Annex E

Bridge Pier Protection Plan

Annex E: Bridge Pier Protection Plan

E.1 General

A field survey, performed in August 1995, identified 25 bridges that could be affected by permanent drawdown of the four lower Snake River reservoirs. These highway and railroad bridges were evaluated to determine the adequacy of the existing bridge foundations and abutment protection to resist post-drawdown flood scouring to natural stream levels. Of the 25, all but two required some degree of protection. These structures included bridges at several locations crossing the Snake and Clearwater rivers and on tributaries to the Snake, adjacent to the reservoirs. The selected bridge identifications and locations are shown on Table E1.

Typical bridge supports for these structures include concrete seals and concrete footings, steel or wood piles, pile bents, and other cofferdam footing foundations for piers. After reservoir drawdown, existing bridge pier foundations may be destabilized or undermined by the following conditions:

- Long-term stream degradation and aggradation
- Local scour due to an accumulation of debris which restricts flow and increases scour severity
- Stream instability, possibly due to the migration of the river channel
- Erosion of approach embankments adjacent to abutments.

E.2 Standard Modifications

The existing road and railroad bridges along the lower Snake River are to remain functional under the proposed reservoir drawdown to natural streambed elevations. Some modifications to the existing bridge piers and abutments may be required where flow depths and velocities change and thus affect local river bottom deposits and native soils. Modifications may be required for older bridges that were in place prior to reservoir impoundment, as these bridges may not be adequately protected against scour when evaluated by modern scour analysis techniques. The two categories of bridge pier modification are Abutment Erosion Protection and Bridge Pier Foundation Reinforcement.

E.2.1 Abutment Erosion Protection

The study team's key concern was protecting existing bridge support structures from flowing water erosion and from undermining after drawdown by potential flood events. In general, the study team determined that abutment erosion protection should be placed between the elevations of the 500-year flood event (flows vary depending upon location), and normal low flow (820 m^3/s) in areas where available information indicates that adequate protection (rock or riprap) does not currently exist on exposed banks and abutments.

The size of riprap to be used for erosion protection can be determined from established tables (Corps, Waterways Experiment Station, Hydraulic Design Chart 712-1), which relate river flow velocity, stone weight, and the diameter of the riprap required. The river flow velocity is determined from river profile and cross-section elevations in conjunction with using Hydrologic Engineering Center's computer program entitled "Water Surface Profiles," version 4.6.2, (commonly referred to as "HEC-2") or its computer program entitled "River Analysis System," version 2.1 (commonly referred to as "HEC-RAS™"). The study team assumed a minimum stone weight of 2,162 kilograms per cubic meter

Table E1. Bridge Types and Locations

Bridge Name	Type	Location
Joso River	Railroad	Snake River/Lower Monumental Reservoir at river kilometer 94.1
Lyons Ferry	Highway	Snake River/Lower Monumental Reservoir at river kilometer 95.3
Snake River	Railroad	Snake River/Lower Monumental Reservoir at river kilometer 99.4
Central Ferry	Highway	Snake River/Little Goose Reservoir at river kilometer 134.1
Red Wolf	Highway	Snake River/Lower Granite Reservoir/Northwest Clarkston at river kilometer 221.1
Snake River (Old US 12)	Highway	Snake River/Lower Granite Reservoir/Clarkston at river kilometer 224.5
Southway	Highway	Snake River/Lower Granite Reservoir/Clarkston at river kilometer 227.6
Lewiston (Camas Prairie)	Railroad	Clearwater River/Lower Granite Reservoir at river kilometer 0.6
Clearwater Memorial	Highway	Clearwater River/Lower Granite Reservoir at river kilometer 3.4
Tributary Bridge No. 1 (Steptoe Canyon)	Hwy. & RR	Lower Granite Reservoir at river kilometer 206.0
Tributary Bridge No. 2 (Nisqually John Canyon)	Hwy. & RR	Lower Granite Reservoir at river kilometer 198.2
Tributary Bridge No. 3 (Yakawawa Canyon)	Hwy. & RR	Lower Granite Reservoir at river kilometer 189.6
Tributary Bridge No. 4 (Keith Canyon)	Hwy. & RR	Lower Granite Reservoir at river kilometer 188.8
Tributary Bridge No. 5 (Wawawai Canyon)	Railroad	Lower Granite Reservoir at river kilometer 178.1
Tributary Bridge No. 6 (Buck Canyon)	Hwy. & RR	Lower Granite Reservoir at river kilometer 175.8
Tributary Bridge No. 7	Hwy. & RR	Lower Granite Reservoir at river kilometer 198.6
Tributary Bridge No. 8	Railroad	Little Goose Reservoir at river kilometer 124.7
Tributary Bridge No. 9	Railroad	Little Goose Reservoir at river kilometer 121.2
Tributary Bridge No. 10	Railroad	Little Goose Reservoir at river kilometer 118.9
Tributary Bridge No. 11	Railroad	Little Goose Reservoir at river kilometer 116.2
Tributary Bridge No. 12	Highway	Little Goose Reservoir at river kilometer 133.7
Tributary Bridge No. 13	Highway	Little Goose Reservoir at river kilometer 167.0
Tributary Bridge No. 14	Railroad	Little Goose Reservoir at river kilometer 149.9
Tributary Bridge No. 15	Railroad	Little Goose Reservoir at river kilometer 147.6

(kg/m^3) (135 pounds per cubic foot [pcf]) for the riprap sources available on the lower Snake River. These values were used to determine the diameter, D_{50}, of the riprap to be placed on the slope to be protected. The subscript in D_{50} refers to the percent of rock in which the diameter is less than the size noted. The thickness of the bank or abutment protection is chosen as two times the D_{50} of the riprap (i.e., if the D_{50} is determined to be 0.3 meter, the thickness of the bank protection would be 0.6 meter).

The lateral extent (parallel to stream flow) of the bank protection is determined from U.S. Department of Transportation criteria set forth for protection of bridge piers (WSDOT, 1990). This criteria requires a riprap mat width of at least two times the pier width measured from the face of the pier in the upstream and downstream directions. This results in a mat equal to four times the width of the pier plus the length of the pier. If the area to be riprapped does not include a bridge pier, then the nearest bridge pier is used as a reference to size the area that needs the riprap protection. It should also be noted that the riprap mat is symmetrical with the centerline of the bridge and abutment in question.

Placing additional riprap armor surrounding the bridge support interface with the native soils or rock would provide a cost-effective modification to reduce the effects of scour. Figure E1 illustrates a typical abutment protection modification.

E.2.2 Bridge Pier Foundation Reinforcement

Drawdown also could require protection or reinforcement of existing bridge pier foundations. Reinforcement of the bridge support foundations would be necessary because all streambed material in the new scour prism could be removed and, thus, not be available for bearing or lateral support of the piers.

The study team made the following assumptions in evaluating remedial measures for the piers:

- Where the calculated scour depth is above the top of the existing footing, no protection would be required.
- Where footings of piers are founded on rock, no additional protection of the footing would be required. The team assumed that existing concrete footings are founded on competent rock, resistant to scour erosion.

Where the calculated scour depth for a concrete footing resting on soil falls between the top of the footing and the bottom of the footing, interlocking steel sheetpiles would be driven in a circular cell configuration to 2 meters below the calculated scour depth. This additional margin of safety would be provided because of the uncertainties in the scour prediction methods.

Where the calculated scour depth for a concrete footing resting on soil falls below the bottom of the footing, interlocking steel sheetpiles would be driven to at least 2 meters below the calculated scour depth. If the calculated scour depth is at or near the level of bedrock, the circular cell sheetpiles would be driven to refusal into bedrock.

For all interlocking steel sheetpile installations, the annular space between the new sheetpiles and the existing concrete structure would be filled with concrete to serve as a cap protection from erosion. This cap would be at least 0.5 meter thick. In some cases, excavation of up to 1 meter depth of river bottom material, between the pier foundation and the surrounding sheetpile, would be needed to place the concrete cap. Figure E2 provides a typical treatment of bridge pier foundations.

Generally, for all interlocking circular cell steel sheetpile installations, the top of the steel sheetpile wall would be established by the higher of two elevations: 1) the elevation of the streambed, or 2) the construction season low water surface level. The top of the steel sheetpile circular cell wall would be cut off 0.5 meter above the higher of the two. This removal of excess sheet pile material, which may have to be accomplished underwater, would not adversely affect scour protection or hinder river navigation.

E.3 Evaluation of Modifications

Conceptual modifications for each site-specific existing bridge structure were selected, based on flow parameters and scour analyses as they applied to that bridge's pier configurations. Potential scour, evaluated at flows for the 500-year flood event for each bridge, was estimated to range from 2.75 meters to 8.2 meters (9 feet to 27 feet) below streambed elevation. Calculations for each bridge analyzed are given in Appendices C and G of a separate report titled *Lower Snake River Reservoir Stabilization Plan* (Raytheon, 1997).

The following two subsections describe the methodology and river flow values that were used to determine the modifications needed for each bridge analyzed.

E.3.1 Scour Evaluation Methodology

Calculations of scour depth for bridge piers were performed for each of the bridge sites. These calculations were performed using the HEC-RAS™ program for the 500-year flood event to determine flow characteristics at each site during this event. The HEC-RAS™ software program, along with river profile and cross-section elevations, provides information on total flow, velocity, water surface elevations, and channel dimensions for all data stations on the lower Snake River during this event. These hydraulic calculations were performed for river water surface elevations resulting from the removal of the dams and the return to the original streambed conditions prior to reservoir impoundment. Because of the long span between bridge piers and the large size of the existing Snake River valley, contraction scour was considered to be minimal and, therefore, was ignored. Consequently, total scour was estimated by calculation of local scour only. Contraction scour also was not considered by the Washington State Department of Transportation (WSDOT) in the calculation of total scour for two bridges (Snake River and Central Ferry Highway bridges) on the lower Snake River inspected by WSDOT. Scour depths were estimated from channel bottom elevations shown on as-built drawings of the existing bridges. Because of the high reservoir pools and the controlled velocities resulting from the construction and operation of the dams, it is likely that the river has aggraded and accumulated sediment, resulting in higher stream bottom elevations than originally encountered at the bridge piers.

The methodology used in determining potential scour for all bridge structures was based on that contained in *Evaluating Scour at Bridges, Hydraulic Engineering Circular No. 18* (WSDOT, 1990). This methodology is used throughout the country when performing bridge scour evaluations.

E.3.2 River Flows Evaluated

Bridge scour studies performed throughout the United States have been largely based on 500-year flood flows. To be consistent with these state and Federal criteria, calculations of scour depths for this study are based on the 500-year flood event. The design flow information is summarized as follows:

Table E2. Flow Conditions For River Sections

River Section	500-yr Flow	100-yr Flow	Normal Low Flow
Snake River - above confluence with Clearwater River	8,350 m^3/s (295,000 cfs)	7,415 m^3/s (262,000 cfs)	820 m^3/s (29,000 cfs)
Snake River - below confluence with Clearwater River	10,190 m^3/s (360,000 cfs)	9,050 m^3/s (320,000 cfs)	820 m^3/s (29,000 cfs)
Clearwater River	1,840 m^3/s (65,000 cfs)	1,640 m^3/s (58,000 cfs)	820 m^3/s (29,000 cfs)

E.3.3 Results for Each Bridge

The study team identified various configurations of foundation modifications for the selected bridges within the project area. These are summarized below along with the results of the scour evaluation.

Joso River Railroad Bridge

The Joso River Railroad Bridge is located on the Snake River at river kilometer 94.1. The bridge is supported on multiple concrete piers founded on concrete footings that extend to bedrock. The potential scour was evaluated for a 500-year flood event flow of 10,190 m^3/s (360,000 cfs) with a corresponding water surface elevation of 152.5 meters (500.4 feet). Estimated scour depths were 8.2 meters (27 feet). Since the piers are founded on bedrock and, therefore, are assumed to be resistant to erosion, no additional bridge pier modifications would be required. Abutment protection on the south abutment would be required for the fluctuating water surface.

Lyons Ferry Highway Bridge

The Lyons Ferry Highway Bridge is located on the Snake River at river kilometer 95.3. The bridge is supported on multiple concrete piers founded on concrete footings that terminate on soil or bedrock. The potential scour for this bridge was evaluated for a 500-year flood event flow of 10,190 m^3/s (360,000 cfs) with a corresponding water surface elevation of 153.0 meters (502.1 feet). Estimated scour depths were 5.5 meters (18 feet). There are five piers outside the river flow path that, therefore, do not require treatment. Since the three existing piers are founded on bedrock and, therefore, are assumed to be resistant to erosion, no additional modifications would be required. The remaining piers (piers 4 and 8), as well as both abutments, would require protection.

Snake River Railroad Bridge

The Snake River Railroad Bridge is located on the Snake River at river kilometer 99.4. The bridge is supported on multiple concrete piers founded on concrete footings on bedrock. The potential scour was evaluated for a 500-year flood event flow of 10,190 m^3/s (360,000 cfs) with a corresponding water surface elevation of 156.6 meters (513.9 feet). Calculated scour depths were 8.0 meters (26.3 feet). Because all of the piers are founded on bedrock and, therefore, are assumed to be resistant to erosion, no additional modifications would be performed at this bridge location.

Central Ferry Highway Bridge

The Central Ferry Highway Bridge is located on the Snake River at river kilometer 134.1. The bridge is supported on multiple concrete piers founded on concrete footings and pile-supported concrete footings. The potential scour was evaluated for a 500-year flood event flow of 10,190 m^3/s (360,000 cfs) with a corresponding water surface elevation of 176.6 meters (579.5 feet). Calculated scour depths were 5.4 meters (18 feet) for the shallow piers (piers 2 and 7) and 6.4 meters for the larger, deeper piers (piers 3 through 6). This condition could undermine the foundations of the piers and, thus, would require modifications at each of the pier locations. See Figures E3 and E4 are pier modifications for Central Ferry Highway Bridge and typical for most other bridges. Abutment protection against erosion would also be needed.

Red Wolf Bridge

This bridge is located on the Snake River at river kilometer 221.1 and crosses the Snake River at the northwest part of Clarkston. Concrete piers founded on concrete footings support the bridge. Piers 3 and 4 have rock anchors in their foundations that extend to bedrock. The remaining piers (piers 2 and 5) are founded below the level of the existing streambed.

Scour calculations were performed for 500-year flood event flows of 10,190 m^3/s (360,000 cfs) corresponding to a water surface elevation of 221.6 meters (727 feet). With these criteria, the projected scour depth is 6.7 meters (22 feet). This condition could undermine the foundations for piers 2 and 5. To provide adequate protection, sheetpile isolation of piers 2 and 5 and riprap for abutment protection would be required.

Snake River Highway Bridge (Route 12)

The Snake River Highway Bridge is located on the Snake River just upstream from its confluence with the Clearwater River. The existing bridge is supported by multiple concrete piers founded on concrete footings that are either on bedrock or on piles driven into bedrock. Scour potential was calculated based on a 500-year flood event flow of 8,350 m^3/s (295,000 cfs) and a water surface elevation of 223 meters (733 feet). Based on recent soundings (WSDOT, 1990), it appears that aggradation of streambed materials has occurred in the vicinity of the bridge since original construction. For scour analysis purposes, the study team assumed that drawdown conditions would result in original streambed elevations. Therefore, potential scour was estimated to be 5.2 meters (17 feet) for the largest piers supporting the lift section of the bridge and about 2.7 meters to 3.0 meters (9 feet to 10 feet) for the remaining smaller piers. This condition could undermine the foundation for larger Pier 3, supported on piles, but not those of the smaller piers in the more shallow water. Modifications, including driving interlocking steel sheetpiles to below the depth of calculated scour, would be required for Pier 3, even though it was in place prior to reservoir impoundment. Riprap abutment protection would also be required.

Southway Highway Bridge

The Southway Highway bridge is located approximately 3.2 kilometers (2 miles) south of the confluence of the Snake and Clearwater rivers. The Southway bridge is supported by multiple concrete piers with the base of the concrete footings extending approximately 5.2 meters (17 feet) below the riverbed. These footings appear to extend to bedrock. Based on a 500-year flood event flow of 8,350 m^3/s (295,000 cfs) and a water surface elevation of 225 meters (740 feet), the potential scour depth is approximately 4 meters (13 feet). Since the bedrock is assumed to be resistant to erosion, the footings would not require additional modifications. Riprap abutment protection would be required.

Lewiston (Camas Prairie) Railroad Bridge

The Lewiston (Camas Prairie) Railroad Bridge is located on the Clearwater River in proximity to the confluence to the Snake River. The bridge is supported by multiple concrete piers with all except two of the piers founded on rock. Pier 3 is supported by a grouted concrete column surrounded by a steel sheetpile cofferdam extending to rock. Pier 4 is supported by piles extending through riverbed materials and founded on rock. Project drawings show the pilings ranging in length from about 6.1 meters to

7.6 meters (20 feet to 25 feet). Based on a 500-year flood event flow of 1,840 m^3/s (65,000 cfs) in the Clearwater River, the scour potential is calculated to be approximately 3.4 meters (11 feet). This would expose the pilings on the new Pier No. 4 and subject the pilings to potential lateral motion and failure. Therefore, modifications would be required to protect Pier No. 4 from scour erosion. No abutment protection would be required.

Clearwater Memorial Highway Bridge

The Clearwater Memorial Highway Bridge is located on the Clearwater River approximately 2.4 kilometers upstream from the confluence of the Snake and Clearwater rivers. The bridge is supported on multiple piers founded on footings. The potential scour was evaluated at a 500-year flood event flow of 1,840 m^3/s (65,000 cfs) and a water elevation of 223.5 meters (733 feet) based on Corps river profiles. Estimated potential scour depths were 2.75 meters (9 feet). This depth could undermine piers not founded on rock, even though this bridge was in place prior to reservoir impoundment. Therefore, pier modifications would be required on Piers 2 through 7. Piers 8, 9, and 10 are founded on rock and need no protection. The existing ground surface of Piers 1 and 11 is at or above the 500-year flood level and, therefore, do not require protection. No abutment protection is required.

Tributary Bridges

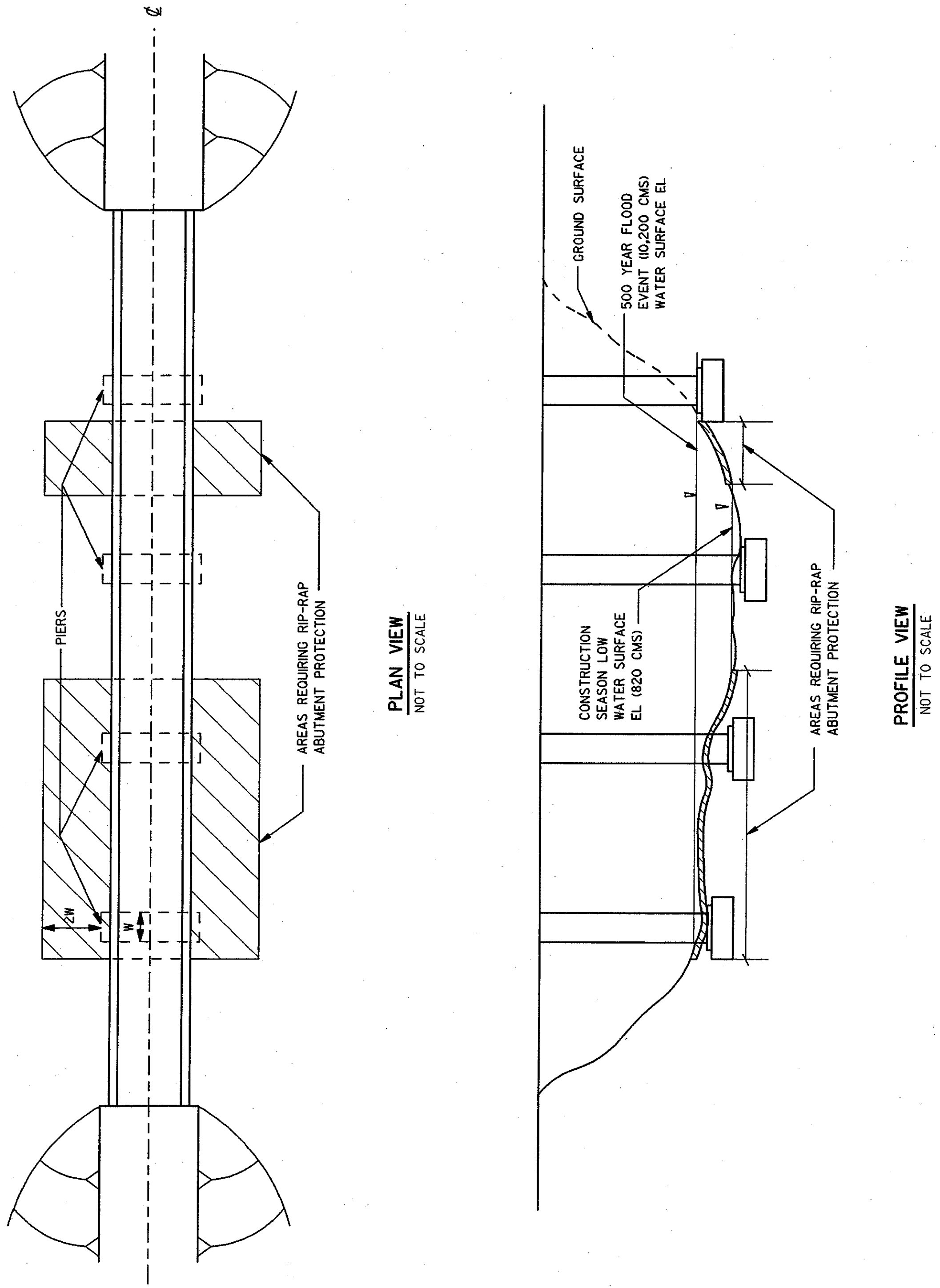
There are 15 bridges located across various tributaries draining into the Snake River on the Lower Monumental, Little Goose, and Lower Granite reservoirs. The bridge axes are generally oriented roughly parallel to the flow of the Snake River. Present inundation of the area by the reservoirs create a slack water condition that would be eliminated under drawdown to natural streambed elevations. The 500-year flood event at 10,190 m^3/s (360,000 cfs) has corresponding Snake River water surface elevations putting the bridge channel elevations higher than the 500-year flood event. Any potential scour to the bridge piers on tributaries to the lower Snake River reservoirs would originate from tributary flows, not from Snake River flows. In general, highway bridges are supported only at the abutments with no intermediate piers or piles, and abutments are heavily armored by riprap. Typically, one-to-three intermediate steel "H" piles, as well as the two end abutments support the railroad bridges.

Because stream flow data and elevations corresponding to the 500-year flood events on tributaries to the lower Snake River are not available, a typical riprap protection measure was established to represent the protection measure needed to safeguard the 15 tributary bridges. This typical treatment measure is shown in Figure E1. An average span bridge crossing of the 15 tributaries along the lower Snake River reservoirs was selected to represent the additional riprap needed to armor abutment and central piers from tributary flows.

E.4 Construction Scenario

The nature of the bridge pier and abutment modifications required to maintain the safe functioning and integrity of existing bridges on the lower Snake River reservoirs is such that each bridge could be considered a separate project and should be performed after drawdown of the reservoirs. Only two (Snake River Highway, Route 12; and Lewiston Railroad, Camas Prairie) of the eight bridges require a barge-supported pier protection installation. The other bridge modifications can all be performed from land-based construction access, assuming mid-December to mid-March time periods. The work could be combined in one contract, or separated into three (one for each reservoir).

For each bridge requiring modifications, a construction schedule was prepared based on a standardized list of construction activities. This base list includes all major functions necessary to complete the entire menu of construction work that was identified for all bridge work considered. Quantities for each site-specific bridge and its modification requirements were added to the schedule. Durations for completion of the construction activities were then calculated based on selected productivity rates and the number of construction crews to perform the work tasks. Construction durations range from 16 workdays for the Joso River Bridge modifications to 47 workdays for the Central Ferry Highway Bridge modifications, which include 22 workdays for driving steel sheetpiles. Annex W summarizes the activities and related timeframe required to implement design and construction of these bridge pier protection measures. The timeframe for this work spans a period of 2 or 3 years.



SHEET MAIN SCALE:

US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

BRIDGE ABUTMENT PROTECTION

Figure:
E1

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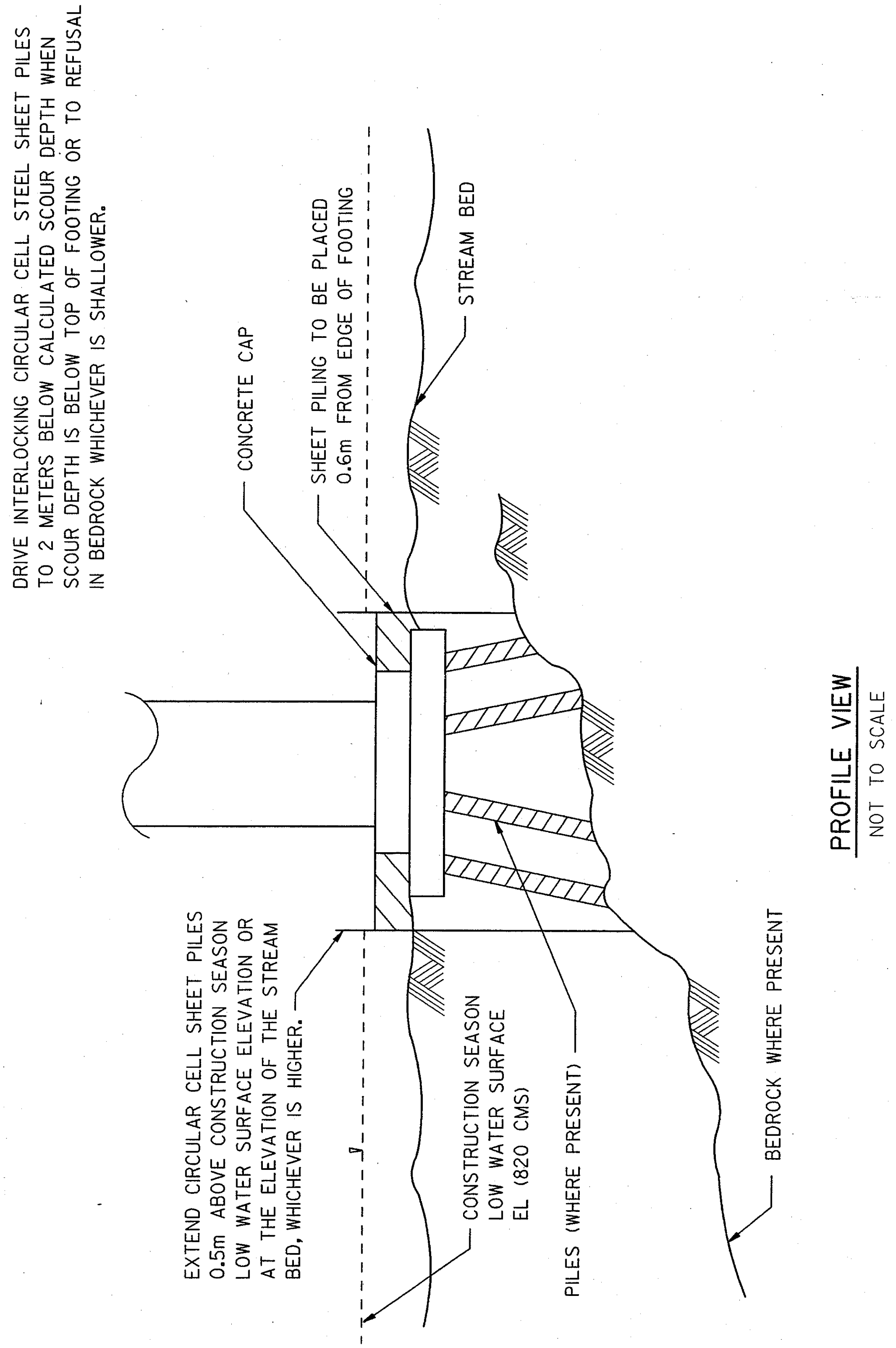

US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

BRIDGE PIER PROTECTION

Figure: E2

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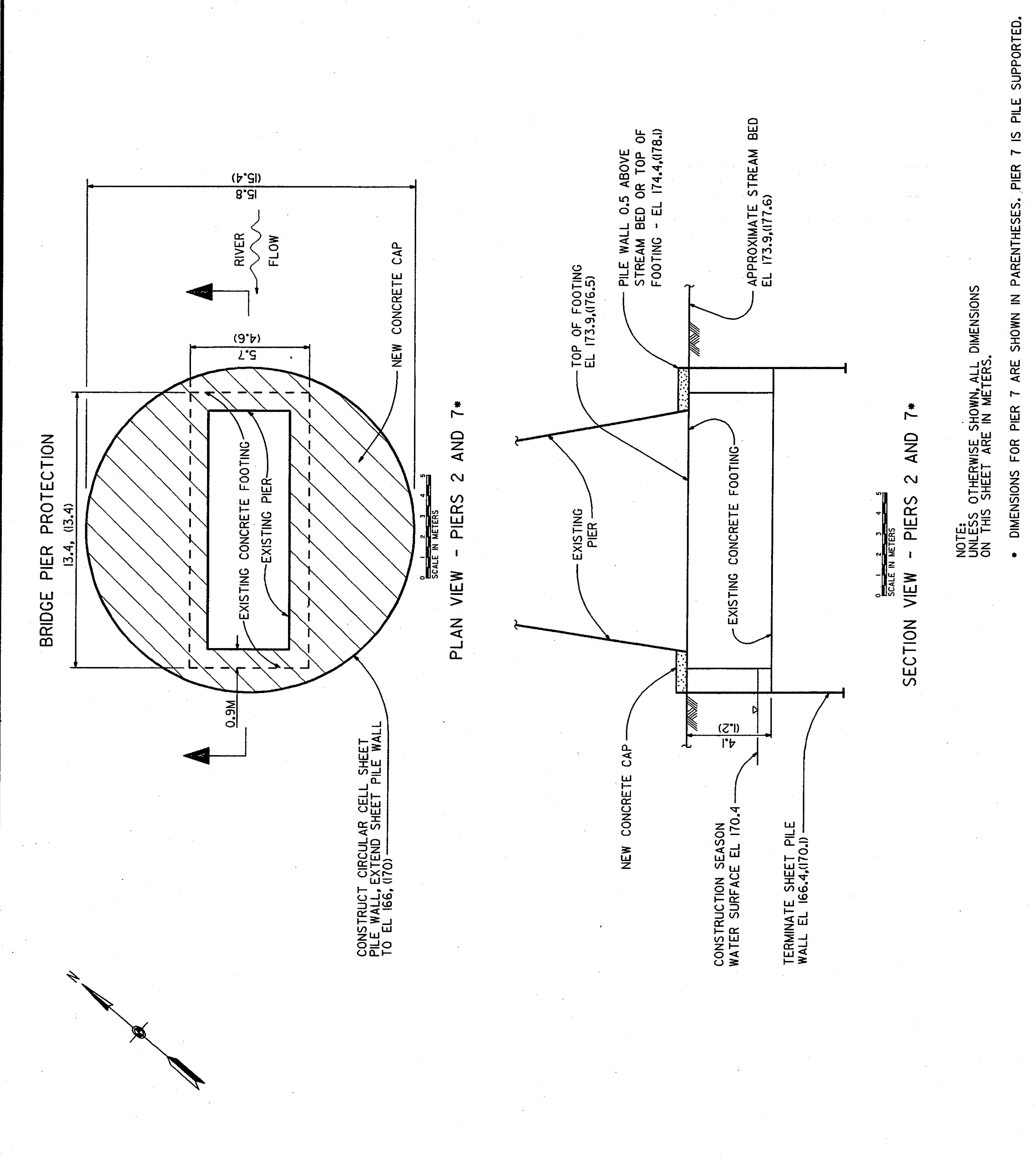
SHEET MAIN SCALE:



SHEET MAIN SCALE:

US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

CENTRAL FERRY HIGHWAY BRIDGE PIERS 2 AND 7
PLAN AND SECTION

Figure: E3

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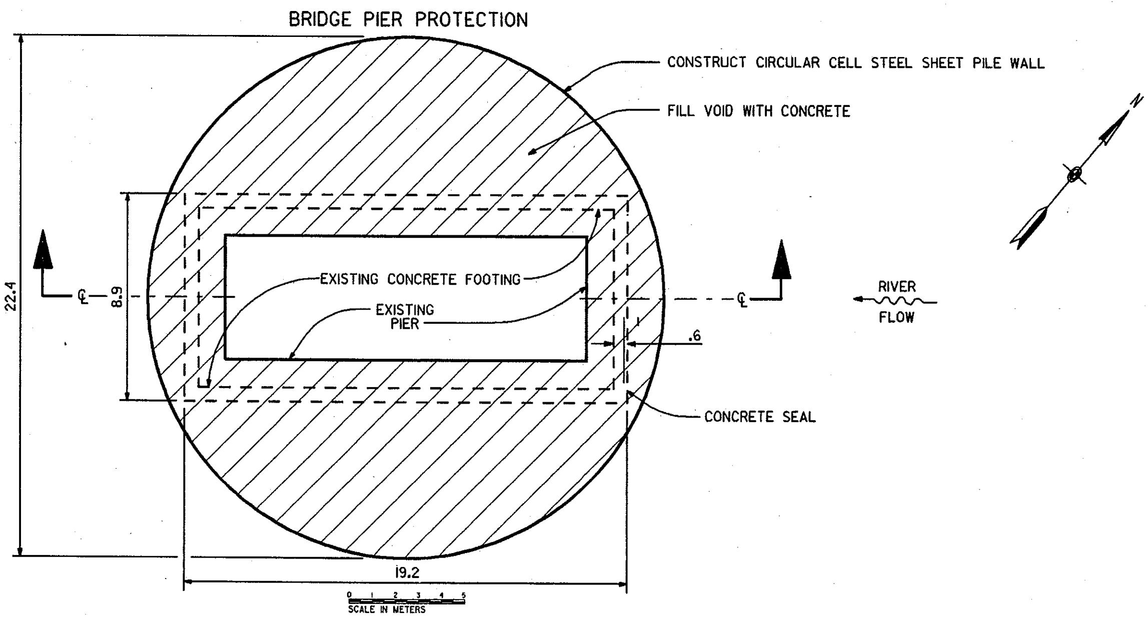
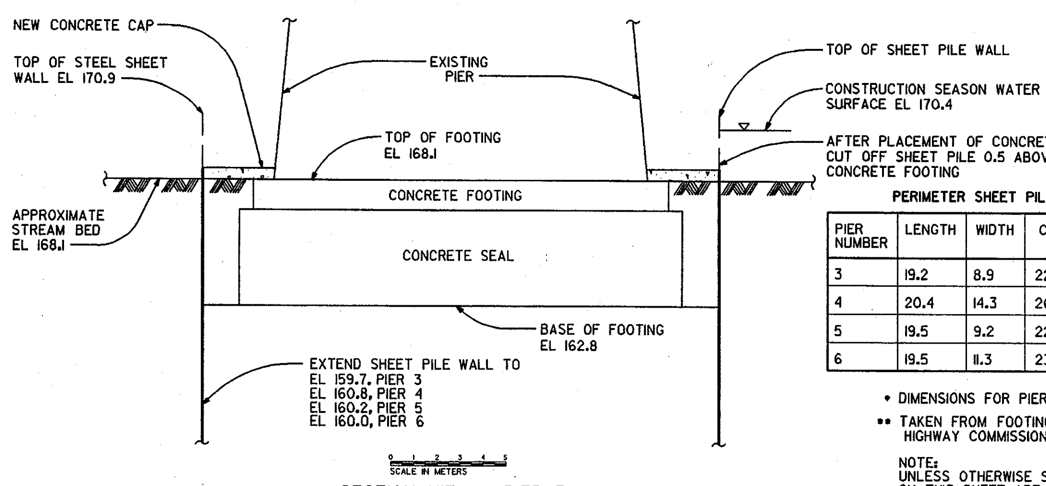
BRIDGE PIER PROTECTION



PLAN VIEW (PIER 3*)



SECTION VIEW - PIER 3*

PERIMETER SHEET PILE DIMENSIONS FOR CENTRAL FERRY HIGHWAY BRIDGE **

PIER NUMBER	LENGTH	WIDTH	CIRCULAR CELL DIAMETER	TOP OF FOOTING EL	TOP OF SHEET PILE WALL - EL
3	19.2	8.9	22.4	168.1	170.9
4	20.4	14.3	26.2	169.2	170.9
5	19.5	9.2	22.8	168.6	170.9
6	19.5	11.3	23.8	168.4	170.9

* DIMENSIONS FOR PIERS 4,5, AND 6 ARE SHOWN IN THE ACCOMPANYING TABLE.

** TAKEN FROM FOOTING LAYOUT DRAWING, SHEET 4 OF 34, WASHINGTON STATE HIGHWAY COMMISSION, OLYMPIA, WASHINGTON.

NOTE:
UNLESS OTHERWISE SHOWN, ALL DIMENSIONS ON THIS SHEET ARE IN METERS.

TASK2.TBL

SHEET MAIN SCALE:

US Army Corps of Engineers
Walla Walla District

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

CENTRAL FERRY HIGHWAY BRIDGE PIERS 3, 4, AND 5
PLAN AND SECTION

Figure: E4

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