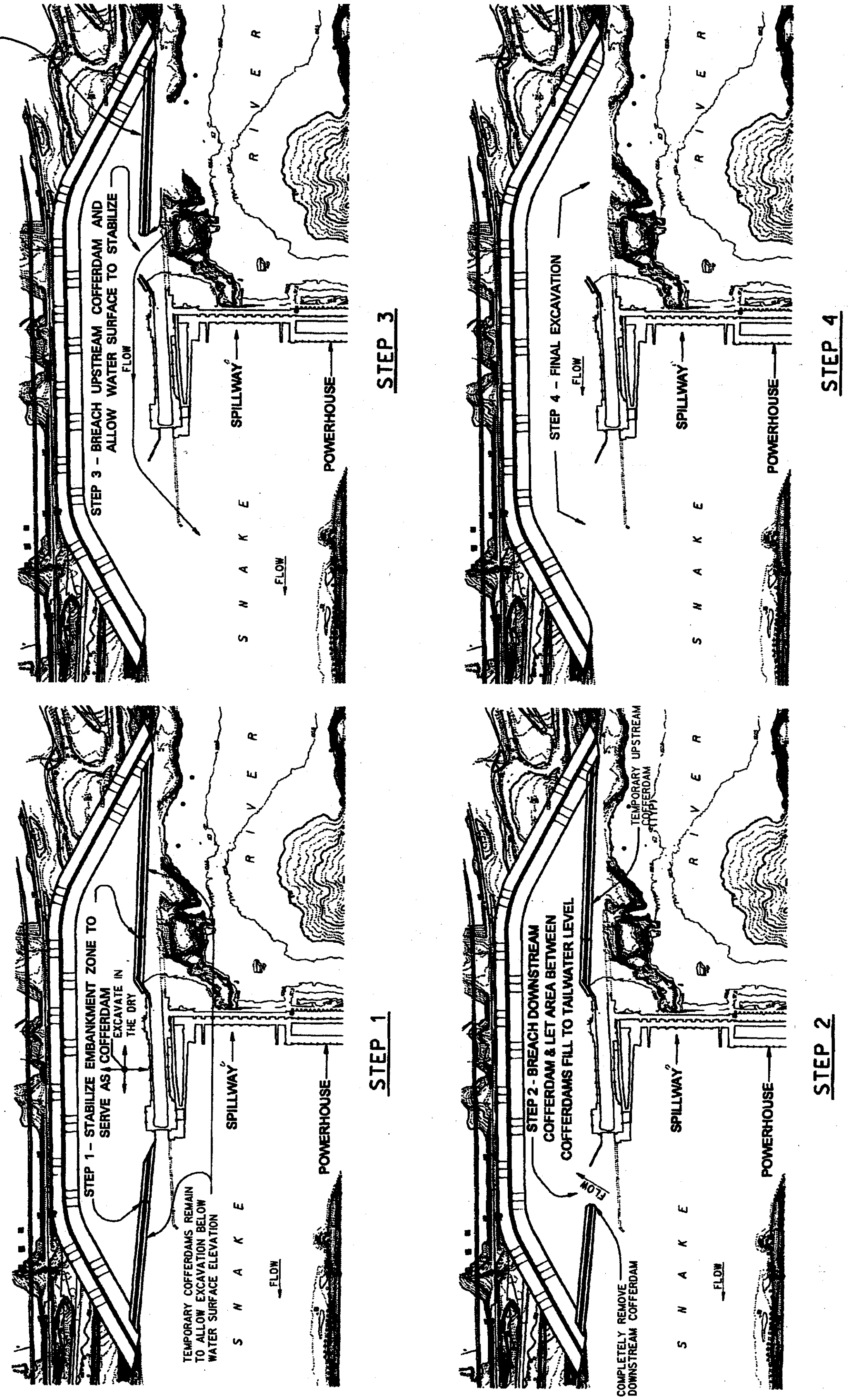
US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY
TYPICAL COFFERDAM AND BREACH PLAN
LOWER GRANITE AND LITTLE GOOSE DAMS

Figure: B16

SHEET MAIN SCALE:

CADD FILENAME: E:\drawdown\plates\b\pltb16.dgn PLOT TIME: 17-SEP-1999 07:59



CONSTRUCTION SEQUENCE

NOTE: STEPS ILLUSTRATE WORK SEQUENCE FOR ICE HARBOR DAM. THE SAME SEQUENCE IS PLANNED FOR THE SOUTH SHORE OF LOWER MONUMENTAL DAM, (OPPHAND).

SHEET MAIN SCALE:

US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY
TYPICAL EARTH DIKE AND BREACH PLAN
LOWER MONUMENTAL AND ICE HARBOR DAMS

Figure: B17

CADD FILENAME: E:\drawdown\plates\b\pltb17.dgn   PLOT TIME: 14-OCT-1999 10:28