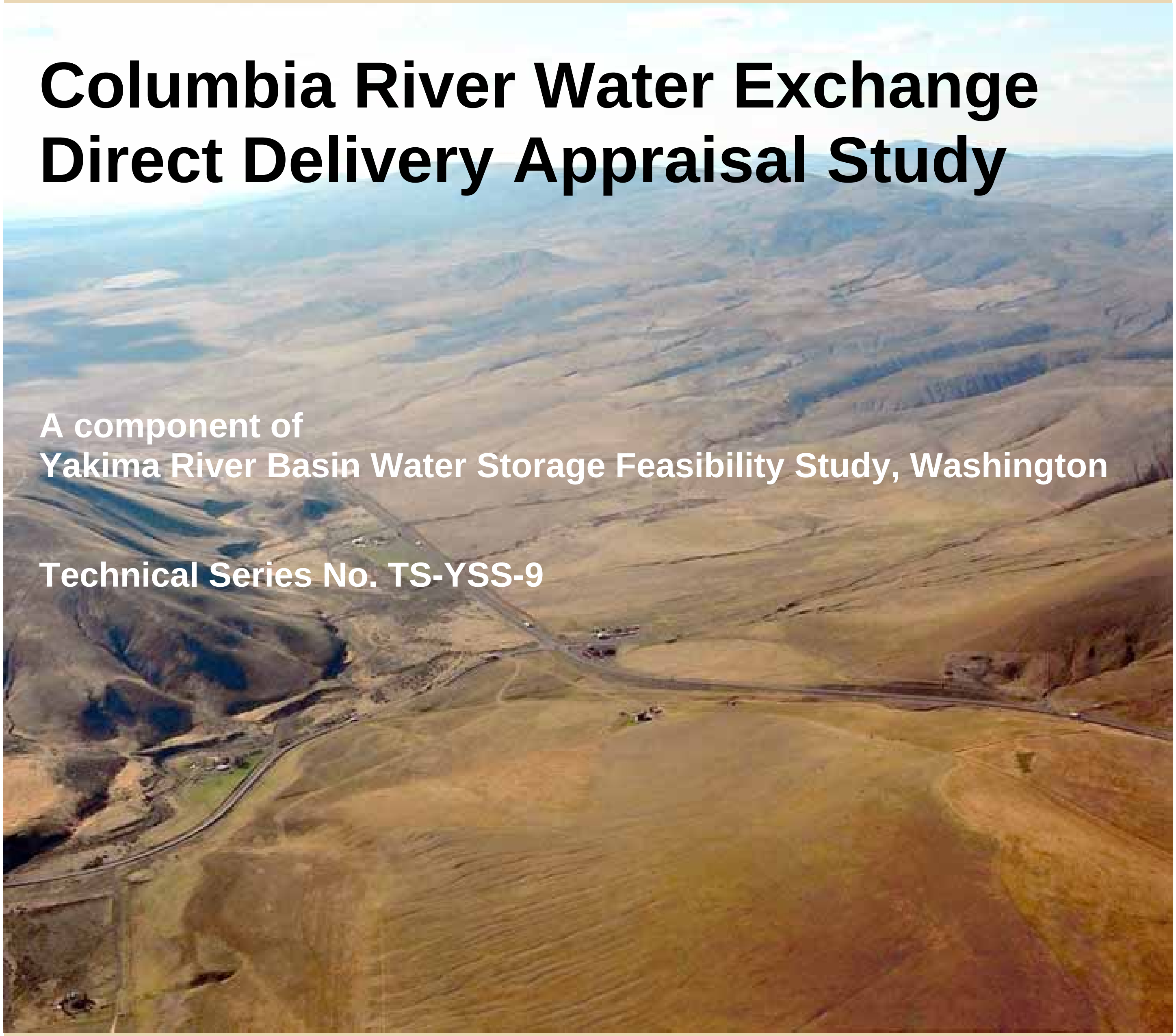
RECLAMATION

Managing Water in the West

Columbia River Water Exchange Direct Delivery Appraisal Study

A component of
Yakima River Basin Water Storage Feasibility Study, Washington

Technical Series No. TS-YSS-9



Black Rock Valley

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

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U.S. Department of the Interior

Mission Statement

The Mission of the U.S. Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.

Mission of the Bureau of Reclamation

The Mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Preface

Congress directed the Secretary of the Interior, acting through the Bureau of Reclamation (Reclamation), to conduct a feasibility study of options for additional water storage for the Yakima River basin. Section 214 of the Act of February 20, 2003, (Public Law 108-7) contains this authorization and includes the provision "… with emphasis on the feasibility of storage of Columbia River water in the potential Black Rock Reservoir and the benefit of additional storage to endangered and threatened fish, irrigated agriculture, and municipal water supply."

Reclamation, through its Upper Columbia Area Office in Yakima, Washington, initiated the *Yakima River Basin Water Storage Feasibility Study* (Storage Study) in May 2003. As guided by the authorization, the purpose of the Storage Study is to identify and examine the viability and acceptability of alternate projects by: (1) diversion of Columbia River water to the potential Black Rock reservoir for further water transfer to irrigation entities in the lower Yakima River basin as an exchange supply, thereby reducing irrigation demand on Yakima River water and improving Yakima Project stored water supplies, and (2) creation of additional storage within the Yakima River basin. In considering the benefits to be achieved, study objectives will be to modify Yakima Project flow management operations to more closely mimic the historic flow regime of a Yakima River system for fisheries, provide a more reliable supply for existing proratable water users, and provide additional supplies for future municipal demands.

State support for the Storage Study was provided in the 2003 Legislative session. The capital budget included a $4 million appropriation for the Department of Ecology (Ecology) with the provision the funds "… are provided solely for expenditure under a contract between the department of ecology and the United States bureau of reclamation for the development of plans, engineering, and financing reports and other preconstruction activities associated with the development of water storage projects in the Yakima river basin, consistent with the Yakima river basin water enhancement project, P.L. 103-434. The initial water storage feasibility study shall be for the Black Rock reservoir project." In accordance with this legislation, Reclamation published the *Appraisal Assessment of the Black Rock Alternative (Black Rock Appraisal Assessment)* in December 2004.

In addition, Reclamation released the *Yakima River Basin Storage Alternatives Appraisal Assessment* in May 2006. That Assessment analyzed three in-basin storage alternatives—Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline.

This *Columbia River Water Exchange Direct Delivery Appraisal Study* report addresses alternatives to deliver Columbia River water directly to irrigation districts or to new storage facilities for distribution on an as-needed basis. It was assumed that the water required for these alternatives would be available from the Columbia River. Water would be delivered directly only to those irrigation districts willing to exchange their Yakima diversions for Columbia River water. The water left in the Yakima basin would be used for fishery uses, to provide irrigation water during dry years and for future municipal water needs.

Further Consultations

The information available at this time is preliminary, has been developed only to an appraisal level of detail, and is therefore subject to change if these alternatives are investigated further in the course of the Yakima River Basin Storage Feasibility Study (Storage Study). Finally, economic, financial, environmental, cultural, and social evaluations of these alternatives have not yet been conducted.

If the Congress provides further funding for the Storage Study, all technically viable alternatives would be compared and an alternative(s) selected for further analyses in the feasibility phase. The selected alternative(s) would then be subject to detailed evaluation in the feasibility phase in terms of engineering, economic, and environmental considerations, and cultural and social acceptability. This feasibility phase would be the last phase of the Storage Study. Preparation of the Feasibility Report/Environmental Impact Statement would be a part of this final phase.

Columbia River Water Exchange
Direct Delivery Appraisal Study

Signature Sheet

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List of Abbreviations and Acronyms

af	Acre-feet
cfs	Flow rate in cubic feet per second
El.	Elevation
fps	Velocity in feet per second
ft	Foot or feet
ft^2	Area in square feet
ft^3	Volume in cubic feet
HGL	Hydraulic Grade Line
hp	Horsepower
H:V	Ratio of horizontal to vertical slope
ID	Inside diameter
kV	Kilovolt
lbs	Pounds
lf	Linear feet
MP	Mile post
NMFS	National Marine Fisheries Service of the National Oceanic and Atmospheric Administration
OD	Outside diameter
psi	Pressure in pounds per square inch
Q	Flow rate
rpm	Revolutions per minute
RTU	Remote terminal unit
SCADA	Supervisory Control and Data Acquisition
TSC	Technical Service Center
USGS	United States Geological Survey
WR^2	Pump Moment of Inertia
WS	Water surface
°	Degree
%	Percent

Related Reclamation Documents

- Preliminary Appraisal Assessment of Columbia River Water Availability for a Potential Black Rock Project, Technical Series No. TS-YSS-1, Prepared by Pacific Northwest Regional Office, 2004.

- Appraisal Assessment of the Black Rock Alternative Facilities and Field Cost Estimates, Technical Series No. TS-YSS-2, Prepared by Technical Service Center, 2004.

- Preliminary Assessment of Black Rock Delivery System for Roza, Terrace Heights, Selah-Moxee, and Union Gap Irrigation Districts, Technical Series No. TS-YSS-3, Prepared by Pacific Northwest Construction Office, 2004.

- Preliminary Assessment of Black Rock Delivery System for Sunnyside Division, Technical Series No. TS-YSS-4, Prepared by Pacific Northwest Region Office, 2004.

- Preliminary Assessment of Geology at Black Rock Damsite, Technical Series No. TS-YSS-5, Prepared by Pacific Northwest Region Office, 2004.

- Preliminary Assessment of Hydrogeology at Black Rock Damsite, Technical Series No. TS-YSS-6, Prepared by Pacific Northwest Region Office, 2004.

- Summary Report – Appraisal Assessment of Black Rock Project, Technical Series No. TS-YSS-7, Prepared by Pacific Northwest Region Office, 2004.

- Yakima river Basin Storage Alternatives Appraisal Assessment, Technical Series No. TS-YSS-8, Prepared by Pacific Northwest Region Office, 2006.

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Direct Delivery Appraisal Study

Technical Findings and Conclusions

The objective of the Columbia River Water Exchange Direct Delivery Appraisal Study is to determine facilities and costs to convey water from the Columbia River to the Yakima River Basin. The water may be delivered directly to irrigation districts or to new storage facilities for distribution on an as-needed basis. It was assumed that the water required for these alternatives would be available from the Columbia River. Water rights will be addressed by other analyses. Water would be delivered directly only to those irrigation districts willing to exchange their Yakima diversions for Columbia River water. The water left in the Yakima basin would be used for fishery uses, to provide irrigation water during dry years and for future municipal water needs. Currently these exchange participants include the Roza, Sunnyside, Union Gap, Selah-Moxee and Terrace Heights Irrigation Districts. Other districts may participate in the water exchange in the future. The alternatives in this report will be compared to other alternatives in the Yakima River Basin Water Storage Feasibility Study (Storage Study).

Three options were considered during this study.

<u>Option 1: Priest Rapids Dam to MP 22.6 of Roza Canal – Direct Long Tunnel</u>

The Priest Rapids Dam to MP 22.6 of Roza Canal – Direct Long Tunnel Option includes an intake with fish screens at Priest Rapids Reservoir, a 2,500 cfs pumping plant to lift the water to the Yakima Basin, a 20.5-mile tunnel to convey water from Priest Rapids Reservoir to an outlet facility at Roza Canal MP 22.6.

<u>Option 2: Priest Rapids Dam to MP 22.6 Roza Canal – Short Tunnel and Roza Connecting Canal</u>

The Priest Rapids Dam to MP 22.6 Roza Canal – Short Tunnel and Roza Connecting Canal Option uses the same intake and pumping plant as Option 1; however, instead of a 20.5-mile tunnel a shorter 6.5-mile tunnel is utilized. The tunnel outlet would be located in the Black Rock Valley, just east of the Yakima Firing Center Military Reservation boundary, about 600 feet higher in elevation than the Option 1 outlet. A 35-mile long connecting canal conveys water from the tunnel outlet to Roza Canal MP 22.6.

Option 3: Vantage to Kittitas Reclamation District (KRD) and Wymer Reservoir

The Vantage to Kittitas Reclamation District (KRD) and Wymer reservoir Option includes an intake with fish screens from Wanapum Reservoir, a 1,000 cfs pumping plant to lift the water to the Yakima Basin, a 14.5 mile long tunnel to an outlet facility located near Whipple Pumping Plant on KRD’s Upper Canal (Pump Ditch), enlargement of KRD’s Pump Ditch to accommodate the additional flow, and a 6.1 mile long tunnel to an outlet facility located at the proposed Wymer reservoir. The outlet facility at KRD’s Pump Ditch would bifurcate the 1,000 cfs flow to provide 500 cfs for irrigating lands within the District and 500 cfs to fill Wymer reservoir.

The following conclusions are based on the technical and cost analyses completed for this assessment study:

1. Construction of facilities to deliver Columbia River water to the Yakima Basin is technically viable; however, the timing of available Columbia River water in excess of current instream flow targets does not meet the timing of irrigation needs in the Yakima Basin. Implementation of any of these direct delivery options will require revisions to current instream flow targets and/or development of offstream storage facilities along the Columbia River.

2. The appraisal-level field cost estimate for providing 2,500 cfs of Columbia River water from Priest Rapids Reservoir to Roza Canal MP 22.6 via a direct, long tunnel (Option 1) is $1.05 billion.

3. The appraisal-level field cost estimate for providing 2,500 cfs of Columbia River water from Priest Rapids Reservoir to Roza Canal MP 22.6 via a short tunnel and connecting canal (Option 2) is $740 million.

4. The appraisal-level field cost estimate for providing 500 cfs of Columbia River water from Wanapum Reservoir to the Kittitas Reclamation District and 500 cfs to the proposed Wymer reservoir (Option 3) is $840 million.

The appraisal-level field cost estimates developed for this study are for the purpose of comparing the direct delivery options to each other and to the alternatives developed in the previous appraisal assessments. **The cost estimates in this report are not intended to be at the feasibility-level required to request project authorization for construction and construction appropriations by Congress.** All field costs are in **April 2004** price level dollars and include mobilization, unlisted items, and contingencies as explained below:

Please note that the Appraisal Assessment of the Black Rock Alternative Facilities and Field Cost Estimates Report, Technical Series No. TS-YSS-2 dated June 2004 [2], incorrectly noted that the appraisal level cost estimates were in June 2004 dollars. Although the estimates were dated June 2004, they represent April 2004 dollars (or April 2004 Price Level). This has no effect on the estimates themselves but is merely a clarification in case those estimates need to be indexed in the future.

Level of Study

This technical document provides the results of an appraisal-level engineering evaluation of options to deliver Columbia River water to the Yakima Basin without providing storage facilities. The purpose of this evaluation is to develop and screen options to be considered during future detailed feasibility investigations and to bring preliminary designs of Direct Delivery Options to the same level of detail as other identified alternatives in the Storage Study. The Appraisal Study's focus was to develop appraisal–level cost estimates using previously generated data from the Black Rock Appraisal Study.

This study is based on available design data from past work accomplished by Reclamation and is generally limited to the references listed at the end of this report. The amount of data collection is not considered to be at the level required for feasibility-level assessment of project features. Design data collected for future studies may increase future cost estimates significantly from the cost estimates presented in this report.

The appraisal-level field cost estimates developed for this Study are for the sole purpose of screening potential delivery options. **The cost estimates in this report are not intended to be at the feasibility-level required to request project authorization for construction and construction appropriations by Congress.**

Columbia River Water Exchange
Direct Delivery Appraisal Study

I. Introduction

Legislation authorizing the Yakima River Basin Water Storage Feasibility Study requests Reclamation to conduct a feasibility study of options for additional water storage in the Yakima River Basin, Washington, with emphasis on the feasibility of storing Columbia River water in the potential offstream Black Rock Reservoir. In 2004, Reclamation completed their appraisal assessment of likely configurations, sizes, and costs of Black Rock Project facilities needed to pump, store, and deliver water to willing exchange participants in the Yakima Basin [2]. In 2006, Reclamation prepared an appraisal assessment of three other alternatives, the Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline. The conclusions reached in these two appraisal assessments were that the Black Rock and Wymer alternatives would be included in the Plan Formulation Phase of the Storage Study. If additional alternatives are identified during Plan Formulation, they will be assessed at the same level and determinations will be made about their technical viability and whether they should be carried forward into the Feasibility Phase of the Storage Study.

This report documents an appraisal assessment of three Columbia River water delivery options that do not include offstream storage as a component. This Appraisal Study is identified as Objective 301.5.1.1/Task 2 of the Yakima River Basin Water Storage Options Feasibility Study, Plan of Study [1] and was requested to be performed by the Denver Technical Service Center (TSC) by the Upper Columbia Area Office (UCAO) of the Bureau of Reclamation's Pacific Northwest Region.

II. Basis of Designs

This study is based on data previously developed for the *Black Rock Appraisal Assessment* [2]. For convenience and to reduce study costs, use of similar sized intakes, pumps, motors, and other essential features were assumed for this study. Additional data to support alignments not considered during the earlier study were obtained from a site visit in February 2006 and from National Geographic topography software that utilizes USGS 7.5 minute maps with 20-foot contour intervals. Appraisal-level field cost estimates were prepared solely to distinguish between the options and to compare these alternatives to other alternatives in the Storage Study.

Water Supply and Needs

The availability of Columbia River water in excess of instream target flows for exchange with willing Yakima River Basin water users was investigated by Reclamation during their 2004 assessment of the Black Rock Storage features. The results of the water availability study are documented in the Preliminary Appraisal Assessment of Columbia River Water Availability for a Potential Black Rock Project Report [3]. The findings of the water availability study with specific impacts on this appraisal assessment of direct delivery options are listed below:

- Columbia River water appears to be available for exchange with willing Yakima River Basin water users contingent on obtaining State authorization in some form of water right approval.

- Instream flow targets at various points on the Columbia River downstream from Priest Rapids Dam limit diversions in every month except September and the October flow target is relatively low.

- Because of the timing of water availability in excess of instream flow targets and Columbia River water supply deficiencies in some dry years, direct delivery (without storage) during the irrigation season to the Roza and Sunnyside Irrigation Districts is not viable.

Based on these findings it is evident that the options developed for this study are not stand-alone options. Implementation of any of these options will require revisions to current instream flow targets and/or development of offstream storage facilities along the Columbia River.

III. Overview of Options

Three direct delivery options were developed for this study. Figure 1 shows the location and principal features of these options. Pertinent engineering characteristics are described below:

<u>Option 1: Priest Rapids Dam to MP 22.6 of Roza Canal – Direct Long Tunnel</u>

The Priest Rapids Dam to Mile Post (MP) 22.6 of Roza Canal – Direct Long Tunnel Option uses a 2,500 cubic feet per second (cfs) pumping plant near Priest Rapids Dam to convey water in the most direct route to the Roza Canal MP 22.6 via a 20.5-mile pressure tunnel. An outlet reservoir near the tunnel portal would be used to dissipate tunnel flow energy and control the releases to the canal system. This outlet reservoir would be located in the area slightly north and east of MP 22.6.

The discharge tunnel would be located under the Yakima Firing Center Military Reservation at depths between 300 to 1500 feet below ground. A surge shaft, similar to the shafts developed for the *Black Rock Appraisal Assessment*, would be used to control hydraulic transients. The shaft would be constructed along the Umtanum Ridge, where the elevation is about 2000 feet. Table 1 summarizes the major features associated with this option and Figure 2 shows their relative locations.

Option 2: Priest Rapids Dam to MP 22.6 Roza Canal – Short Tunnel and Roza Connecting Canal

The Priest Rapids Dam to MP 22.6 Roza Canal – Short Tunnel and Roza Connecting Canal Option uses the same intake and pumping plant as Option 1. However, in lieu of a 20.5-mile tunnel, a shorter 6.5-mile tunnel is utilized. The different tunnel length yields a different pumping head. The tunnel outlet would be located in the Black Rock Valley, just east of the Yakima Firing Center Military Reservation boundary, about 600 feet higher in elevation than the Option 1 outlet. A surge shaft, similar in location to Option 1, would also be used.

The two key distinctions between Options 1 and 2 are the tunnel lengths and static pumping head. The Option 1 tunnel conveys water to the Roza Canal at MP 22.6 and the Option 2 tunnel conveys water to the eastern end of the Black Rock Valley. A 35-mile-long concrete-lined canal then conveys the water to the Roza Canal at MP 22.6. This connecting canal must cross the summit between Black Rock and Moxee Valleys which is at about elevation 1803 feet. To provide sufficient elevation to cross the summit with the canal, the water surface elevation of the outlet reservoir located directly downstream from the Option 2 tunnel outlet portal is set at elevation 1850. Six check structures are used along the connecting canal to dissipate energy downstream of the summit. Table 2 summarizes the major features associated with this option. Figure 3 shows the shorter (6.5-mile) tunnel alignment used to deliver water to the tunnel outlet facility in the Black Rock Valley, and Figure 4 shows the connecting canal system alignment from this outlet facility to MP 22.6 of the Roza Canal.

Option 3: Vantage to Kittitas Reclamation District (KRD) and Wymer Reservoir

The Vantage to Kittitas Reclamation District (KRD) and Wymer reservoir Option includes an intake with fish screens from Wanapum Reservoir, a 1,000 cfs pumping plant to lift the water to the Yakima Basin, a 14.5-mile long tunnel to an outlet facility located near Whipple Pumping Plant on KRD's Upper Canal (Pump Ditch), enlargement of KRD's unlined Pump Ditch to accommodate the additional flow, and a 6.1-mile long tunnel to an outlet facility located at the proposed Wymer reservoir. The outlet facility at KRD's Pump Ditch would bifurcate the 1,000 cfs flow to provide 500 cfs for irrigating lands within the District and 500 cfs to fill Wymer reservoir. Table 3 summarizes the major features associated with this option. Figure 5 shows the proposed tunnel alignment from Wanapum Reservoir to KRD's Pump Ditch, and Figure 6 shows the enlarged Pump Ditch canal and proposed tunnel alignment to Wymer reservoir.

Table 1. Major Features of Option 1

Option 1: Priest Rapids Dam to MP 22.6 of Roza Canal – Direct Long Tunnel

Priest Rapids Intake and Fish Screen
- Intake on right side of Priest Rapids Reservoir
- Normal Reservoir Operating Water Surface, Range = El. 481.5 to 488.0

Priest Rapids Pumping Plant
- Nominal Design Flow Capacity = 2,500 cfs
- Five 500 cfs, two-stage spiral case pumps
- Total Design Head (TDH) = 857 ft, static lift = 788 ft
- Effective operational demand capacity = 2250 cfs (1)
- Operations based on tunnel outlet reservoir

Discharge Tunnel Conveyance System
- Tunnel internal diameter = 20 ft, velocity about 8 fps
- Surge shaft located about 5000 ft from pumping plant (similar to *Black Rock Appraisal Assessment*)
- Tunnel about 20.5 miles long under Yakima Firing Center
- Regulating reservoir outlet operating water surface about El. 1270

Tunnel Outlet Facility near Roza Canal MP 22.6
- Outlet reservoir located near MP 22.6 of Roza Canal, operating WS El. 1270
- Regulating Reservoir Storage: 665 af, approx 1900 ft square, 10 ft min deep
- Energy Dissipation Structure (Baffled Apron): Design Flow Capacity= 2,500 cfs
- Short canal from reservoir and baffled apron to connect with Roza Canal

(1) Effective flow is approximately 90 percent of the design flow. See Section VI.

Table 2. Major Features of Option 2

Option 2: Priest Rapids Dam to MP 22.6 Roza Canal – Short Tunnel and Roza Connecting Canal

Priest Rapids Intake and Fish Screen

- Intake on right side of Priest Rapids Reservoir
- Normal Reservoir Operating Water Surface, Range = El. 481.5 to 488.0

Priest Rapids Pumping Plant

- Nominal Design Flow Capacity = 2,500 cfs
- Five 500 cfs, two-stage spiral case pumps
- Total Design Head (TDH) = 1390 ft, static lift = 1368 ft
- Effective operational demand capacity = 2250 cfs
- Operations based on tunnel outlet reservoir

Discharge Tunnel Conveyance System

- Tunnel internal diameter = 20 ft, velocity about 8 fps, higher pressure than Option 1
- Surge shaft located about 5000 ft from pumping plant (similar to *Black Rock Appraisal Assessment*)
- Tunnel about 6.5 miles long along eastern edge of Yakima Firing Center

Tunnel Outlet Facility in Black Rock Valley and Roza Connecting Canal

- Outlet on North side of Black Rock Valley
- Reservoir outlet operating water surface about El. 1850
- Regulating Reservoir Storage: 665 af, approx 1900 ft square, 10 ft min deep
- Approximate 35 miles of canal for connecting with Roza Canal MP 22.6
- Concrete-lined canal with six check and baffled apron drops at intervals

Table 3. Major Features of Option 3

Option 3: Vantage to Kittitas Reclamation District (KRD) and Wymer Reservoir
Wanapum Intake and Fish Screen
• Intake on right side of Wanapum Reservoir (2 miles south of I-90)
• Normal Operating Water Surface Range= El. 560.0 to 571.5
Wanapum Pumping Plant
• Nominal Design Flow Capacity = 1,000 cfs
• Two 500 cfs, two-stage spiral case pumps
• Total Design Head (TDH) = 1669 ft, static lift = 1589 ft
• Effective operational demand capacity = 900 cfs
• Operations based on tunnel outlet reservoir
Discharge Tunnel Conveyance System
• Tunnel internal diameter = 13 ft, velocity about 8 fps
• Surge shaft located about 30,000 ft from pumping plant
• Tunnel about 14.5 miles long
• Outlet reservoir near existing Whipple Pumping Plant
• Outlet canal from reservoir to enlarged KRD Pump Ditch
Tunnel Outlet Facility and KRD Pump Ditch Enlargement
• Located near KRD Whipple PP outlet to Pump Ditch, operating WS El. 2150
• Regulating Reservoir Storage: 120 af, approx 800 ft square, 10 ft min deep
• Energy Dissipation Structure (Baffled Apron): Design Flow Capacity= 1000 cfs
• Reservoir flow split: 500 cfs to KRD system, 500 cfs to Wymer dam
• Enlarged Pump Ditch Canal to Wymer tunnel, Design Flow Capacity= 550 cfs
• Tunnel 6.1 miles to Wymer reservoir, Design Flow Capacity= 500 cfs
Wymer tunnel and Reservoir Outlet
• Reservoir min WS El. 1450, max WS El. 1730
• Energy Dissipation between canal and Wymer reservoir assumed unnecessary

The following sections describe the components of each option in detail.

IV. Columbia River Intakes

Priest Rapids Intake and Fish Screen – Options 1 and 2

The intake channel for the 2,500 cfs Option 1 and 2 pumping plants is modeled after the 3,500 cfs intake designed for the *Black Rock Appraisal Assessment* [2]. The intake is located approximately 3,600 feet upstream from Priest Rapids Dam on the right bank of Priest Rapids

Reservoir. Priest Rapids Dam is operated by the Grant County Public Utility District and has a maximum operating water surface elevation of 488.0 feet, and a minimum operating water surface elevation of 481.5 feet. The intake facilities were provided with sufficient freeboard to prevent overtopping from the maximum water surface with flood surcharge, elevation 491.5 feet.

The intake channel consists of two different cross-sections. The first section of the intake channel has three channel bays with vertical structural concrete walls. Two of the channel bays are sized for flows of 1,000 cfs each, and a third channel is sized for 500 cfs for a total of 2,500 cfs flow capacity. The channels were laid out with the top of concrete at elevation 495.50 feet and the invert elevation 468.00 feet. At minimum reservoir water surface elevation, the water depth in the channel is 13.5 feet. The widths of the two 1,000-cfs channels are 22 feet-6 inches, and the 500-cfs channel is 15 feet wide based on hydraulics through the fish screens. Three 54-inch-diameter-bypass pipes are located at the end of the fish screens to deliver screened fish to the river channel downstream from Priest Rapids Dam.

Trashracks with an automated rake and a conveyor system are provided to collect trash at the inlet. Three top-sealed radial gates are provided at the reservoir intake to isolate the channels for emergency or short-term maintenance of the fish screens and can also be used to regulate the downstream water surfaces. An access bridge deck is located over the inlet to allow access across the intake channel. Bulkheads and guides are required at locations upstream and downstream of the structural intake channels. Mobile cranes were assumed to be available for installation and removal of bulkheads.

The fish screens are designed to meet the National Marine Fisheries Service (NMFS) Northwest Region screen criteria for salmonid fry criteria which limits the approach velocity to 0.40 fps. The fish screens for the Priest Rapids Intake are vertical flat panels installed within metal guide/support structures. The screen panels were assumed to be stainless steel wedge wire panels bolted to steel backing panels or supports. The NMFS screen criteria states that the screen slot openings (narrowest dimension) shall not exceed 0.0689 inches (1.75 mm). Adjustable baffles are provided in guides directly downstream of the screens to provide for uniform flow distribution over the screen surface. The fish screens will be cleaned by horizontal brush-type fish screen cleaners. Since the screens are designed for the maximum flow at the minimum operating water depth, metal barrier panels are provided above the screens to extend above the maximum design operating water surface.

Downstream from the fish screens, the three structural channels open to a single channel having a trapezoidal cross-section with side slopes of 1.5:1 (H:V). The top of the channel is at elevation 500.0 feet. The channel would be lined with a 3.5 inch unreinforced concrete lining. The channel widens and transitions to the pumping plant. The width of the channel at the pumping plant face is approximately 212 feet.

Priest Rapids Pumping Plant and Switchyard – Options 1 and 2

The pumping plant for the 2,500 cfs Option 1 or 2 is modeled after the 3,500 cfs pumping plant designed for the Black Rock Storage study [2]. The location of the pumping plant and service yard was controlled by the intake channel location, fish bypass requirements, location and alignment of the tunnel portal to the discharge line, space requirements for the plant and switchyard, access into and around the plant, and access into the service bay. The service yard was set at elevation 507.5 feet for compatibility with the existing ground elevation and to reduce the visibility of the plant structure and switchyard from the Wanapum Indian Village. Access to the service yard would be via a new access road developed along the right side of the Columbia River from State Highway 24 (SH24) to the Intake facilities. The proposed road follows the alignment of the abandoned railroad tracks.

Pumping units with 500 cfs capacity were selected to permit direct modification of plant designs from the earlier study. The lift from Priest Rapids Reservoir to the Yakima basin is very high and the size of the units led to the use of spiral case pumps. Two-stage pumps were selected to reduce the pump submergence requirements and thus the depth of excavation for the pumping plant.

General Description

The pumping plant is a reinforced concrete structure approximately 358 feet long by 163 feet wide. The indoor-type structure will house five 500-cfs units. The rated head of the pumps for Option 1 is 860 feet, and the rated head for the pumps for Option 2 is 1,390 feet. The motors for Option 1 are 65,000 hp, and the motors for Option 2 are 110,000 hp. The pumping units require 62 feet of submergence below the minimum intake water surface elevation of 481.5 feet which set the centerline elevation for the lower stage of the pump impeller at elevation 419.5 feet. See Table 4 for unit data. Handling requirements for the rotor/shaft assembly controlled building and overhead crane elevations and the estimated weight of the rotor/shaft assembly (350,000 lbs) controlled the selection of one 200-ton overhead crane in the Unit Bays. In the service bay, a 100-ton overhead crane is provided. Space was provided in the plant for unit disassembly, auxiliary mechanical, and electrical equipment. Precast concrete double tees were selected for the roof structure based on span and anticipated availability. See Figures 7 through 11 for Option 1 and 2 pumping plant general arrangement details.

Table 4. Priest Rapids Pumping Plant Unit Data

Unit Data	500-cfs Unit
Type of Units:	Two-stage spiral case
Design Discharge:	500 cfs
Total Design Head: Option 1: Option 2:	857 feet 1,390 feet
Min. Impeller Submergence	62 feet
Max. Spiral Case Dimension	18.2 feet
Top of Suction Tube Invert	El. 468.0
Guard Valve:	60-inch spherical

The pumping plant switchyard will include transformers, circuit breakers, and disconnect switches. For this study, it was assumed that the switchyard could tap into the existing 230-kV transmission network at Priest Rapids Dam.

Pumping Plant - Operation

The pumping plant would be operated using Supervisory Control and Data Acquisition (SCADA) from the radial gate-controlled outlet reservoirs located at the downstream tunnel portals. A Remote Terminal Unit (RTU) will be installed at the tunnel outlet. The RTU will communicate with a master station at Priest Rapids Pumping Plant to allow the radial gates at the tunnel outlet to be operated remotely and provide remote indication of the reservoir depth. Electrical power to the gate hoists will provide the ability to regulate flow from the reservoirs. Backup engine generator combinations will provide the emergency power source.

Option 2 will require additional power, backup power, and SCADA for the check radial gates. SCADA monitoring would include water depths and gate positions. The signal will be transmitted to the pumping plant for remote operations of the gates. RTUs will be installed at the tunnel outlet and each of the six check structures. The RTUs will communicate with a master station at Priest Rapids Pumping Plant to allow the radial gates at the tunnel outlet and check structures to be operated remotely. It will also provide remote indication of the reservoir depth and canal depth at each check structure.

A 13.8-kV distribution line will be constructed along the tunnel route to provide power for the radial gates at the tunnel outlet and check structures. A 12-fiber optical ground wire will be installed on the distribution line to provide communication between the RTU and the pumping plant. It is assumed that 480-volt power for the loads will be by a step-down transformer on one of the distribution line poles. As this step-down transformer is an incremental cost, it is assumed to be covered by the unlisted line item of the cost estimates.

Wanapum Intake and Fish Screen – Option 3

The intake channel for the 1,000-cfs Option 3 pumping plant is also modeled after the 3,500-cfs intake designed for the Black Rock Storage study [2] however, due to its location relative to Wanapum Dam, an alternate fish bypass system is required. The intake is located approximately 3 miles upstream from Wanapum Dam on the right bank of Wanapum Reservoir (see Figure 13). Wanapum Dam is operated by the Grant County Public Utility District and has a maximum operating water surface elevation of 571.5 feet and a minimum operating water surface elevation of 560.0 feet. The intake facilities were provided with sufficient freeboard to prevent overtopping from the maximum water surface with flood surcharge, elevation 575.0 feet.

The intake channel consists of two different cross-sections. The first section of the intake channel has one bay with vertical structural concrete walls. The bay is sized for a flow of 1,000 cfs. The channel is laid out with the top of concrete at elevation 572.5 feet and the invert elevation at 546.5 feet. At minimum reservoir water surface elevation, the water depth in the channel is 13.5 feet. The width of the 1,000-cfs channel is 22 feet 6 inches.

Trashracks with an automated rake and a conveyor system are provided to collect trash at the inlet. One top-sealed radial gate is provided at the reservoir intake to isolate the channel for emergency or short-term maintenance of the fish screens and can also be used to regulate the downstream water surface. An access bridge deck is located over the inlet to allow access across the intake channel. Bulkheads and guides are required at locations upstream and downstream of the structural intake channel. Mobile cranes were assumed to be available for installation and removal of bulkheads.

The fish screens are designed to meet the NMFS, Northwest Region, screen criteria for salmonid fry which limits the approach velocity to 0.40 fps. The fish screens are vertical flat panels installed within metal guide/support structures. The screen panels were assumed to be stainless steel wedge wire panels bolted to steel backing panels or supports. Adjustable baffles are provided in guides directly downstream of the screens to provide for uniform flow distribution over the screen surface. The fish screens will be cleaned by horizontal brush-type fish screen cleaners. Since the screens are designed for the maximum flow at the minimum operating water depth, metal barrier panels are provided above the screens to extend above the maximum design operating water surface.

The Wanapum intake is located sufficiently upstream from Wanapum Dam to make a gravity bypass system similar to that designed for the Priest Rapids Intakes impractical. To deliver screened fish back to Wanapum Reservoir, two Wemco-type fish bypass pumps (one primary and one backup) with 100-cfs capacity each would be installed alongside the fish screening facility. Screened fish would be diverted to a pump bypass vault and lifted into a single 54-inch-diameter bypass pipe to deliver screened fish back to Wanapum Reservoir (see Figure 12). This type of pumped bypass facility is similar to the installation at the Red Bluff Diversion Dam in California.

Downstream from the fish screens, the structural channel opens to a single channel having a trapezoidal cross-section with side slopes of 1.5:1 (H:V). The top of the channel is at elevation 572.5 feet. The channel would be lined with a 3.5 inch unreinforced concrete lining. The channel then widens and transitions to the pumping plant. The width of the channel at the pumping plant face is approximately 73 feet 6 inches.

Wanapum Pumping Plant and Switchyard – Option 3

The 1,000-cfs Option 3 pumping plant is modeled after the 3,500-cfs pumping plant designed for the *Black Rock Appraisal Assessment* [2] using two 500-cfs pumping units. The location of the pumping plant was established taking into consideration existing topography, state property boundaries (Gingko State Park), reservoir bank geometry, and nearby rock outcroppings that would permit establishment of a tunnel portal on the west side of Huntzinger Road (see Figure 13). The service yard was set at elevation 586.0 feet for compatibility with the existing ground elevation and to ensure the yard does not become inundated during floods. Access to the service yard would be via a new 12-foot wide access road from Huntzinger Road.

Two pumping units with 500-cfs capacity were selected to utilize previously developed pump data and plant layouts; however, future studies should consider utilizing units that are smaller to improve flexibility of operations, reduce submergence requirements, and permit unit maintenance without sacrificing a large percentage of the plant capacity. The lift from Wanapum Reservoir to the Yakima Basin is very high which necessitated the use of two-stage spiral case pumps.

General Description

The pumping plant is a reinforced concrete structure approximately 223 feet long by 163 feet wide. The indoor type structure will house two 500-cfs units with 125,000-hp motors. The rated head of the pumps is 1,670 feet. The pumping units require 62 feet of submergence below the minimum intake water surface elevation of 560.0 feet which set the centerline elevation for the lower stage of the pump impeller at elevation 498.0 feet. See Table 5 for unit data. Handling requirements for the rotor/shaft assembly controlled building and overhead crane elevations and the estimated weight of the rotor/shaft assembly controlled the selection of a single 200-ton overhead crane to service both the Unit and Service Bays. Space was provided in the plant for unit disassembly, auxiliary mechanical, and electrical equipment. Precast concrete double tees were selected for the roof structure based on span and anticipated availability. See Figures 14 through 18 for pumping plant general arrangement details.

Table 5. Wanapum Pumping Plant Unit Data

Unit Data	500-cfs Unit
Type of Units:	Two-stage spiral case
Design Discharge:	500 cfs
Total Design Head: Option 3:	1,670 feet
Min. Impeller Submergence	62 feet
Max. Spiral Case Dimension	18.2 feet
Top of Suction Tube Invert	El. 542.0
Guard Valve:	60-inch spherical

The pumping plant switchyard will include transformers, circuit breakers, and disconnect switches. For this study, it was assumed that the switchyard could tap into the existing 230-kV transmission network at Wanapum Dam.

Pumping Plant - Operation

The pumping plant would be operated using SCADA from the radial gate-controlled outlet reservoirs located at the downstream tunnel portal. An RTU will be installed at the tunnel outlet that will communicate with a master station at Wanapum Pumping Plant. This will allow the radial gates at the tunnel outlet to be operated remotely and will provide remote indication of the reservoir depth. Electric power will be provided to the radial gate hoists for normal operation and backup engine generator combinations will be provided for emergency power.

A 13.8-kV distribution line will be constructed along the tunnel route to provide power for the radial gates at the tunnel outlet. A 12-fiber optical ground wire will be installed on the distribution line to provide communication between the RTU and the pumping plant. It is assumed that 480-volt power for the loads will be by a step-down transformer on one of the distribution line poles. As this step-down transformer is an incremental cost, it is assumed to be covered by the unlisted line item of the cost estimate.

V. Conveyance Systems

Columbia River to Yakima Basin Discharge Tunnels - Options 1, 2, & 3

The discharge tunnels for all three direct delivery options were sized for a velocity of about 8 fps which is slower than the 16 fps-velocity used to size the discharge tunnels in the *Black Rock Appraisal Assessment* [2]. In this study, the friction effects was substantially greater due to longer tunnel lengths and smaller diameters associated with smaller flows. If the higher velocity were used, the dynamic pumping friction headloss would be about 5 times greater. This would create difficulties keeping the pumps at an efficient operating head if only one pump were operating. Thus, to reduce the head impacts on sizing and cost estimating, lower velocities were selected.

Tunnel alignments for Options 1 and 2 encroach on the Yakima Firing Center Military Reservation; however, the Option 2 alignment is on the southeast edge of the Reservation. Except for the surge shafts that will daylight on Reservation property, the tunnels would be located at depths of 300 to 1,500 feet below ground. A surge shaft, similar to the shaft developed for the *Black Rock Appraisal Assessment*, would be used to control hydraulic transients. The shaft would be constructed along the Umtanum Ridge, where the ground surface elevation is about 2000 feet MSL. The finished tunnel and surge shaft for Option 1 are 20 feet and 18 feet in diameter, respectively, while the finished tunnel and surge shaft diameters for Option 2 are both 20 feet.

For Option 3, the finished tunnel diameter between Wanapum Reservoir and the Yakima Basin is 13 feet and the finished surge shaft diameter is 22 feet.

Steel lining was extended from the inlet portal of each tunnel option to the point in the tunnel alignment where the rock cover was equal to 0.4 times the operating head of the tunnel at that location.   Depending on the actual rock quality encountered along the alignment and considerations for leakage, a significantly longer length steel lining may be required for each tunnel. Increasing the size of the surge shafts to decrease transient pressures and hence decrease the thicknesses of the steel liners should be investigated in future studies.

The length of reinforced and un-reinforced lining was chosen to approximate the ratio of the length of a particular type of lining to the total tunnel length (after adjustment for steel lining lengths) previously used in the Black Rock Appraisal Assessment [2]. Similarly, the lengths used for the various types of support were selected to approximate the same ratio of length of a particular support type to total tunnel length used in the Black Rock Appraisal Assessment.

Roza Connecting Canal - Option 2

The proposed connecting canal between the tunnel outlet portal and MP 22.6 of the Roza Canal would be a concrete-lined channel with a bottom width of 20-feet and 1.5:1 (H:V) side slopes. The slope of the canal would be 0.00010 and the normal water depth would be about 14.1 feet. Design velocities were limited to about 4.5 fps maximum in the concrete lined canal. Please refer to Figure 4 for location and layout; hydraulic properties are shown on Figures 4 and 19. For estimating purposes it was assumed that the canal excavation would provide about an equal amount of material for use as compacted embankment and that the excavated materials are suitable for use as embankment.

Two canal sections were developed for estimating purposes and are shown on Figure 19. One section represents the condition where top of bedrock is about 8 feet deep, the other section represents the condition where the top of bedrock is greater than about 15 feet deep along the reach. Without knowledge of actual bedrock depths along the proposed alignment, it was assumed that 60 percent of the canal alignment would have bedrock at 8 feet below the surface and 40 percent of the alignment would have bedrock greater than 15 feet below the surface.

Two potential alignment options were evaluated in Moxee Valley. The first alignment would keep the canal following the elevation 1830 contour from Black Rock Valley and through the Moxee Valley. If no intervening energy drops were employed, the canal would be located about 600 feet above the Roza Canal at MP 22.6 (El. 1170.0). The second alignment would keep the canal following the elevation 1830 contour in the Black Rock Valley but once it crossed the summit between Black Rock and Moxee Valleys, a series of check and baffled apron drop structures would be constructed to lower the canal gradually to MP 22.6 of the Roza Canal. The advantage of using a series of checks with baffled apron drops is that the canal could be located closer to the valley floor where the chance of encountering bedrock along the alignment should be lower. Quantity estimates prepared for this study assumed this second alignment.

Check structures are needed to control flow and maintain the canal water depths at constant levels regardless of pumping plant flow changes. A typical recommendation is to place checks at about 2- to 3-foot drops in canal invert elevations. Based on a canal slope setting of 0.00010, this would place the checks at about 4- to 6-mile intervals. The checks would be combined with baffled apron drops. The ability to modulate flows for changing pumping plant operations is important to stay within typical canal drawdown restrictions. As an example, the normal depth in the designed canal section is 14.1 feet at 2,500 cfs flow. If one unit were to go off-line, the flow would be 2,000 cfs and the normal depth would drop to 12.65 feet. This is a change of 1.45 feet which exceeds typical concrete-lined canal drawdown restriction of 1.0 foot in 24 hours. Radial gates located at the check structures would be used to keep the canals at constant water levels and adjust the opening for changing downstream demands.

Six check and baffled apron drops were assumed for cost estimating. Each would have about a 100-foot drop. The first check should be close to the upper summit end of Moxee Valley. This would leave a reach between the Black Rock Valley tunnel outlet and the summit about 15 miles long. Typical check and baffled apron drops can be either in-line or left-offset drops. These variations are shown on Figure 19. Power and backup power to operate the radial gates is required. Trashracks were not included at the check structures.

Enlarged KRD Pump Ditch Canal and Siphon – Option 3

To convey water from the outlet facility at KRD's Pump Ditch to Wymer reservoir, about 6 miles of the Pump Ditch must be enlarged and a tunnel constructed under the Manastash Ridge. These additional canal and tunnel components are shown on Figure 6. The Wymer tunnel inlet portal is located on the north side of Manastash Ridge after crossing the KRD siphons.

Characteristic data for the potential enlarged KRD Pump Ditch are shown on Figure 20. Existing data indicates that the ditch is unlined earth and has a flow capacity of about 50 cfs. To accommodate the 500-cfs water conveyance to Wymer reservoir, enlargement of the ditch to a capacity of 550 cfs is required to handle both current and future flows. Two siphons must also be enlarged to 550-cfs capacity. Hydraulic data for the ditch and siphon enlargement are shown on Figure 20.

Figure 21 shows preliminary details for enlarging the KRD Pump Ditch Canal and the two siphons. Using the KRD Pump Ditch appears contingent on keeping the same water level elevations and slope. Differing cross-sections were evaluated and the table on Figure 20 shows some of the options considered. An important aspect is that the existing ditch has a small flow capacity and is unlined. As such, the ditch has a relatively steep slope. Velocity limitations required the enlarged canal to become wider rather than deeper.

Wymer Tunnel - Option 3

The proposed Wymer tunnel is estimated to be 34,000 feet long (see Figure 6). The inlet portal is at about elevation 2110 which coincides with the water surface elevation of the enlarged KRD canal downstream from the second siphon. The outlet portal is set at elevation 1430 which is below the minimum water surface of the proposed Wymer reservoir (see Figure 22).

The finished diameter of the circular shaped tunnel is 8.5 feet and the minimum bore diameter is 10.5 feet. The finished lining is assumed to be concrete. The estimated tunnel will be a gravity flow tunnel constructed on an hydraulically steep (about 2%) slope. Water from the supply canal is assumed to be clean and not transporting sediment. Therefore, erosion of the invert was assumed not to be a problem. Velocities in excess of 27 feet per second are possible—therefore, careful attention to the placement of the concrete lining will be required to avoid the potential for cavitation.

Hydraulic Transient Analyses

Transient hydraulic analyses were performed for all three options using Reclamation's Transient Analysis for Pipe Systems (TAPS). The critical case is a pumping plant loss of power when pumping at full design flow. These occurrences result in substantial transient pressure fluctuations. Surge shafts were the assumed devices for limiting the transients. Surge shaft locations were adjusted for the particular option analyzed based on the ground profile. Input parameters were based on using the 500 cfs pump and motor combinations similar to the *Black Rock Appraisal Assessment* [2]. Each option had the rated head and flow adjusted to the option characteristics and about 5% over-design was used for flow input. Pumping unit parameters were:

Speed	400 rpm
WR^2	5,000,000 per unit
Efficiency	0.85
Equal sized pumps, 2 stages	

Results for a loss of power case show typical positive and negative fluctuations above and below the steady state pumping hydraulic grade line in the surge shaft water levels. The most critical area is between the pumping plant and the surge shaft. Based on the transient results, the surge shaft diameters were varied until the water levels corresponded with the setting of the shaft at the available ground elevation for the particular distance from the pumping plant; then the tunnel downstream was checked to maintain the tunnel top below the minimum pressure water level. Figures 23, 24, and 25 portray the results of the transient analyses.

Power Generation

Power generating facilities were not considered for the options developed for this study. For Option 1, the excess energy available for generation is not considered sufficient to warrant the construction of a powerplant at the downstream tunnel portal. To increase this available energy, the pumping plants along the Columbia River would need to pump to a higher head which would increase the construction and operating costs of these plants. For Option 2, there may be some benefit to installing generating facilities in the Moxee Valley to take advantage of the 600 feet of excess head and to move the canal towards the floor of the valley. For Option 3, the excess energy available for generation between the Columbia River and Yakima Basin is not considered sufficient to warrant the construction of a powerplant at the downstream tunnel portal. However, power generation facilities could be considered at the downstream portal of the Wymer tunnel. Power generation could be considered in future studies.

VI. Outlet Facilities

Normal pumping plant operation for all options is assumed to be controlled by floats at regulating reservoirs located very near or over the tunnel outlet portals. Typical reservoir conceptual sketches are shown on Figure 26. All reservoirs were sized to provide emergency water in case the pumping plants were temporarily off line due to a power outage. If the pumping plants lose power, pumping operations would cease. Since most concrete-lined canals are typically limited to about 6 inches drawdown in 1 hour, or 12 inches in 24 hours, a backup water supply is furnished in the reservoirs. When power is lost, gates would be gradually opened to allow this water to be released for flow continuity.

According to information received from the PN Region [4], 80 percent of power outages in the study area lasted under 3 hours. For this study 4 hours of flow volume was used to size the regulating reservoirs. This stored volume must be fully above the normal depth in the canals. Radial gates were assumed to control the outlet flow and baffled apron drops were assumed for dissipating the energy between the reservoir water surface and the canal. Emergency generators are included to operate the hoists when power is lost. Water entering the reservoirs through the pumping plant and tunnel system is assumed free from trash accumulation and no trashracks were assumed needed before the radial gate outlet.

Analogous operating modes were studied at the Kennewick project [5] and are compared in Table 6, Operations Sizing Table. At Kennewick, the pumping plant nominal capacity was sized 10% greater than the demand capacity of 215 cfs. This allowed the outlet reservoir to refill and normal operations to resume about 15 hours after a pumping plant shutdown.

Table 6. Reservoir Operations Sizing Table

Criteria	Kennewick	Options 1 and 2	Option 3
Demand sizing	215 cfs	2250 cfs	900 cfs
Nominal – Pumping plant size	236 cfs	2500 cfs	1000 cfs
Oversize – with wear factors	248 cfs	See Black Rock Appraisal Assessment	See Black Rock Appraisal Assessment

Since this study is based on using the same 500-cfs pumps from the previous study, the effective "demand sizing" is assumed to be about 90% of the nominal capacity. This is the flow required to refill the outlet regulating reservoirs if the power were lost while still making canal deliveries. For example, during reservoir refilling, the plant would be pumping at full capacity (2,500 cfs) and the canal flow would be restricted to 2,250 cfs so that 250 cfs could be used to refill the reservoir from completely empty to full in about 40 hours.

Special note must be given to the operating band of the reservoirs. This band must be above the emergency reserve. The ON or OFF signals would be controlled by floats in a 6" level at the bottom or top of the band. The 1-foot neutral volume in the middle would have a capacity of about 0.5 hours between signals. This is a short time and may result in frequent starts for the large pump and motor combinations. Use of smaller pump-motor combinations should be considered in future studies. Alternatively, the reservoirs could be sized for a larger operating band volume than currently estimated by limiting motor starts to specified time intervals in the "neutral" zone. This would require the operating band depth to increase which would thereby increase the overall reservoir depth and accompanying dike heights.

The outlet regulating reservoirs in this study have been proposed as square dike areas. Other geometric configurations can be studied in the future. The square configurations were used solely to develop appraisal-level costs. A 500-foot short section of transition is assumed needed for Options 1 and 3. In Option 1, the ground is flat and the reservoir and tunnel portal may need to be located a short distance away. In Option 3, the reservoir outlet must operate in combination with a potential release for the KRD system.

The tunnel outlet regulating reservoirs would have side channel emergency spillways each side of the radial gate outlet structure. The purpose of these side channels is to allow flow to bypass the radial gates if the pumping plant did not stop upon an OFF signal from the reservoir floats. If the gates were regulating a low flow or if the gates were lowered to the closed position, the side channels would allow release of the full design pumping plant flow. The top crest elevation for the side channels would be at the maximum operating water level for the reservoir. Provisions for handling emergency spills beyond the spillway sections should be considered in future studies.

VII. Construction Considerations

Columbia River Intakes

Cofferdam: A cofferdam will be required in the reservoirs to permit construction of the intakes. Our estimates assumed a circular-type, cellular cofferdam would be constructed similar to the cofferdam sized for the *Black Rock Appraisal Assessment* [2]. A cellular cofferdam is a gravity retaining structure formed by a series of interconnected straight web steel sheet pile cells filled with free draining granular soil. The circular-type cofferdam consists of individual large diameter circles connected together by arcs of smaller diameter. The 380-foot-long cofferdam was assumed to be constructed with 32-foot-diameter cells that are 28 feet high.

Conveyance Systems

Tunnel Excavation: The use of Tunnel Boring Machines (TBMs) was assumed for construction of the tunnels. Basalt generally does not preclude this method of excavation and the design does not anticipate unusual bit (disk cutter) wear. Shorter tunnels with lengths less than 4,000 feet could be excavated by drill and blast methods. Intermediate length tunnels may be excavated by either method, depending on the particular contractor's resources. Most shaft excavation will probably be by full raise bore, raise bore and slash down, or raise bore and ream down excavation methods.

Tunnel Water Control: Water is always a major concern in tunneling; however, all of the potential tunnels are above the current water table so groundwater should not be a major problem. Surface waters coming from rains will eventually enter the tunnel. All tunnels can be excavated uphill, alleviating minor water problems. The initial tunnel support will depend on the intercepted geology, and may be interdependent with the final lining for a particular reach.

Outlet Facilities

Canal Bypass: The need for a temporary canal bypass at the Roza Canal MP 22.6 tie-in was assumed in the estimates for Options 1 and 2. Upstream and downstream earthen cofferdams with geomembrane linings would be constructed to connect the transition structures to the canals. Three 9-foot-diameter corrugated metal pipes between the cofferdams would permit canal operation during construction.

VIII. Field Cost Estimates

Field cost estimates were prepared for the major features identified for each option by comparing proposed layouts to quantities and costs developed for the *Black Rock Appraisal Assessment* [2]. Field cost estimates include construction contract costs and contingencies. Construction contract costs include itemized pay items and mobilization, plus an allowance for unlisted items. Field cost estimates do not include noncontract distributive-type costs (environmental studies, site investigations, design, construction management, etc.) and noncontract corollary-type costs. Field cost estimates do not include land acquisition, relocation, or right-of-way costs that may be required for construction of the project features. Operation, maintenance, and replacement costs are also not included in field cost estimates.

Field cost estimates were prepared using available design data from past work. The amount of data is not considered to be at the level required for feasibility-level assessment of project features. Design data collected for future studies can cause future cost estimates to significantly deviate from the cost estimates presented in this report. Quantities for major cost items are based on preliminary general designs and alignments and comparisons to the *Black Rock Appraisal Assessment*. With some adjustment to account for variation of quantities or new pay items, unit prices were taken from the *Black Rock Appraisal Assessment* [2] to develop field costs that could be compared directly to those developed in 2004.

The appraisal-level field cost estimates developed for this study are for the purpose of comparing the direct-delivery options to each other and to the alternatives developed in the previous appraisal assessments. **The cost estimates in this report are not intended to be at the feasibility-level required to request project authorization for construction and construction appropriations by Congress.** All field costs are in **April 2004** price level dollars and include mobilization, unlisted items, and contingencies as explained below:

- <u>Mobilization</u> **-** Mobilization costs include mobilizing contractor personnel and equipment to the project site during initial project start-up. The assumed 5 (+/-) percent of the subtotal cost used in the cost estimates contained in this report is based on past experience of similar projects. The mobilization line item is a rounded value per Reclamation rounding criteria which may cause the dollar value to deviate from the actual percentage shown.

- <u>Unlisted Items</u> **-** Unlisted items are a means to recognize the confidence level in the estimate and the level of detail and knowledge that was used to develop the estimated cost. This line item may be considered as a contingency for minor design changes and also as an allowance to cover minor pay items that have not been itemized, but will have some influence on the total cost. As per Reclamation Cost Estimating Handbook guidelines, the allowance for unlisted items in appraisal estimates should be at least 10 (+/-) percent of the listed items. Based on the level of detail provided for this study's cost estimates, the unlisted items line item was set at 12 (+/-) percent of the subtotal cost plus mobilization for all features. The unlisted items line item is a rounded value per Reclamation rounding criteria which may cause the dollar value to deviate from the actual percentage shown.

• <u>Contingencies</u> **-** Contingencies are considered funds to be used after construction starts and not for design changes during project planning. The purpose of contingencies is to identify funds to pay contractors for overruns on quantities, changed site conditions, change orders, etc. As per Reclamation Cost Estimating Handbook guidelines, appraisal-level estimates should have 25 (+/-) percent added for contingencies. Based on the current level of design data, geologic information, and general knowledge of the conditions at the various sites, the contingency line item was set at 25 (+/-) percent of the contract cost for all features. The contingency line item is a rounded value per Reclamation rounding criteria which may cause the dollar value to deviate from the actual percentage shown.

Table 7 is a summary table of the appraisal-level field cost estimates that were prepared for this study. Estimate worksheets showing a detailed breakdown of these field cost estimates are shown in Appendix A. For this study, cost estimates for features beyond delivery of Columbia River water to Roza Canal MP 22.6 (Options 1 and 2) were not identified. Similarly, cost estimates for delivery of water within the KRD irrigation district or beyond Wymer reservoir (Option 3) were not identified. For Options 1 and 2 that means modifications to the Roza canal to handle the higher flows are not included. For Option 3, no costs were developed for distribution of the 500 cfs water available for release directly to the KRD system.

Table 7. Summary of Appraisal-level Field Cost Estimates

Feature	Option 1 Priest Rapids to Roza Canal – Long Tunnel	Option 2 Priest Rapids to Roza Canal – Short Tunnel	Option 3 Vantage to KRD and Wymer
Columbia River Intake	$51,379,645	$51,379,645	$16,513,216
Pumping Plant	$130,189,404	$139,944,404	$70,996,732
Switchyard and Transmission Line	$6,010,000	$10,800,000	$5,130,000
Conveyance System – Columbia River to Yakima Basin	$528,383,280	$290,147,000	$417,639,630
Outlet Facility	$12,869,960	$12,661,390	$3,554,045
Conveyance System – KRD Pump Ditch to Wymer reservoir	$0	$0	$56,718,000
Mobilization	$36,000,000	$25,000,000	$29,000,000
Unlisted Items	$95,167,711	$60,067,561	$70,448,377
Contingencies	$190,000,000	$150,000,000	$170,000,000
Field Cost	**$1,050,000,000**	**$740,000,000**	**$840,000,000**

Please note that the Appraisal Assessment of the Black Rock Alternative Facilities and Field Cost Estimates Report, Technical Series No. TS-YSS-2 dated June 2004, incorrectly noted that the appraisal level cost estimates were in June 2004 dollars. Although the estimates were dated June 2004, they represent April 2004 dollars (or April 2004 Price Level). This has no effect on the estimates themselves but is merely a clarification in case those estimates need to be indexed in the future.

IX. Conclusions

Construction of facilities to deliver Columbia River water to the Yakima Basin is technically viable; however, the timing of available Columbia River water in excess of current instream flow targets does not meet the timing of irrigation needs in the Yakima Basin. Implementation of any of these direct delivery options will require revisions to current instream flow targets and/or development of offstream storage facilities along the Columbia River. The following conclusions are based on the cost analyses completed for this study:

1. The appraisal-level field cost estimate for providing 2,500 cfs of Columbia River water from Priest Rapids Reservoir to Roza Canal MP 22.6 via a direct, long tunnel (Option 1) is $1.05 billion.

2. The appraisal-level field cost estimate for providing 2,500 cfs of Columbia River water from Priest Rapids Reservoir to Roza Canal MP 22.6 via a short tunnel and connecting canal (Option 2) is $740 million.

3. The appraisal-level field cost estimate for providing 500 cfs of Columbia River water from Wanapum Reservoir to the Kittitas Reclamation District and 500 cfs to the proposed Wymer reservoir (Option 3) is $840 million.

X. Recommendations

Should the decision be made to carry any of these alternatives into the feasibility design stage, it is recommended that additional data be collected and the options refined for the collected data. Value Engineering methods of analysis should be applied to the identified concepts to identify needs, major cost components, and to reduce overall costs. Evaluation of the options should include operating costs as well as capital costs of construction.

Future Investigations and Studies

<u>All Options:</u>

1. Obtain topographic, bathymetric, and geologic data at major features and along water conveyance alignments.

2. Obtain data on annual water service, power costs, and project interest rate. Use data for present worth comparisons and add to construction costs for a total cost analysis.

3. Consider using smaller pump-motor combinations for better system operating flexibility.

4. Evaluate alignment right-of-way for potential land use and costs. Refine discharge outlet portal locations with the outlet regulating reservoir site.

5. Determine preferred pumping plant operating criteria and coordinate with water demands and available rights.

<u>Option 2:</u>

1. Perform bedrock depth investigations along proposed canal alignment. Canal should also be studied for check structure intervals.

2. Consider power generating facilities in the Moxee Valley to take advantage of excess head.

Option 3:

1. Investigate alternatives to the proposed Wymer tunnel to reduce costs. The first alternative would be a tunnel of similar size, constructed along the same gradient as the proposed tunnel but pressurized with a valve attached at its end to regulate flow. The second alternative should consider a shorter nonpressurized (free flow) tunnel. The conveyed water would be transported from the outlet portal of this tunnel via a canal to a rectangular chute to the reservoir.

2. Consider utilizing more smaller size units to improve flexibility of operations, reduce submergence requirements, and permit unit maintenance without sacrificing a large percentage of the plant capacity. Also consider relift plants in lieu of a single lift to reduce design head of pumping plants.

3. Consider constructing a completely new canal system from the discharge tunnel outlet reservoir to the Wymer tunnel inlet in lieu of enlarging the KRD Pump Ditch to reduce impacts to KRD operations during construction..

4. Evaluate alternatives that incorporate power generation at the Wymer tunnel outlet.

XI. References

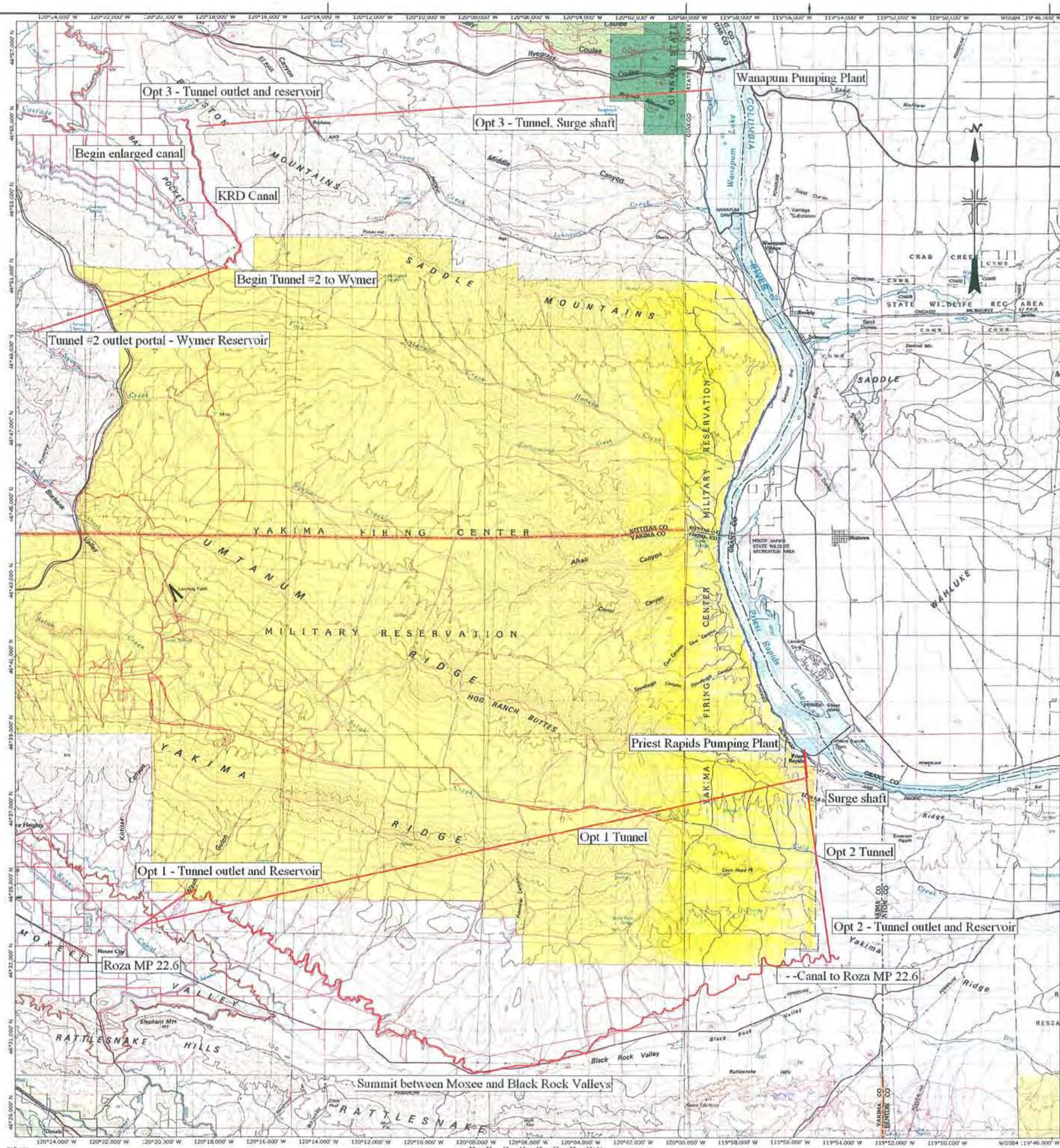
[1] Yakima River Basin Water Storage Options, Feasibility Study, Washington, Plan of Study, dated September 2003.

[2] Appraisal Assessment of the Black Rock Alternative Facilities and Field Cost Estimates, Technical Series No. TS-YSS-2, Prepared by Technical Service Center, 2004.

[3] Preliminary Appraisal Assessment of Columbia River Water Availability for a Potential Black Rock Project, Technical Series No. TS-YSS-1, Prepared by Pacific Northwest Regional Office, March 2004.

[4] E-mail from Wendy Christensen, Pacific Northwest Construction Office, dated March 7, 2006, Subject: Canal Drawdown.

[5] Kennewick Irrigation District and Columbia Irrigation District Pump Exchange Feasibility Study, Reservoir and Flow Control Structures” prepared by Bureau of Reclamation, Pacific Northwest Construction Office, Yakima, Washington and Regional Office, Boise, Idaho, dated October 12, 2004 (amended).



GENERAL THREE OPTIONS PLAN

OPTIONS TABLE

OPTION	DESCRIPTION	FLOW, cfs	REFERENCE FIGURES
1	Direct long tunnel to Roza	2500	2
2	Short tunnel and canal	2500	3 and 4
3	Vantage to KRD	1000	5, 6, and 7

PERTINENT SYSTEM CHARACTERISTICS FOR OPTIONS

COMPONENT OR DESCRIPTION	OPTION		
	1	2	3
Inlet reservoir water elevations	482 to 488	482 to 488	560 to 572
Tunnel outlet reservoir elevation	1270	1850	2150
Approx. static lift, feet	788	1368	1590
Tunnel Length (mi) and Diameter (ft)	20.0 m, 20'	6.5 m, 20'	15.0 m, 13'
Max Surge water surface elevation	1650	2095	2275
Min Surge water surface elevation	825	1585	1985
Surge shaft dia (ft) and bottom EL	18', 700'	20', 1450'	22', 1300'
Approx Surge shaft height (ft)	1200	750	1050
Max Surge WS elevation at PP	1735	2395	2975
Canal system use, L miles (m)	NA	35 m	6 m
Tunnel #2 to Wymer Reservoir, L and D	NA	NA	6.1 m, 8.5'
Wymer Reservoir elevations	NA	NA	1450 to 1730

NOTES

1. No alignments have been specifically assumed beyond the general areas shown. Available topographic data is based on National Geographic Topography software.

2. Geologic foundation data is unknown along proposed corridors. General assumptions for tunnels and shafts are based on the first study.

3. The three options shown here are for comparison with the first "Appraisal Assessment of the Black Rock Alternative Facilities and Field Cost Estimates" study dated December 2004.

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YAKIMA RIVER BASIN WATER STORAGE STUDY

COLUMBIA RIVER WATER EXCHANGE DIRECT DELIVERY APPRAISAL STUDY

OPTIONS VICINITY MAP

DESIGNED Jeff Boysinger

REVIEWED BY Jedd R. Calhoun, P.E.

Water Conveyance Group

CADD SYSTEM AutoCAD Rel. 16.0s | CADD FILENAME typ canal.DWG

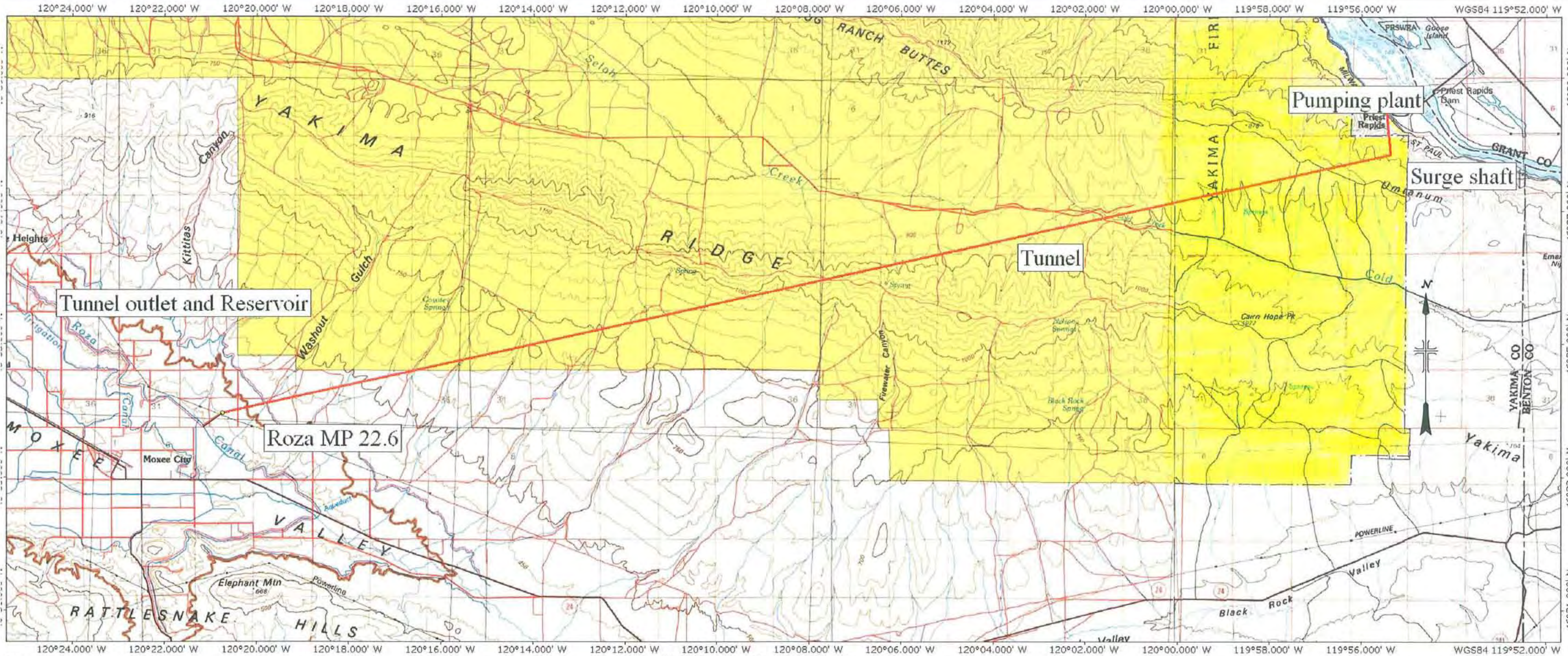
DENVER, COLORADO MAY 2006

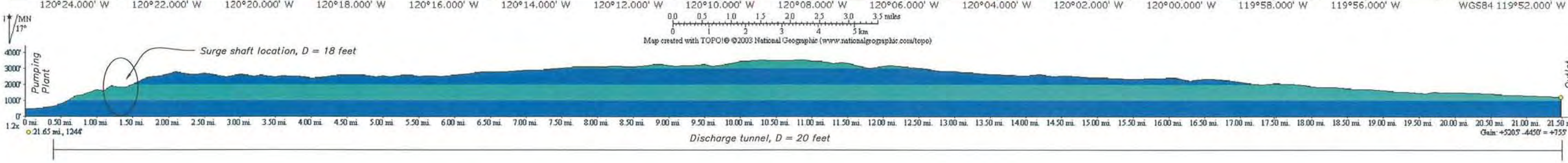
SHEET 1 OF 1

Figure 1

FILE PATH: H:\HOME\CIVIL ENG SHARE\PROJ\YAKIMA STORAGE STUDY\BRR ASSESSMENT STUDY\WATER CONVEYANCE\
PLOTTED BY:

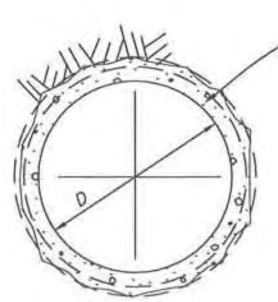
FIGURE 2





DIRECT TUNNEL TO ROZA CANAL PLAN

OPTION 1



TYPICAL DISCHARGE TUNNEL OR SURGE SHAFT

NOTES

1. See Figure 8 for a typical outlet regulating reservoir.

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YAKIMA RIVER BASIN WATER STORAGE STUDY

COLUMBIA RIVER WATER EXCHANGE
DIRECT DELIVERY APPRAISAL STUDY
PRIEST RAPIDS PP TO ROZA MP 22.6 – 2500 CFS
OPTION 1 – DIRECT TUNNEL TO ROZA

DESIGNED Jeff Baysinger
REVIEWED BY Todd R. Caldon, P.E.
Water Conveyance Group

CADD SYSTEM AutoCAD Rel. 16.0s
CADD FILENAME typ canal.DWG
DENVER, COLORADO MAY 2006 SHEET 1 OF 1
FIGURE 2

FILE PATH: H:\HOME\CIVILENG SHARE\PROJ\YAKIMA STORAGE STUDY\BRR ASSESSMENT STUDY\WATER CONVEYANCE\
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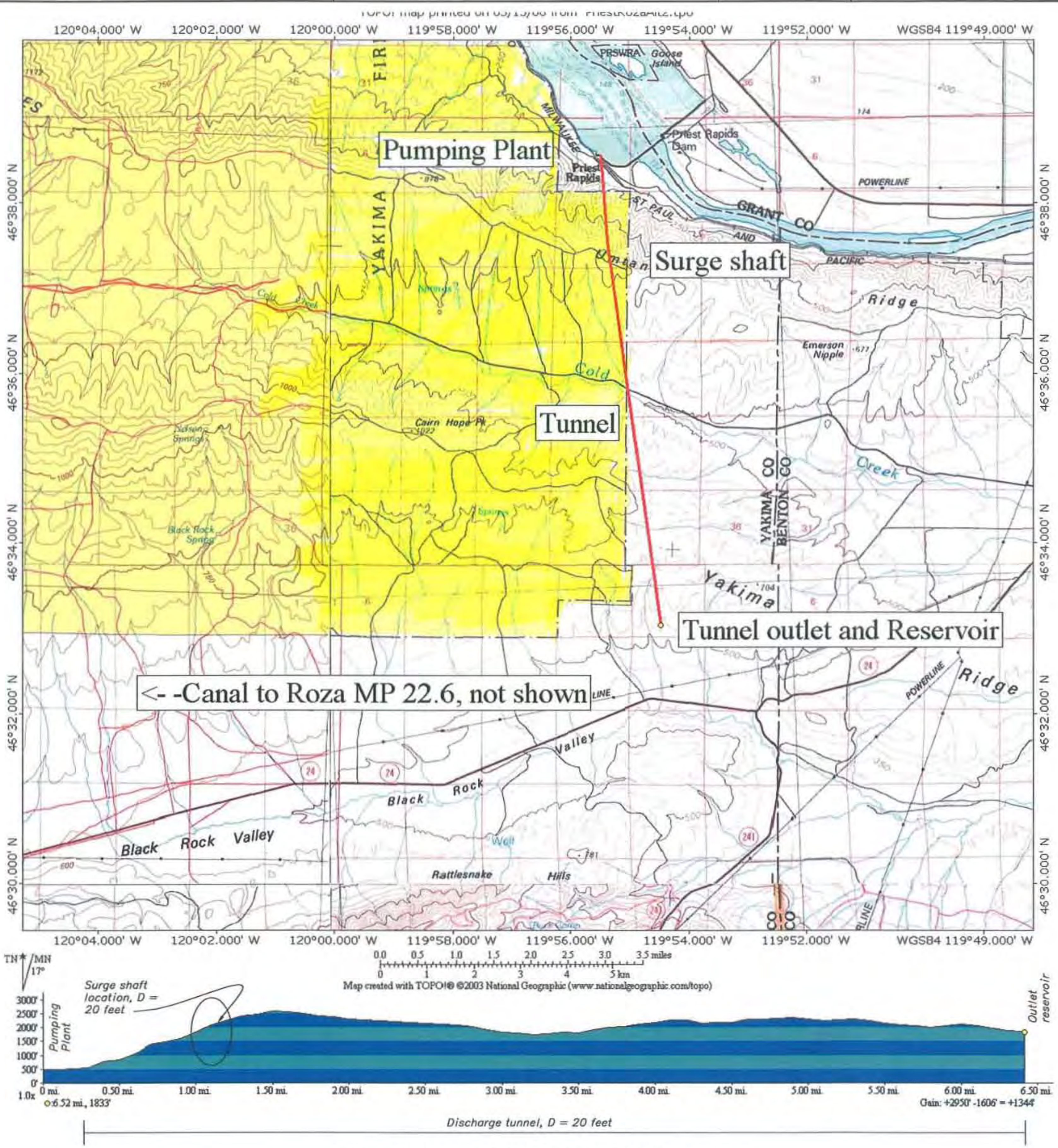
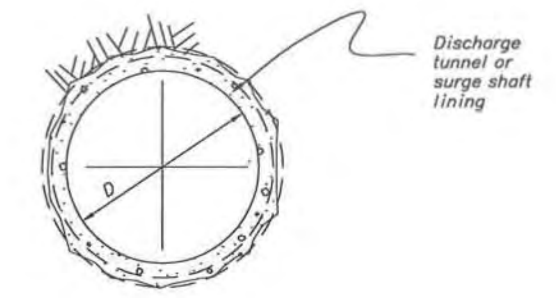


SHORT TUNNEL TO OUTLET RESERVOIR PLAN

OPTION 2



TYPICAL DISCHARGE TUNNEL OR SURGE SHAFT

NOTES

1. See Figure 8 for a typical outlet regulating reservoir.

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DIRECT DELIVERY APPRAISAL STUDY
PRIEST RAPIDS PP TO ROZA MP 22.6 – 2500 CFS
OPTION 2 – SHORT TUNNEL TO OUTLET

DESIGNED Jeff Boysinger
REVIEWED BY Todd R. Calhoun, P.E.
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Figure 3

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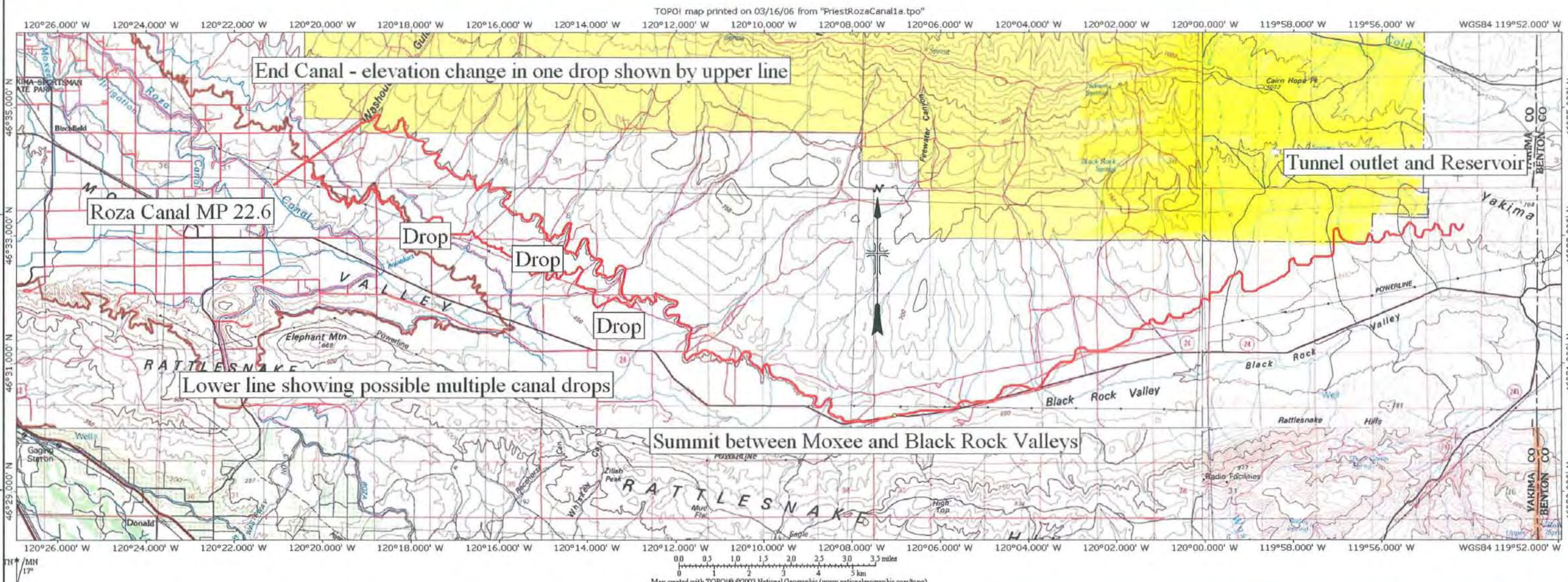

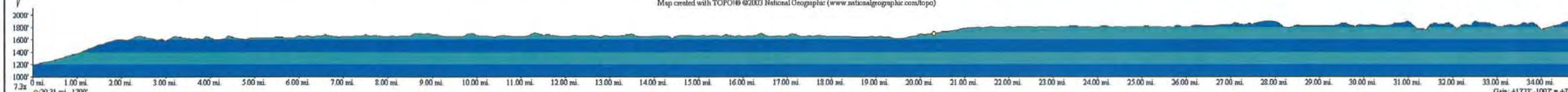

Canal drop

2500 cfs capacity canal

OPTION 2 – ROZA CONNECTING CANAL PLAN

PROFILE FOR CANAL ELEVATION CHANGE IN ONE DROP

PROPOSED CONCEPT CANAL HYDRAULIC PROPERTIES

Reach lining	Q	B	S	Side slopes	n	dn	A	V	R	Hl	Hb
Concrete	2500	20.0	0.00010	1.5:1	.014	14.1	579.6	4.31	8.19	16.5	18.5

NOTES

1. See Figure 9 for typical canal sections.

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COLUMBIA RIVER WATER EXCHANGE
DIRECT DELIVERY APPRAISAL STUDY
PRIEST RAPIDS PP TO ROZA MP 22.6 – 2500 CFS
OPTION 2 – ROZA CONNECTING CANAL

DESIGNED Jeff Baysinger

REVIEWED BY Todd R. Calhoun, P.E.
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SHEET 2 OF 2

Figure 4

FILE PATH: H:\HOME\CIVILENG SHARE\PROJ\YAKIMA STORAGE STUDY\BRR ASSESSMENT STUDY\WATER CONVEYANCE\
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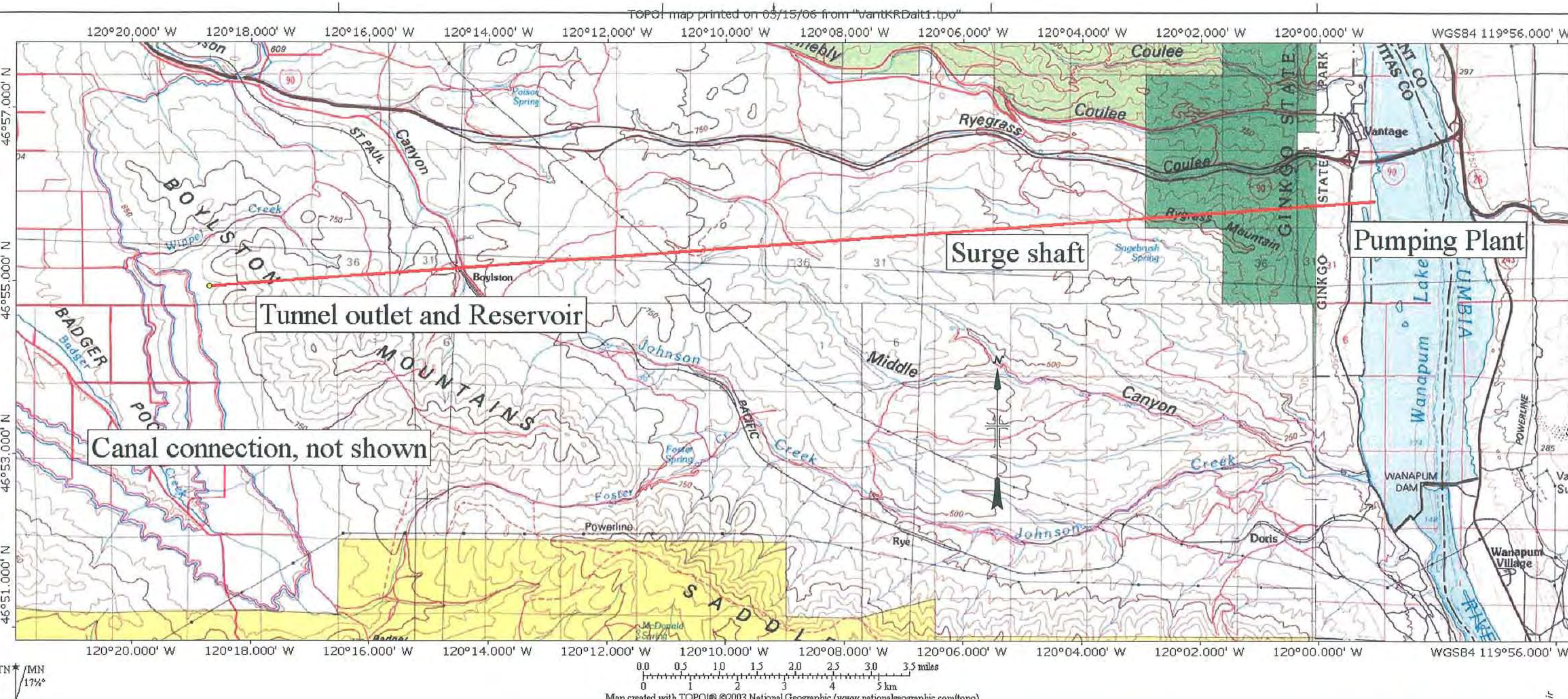

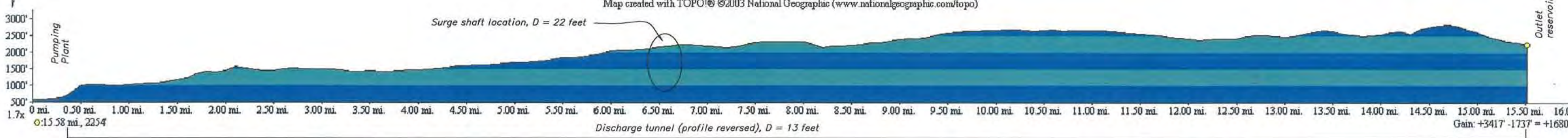

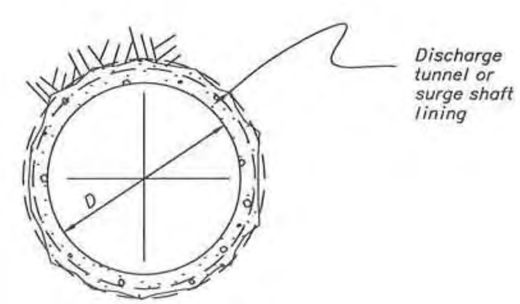

TYPICAL DISCHARGE TUNNEL OR SURGE SHAFT

PUMPING PLANT TUNNEL TO OUTLET RESERVOIR PLAN

VANTAGE TO KRD OPTION 3

NOTES

1. See sheet 2 of this set for the enlarged KRD canal and tunnel to Wymer Reservoir plan.

2. See Figure 8 for a typical outlet regulating reservoir.

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DIRECT DELIVERY APPRAISAL STUDY
WANAPUM PP TO KRD SYSTEM – 1000 CFS
OPTION 3 – TUNNEL TO KRD OUTLET

DESIGNED Jeff Baysinger
REVIEWED BY Vell R. Callum, P.E.
Water Conveyance Group

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CADD FILENAME typ canal.DWG
DENVER, COLORADO MAY 2006
SHEET 1 OF 3

Figure 5

FILE PATH: H:\HOME\CIVILENG SHARE\PROJ\YAKIMA STORAGE STUDY\BRR ASSESSMENT STUDY\WATER CONVEYANCE\
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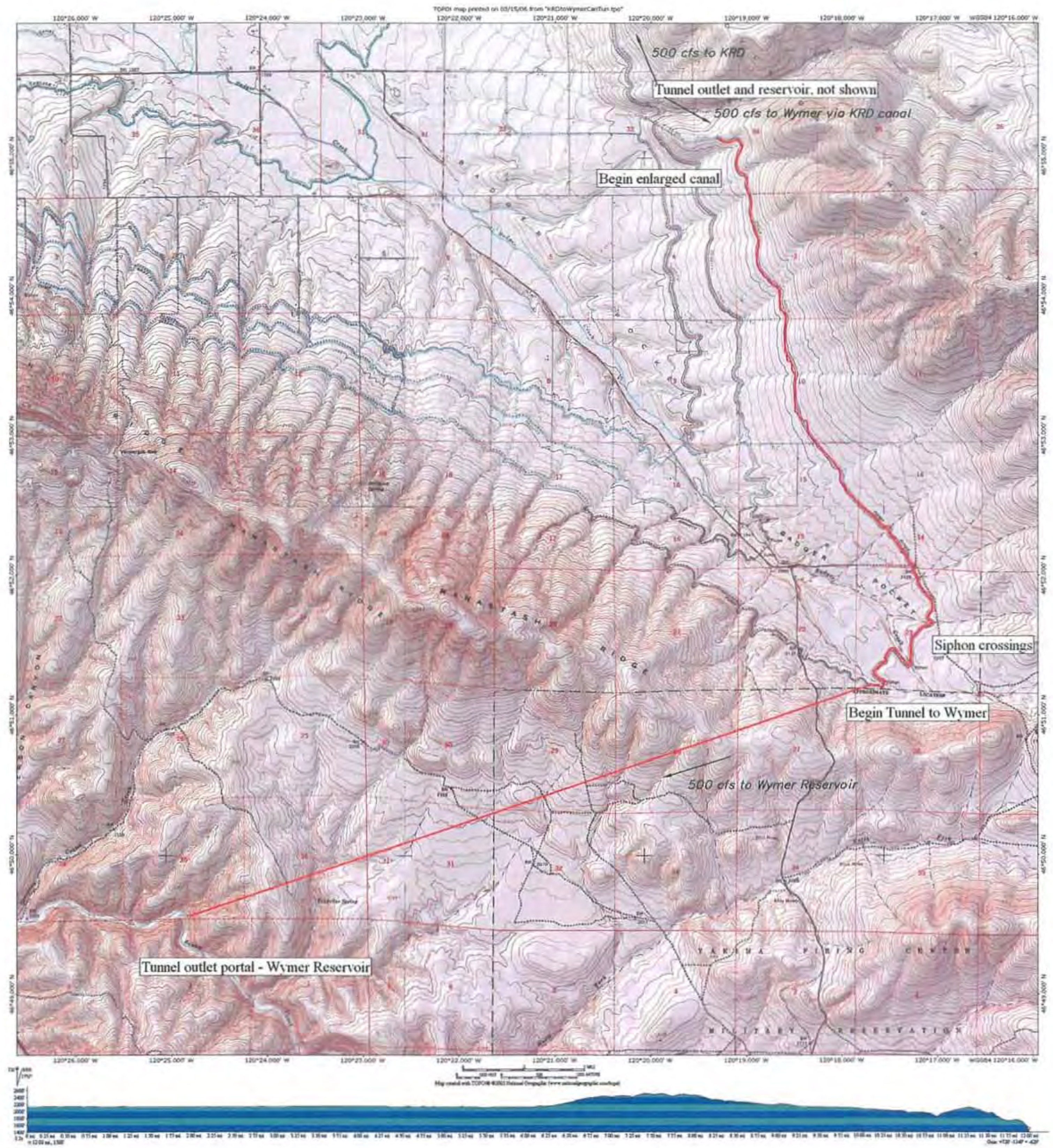

Canal enlarged from 50 to 550 cfs | 500 cfs Tunnel to Wymer Reservoir

500 CFS KRD CANAL USE TO WYMER RESERVOIR PLAN

ENLARGED CANAL AND TUNNEL OPTION

EXISTING KRD PUMP DITCH CANAL HYDRAULIC PROPERTIES

Sta to	Sta	Reach lining	Q	B	S	Side slopes	n	dn	A	V	R	HI	Hb
36	164	Unlined	50.5	7.0	0.00070	1.5:1	.025	2.32	24.31	2.06	1.58	NA	3.7
164	295	Unlined	43.5	6.0	0.00070	1.5:1	.025	2.3	21.73	2.00	1.52	NA	3.7
295	490	Unlined	39.9	6.0	0.00070	1.5:1	.025	2.2	20.43	1.95	1.47	NA	3.7

NOTES

1. See Figure 7 for enlargement options for KRD Pump Ditch Canal.

2. See Figure 10 for a typical Wymer Tunnel section.

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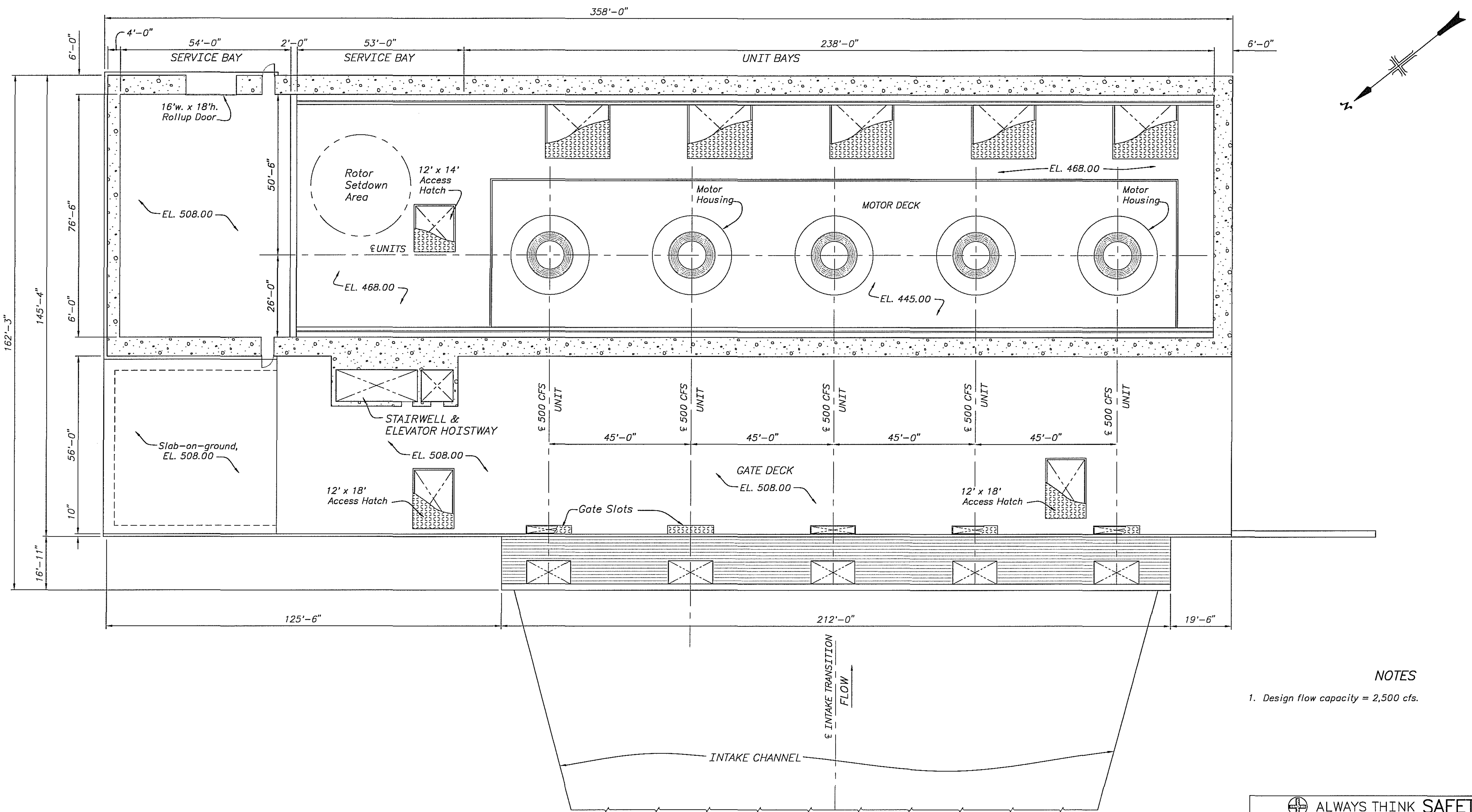
COLUMBIA RIVER WATER EXCHANGE
DIRECT DELIVERY APPRAISAL STUDY
WANAPUM PP TO KRD SYSTEM – 1000 CFS
OPTION 3 – CANAL AND WYMER TUNNEL PLAN

DESIGNED Jeff Baysinger
REVIEWED BY Todd R. Calhoun P.E.
Water Conveyance Group

CADD SYSTEM AutoCAD Rel. 16.0s | CADD FILENAME typ canal.DWG
DENVER, COLORADO MAY 2006 SHEET 2 OF 3

Figure 6

FILE PATH: H:\HOME\CIVILENG SHARE\PROJ\YAKIMA STORAGE STUDY\BRR ASSESSMENT STUDY\WATER CONVEYANCE\
PLOTTED BY:



PLAN – EL. 508.00, EL. 468.00 & El. 445.00 – SERVICE BAY, GATE DECK & MOTOR DECK

16 0 16 32
SCALE OF FEET

NOTES

1. Design flow capacity = 2,500 cfs.

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PRIEST RAPIDS PUMPING PLANT – OPTIONS 1 AND 2

PLAN – EL. 508.00, EL. 468.00 & EL. 445.00

DESIGNED BY B. D. VANOTTERLOO
REVIEWED BY R. W. LAFOND, P.E.
STRUCTURAL AND ARCHITECTURAL GROUP

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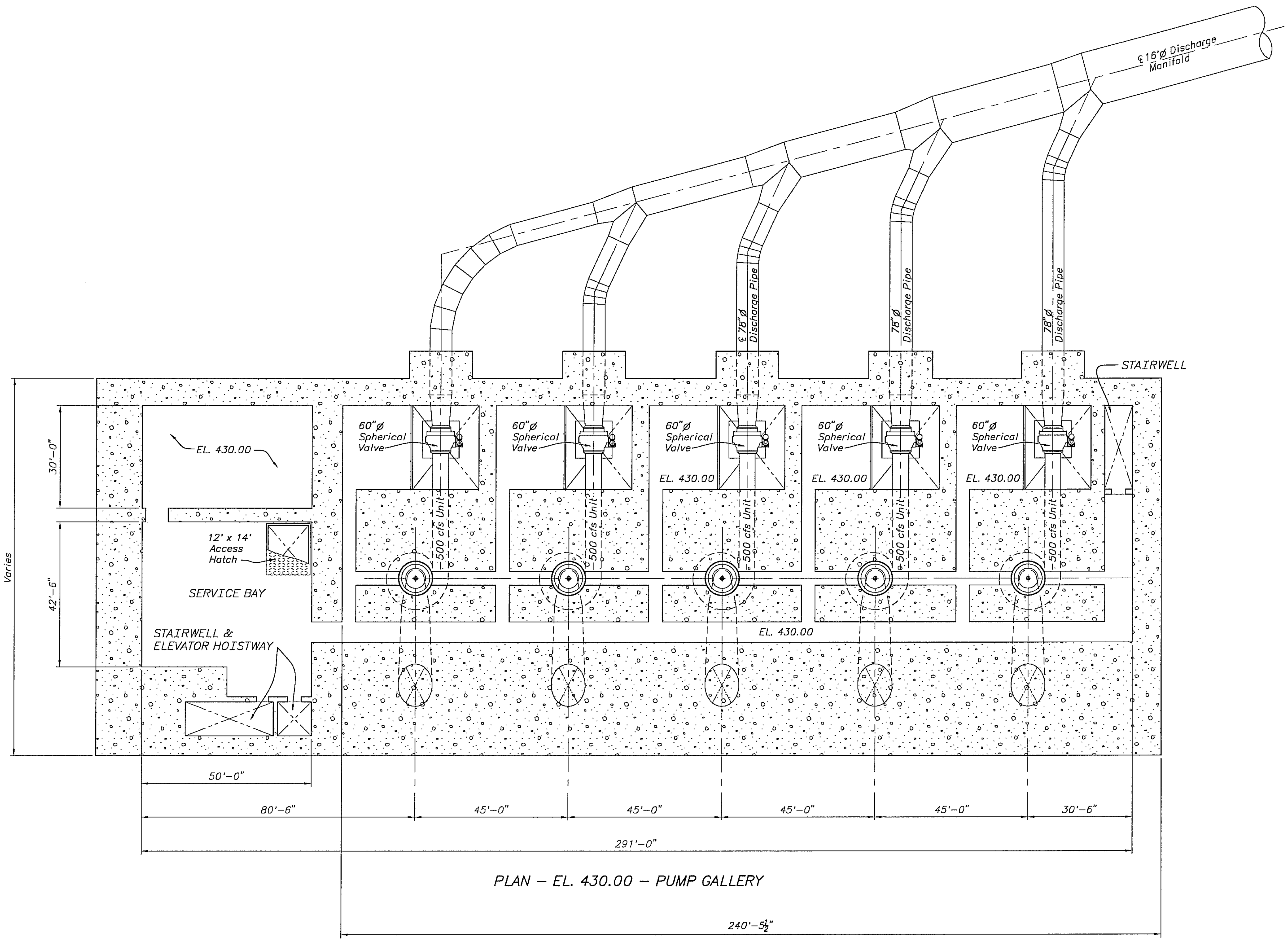
Figure 7



PLAN – EL. 430.00 – PUMP GALLERY

16 0 16 32
SCALE OF FEET

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PRIEST RAPIDS PUMPING PLANT – OPTIONS 1 AND 2

PLAN – EL. 430.00 – PUMP GALLERY

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Figure 8

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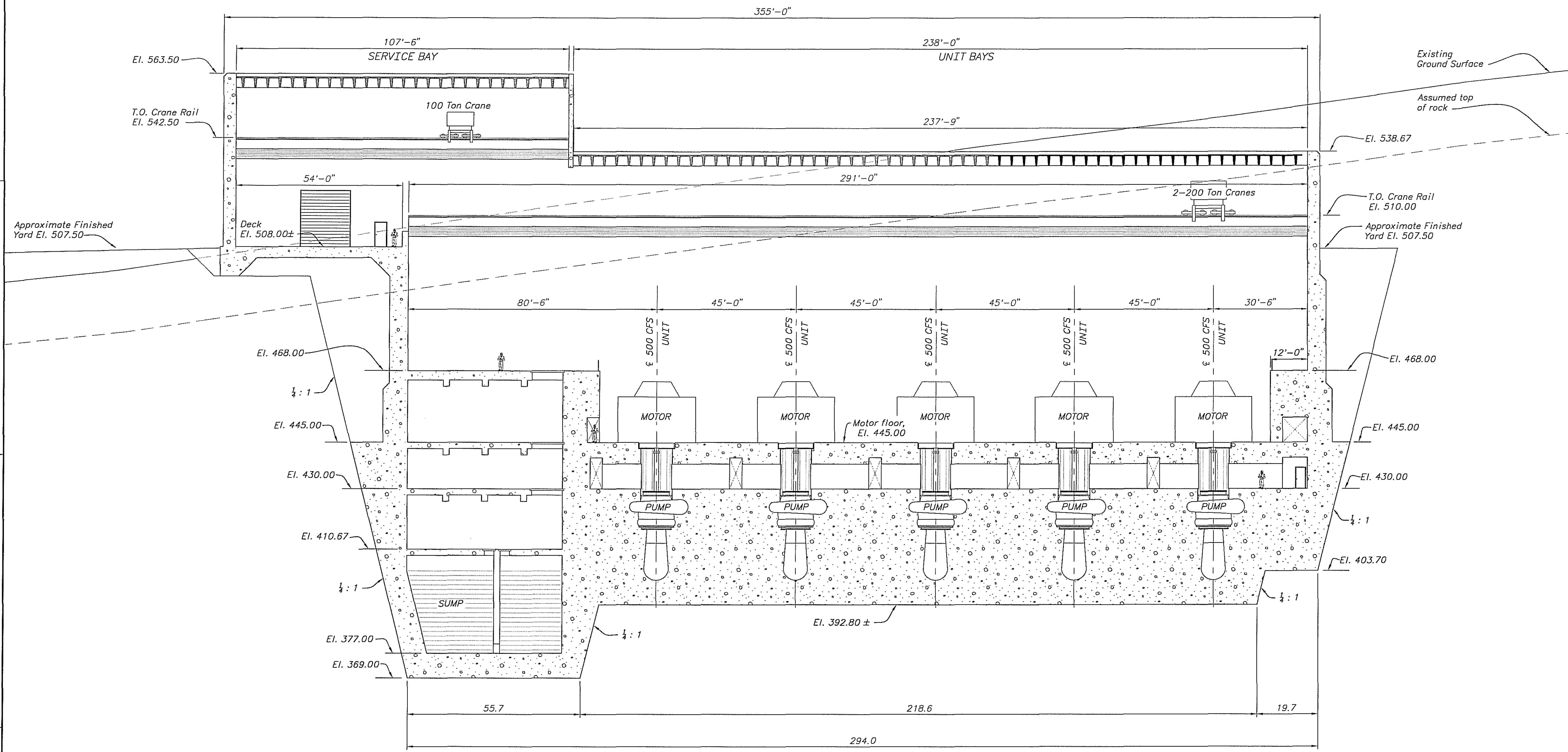

LONGITUDINAL SECTION THRU UNITS

16 0 16 32
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PRIEST RAPIDS PUMPING PLANT – OPTIONS 1 AND 2
LONGITUDINAL SECTION THRU UNITS

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FIGURE 9

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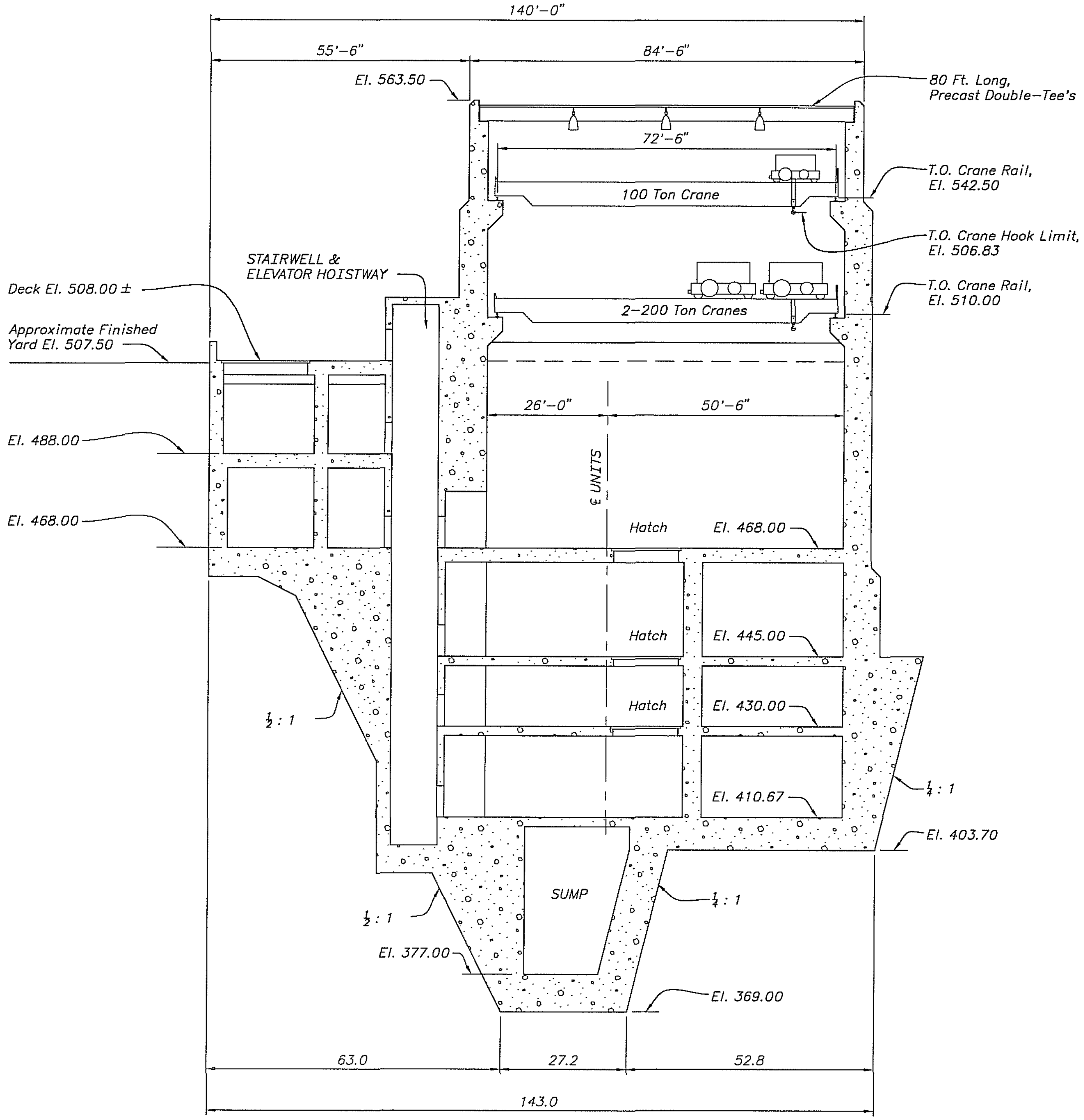
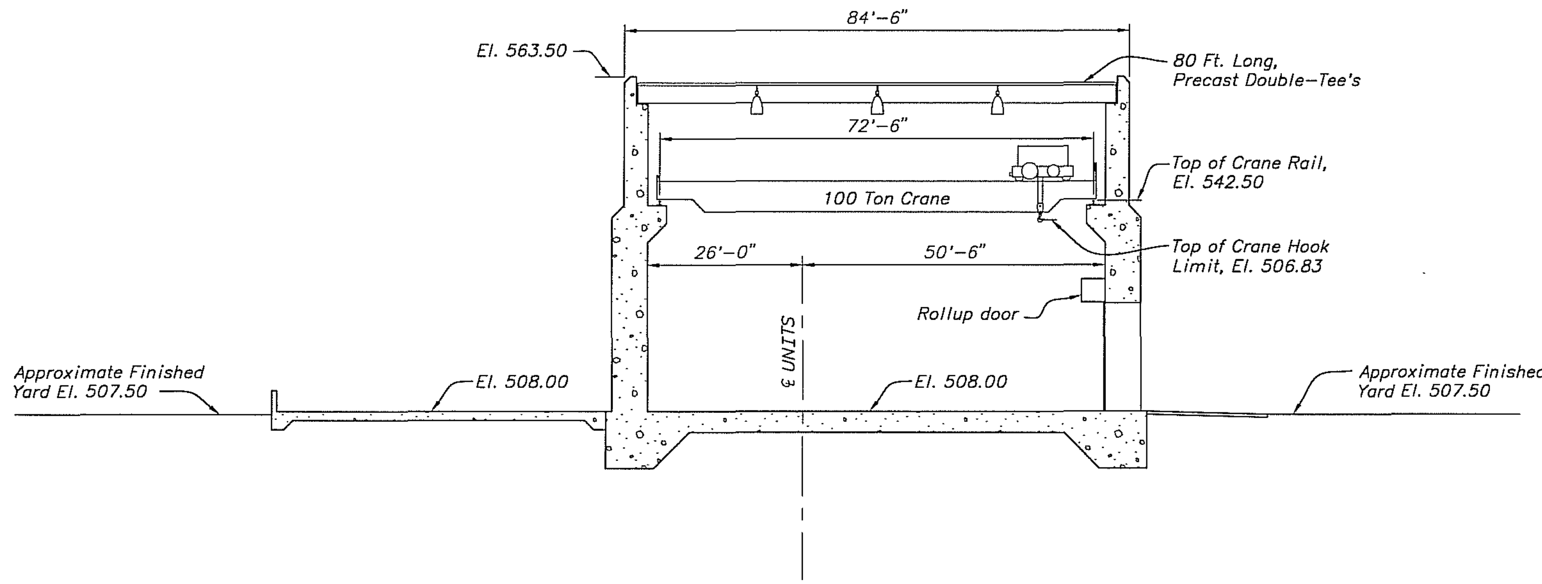


TRANSVERSE SECTION THRU SERVICE BAY



TRANSVERSE SECTION THRU SERVICE ENTRANCE

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SCALE OF FEET

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PRIEST RAPIDS PUMPING PLANT – OPTIONS 1 AND 2

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Figure 10

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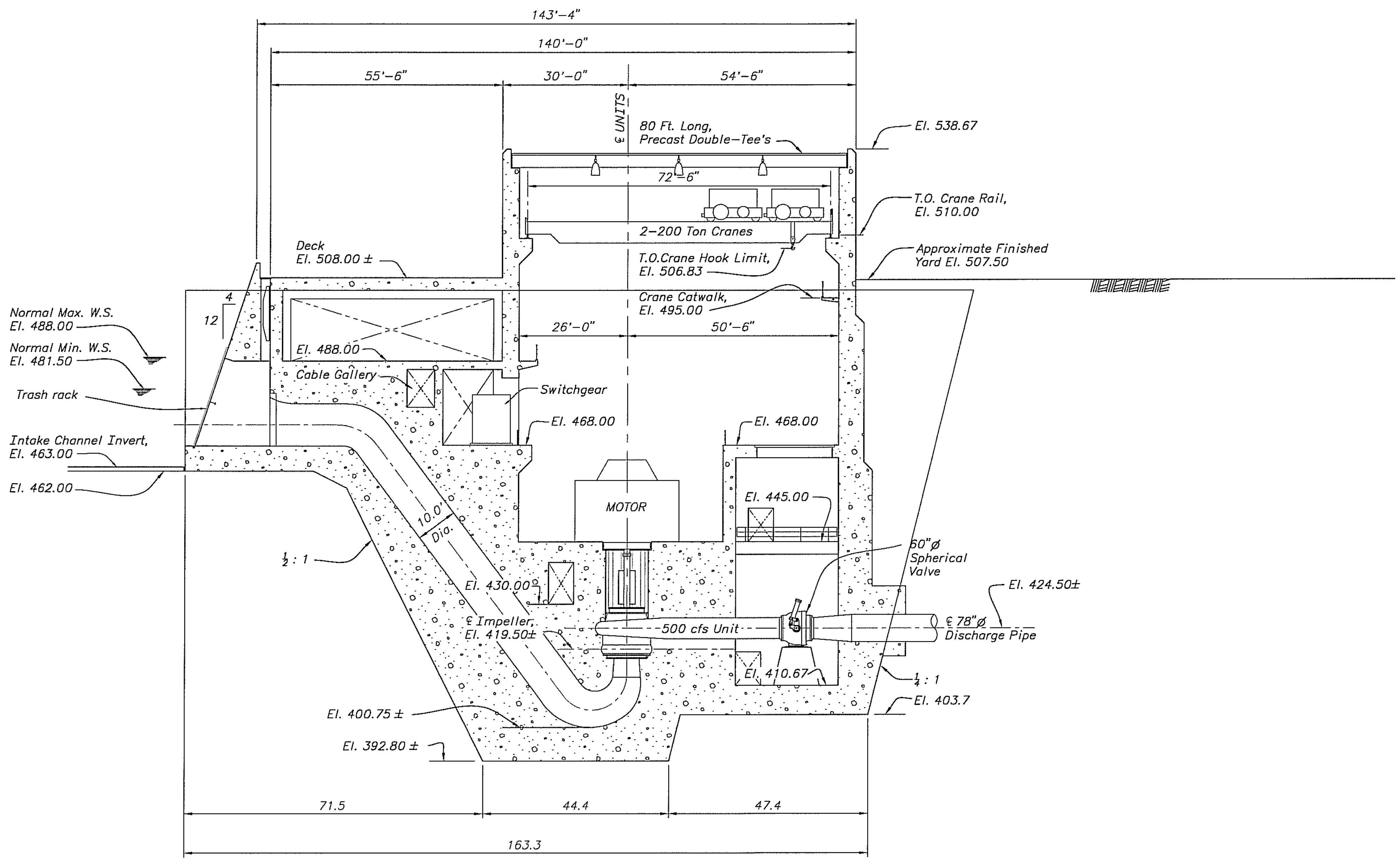

TYPICAL SECTION THRU UNIT

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PRIEST RAPIDS PUMPING PLANT – OPTIONS 1 AND 2
TYPICAL SECTION THRU UNIT

DESIGNED BY B. D. VANOITERLOO
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APRIL 14, 2006

Figure 11

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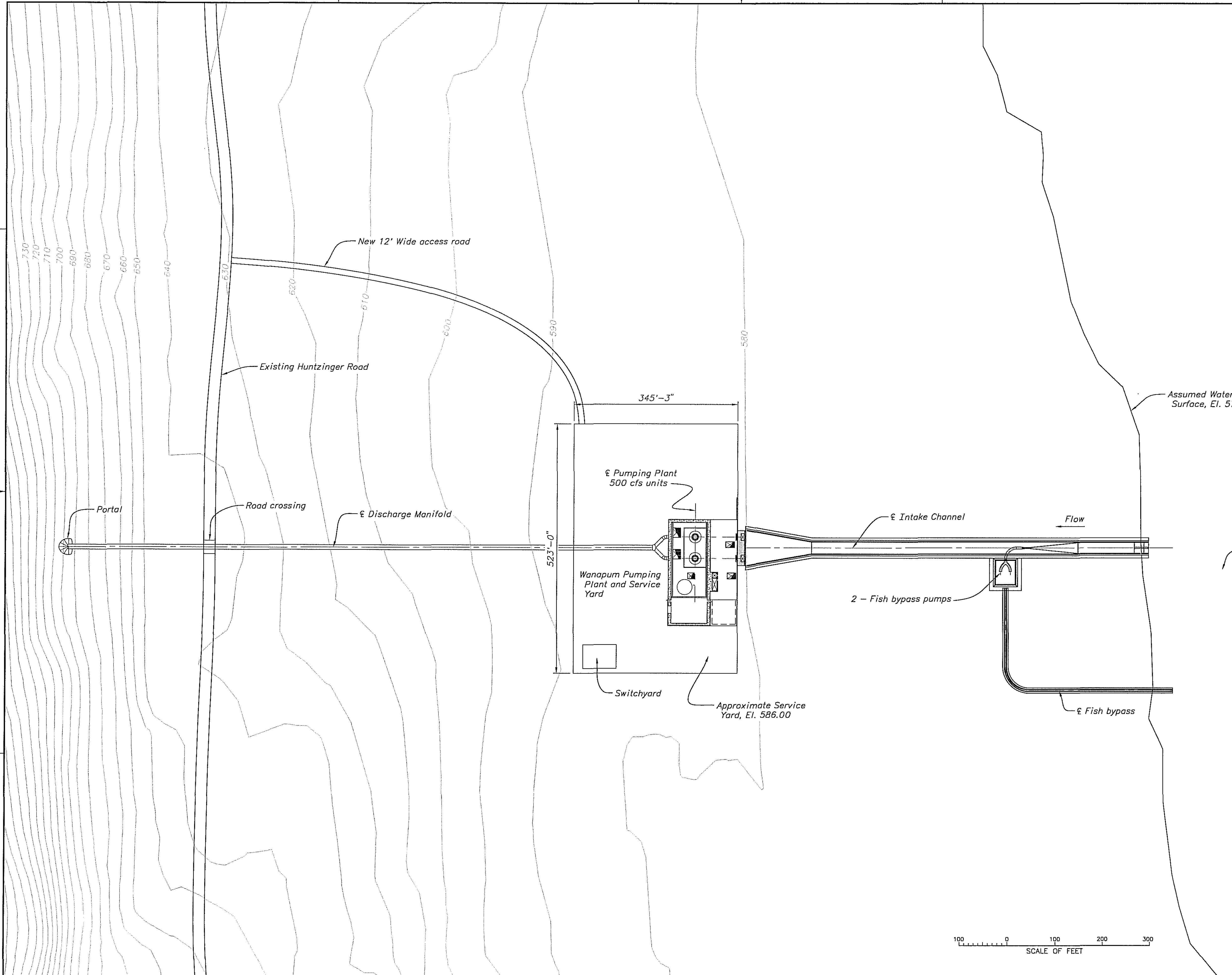

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DIRECT DELIVERY APPRAISAL STUDY

WANAPUM PUMPING PLANT – OPTION 3

SITE PLAN

DESIGNED BY B. D. VANOTTERLOO

REVIEWED BY R. W. LAFOND, P.E.

STRUCTURAL AND ARCHITECTURAL GROUP

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FIGURE 12

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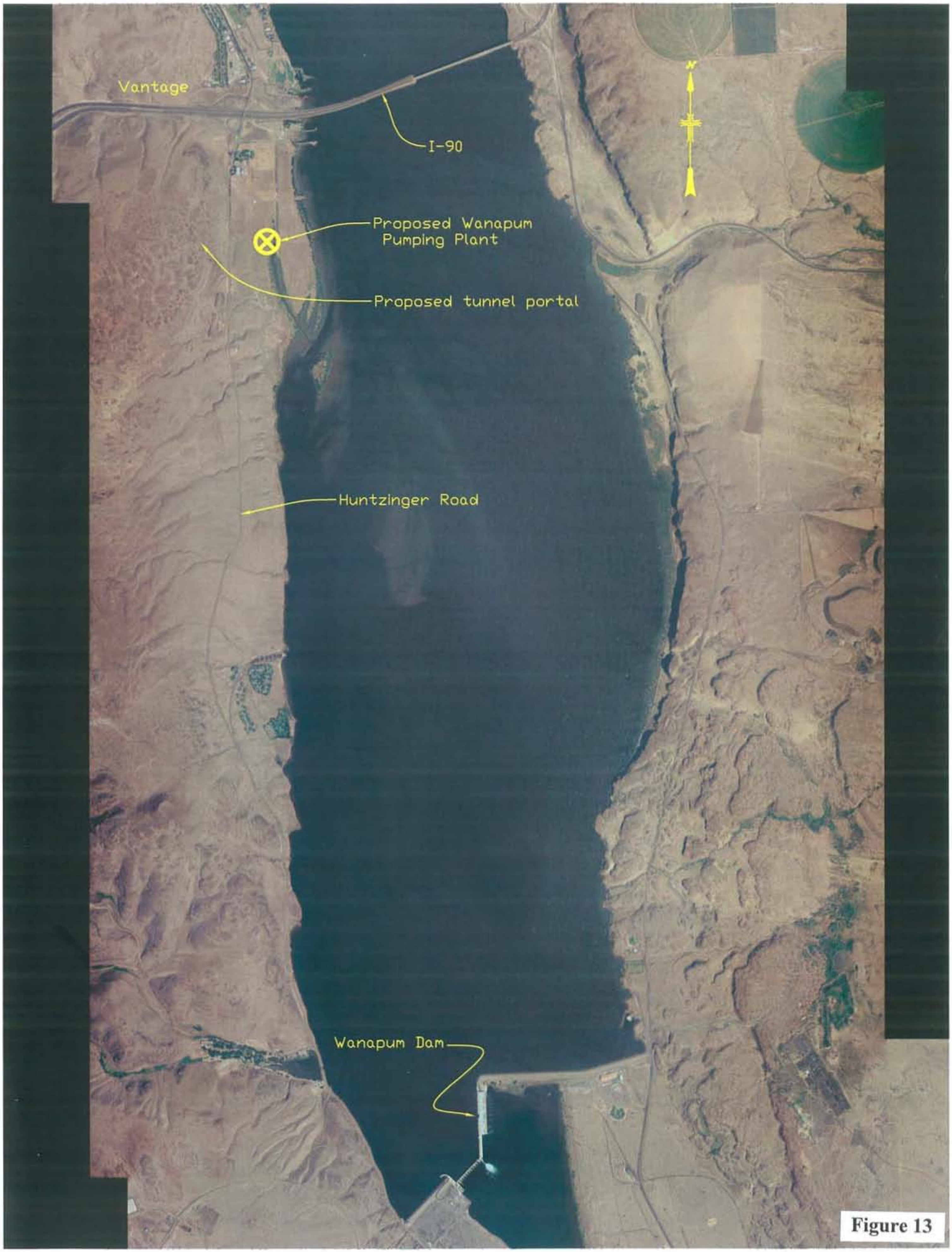
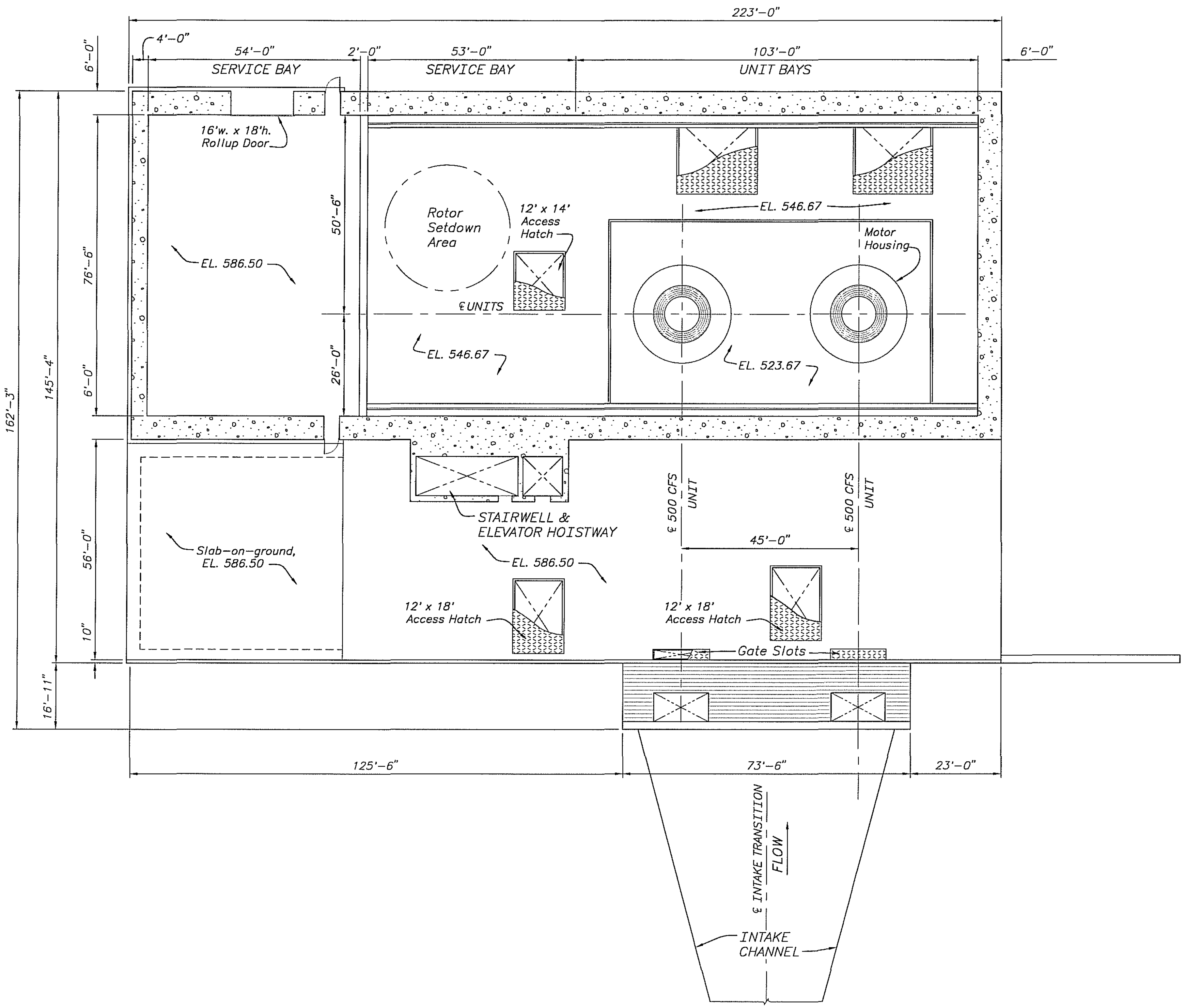


Vantage
I-90
N
Proposed Wanapum Pumping Plant
Proposed tunnel portal
Huntzinger Road
Wanapum Dam

Figure 13



PLAN – EL. 586.50, EL. 546.67 & El. 523.67 – SERVICE BAY, GATE DECK & MOTOR DECK

16 0 16 32
SCALE OF FEET

NOTES

1. Design flow capacity = 1,000 cfs.

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WANAPUM PUMPING PLANT – OPTION 3
PLAN – EL. 586.50, EL. 546.67 & EL. 523.67

DESIGNED BY B. D. VANOTTERLOO
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Figure 14

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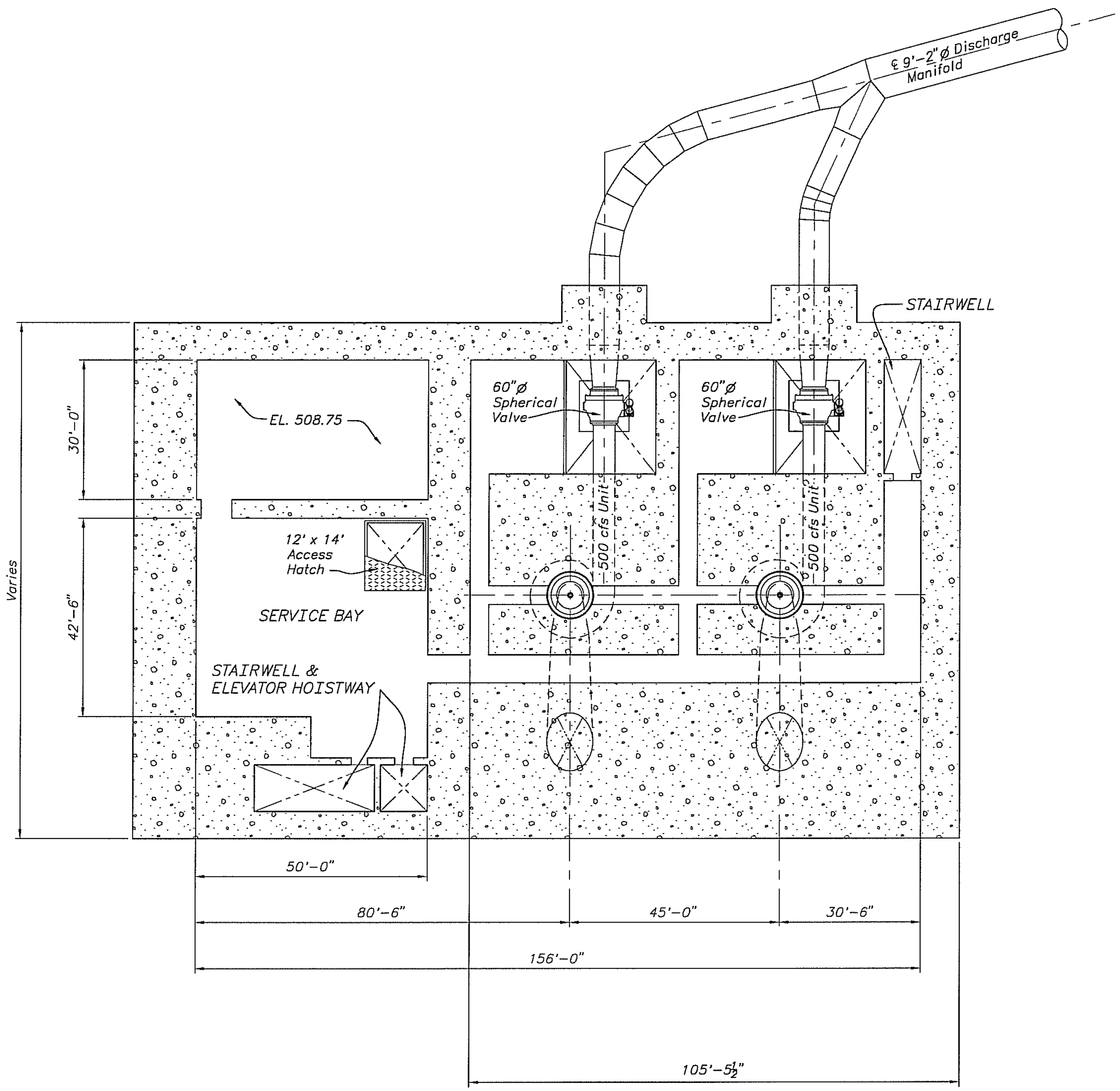

PLAN – EL. 508.75 – PUMP GALLERY

16 0 16 32
SCALE OF FEET

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WANAPUM PUMPING PLANT – OPTION 3
PLAN – EL. 508.75 – PUMP GALLERY

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Figure 15

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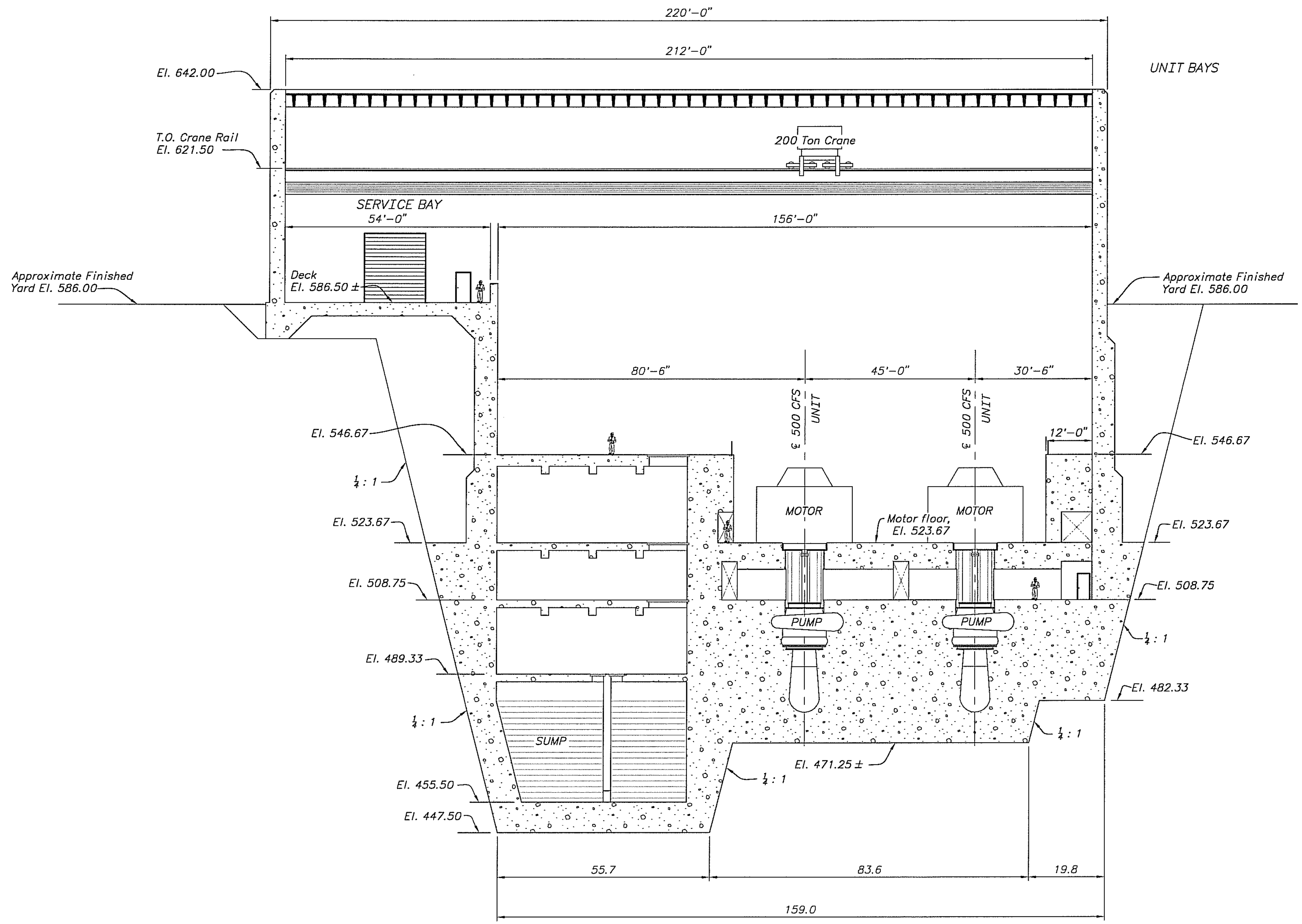

LONGITUDINAL SECTION THRU UNITS

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SCALE OF FEET

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Figure 16

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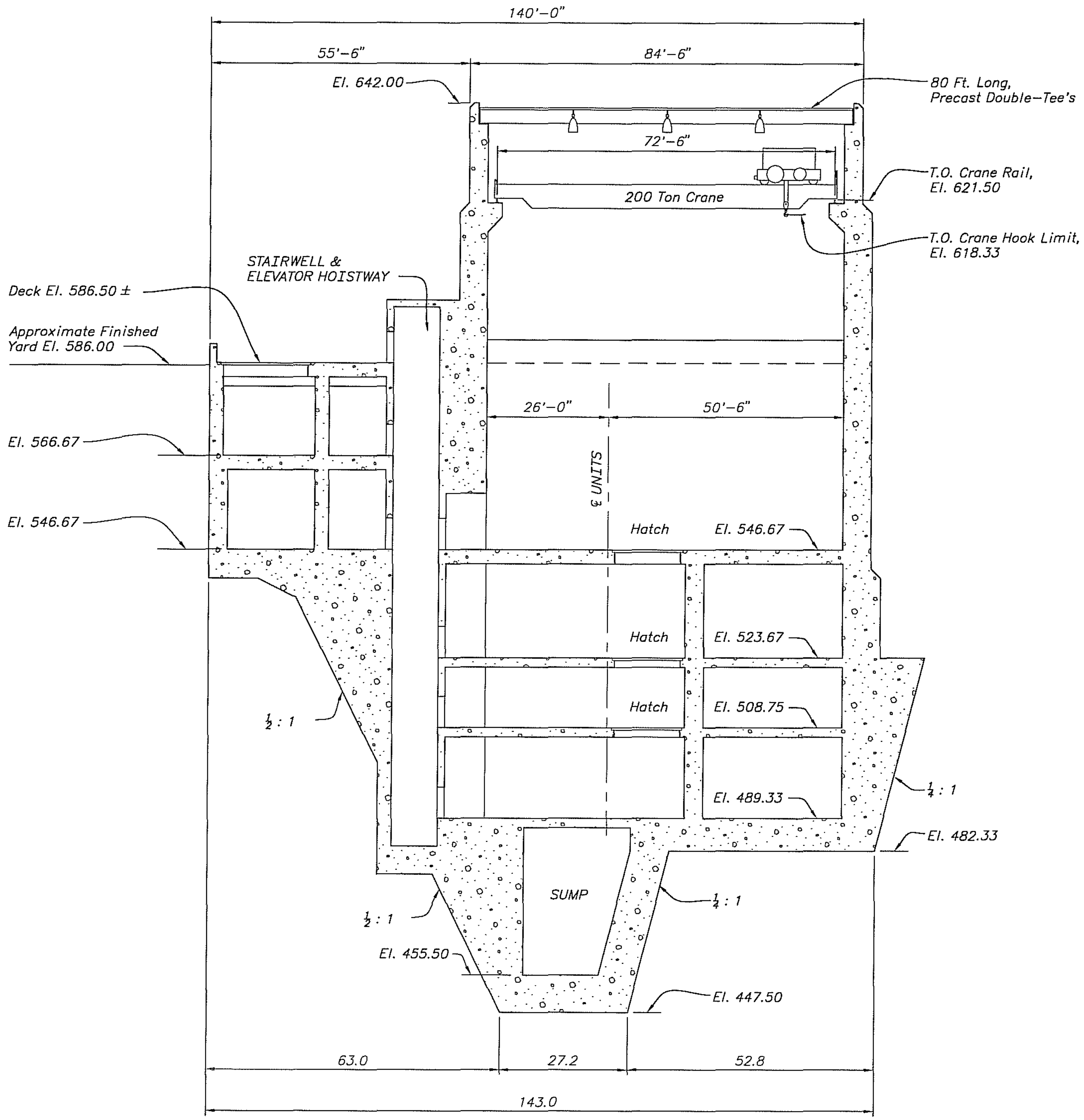
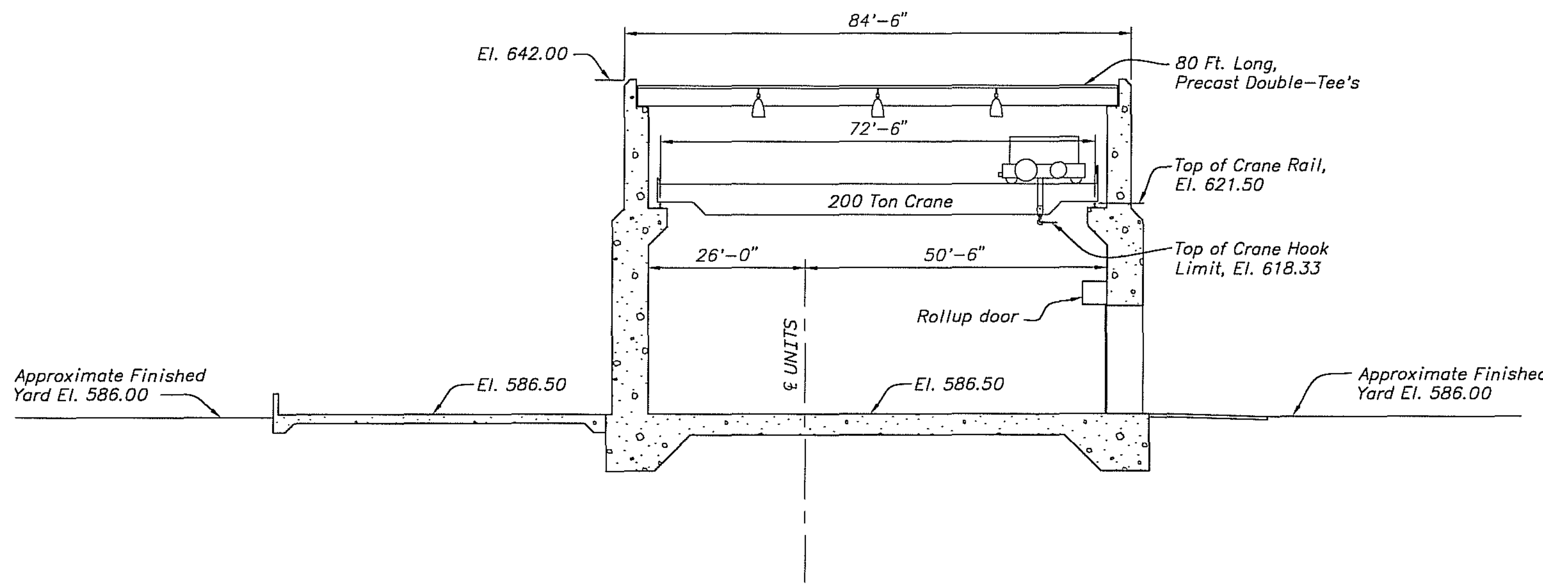


TRANSVERSE SECTION THRU SERVICE BAY



TRANSVERSE SECTION THRU SERVICE ENTRANCE

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WANAPUM PUMPING PLANT – OPTION 3

TRANSVERSE SECTIONS THRU THE SERVICE BAY

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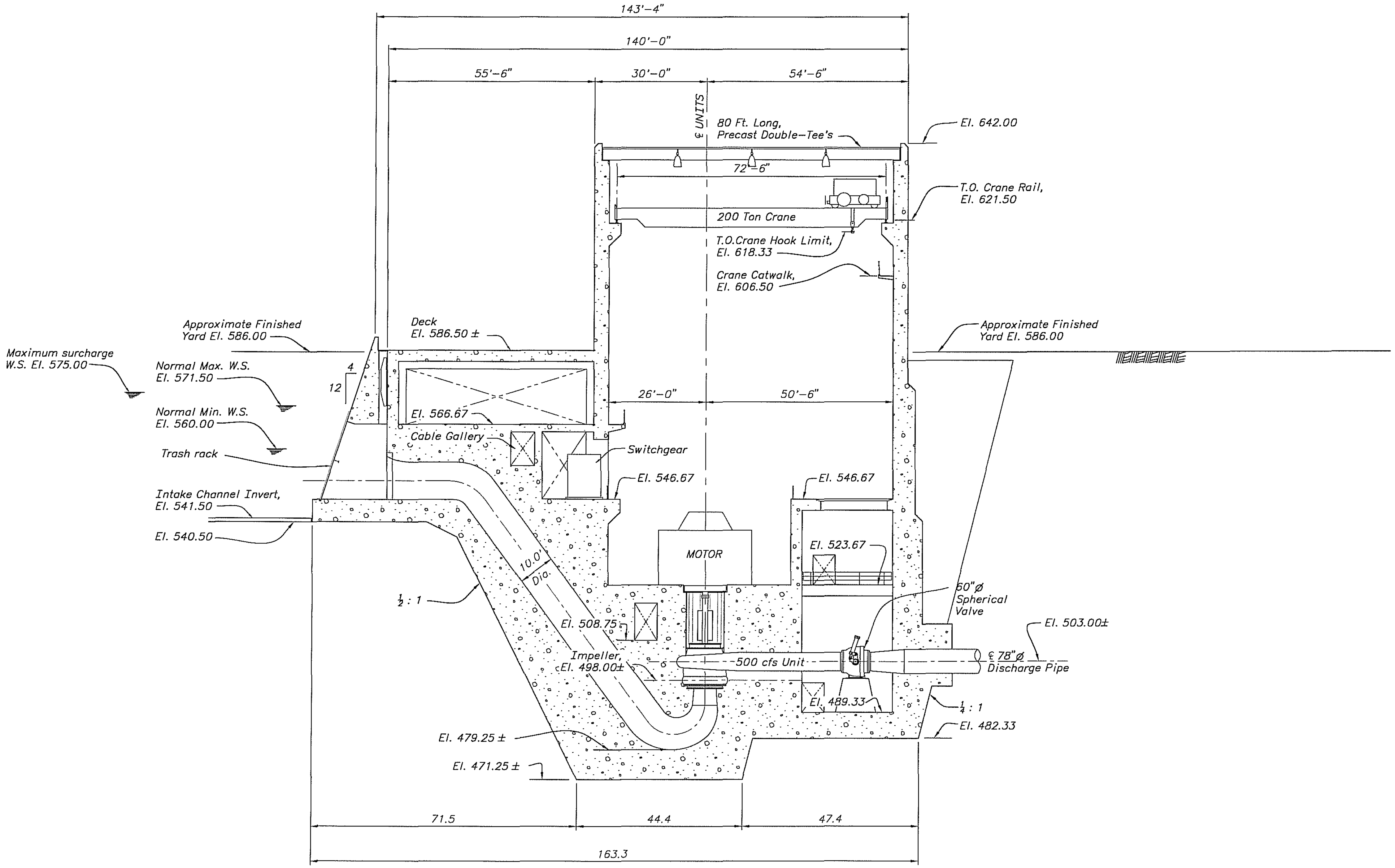
Figure 17



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TYPICAL SECTION THRU UNIT

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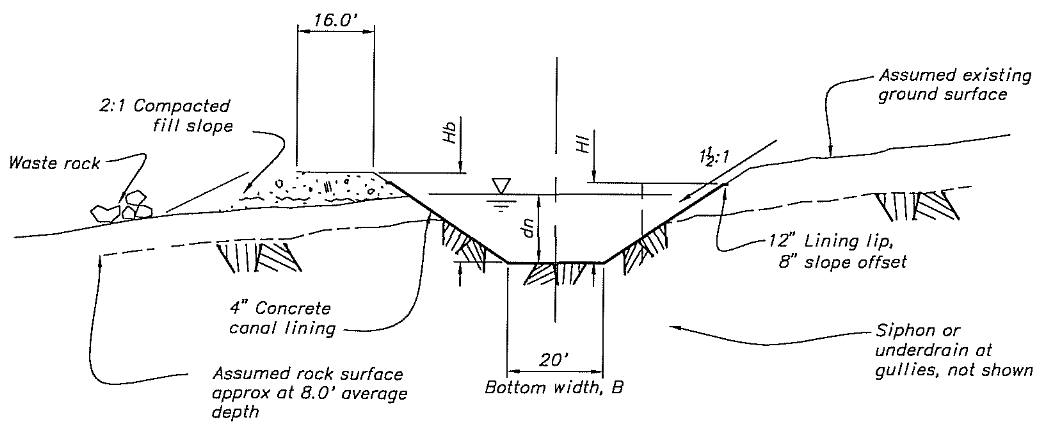
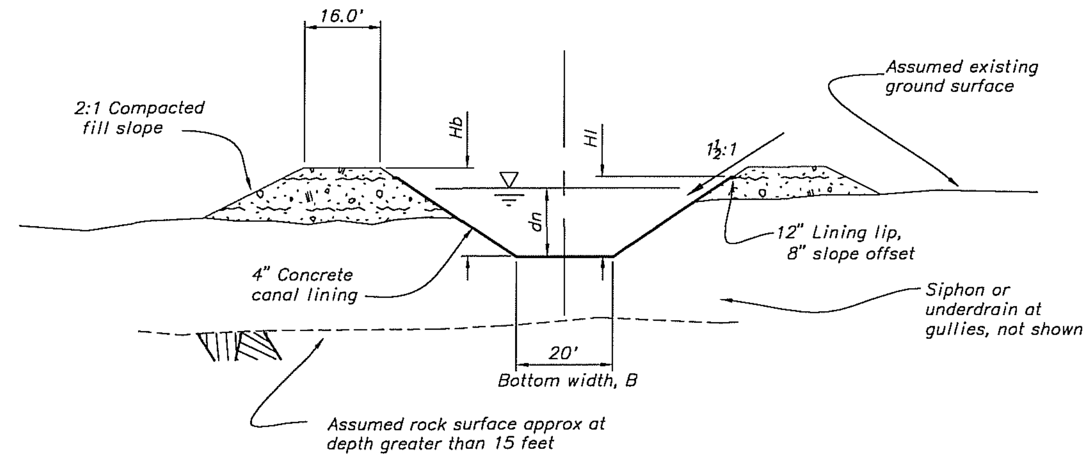
Figure 18

FIGURE 19



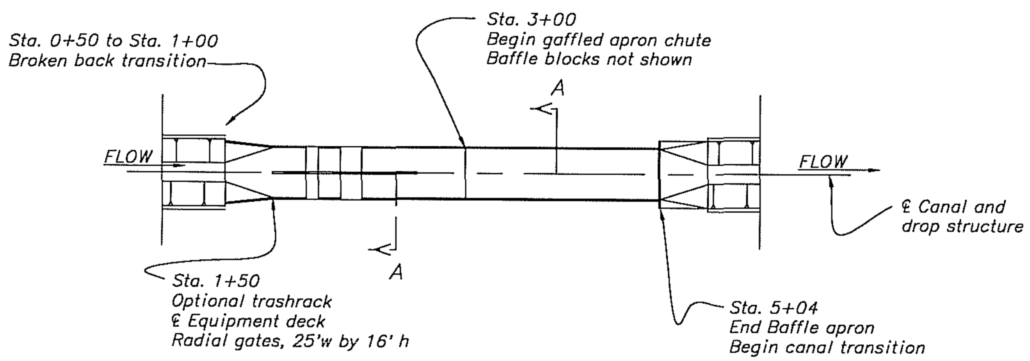
TYPICAL CANAL – SHALLOW ROCK SECTION



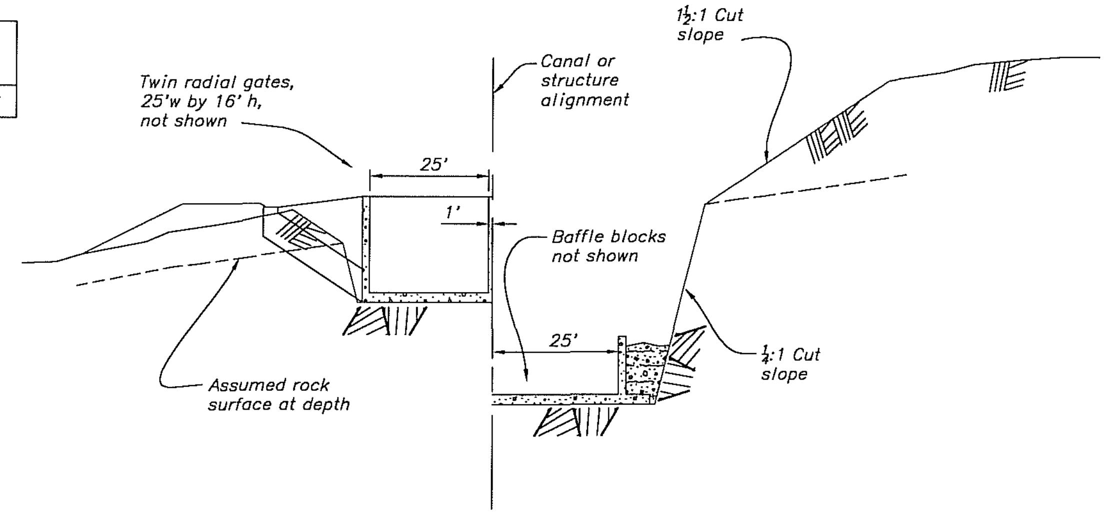
TYPICAL CANAL – DEEP ROCK SECTION

CANAL HYDRAULIC PROPERTIES

Reach lining	Q	B	S	Side slopes	n	dn	A	V	R	Hl	Hb
	cfs	ft	Slope, ft/ft	H:V	Man.	ft	sq ft	fps	ft	ft	ft
Concrete	2500	20.0	0.00010	1.5:1	.014	14.1	579.6	4.31	8.19	16.5	18.5

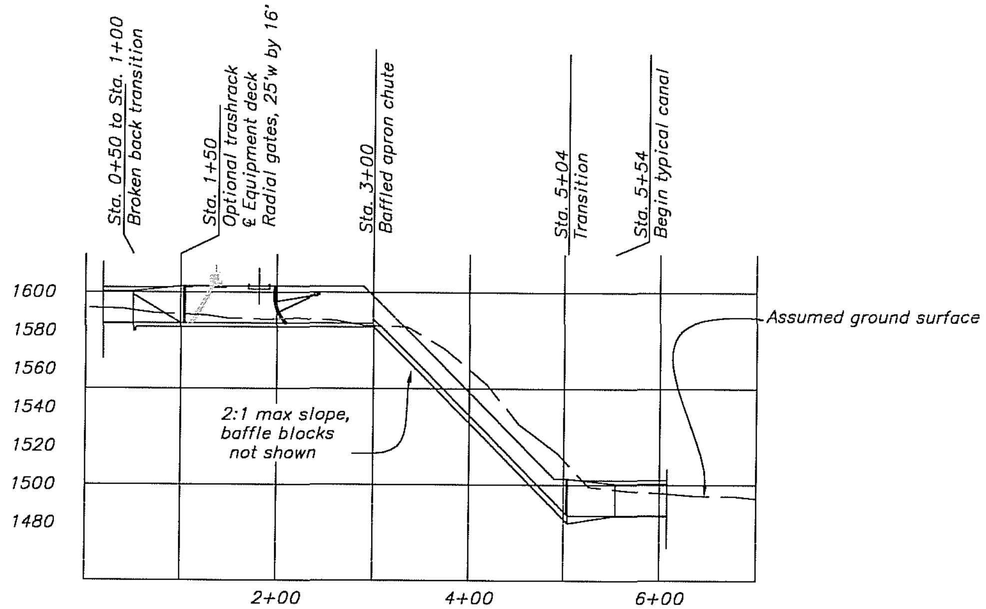


PLAN AT TYPICAL CHECK AND BAFFLED APRON DROP
SEE PROFILE BELOW

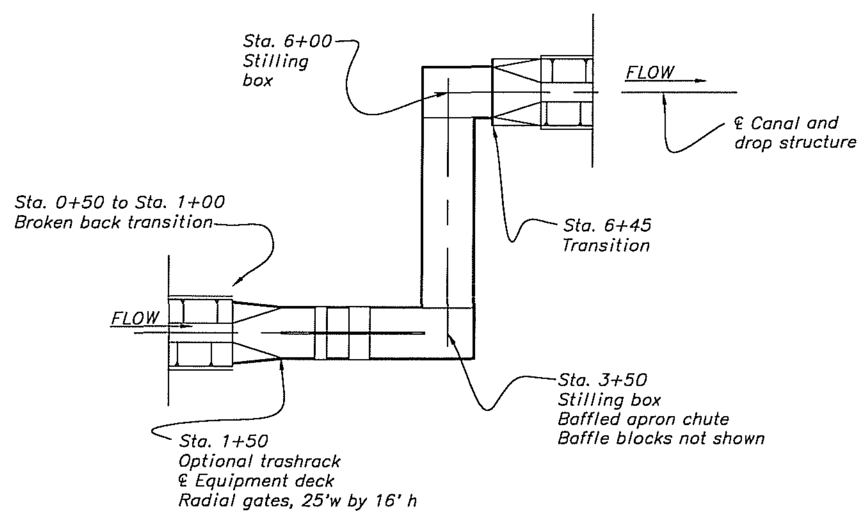


SECTION A–A

20 0 20 40 60
SCALE OF FEET



PROFILE AT TYPICAL CHECK AND BAFFLED APRON DROP



PLAN AT ALTERNATIVE BAFFLED APRON DROP

NOTES

1. The connecting canal could use either the in–line check and baffled apron drop or the alternative baffled apron drop, depending upon topography. Radial gates are recommended to maintain a typical high canal water depth independent of flow.

2. Typical drops will be 100' in elevation difference. For baffled apron designs, see Reclamation "Design of Small Canal Structures" and Engineering Monograph No. 25 "Hydraulic Design of Stilling Basins and Energy Dissipators."

3. Typical canal hydraulic properties are Q (cfs), bottom slope (S), side slopes, Manning's "n" value, bottom width (B), normal depth (dn), area (sq ft), hydraulic radius (R), velocity (fps), lining height (Hl), and bank height (Hb).

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YAKIMA RIVER BASIN WATER STORAGE STUDY

COLUMBIA RIVER WATER EXCHANGE
DIRECT DELIVERY APPRAISAL STUDY
2500 CFS ROZA OPTION 2
CONNECTING CANAL SYSTEM

DESIGNED Jeff Baysinger
REVIEWED BY Todd R. Calhoun, P.E.
Water Conveyance Group

CADD SYSTEM AutoCAD Rel. 16.0s
CADD FILENAME typ canal.DWG
DENVER, COLORADO MAY 2006 SHEET 1 OF 1
FIGURE 19

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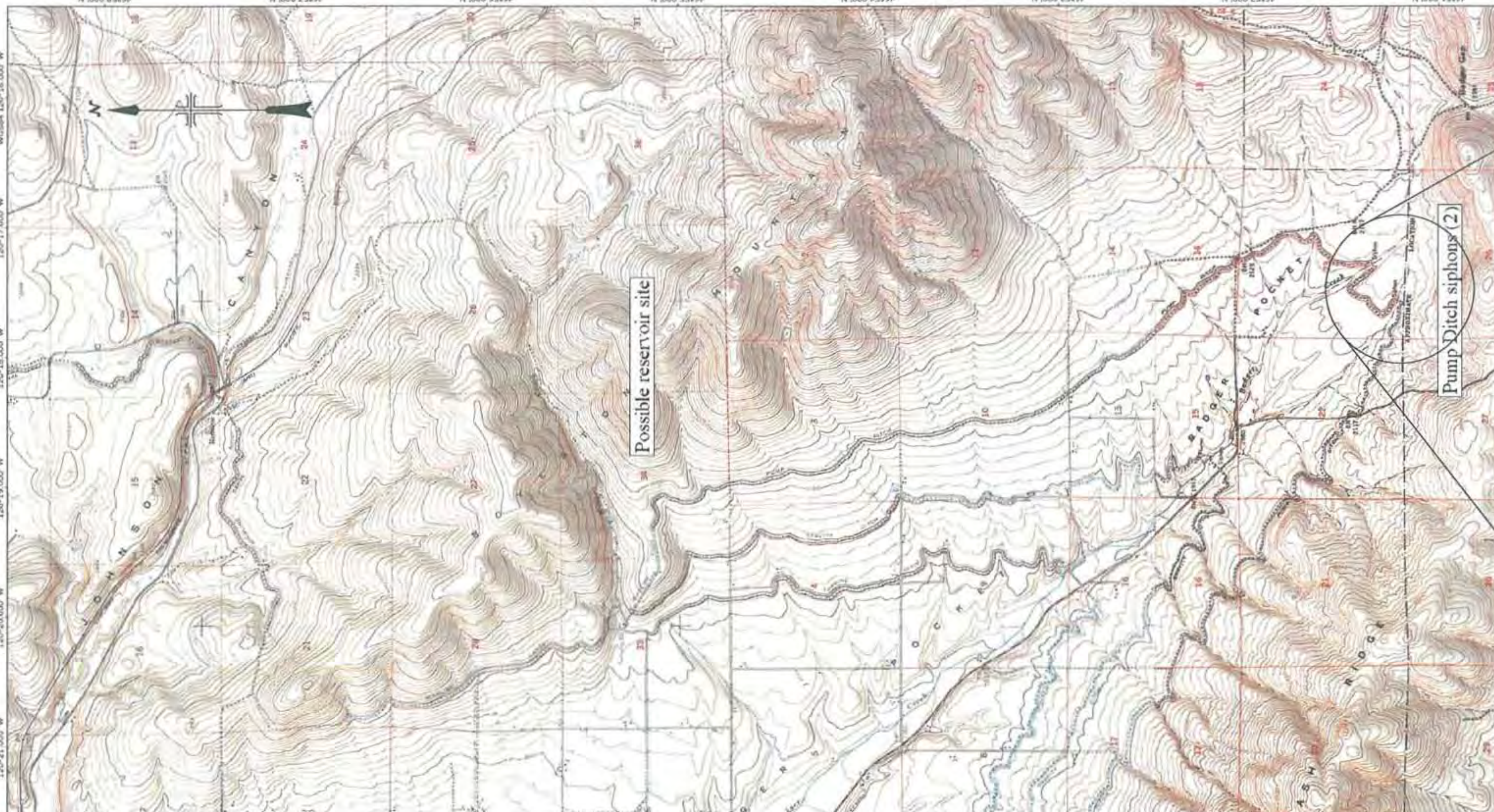
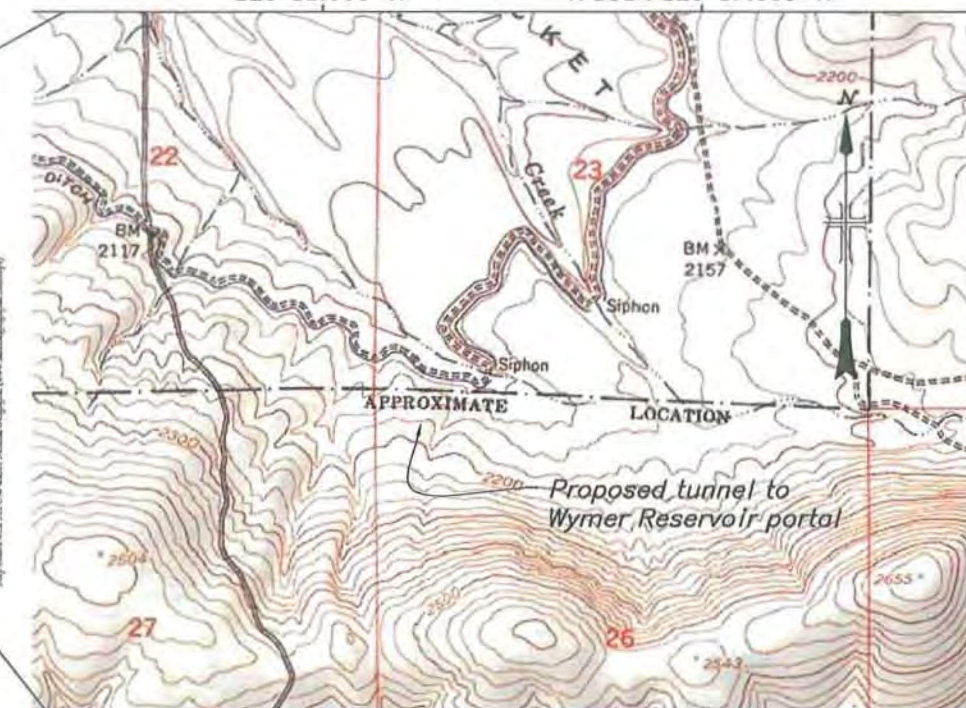
PLOTTED BY:



TOPO! map printed on 03/15/06 from "KRD siphons.tpo"
120°18.000' W WGS84 120°17.000' W



120°18.000' W WGS84 120°17.000' W

0 .5 1 MILE
0 1000 FEET 0 500 1000 METERS

MN 17½°

Map created with TOPO!® ©2003 National Geographic (www.nationalgeographic.com/topo)

SIPHON LOCATIONS

UPGRADED KRD SIPHON HYDRAULIC PROPERTIES

Sta	Estimated Length, ft	Q	Pipe Dia., in	V	Headloss, ft *
318+22	135	550	114	7.76	0.71
352+86	80	540	108	8.49	0.75

* Pipe sized to be less than or match these headlosses in existing siphons

See Figure 21 for a typical enlarged siphon example

500 CFS ADDED INTO KRD CANAL SYSTEM, CONTINUING TO WYMER RESERVOIR VIA TUNNEL PLAN

ENLARGED CANAL AND TUNNEL #2 – OPTION 3

NOTES

1. See Figure 10 for the enlarged canal and siphon sections.

PROPOSED ENLARGED KRD PUMP DITCH CANAL – HYDRAULIC PROPERTIES AT SAME SLOPE

Reach lining	n	Q	S	Side slopes	B	dn	A	V	R	Hl	Hb	Comment
Unlined, earth	.025	550	0.00070	1.5:1	35.0	3.90	159.4	3.45	3.25	NA	7.0	Velocity too high for unlined earth
Unlined, earth	.025	550	0.00070	1.5:1	65.0	2.73	188.7	2.91	2.52	NA	5.9	Velocity OK, but quite wide, big area
Concrete lined	.014	550	0.00070	1.5:1	20.0	3.77	96.8	5.68	2.88	5.1	6.9	Velocity too high for concrete
Concrete lined	.014	550	0.00070	1.5:1	50.0	2.26	120.5	4.56	2.07	3.6	5.4	Velocity approx OK, but wide – SELECT

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YAKIMA RIVER BASIN WATER STORAGE STUDY

COLUMBIA RIVER WATER EXCHANGE
DIRECT DELIVERY APPRAISAL STUDY
WANAPUM PP TO KRD SYSTEM – 1000 CFS
OPTION 3 – KRD CANAL ENLARGEMENT

DESIGNED Jeff Boysinger
REVIEWED BY Todd R. Calhoun, P.E.
Water Conveyance Group

CADD SYSTEM AutoCAD Rel. 16.0s
DENVER, COLORADO MAY 2006 SHEET 3 OF 3
CADD FILENAME tvp canal.DWG

FIGURE 20

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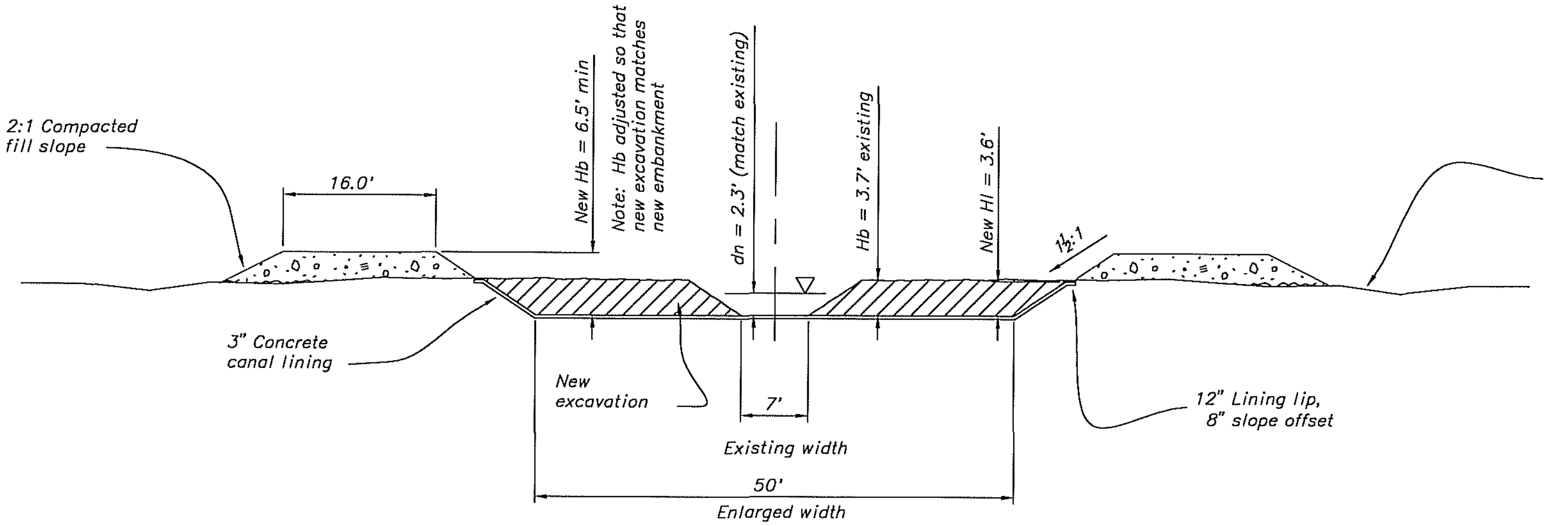
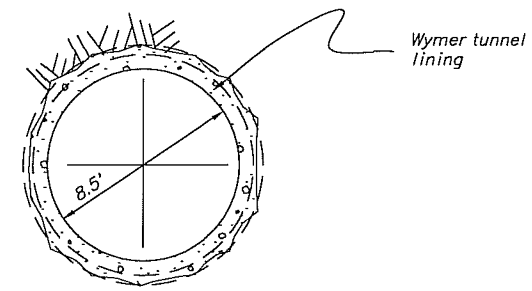
PLOTTED BY:

FIGURE 21



TYPICAL ENLARGED KRD PUMP DITCH SECTION

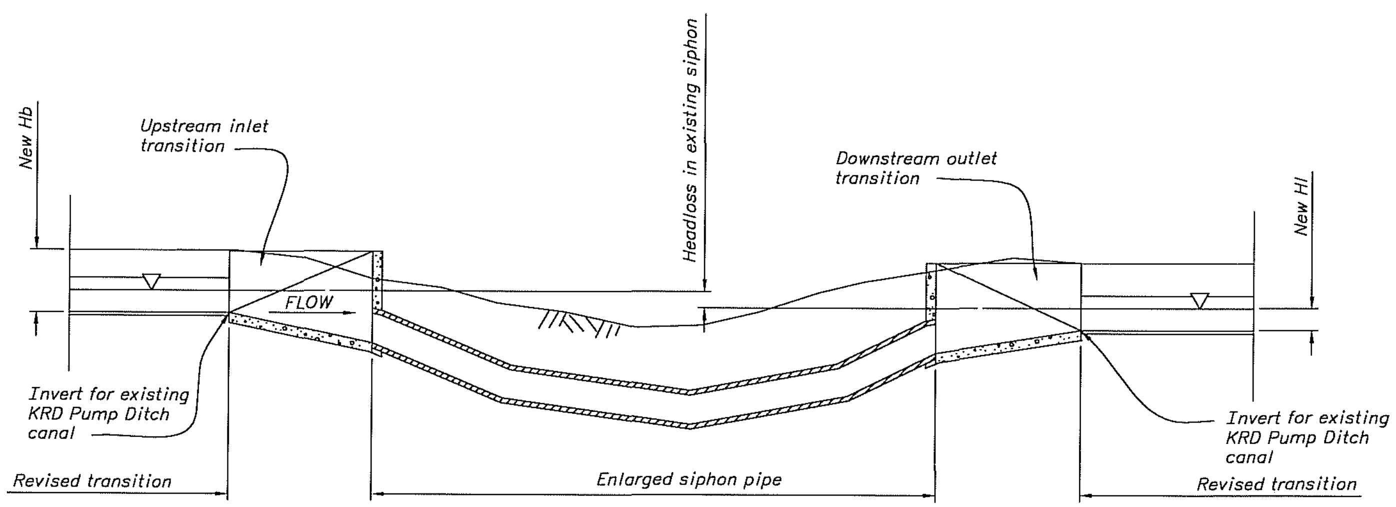
10 0 10 20 30 SCALE OF FEET



WYMER TUNNEL

ENLARGED CANAL HYDRAULIC PROPERTIES

Reach lining	n	Q	S	Side slopes	B	dn	A	V	R	Hl	Hb
	Man.	cfs	Slope, ft/ft	H:V	ft	ft	sq ft	fps	ft	ft	ft
Concrete lined	.014	550	0.00070	1.5:1	50.0	2.26	120.5	4.56	2.07	3.6	5.4



TYPICAL ENLARGED KRD PUMP DITCH SIPHON

NO SCALE

NOTES

1. See Figure 20 for the hydraulic considerations used for this selection.

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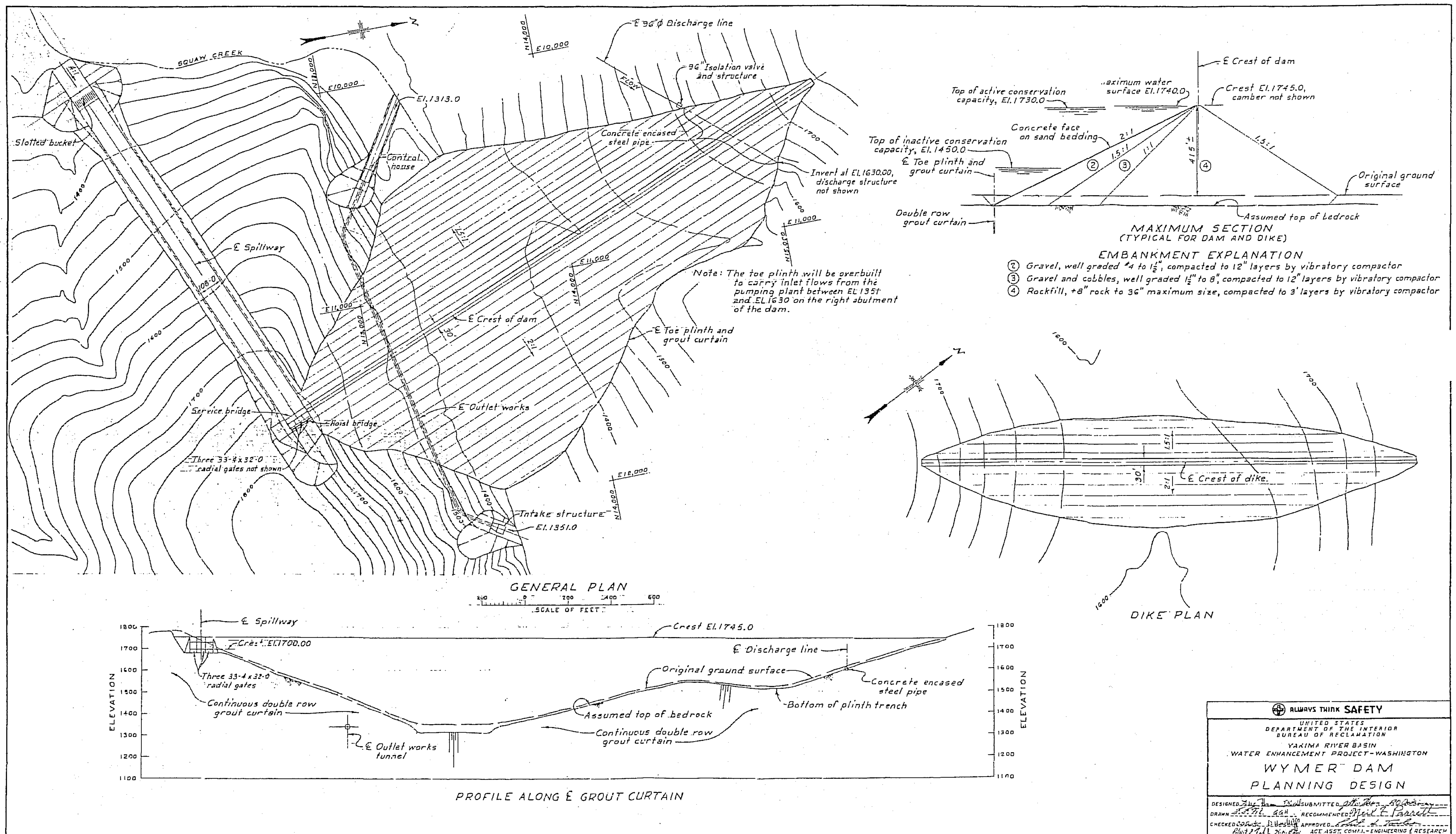
YAKIMA RIVER BASIN WATER STORAGE STUDY

COLUMBIA RIVER WATER EXCHANGE
DIRECT DELIVERY APPRAISAL STUDY
WANAPUM PP TO KRD SYSTEM – 1000 CFS
ENLARGED KRD CANAL AND SIPHON SECTIONS

DESIGNED Jeff Baysinger
REVIEWED BY Todd R. Calhoun, P.E.
Water Conveyance Group

CADD SYSTEM AutoCAD Rel. 16.0s
DENVER, COLORADO MAY 2006 SHEET 1 OF 1
CADD FILENAME typ canal.DWG
FIGURE 21


SQUAW CREEK
Slotted bucket
℄ Spillway
108-0
℄ 96"∅ Discharge line
96" Isolation valve and structure
FLOW
El. 1313.0
Control house
Concrete encased steel pipe
Invert at El. 1630.00, discharge structure not shown
Note: The toe plinth will be overbuilt to carry inlet flows from the pumping plant between El. 1351 and El. 1630 on the right abutment of the dam.
℄ Crest of dam
℄ Toe plinth and grout curtain
℄ Outlet works
Service bridge
Hoist bridge
Three 33-4 x 32-0 radial gates not shown
Intake structure
El. 1351.0
GENERAL PLAN
SCALE OF FEET
℄ Crest of dam
Top of active conservation capacity, El. 1730.0
Maximum water surface El. 1740.0
Crest El. 1745.0, camber not shown
Concrete face on sand bedding
Top of inactive conservation capacity, El. 1450.0
℄ Toe plinth and grout curtain
Original ground surface
Double row grout curtain
Assumed top of bedrock
MAXIMUM SECTION
(TYPICAL FOR DAM AND DIKE)
EMBANKMENT EXPLANATION
② Gravel, well graded #4 to 1½", compacted to 12" layers by vibratory compactor
③ Gravel and cobbles, well graded 1½" to 8", compacted to 12" layers by vibratory compactor
④ Rockfill, +8" rock to 36" maximum size, compacted to 3' layers by vibratory compactor
℄ Crest of dike
DIKE PLAN
℄ Spillway
Crest El. 1745.0
Crest El. 1700.00
℄ Discharge line
Three 33-4 x 32-0 radial gates
Original ground surface
Concrete encased steel pipe
Continuous double row grout curtain
Assumed top of bedrock
Bottom of plinth trench
℄ Outlet works tunnel
Continuous double row grout curtain
ELEVATION
PROFILE ALONG ℄ GROUT CURTAIN
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WATER ENHANCEMENT PROJECT-WASHINGTON
WYMER DAM
PLANNING DESIGN
DENVER, COLORADO
MARCH 22, 1985
SHEET 2 OF 3

Figure 22

Priest Rapids to Roza - Opt 1
20 mile Tunnel D=20', Shaft D=18'
Long tunnel to Roza MP 22.6, Q =2500 cfs
Hydraulic transient results - Pump Shutdown

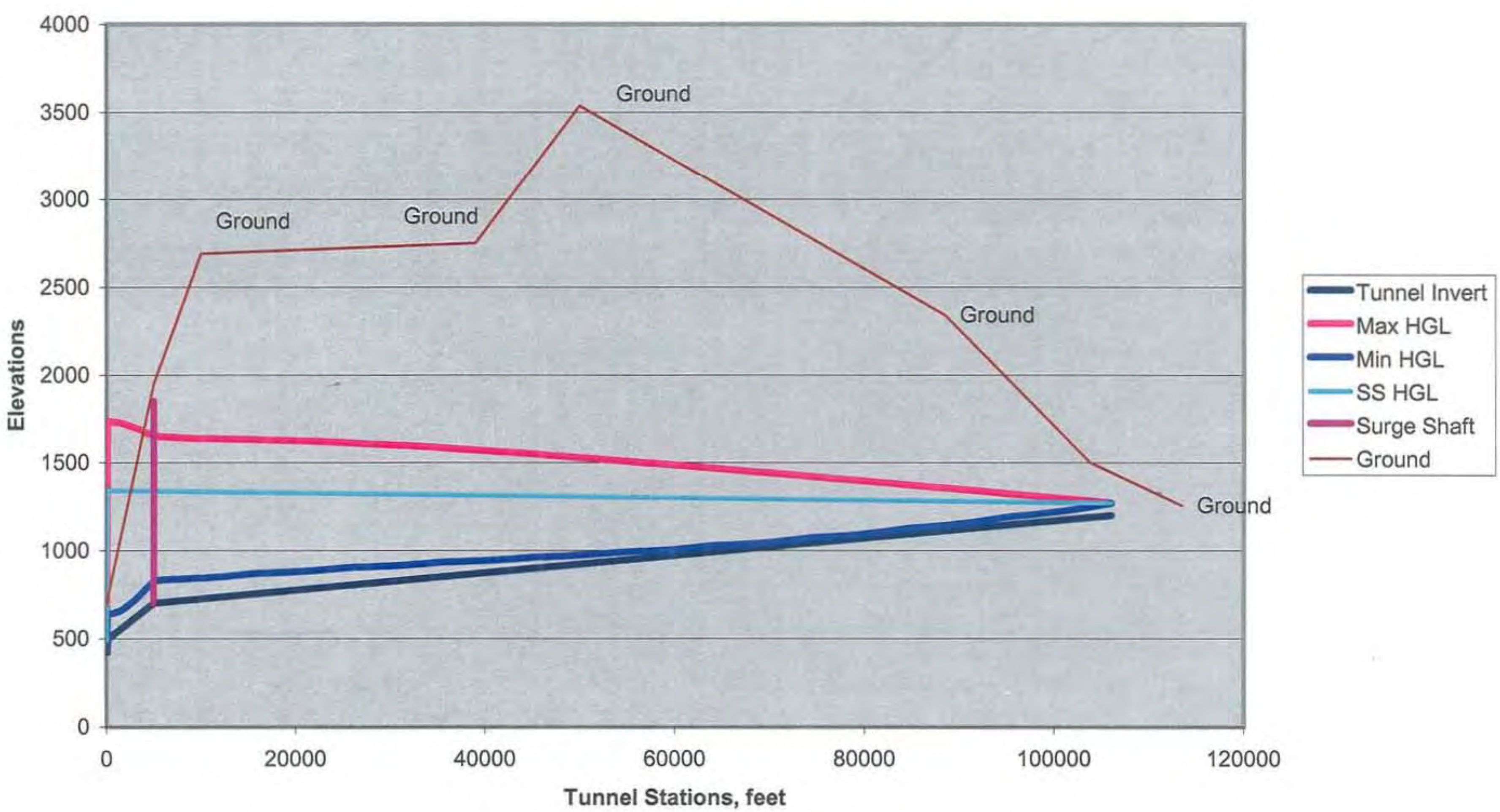
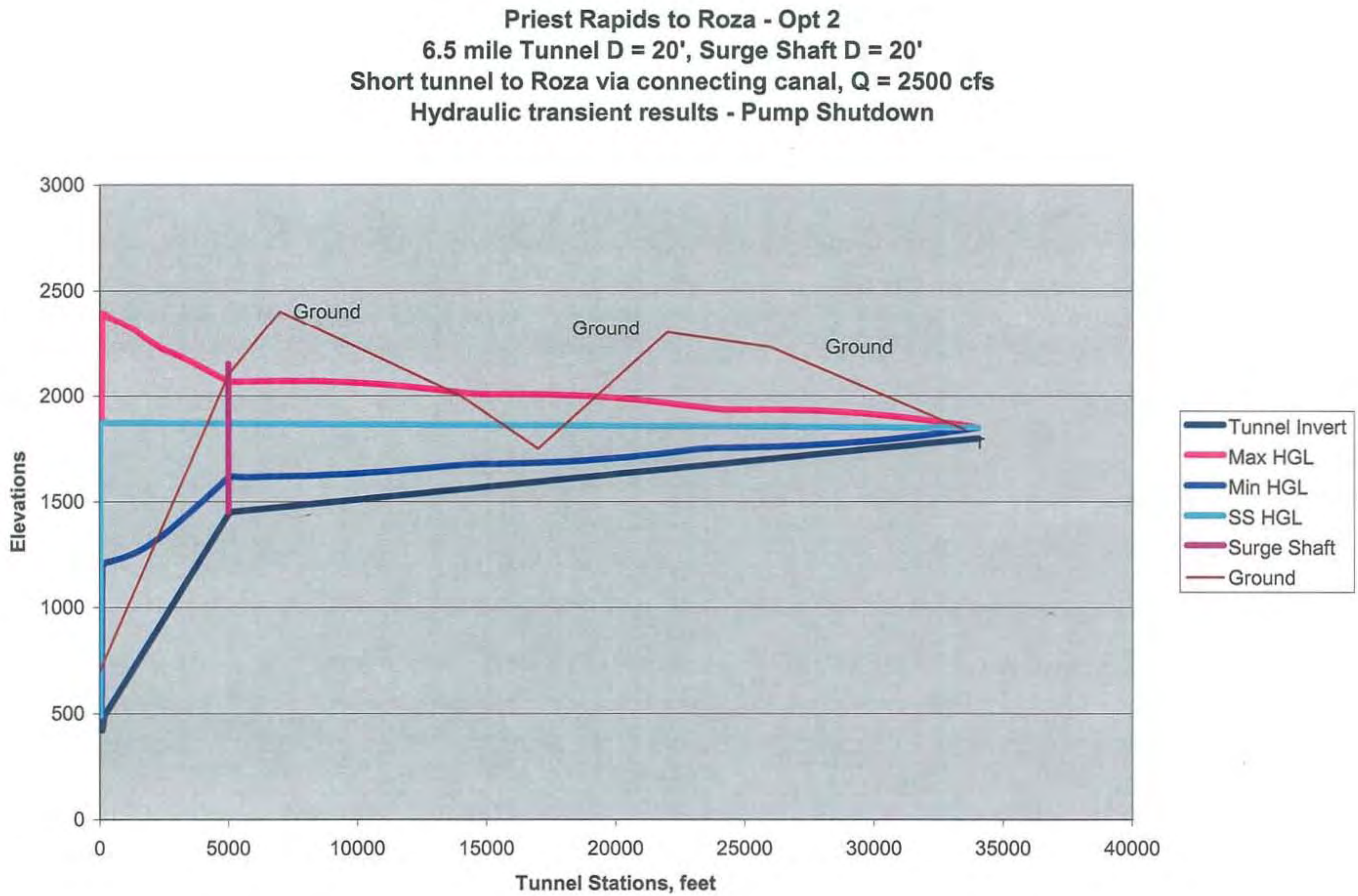


Figure 23



Priest Rapids to Roza - Opt 2
6.5 mile Tunnel D = 20', Surge Shaft D = 20'
Short tunnel to Roza via connecting canal, Q = 2500 cfs
Hydraulic transient results - Pump Shutdown
Ground
Ground
Ground
Elevations
3000
2500
2000
1500
1000
500
0
0
5000
10000
15000
20000
25000
30000
35000
40000
Tunnel Stations, feet
Tunnel Invert
Max HGL
Min HGL
SS HGL
Surge Shaft
Ground

Figure 24

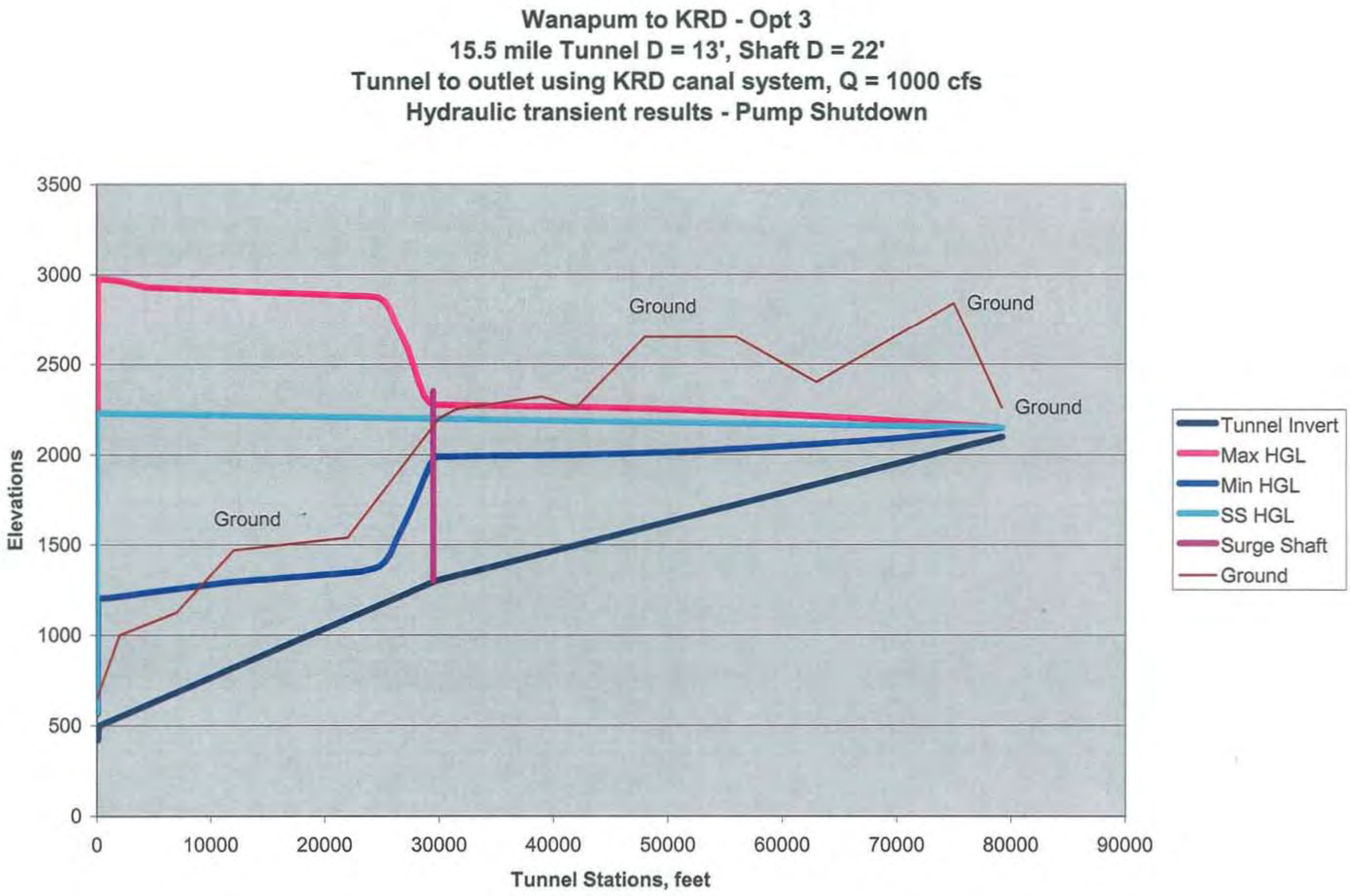
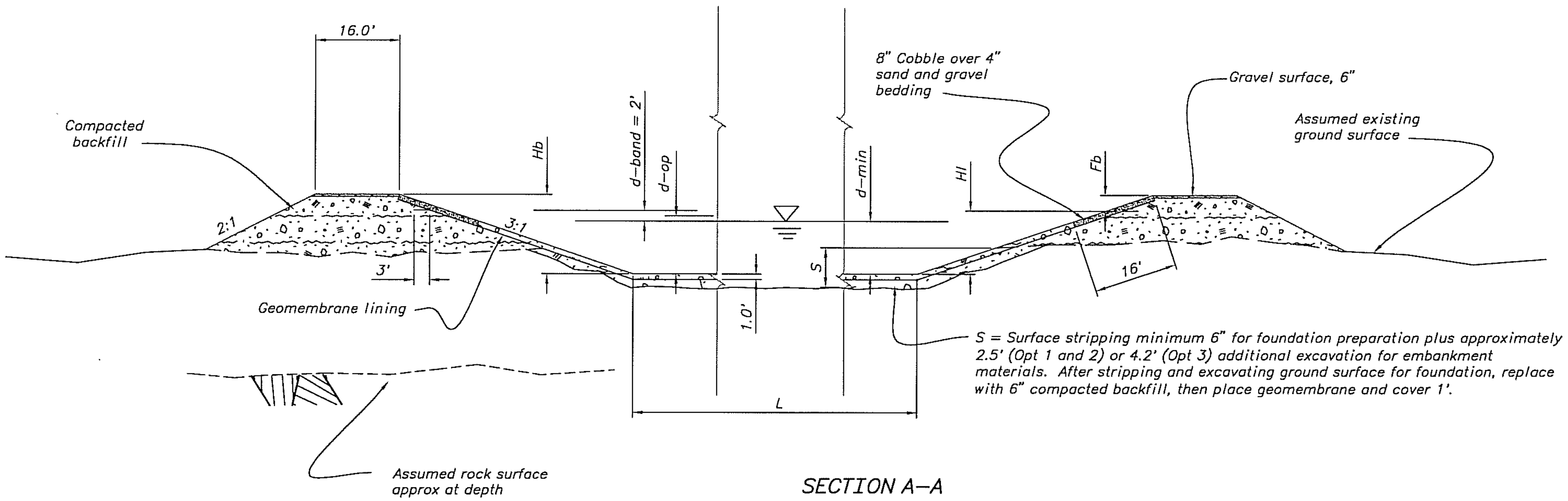
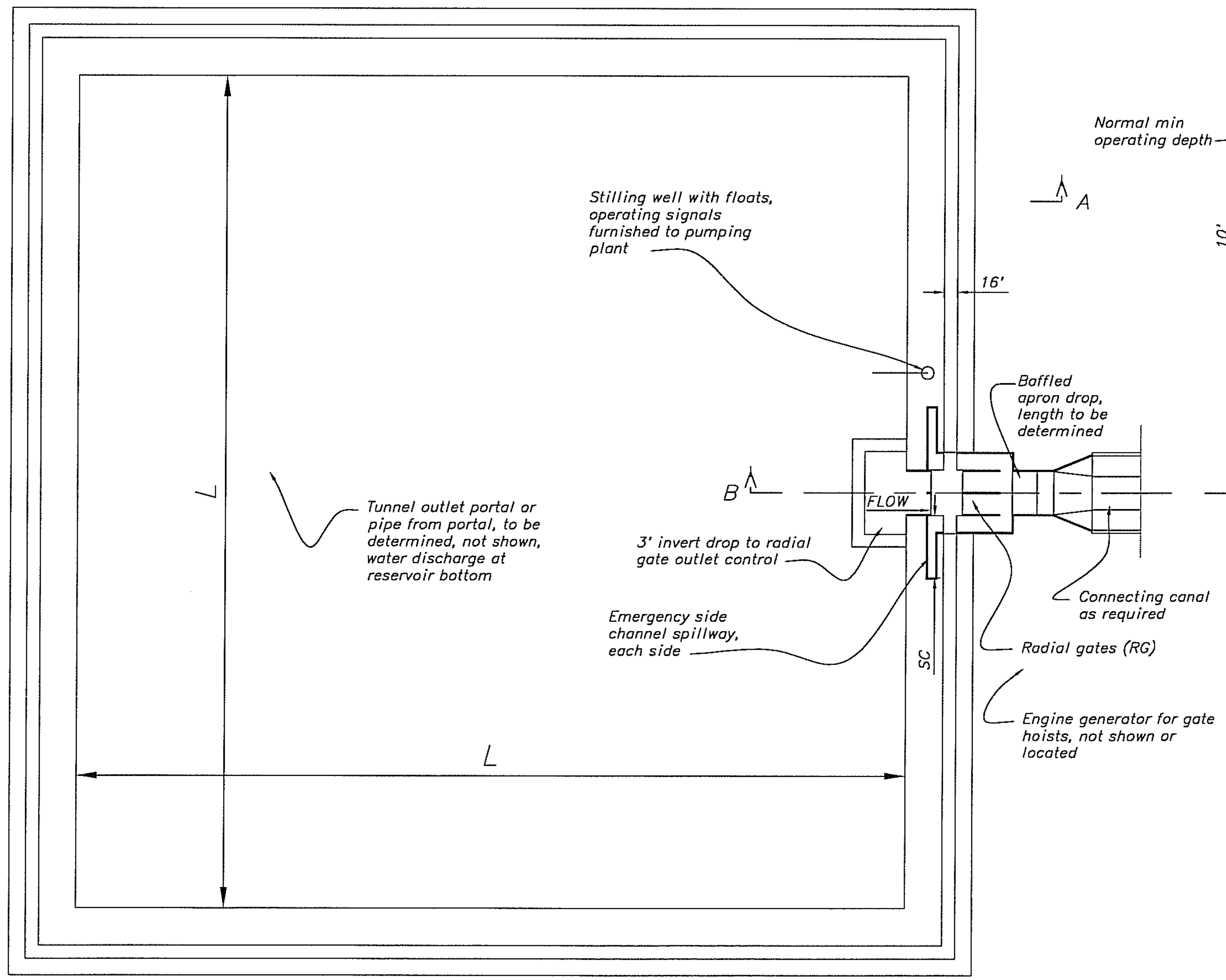

Wanapum to KRD - Opt 3
15.5 mile Tunnel D = 13', Shaft D = 22'
Tunnel to outlet using KRD canal system, Q = 1000 cfs
Hydraulic transient results - Pump Shutdown
Elevations
Tunnel Stations, feet
Ground
Ground
Ground
Ground
Tunnel Invert
Max HGL
Min HGL
SS HGL
Surge Shaft
Ground
0
500
1000
1500
2000
2500
3000
3500
0
10000
20000
30000
40000
50000
60000
70000
80000
90000

Figure 25

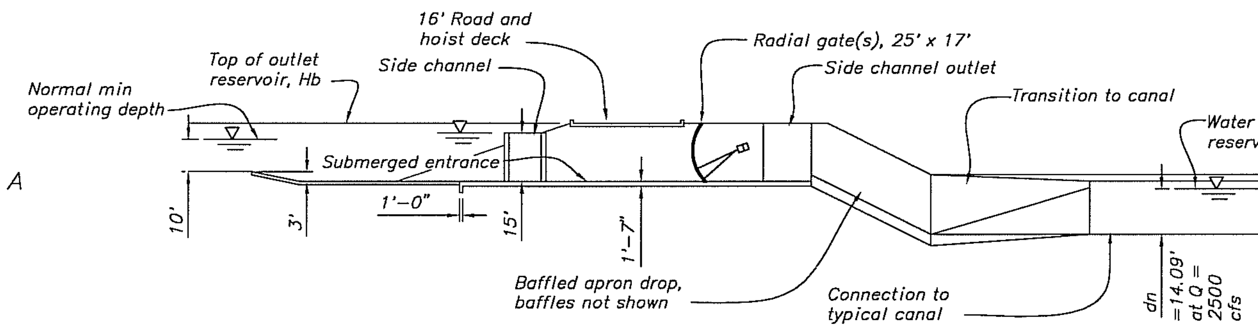


SECTION A–A
TYPICAL OUTLET RESERVOIR
NO SCALE

RESERVOIR VOLUME PROPERTIES		
REQUIREMENT	SYMBOL	DEPTH
Min. operating depth	d–min	10.0
Typical operating depth	d–op	11.0
Operating band	d–band	2.0
Membrane lining height	Hl	12.0
Freeboard depth	Fb	3.0
Bank height	Hb	15.0



TYPICAL OUTLET RESERVOIR PLAN



SECTION B–B

RESERVOIR SIZING AND CONTROL PROPERTIES			
REQUIREMENT	SYMBOL	Options 1 and 2	Option 3
Internal length, ft	L	1900	800
No. of outlet radial gates	RG	2	1
Size of outlet radial gates	RG	25' w x 17' h	25' w x 17' h
Side channel length, ft	SC	75	30
Stilling well with floats	See written description about operations		

NOTES

1. For baffled apron designs, see Reclamation "Design of Small Canal Structures" and Engineering Monograph No. 25 "Hydraulic Design of Stilling Basins and Energy Dissipators."

2. Reservoir floats will control the pumping plant, turning pumps ON or OFF depending upon water surface levels above or below normal operating depth. The operating band assumes ON and OFF floats are set 6" above or below the typical depth.

3. For an analogous study on reservoir and flow control, see the "Kennewick Irrigation District ..... Pump Exchange Feasibility Study" by PN and Yakima Offices, dated October 12, 2004.

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YAKIMA RIVER BASIN WATER STORAGE STUDY

COLUMBIA RIVER WATER EXCHANGE
DIRECT DELIVERY APPRAISAL STUDY
TYPICAL TUNNEL OUTLET RESERVOIRS
PLAN AND SECTION

DESIGNED Jeff Baysinger
REVIEWED BY Todd R. Calhoun, P.E.
Water Conveyance Group

CADD SYSTEM AutoCAD Rel. 16.0s
CADD FILENAME typ canal.DWG
DENVER, COLORADO MAY 2005
SHEET 1 OF 1

Figure 26

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