US Army Corps of Engineers ®
Portland District

90 Percent

Design Documentation Report

The Dalles East Fish Ladder Auxiliary Water Backup System

Columbia River, Oregon-Washington

Prepared by:
U.S. Army Corps of Engineers
Walla Walla District
January 2014

EXECUTIVE SUMMARY

The purpose of The Dalles East Fish Ladder Auxiliary Water Backup System Design Documentation Report (DDR) is to develop a design to provide an emergency backup supply of water to the auxiliary water system (AWS). Water is currently supplied to the AWS by two fish turbine units located on the west end of the powerhouse. If one or both fish turbine units fail, water supplied to the AWS would be severely limited or eliminated. The AWS supplies water to the east, west, and south fish ladder entrances in order to attract upstream migrating adult fish. An alternative to provide a backup supply of water to the AWS in case both fish turbine units fail is evaluated in this DDR as a reasonable temporary (maximum 1 year) means of passing fish upstream of The Dalles Project when the design AWS flow is not available.

The alternative evaluated in this DDR provides a flow of 1,400 cubic feet per second (cfs). With a discharge of 1,400 cfs, the west and south fish entrances are closed and two of the three weirs at the east fish ladder (EFL) will be operational. This emergency operating condition was developed by the U.S. Army Corps of Engineers (USACE) and regional fishery agencies. The fish passage system will be operational, but under less than ideal flow conditions.

Based on the engineering analysis for this DDR, evaluation criteria for this project, and USACE team input, a single 10-foot-diameter conduit will convey the entire design discharge by routing flow through Monolith 5 into the auxiliary water supply chamber (AWSC). Flow bifurcates and is released into the existing AWSC via two 7.5-foot-diameter diffuser conduits. The recommended alternative reduces the required volume of concrete borings and associated setups compared to the proposed EDR alternative. The recommended design also utilizes a buried conduit to eliminate structural supports while providing simplified thrust restraint and reduced impact to project access. The design eliminates the need for energy dissipation valves, reducing operational complexity and improving serviceability. The design also incorporates two multi-ported 7.5-foot-diameter conduits within the AWSC to improve flow conveyance and energy dissipation. The design also eliminates the cost to alter the fish lock valve room and fish lock approach channel.

Two options for dewatering the face of the monolith were evaluated. Option 1 is to dewater with a contractor designed cofferdam. Option 2 is to dewater by installing precast piers with bulkheads. Option 1 was chosen because of lower cost, reduced risk from less dive time, and better quality control expected by dewatering prior to installation of the trash rack guides.

The construction cost with contingency for this design, based on the Option 1 dewatering approach, is estimated to be approximately $11,037,000. The total fully funded project cost is currently estimated to be approximately $14,531,000.

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PERTINENT PROJECT DATA

PERTINENT PROJECT DATA THE DALLES LOCK AND DAM - LAKE CELILO		
GENERAL		
Location	Columbia River, Oregon and Washington, River Mile 192	
Drainage area	Square miles	237,000
RESERVOIR – LAKE CELILO (elevations referenced to 1929 datum 1947 adjustment)		
Normal minimum pool elevation	Feet, msl	155
Normal maximum pool elevation	Feet, msl	160
Maximum pool elevation (PMF regulated, 2009)	Feet, msl	178.4
Minimum tailwater elevation	Feet, msl	76.4
Maximum tailwater elevation (PMF regulated, 2009)	Feet, msl	127.2
Reservoir length (to John Day Dam)	Miles	23.5
Reservoir surface area – normal maximum power pool (EL 160.0)	Acres	9,400
Storage capacity (EL. 160.0)	Acre-feet	332,500
Power drawdown pool (EL. 155)	Acre-feet	53,500
Length of shoreline at full pool (EL. 160.0)	Miles	55
FLOOD CONDITIONS		
Probable maximum flood (unregulated)	- $feet^3/s$	2,660,000
Probable maximum flood (regulated)	- $feet^3/s$	2,060,000
Standard project flood (unregulated)	- $feet^3/s$	1,580,000
Standard project flood (regulated)	- $feet^3/s$	840,000
100-year flood event (regulated)	- $feet^3/s$	680,000
SPILLWAY		
Type	Gate-controlled Gravity Overflow	
Length	Feet	1,447
Elevation of crest	Feet, msl	121
Number of gates		23
Height (apron to spillway deck)	Feet	130
NAVIGATION LOCK		
Type	Single Lift	
Lift – normal	Feet	87.5
Lift – maximum	Feet	90
Net clear length	Feet	650
Net clear width	Feet	86
Normal depth over upper sill	Feet	20
Minimum depth over upstream sill	Feet	15
Minimum depth over downstream sill	Feet	15

PERTINENT PROJECT DATA THE DALLES LOCK AND DAM - LAKE CELILO		
POWER PLANT		
Powerhouse type	Conventional (indoor)	
Powerhouse width	Feet	239
Powerhouse length	Feet	2,089
Number of Main Generating Units		***22***
Installed power capacity	Kilowatts	1,806,800
Peak generating efficiency flow	- $feet^3/s$	260,000
Maximum flow capacity	- $feet^3/s$	320,000
Fishway Units (Not Included Above)		***2***
Installed power capacity	Kilowatts	28,000
Peak generating efficiency flow	- $feet^3/s$	2,500
Maximum flow capacity	- $feet^3/s$	2,500
Station Service Units (Not Included Above)		***2***
Installed power capacity	Kilowatts	6,000
Peak generating efficiency flow	- $feet^3/s$	300
Maximum flow capacity	- $feet^3/s$	300
FISH FACILITIES		
Adult ladders		2
Ladder designations		North and East
North ladder width	Feet	24
East ladder width	Feet	30
Ladder slope (typical)		1v:16h
Ladder elevation change (typical)	Feet	84
NORTHERN WASCO PEOPLE'S UTILITY DISTRICT POWER PLANT (OPERATING AT THE NORTH FISH LADDER AWS)		
Powerhouse type	Conventional (indoor)	
Powerhouse width	Feet	44
Powerhouse length	Feet	48
Intake Structure width	Feet	25
Intake Structure length	Feet	125
Number of Main Generating Units		***1***
Installed power capacity	Kilowatts	5,000
Peak generating efficiency flow	- $feet^3/s$	800
Maximum flow capacity	- $feet^3/s$	800

PREVIOUS STUDIES

The issue of providing backup auxiliary water has been studied from the 1990s in several alternative reports. Below are the six studies conducted to date and the corresponding alternatives evaluated.

1. The Dalles Emergency Fish Attraction Water System Study, U.S. Army Corps of Engineers Hydroelectric Design Center (HDC), September 1991.

The Hydroelectric Design Center developed a conceptual report that generated six alternatives:

1. New Penstock from non overflow monolith to AWS ($8.8M*)
2. Modify fishlock at east end of AWS ($5.94M*).
3. Modify I&T chute to feed into AWS (Not Feas.).
4. ***Modify main unit draft tube (gate in AWS flr.) ($1.78M* Report Rec.).***
5. Modify station service draft tubes, same as No. 4, 1200 cfs only ($0.953M*).
6. Build new fish attraction water pumphouse ($40M*).

* Cost in 1994 dollars from Project Improvements for Endangered Species report.

2. Study of AFA Auxiliary Water Supply, The Dalles Project Improvements for Endangered Species, EBASCO, Bellevue, June 1994.

EBASCO under contract to the COE developed and alternatives report for the Passage Improvement for Endangered Species Program. The report showed a total 15 Alternatives (9 new ones and the 6 from HDC report).

1. New penstock from the eastern non-overflow monolith to AWS ($9.8M*).
2. Modify main unit 5 draft tube (gate in roof) ($2.92M*).
3. Bonneted slide gates in main unit scroll case ($2.72M*).
4. Pump station at the south end of East Fish Ladder ($27.5M*).
5. Screened double chambered conduit hanging on non-overflow monoliths with pipe routed near dewatering facility ($16.4M*).
6. Pump station from the east end cul-de-sac ($37.8M*).
7. New penstock from non-over flow monolith using 6 conduits with modular inclined screens ($23.1M*).
8. New fish turbines at main unit bay 22 ($19.0M*).
9. Replacement of runner on main unit 22 ($5.2M*).

*Cost in 1994 dollars

3. The Dalles Dam Auxiliary Water System Upgrade Alternatives Evaluation, INCA and Associates, September 1997.

INCA and Associates, under contract to the COE developed two alternatives (A and B).

Alternative A – Forebay Intake with Screen Structure

- Gated intake structure in the fish lock monolith with an elevated V-screen dewatering facility downstream of the east non-overflow dam.
- Cost estimate - $47.9 million (updated 2011).
- Discharge 2500 ft^3/sec.

Alternative B – Tailrace Pump Station at East Fishway

- Pumphouse located next to the East Fish Ladder, adjacent to the existing junction pool.
- Cost estimate - $41.6 million (updated 2011).

4. The Dalles Fish Water Units Risk of Failure Analysis, USACE Hydroelectric Design Center, November 21, 2008.

The COE Hydroelectric Design Center developed a report that documents their findings of a risk of failure analysis for the two fish turbine units using a simplified methodology similar to that used as part of a Major Rehabilitation Evaluation Report. The conclusions of the analysis are:

- There is a 25 percent probability that a least one of the two fish turbines will experience a significant failure sometime in the next 10 years.
- The probability of failure of both units failing at the same time is 1.4% within the next ten years.
- Probability of failure can be further reduced by increased periodic inspection and maintenance, but some of the equipment is in excess of 50 years old, the probability of failure will increase in time.
- Outage time can be reduced by having critical (long lead time) components on site as spares.

5. The Dalles East Fish Ladder Auxiliary Water Backup System Letter Report, HDR, Inc. May 4, 2009.

Under contract to the COE, HDR, Inc. developed a Letter Report that evaluated two alternatives and recommended one alternative that involve taking water from a main turbine unit draft tube or scroll case. The draft tube option was recommended. The recommended option also requires:

- 2 Main Units to supply water.
- 2 seasons to construct.
- Cost Estimate – $43.6M =>$27.2M direct + $8.2M KTR profit indirect & OH + $8.2M contingency on direct.

6. The Dalles East Fish Ladder Auxiliary Water System Emergency Operation Backup System Alternatives – Brainstorm Meeting Report, HDR February 3, 2011.

Under contract to the COE, HDR, Inc. developed a report, based on the results of a brainstorming meeting held on December 8, 2010.

- 15 alternative ideas generated as potential sources for makeup water: Siphon to Fish Lock, River Wet Trap, Ice and Trash Sluice Water Tap, Fish Lock Direct Tap to Reservoir, Install Concrete Lid on Open Channel Fishway, Stop Log Modifications at Tainter Gate 23, New Third Fish Turbine, Pipe(s) to AWS Culvert, Remove Flow Restrictions on Current System, Single Pump/Pumphouse on East Side, Upstream Intake Tower with Siphon, Floating Plant Pump Station, Fish Turbine Speed No Load, Ice and Trash Sluice Intake Channel Water Tap and Diversion, Siphon with Entrance at Fish Ladder Exit to AWS Conduit.
- Conceptual level evaluation was conducted. Alternatives were ranked and scored based on criteria developed by the participants of the brainstorm meeting.
- The top three ideas that HDR recommended: Fish Turbine speed-no-load operation; a deep intake siphon that feeds directly into AWS conduit, and a siphon that feeds into the fish lock/elevator caisson.

7. The Dalles East Fish Ladder Auxiliary Water Backup System – Engineering Documentation Report, HDR, December 18, 2012.

Under contract to the COE, HDR, Inc. developed a report, based on the results of an alternatives report developed on February 3, 2011.

- 4 alternatives evaluated: Siphon for Addition Water to the Fishlock, Low Level Intake, Single Cud-de-sac Pump/Pumphouse, Upstream Intake Tower with Siphon.
- 3 improvements evaluated: Valve Room, Fish Lock, and Fishway Approach Channel.
- Preliminary engineering evaluation was conducted. Alternatives and improvements were ranked and scored based by USACE and fisheries agencies.
- HDR recommended: Low Level intake with valve room, fish lock, approach channel.
- Construction cost with contingency $10,800,000. Fully funded project cost without operations and maintenance $16,590,000.

ABBREVIATIONS AND ACRONYMS

ACI	American Concrete Institute
ADCP	acoustic doppler current profile
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
AWC	auxiliary water conduit
AWS	auxiliary water supply
AWSC	auxiliary water supply chamber
AWWA	American Water Works Association
CDF	controlled density fill
cfs	cubic feet per second
CWA	Clean Water Act
DDR	Design Documentation Report
EA	Environmental Assessment
EAWS	Emergency Auxiliary Water Supply
EDR	Engineering Documentation Report
EFL	east fish ladder
EIS	Environmental Impact Statement
EM	Engineering Manual
ER	Engineering Regulation
ESA	Endangered Species Act
FAC	fish lock approach channel
FCC	fish collection channel
fps	feet per second
FFDRWG	Fish Facility Design and Review Work Group
FONSI	Finding of No Significant Impact
fps	feet per second
ft	feet
FTC	fish transportation channel
gpm	gallons per minute
HDR	HDR Engineering, Inc.
HDC	Hydroelectric Design Center
hp	horsepower
HSS	hollow structural sections
ICEA	Insulated Cable Engineers Association
IEEE	Institute of Electrical and Electronic Engineers
IES	Illuminating Engineering Society
ISA	International Society of Automation
IWWW	in-water work window
JBS	juvenile bypass system
kips	kilo pounds

kV	kilovolt
kVA	kilovolt-ampere
kW	kilowatt
MCE	Maximum Credible Earthquake
MDE	Maximum Design Earthquake
msl	mean sea level
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NEPA	National Environmental Policy Act
NETA	InterNational Electrical Testing Association
NFPA	National Fire Protection Association
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NTP	Notice to Proceed
NWP	USACE, Portland District
NWW	USACE, Walla Walla District
O&M	Operations and Maintenance
OBE	Operational Based Earthquake
OSHA	Occupational Safety and Health Administration
PCF	pounds per cubic foot
PGA	peak ground acceleration
PH	phase
psf	pounds per square foot
psi	pounds per square inch
PUD	People's Utility District
RCC	Reservoir Control Center
TSW	top spillway weir
USBR	U.S. Bureau of Reclamation
USFWS	U.S. Fish and Wildlife Service
V	volt
UFC	Unified Facilities Criteria
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

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APPENDIXES

CHAPTER 1 – PURPOSE AND INTRODUCTION

1.1 PURPOSE

Providing backup auxiliary water for the east fish ladder (EFL) is critical to the overall success of adult fish passage at The Dalles Dam.

Auxiliary water supply (AWS) systems provide added flow to fish ladder entrances, improving attraction for adult fish. Maintaining attraction flow at fish ladder entrances is important in the turbulent environment of dam tailraces. Proper attraction flow allows adult salmonids and lamprey to find fish ladder entrances relatively quickly and reduces migration delay.

The Dalles Dam has two turbine units that provide attraction flow to the EFL as a primary water supply; however, no auxiliary water supply backup system exists, despite several AWS backup designs being studied since 1990. The 2008 Biological Opinion (NMFS 2008) states a requirement for the Corps to implement an auxiliary water supply system at The Dalles (RPA 28) as a backup to the fish turbines in case of simultaneous failure of both units. A 2008 risk failure analysis report for the fish turbines confirmed that after more than 50 years in service, the probability of turbine unit failure within 10 years is elevated. Consequently, an increased risk is imposed, with substantial consequences for upriver migrating adult salmonids. Therefore, this project has been further pursued, expanded, and developed from prior design efforts to provide a constructible AWS backup system for The Dalles EFL.

1.2 REFERENCES

a. HDR Engineering, Inc. (HDR). 2009. The Dalles East Fish Ladder Auxiliary Water Backup System. May. Report to U.S. Army Corps of Engineers, Portland District.

b. HDR. 2011. The Dalles East Fish Ladder Auxiliary Water System Emergency Operation Backup System Alternatives – Brainstorm Meeting Report. February. Report to U.S. Army Corps of Engineers, Portland District.

c. HDR. 2012. The Dalles East Fish Ladder Auxiliary Water Backup System Engineering Documentation Report. December. Report to U.S. Army Corps of Engineers, Portland District.

d. National Marine Fisheries Service (NMFS). 2008. Biological opinion – consultation on remand for operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program. National Marine Fisheries Service (NOAA Fisheries) - Northwest Region. Seattle, Washington.

e. Public Law 104-46. 1995. Energy and Water Development Appropriations Act, 1996.

f. U.S. Army Corps of Engineers (USACE). 2008. The Dalles Fish Water Units Risk Failure Analysis. November 2008.

g. USACE. 2008. 2008 Fish Passage Plan. U.S. Army Corps of Engineers, Northwestern Division.

1.3 BACKGROUND

In 2008, the USACE Hydroelectric Design Center (HDC) conducted a risk failure analysis and report on the fish turbine units (USACE 2008). The HDC concluded that there is a 25 percent probability that at least one of the two fish water units will experience a significant failure in the next 10 years. Additionally, the probability of failure of both units at the same time is 1.4 percent in the next 10 years.

Subsequently, HDR Engineering, Inc. (HDR), under contract to USACE, completed a letter report (HDR 2009) that investigated in further detail the concept of utilizing the draft tube of a main turbine unit to provide full flow backup water supply of 5,000 cubic feet per second (cfs) for the AWS. The estimated cost of the recommended alternative from the HDR report was much greater than expected. Due to the high cost and risk of draft tube modifications, this alternative was no longer considered.

Recognizing that providing a full flow backup AWS is cost prohibitive, USACE and representatives from fisheries agencies discussed operational options that would require less flow and still provide good fish passage during an "emergency operation." The group agreed that in the event both fish units failed, the duration of the "emergency operation" is 1 year. It was also agreed that the EFL entrance is the priority, and two of the three entrance weirs will remain operational. The south and west entrances to the EFL will be closed. Considering this east-entrance-only scenario, USACE estimated 1,400 cubic feet per second (cfs) is the minimum required AWS discharge. With 1,400 cfs established as the minimum hydraulic AWS needs, it was recommended that a brainstorming session be conducted to identify potential backup AWS system alternatives.

In late 2010, USACE contracted with HDR to facilitate a brainstorming meeting (HDR 2011) to help identify other sources of water that focused on a collective set of processes to pull water from various sources and volumes, in concert with perhaps a smaller, cost effective alternative feature that could help meet the hydraulic need for the "emergency operation."

A Fish Facility Design Review Work Group (FFDRWG) meeting with regional fisheries agencies and tribes was held in May 2011, with the goal to discuss the brainstorm report and to decide which alternatives from the report should be considered in an Engineering Documentation Report (EDR). It was agreed that several be kept for further investigation. Each alternative was considered to be a stand-alone feature.

USACE contracted with HDR to produce an EDR to further develop the chosen alternatives to provide backup AWS (HDR 2012). The preferred alternative selected from the EDR is Alternative #2 – Low Level Intake.

1.4 CHANGES SINCE EDR

The following changes have been made to the proposed layout of the East Fish Ladder Auxiliary Water Backup System since completion of the EDR (HDR 2012).

- Single Intake – The DDR design reduces the number of forebay intakes from four to one. The EDR utilized a configuration encompassing (2) 6-foot-diameter borings and the use of the two fish lock supply intakes. The reduction of intakes maintains the required discharge capacity while reducing the cost of the project by reducing the size of the forebay intake structure and the volume of monolith boring. The proposed configuration eliminates the use of the fish lock intakes located higher in the water column near to the adult fish ladder exit. Eliminating the need for the fish lock intakes should reduce exposure to adult and juvenile salmonid.

- Vertical Trash Rack – The horizontal trash rack configuration and assumed construction technique identified in the EDR precluded the usage of a cofferdam during construction. Modifying the orientation of the trash rack to a vertical alignment reaching above the water surface reduces the footprint of the intake structure, allowing for increased construction flexibility. The vertical alignment also simplifies the design and operation by reducing overall width of the rack and associated rake and allows for the removal of the trash rack without the need for divers.

- Single Emergency Bulkhead – The DDR design replaced the dual bulkhead EDR design with a single emergency bulkhead capable of closure under flow. This modification reduced forebay structure and material, resulting in lower project costs. A single butterfly valve was placed downstream to maintain closure redundancy. The addition of the butterfly valve also allows for swift pushbutton on/off operation by a single individual after initial water-up.

- Pipe Alignment – The DDR design lowers the vertical alignment, allowing for simplified structural support and thrust restraint as compared to the EDR alternative. The DDR alignment also reduces long-term impact on project parking and tailrace deck access.

- Orifice Plates – The DDR replaces the sleeve valves proposed in the EDR with large-diameter orifice plates. The orifice plates provide the same discharge and energy dissipation requirement while simplifying operation and reducing maintenance. Modification also eliminates potential for debris plugging the smaller ports of a sleeve valve.

- Direct Supply – The conveyance system described in the EDR was unable to provide the required design discharge for the given AWSC water surface elevations. The DDR design splits the 10-foot-diameter pipe into two 7.5-foot-diameter pipes. These pipes bridge themselves over the fish ladder junction pool and through the side of the AWSC. Once inside, the pipes turn downward and anchor to the AWSC floor. The ends of the pipes are multi-ported outlets designed to increase energy dissipation, while also aimed to reduce potential damage to structures within the AWSC. Directly supplying flow to the AWSC eliminated the need to modify the fish lock or the approach channel, while increasing conveyance capacity to the design discharge levels.

1.5 SCOPE

The scope of this Design Documentation Report (DDR) involves developing a detailed design of a variation of Alternative #2 – Low Level Intake concept, as described in the EDR. This DDR will include hydraulic, structural, mechanical, electrical, geotechnical, biological, environmental, cost engineering, constructability, and operations and maintenance considerations. Engineering and analysis will be sufficient to develop a complete project schedule and cost estimate with reasonable contingency factors. Reports will be written at 30 percent, 60 percent, 90 percent, and final 100 percent design levels. The report will contain text, photos, charts, diagrams, calculations, assumptions, costs, discussion of constructability and drawings as required fully documenting the design and basis for decisions. USACE Portland District (NWP) and agency review comments will be provided throughout the development for Walla Walla District (NWW) consideration and inclusion, as appropriate. Site visits to the project will be necessary.

1.6 AUTHORIZATION

The 1995 Energy and Water Development Appropriations Act (Public Law 104-46) directed USACE to use additional appropriations to evaluate the effectiveness and efficiency of the bypass systems, reduce mortality by predators, and enhance passage conditions.

1.7 EXISTING FISHWAY FACILITIES

1.7.1 East Fish Ladder

The adult fish passage facilities at The Dalles Dam consist of the north fish ladder and the EFL. This report focuses on the EFL. Attraction and transportation flow for the south, west, and east entrances of the EFL is provided by two fish turbine units (F1 and F2) located on the west end of the powerhouse. Water discharged (5,000 cfs) from the fish turbines enters the auxiliary water conduit (AWC) and is released into the system through diffusers. Water enters the EFL at the junction pool in the east entrance where flow also enters from lower ladder diffusers, the south and west entrances, and transportation channel after passing through diffusers. It can enter the collection channel, but these diffusers were closed because fish entrances along the collection channel are not currently operational. Fish enter the south and west fish ladders and travel through the transportation and collection channels, respectively, to the EFL (see figures 1-1, 1-2, and 1-3).

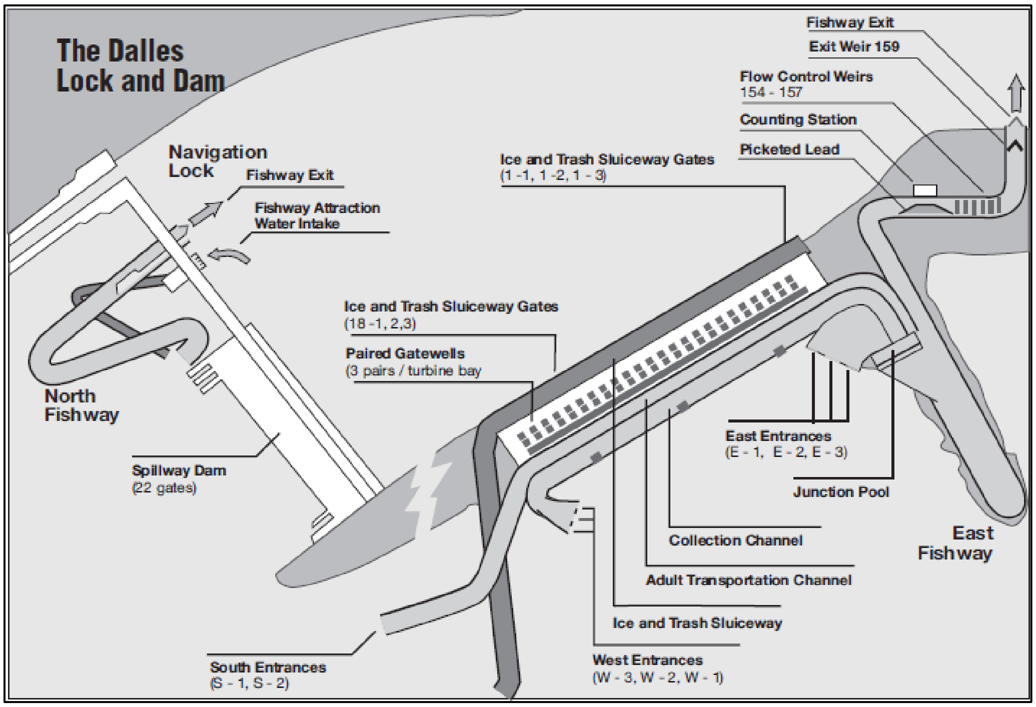

Figure 1-1. The Dalles Dam Fish Ladder System (USACE 2008)

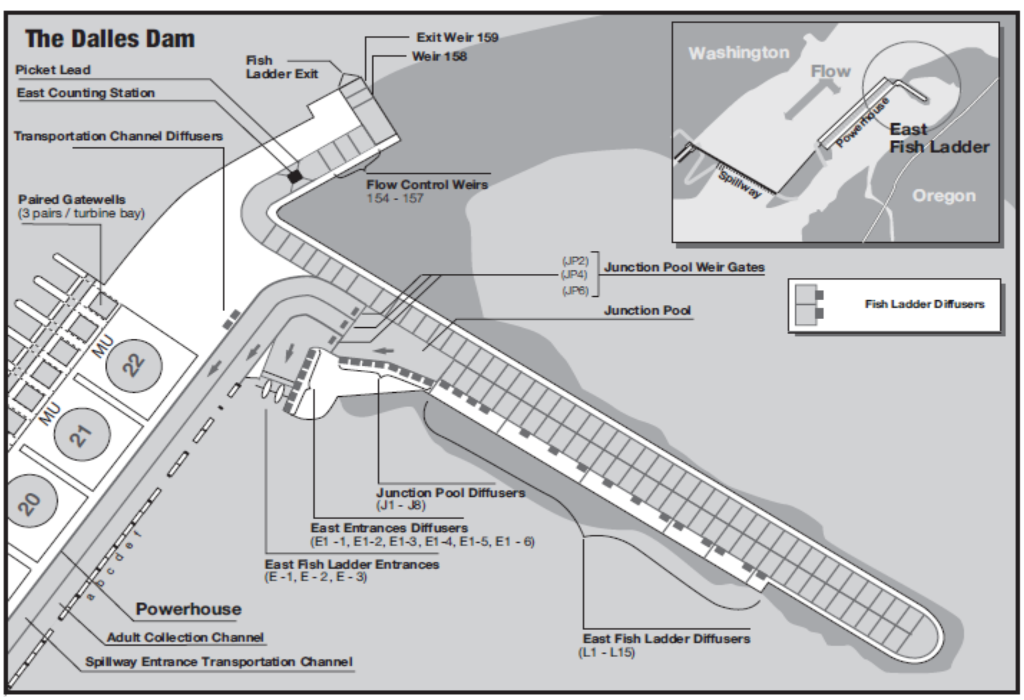

Figure 1-2. The Dalles Dam East Fish Ladder (USACE 2008)

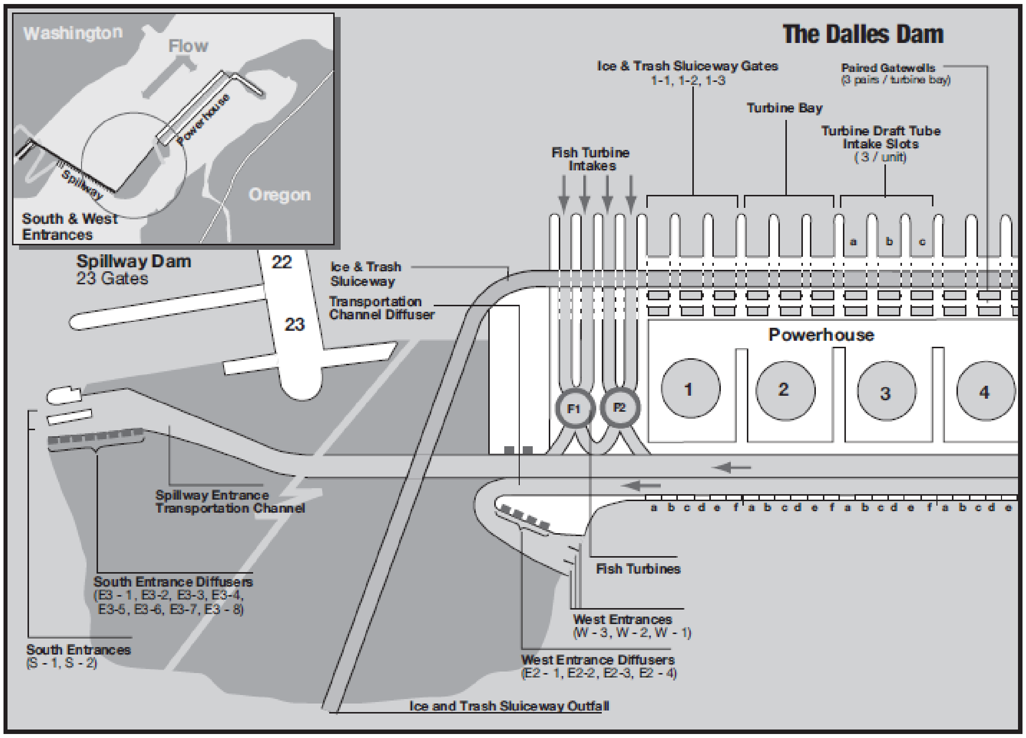

Figure 1-3. The Dalles Dam West and South Fish Ladders (USACE 2008)

1.7.2 Fish Turbine Units

The two fish turbine units, F1 and F2, are located at the west end of the powerhouse. The turbine units have a combined power capacity of 28,000 kilowatts (kW) and a maximum flow capacity of 2,500 cfs each. Water (5,000 cfs) is discharged from the fish turbine units into the AWC. Trash racks with 1-inch spacing are installed in the fish turbine unit intakes.

1.7.3 Auxiliary Water System

As shown on figures 1-1, 1-2, and 1-3, the AWS consists of an AWC, a fish transport channel, fish collection channel, junction pool, weir gates, and a series of diffusers along the AWC that convey water to the junction pool and lower ladder diffusers. Water is supplied to the AWC from the two fish turbine units. This system is complex to operate, but is an integral part of the overall operation of the EFL system. Based on a numerical model provided by USACE, CENWP-EC-HD, the hydraulic head within the AWS conduit near the east entrance is approximately 5 feet greater than the pool elevation. This is consistent with a rough estimate based on the field data differentials to tailwater obtained at similar ladders (John Day, Little Goose, and Lower Granite). The hydraulic head is important for maintaining appropriate flow through diffusers and attraction flow to the east entrance of the EFL at The Dalles. The original model was developed by Northwest Hydraulics, Inc. for USACE.

Prior to flowing through the EFL entrance into the tailrace, water is sent through a series of diffusers in the junction pool and lower ladder. The junction pool provides water to the fish transportation channel (FTC), which supplies the south fish entrance, and the fish collection channel (FCC), which supplies the west fish entrance. The AWS normally operates with a total flow of up to 5,000 cfs, but should be able to be operated in a temporary emergency capacity with a minimum discharge of 1,400 cfs with the south and west entrances closed.

1.8 AGENCY COORDINATION

This report was fully coordinated with the regional fisheries agencies and tribes through FFDRWG.

CHAPTER 2 – BIOLOGICAL DESIGN CONSIDERATIONS AND CRITERIA

2.1 GENERAL

The Dalles Dam has two primary fish ladders referred to as the north and east fish ladders. The east fish ladder (EFL) has east, south, and west entrances for upstream migrating fish. The east entrance leads directly to the EFL. The south and west entrances direct fish into channels that pass along the downstream side of the powerhouse and join the EFL upstream of the east entrance at a junction pool.

Anadromous salmonid and lamprey passage criteria are described in this section, as these are the primary taxa of concern with respect to operation of the EFL. The primary source of general criteria for adult and juvenile salmon passage is taken from the *Anadromous Salmonid Passage Facility Design* Report (NMFS 2011). Passage criteria specific to the EFL is provided in the 2013 *Fish Passage Plan* (USACE 2013). Lamprey criteria are under development by the scientific community concerned about lamprey passage.

Species of fish migrating past The Dalles Dam include Chinook (*Oncorhynchus tshawytscha*), Coho (*O. kisutch*), and sockeye (*O. nerka*) salmon, steelhead (*O. mykiss*), Pacific lamprey (*Entosphenus tridentatus*), white sturgeon (*Acipenser transmontanus*), and American shad (*Alosa sapidissima*). Bull trout (*Salvelinus confluentus*) have also been observed occasionally in the fish ladders. Upstream migrants are present at the dam year-round, whereas downstream migrating juvenile salmonids and shad are present primarily from April through November. No information has been collected to verify this, but it is likely that downstream migrating ammocoetes and juvenile Pacific lamprey are present during the winter.

2.2 REFERENCES

a. BioAnalysts Inc. 2000. A Status of Pacific Lamprey in the Mid-Columbia: Rocky Reach Hydroelectric Project. Final Report to the Public Utility District No. 1 of Chelan County, Wenatchee, WA.

b. Burke, B. J., K .E. Frick, M. L. Moser, T. J. Bohn, and T. C. Bjornn. 2005. Adult fall Chinook salmon passage through fishways at lower Columbia River dams in 1998, 2000, and 2001. Report to U.S. Army Corps of Engineers, Portland District.

c. Cash, K. M., D. M. Faber, T. W. Hatton, E. C. Jones, R. J. Magie, N. M. Swyers, R. K. Burns, M. D. Sholtis, S. A. Zimmerman, J. S. Huges, T. L. Gilbride, N. S. Adams, and D. W. Rondorf. 2005. Three-dimensional behavior and passage of juvenile salmonids at The Dalles Dam, 2004. Report of the US Geological Survey and Pacific Northwest National Laboratory to the US Army Corps of Engineers, Portland, Oregon.

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2.3 ADULT PASSAGE PERIOD

Upstream migrating adult salmonids are present at The Dalles Dam throughout the year and adult passage facilities are operated year-round. Adult salmon, steelhead, lamprey, and shad are normally counted from April 1 through October 31. Counts are visual, and occur from 0500 to 2100 Pacific Daylight Time. Peak numbers of upstream migrating salmon and steelhead occur from April through October (figure 2-1). Adult Pacific lamprey also migrate past The Dalles Dam. Counts have ranged from almost 29,000 to fewer than 2,000 since 2002, with numbers generally decreasing in recent years. Count data can only serve as a relative index of adult passage because most adult lamprey pass at night when counting is not conducted, and numerous routes are available for lamprey to pass dams without being detected (Moser and Close 2003; Robinson and Bayer 2005). River discharge and temperature play important roles in migration timing, but in most years, passage occurs primarily between late June and early September (table 2-1).

Although numbers are far less than those of adult salmon or Pacific lamprey, limited upstream movement of white sturgeon occurs at The Dalles Dam. Upstream passage is generally highest during July and August. Sturgeon almost exclusively use the EFL for upstream passage (Parsley et al. 2007), although they may reside for periods of time in both the east and north fish ladders.

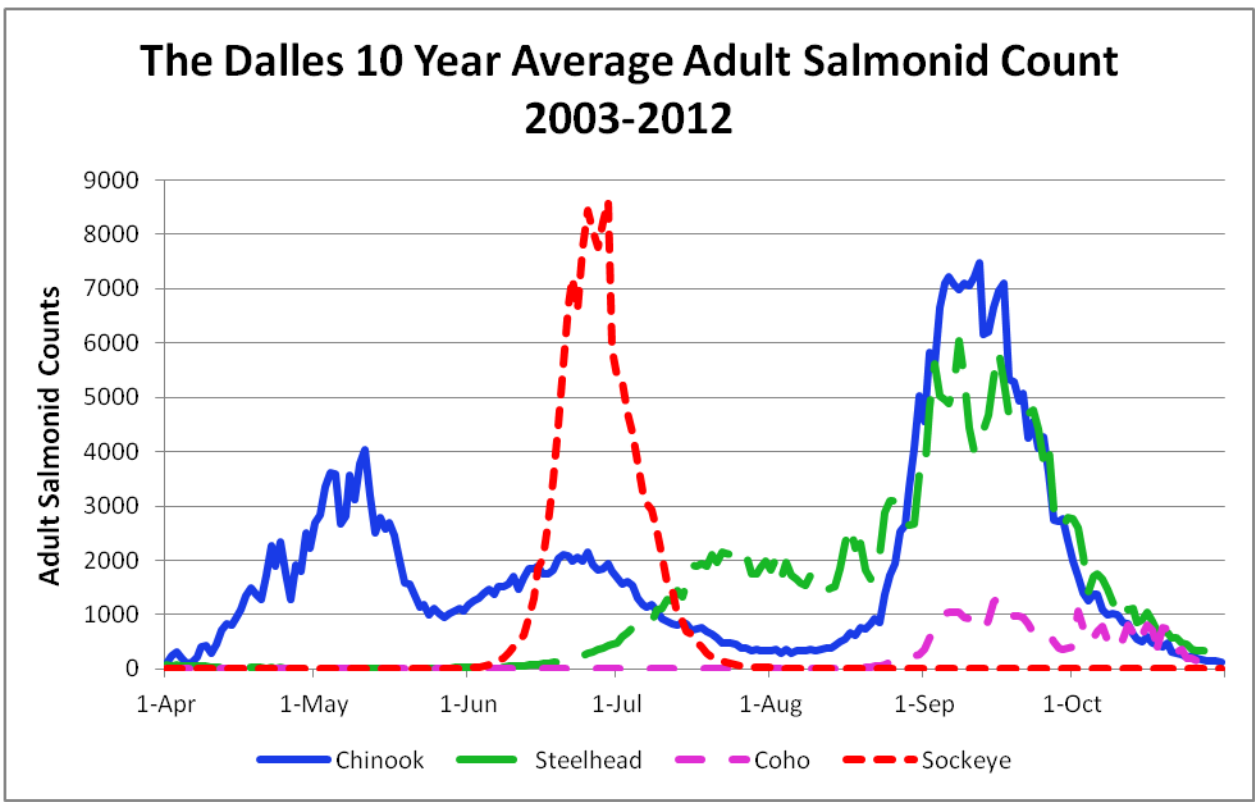

Figure 2-1. 10-Year Average (2003-2012) of Adult Migrating Salmonids at The Dalles Dam (Data Access in Real Time [DART] 2013)

2.4 ADULT SALMONID PASSAGE CRITERIA

The auxiliary water supply (AWS) backup system considered in this report allows for operation of the EFL in the event that the two fish turbine units are not operational. Per consultation with regional fish managers, the backup system considered will provide a design flow of at least 1,400 cubic feet per second (cfs), the discharge required to meet adult fish passage criteria for the east entrances of the EFL (HDR 2012, Appendix A). In the event of a double outage of the fish turbine units, the west and south entrances will be closed and the proposed backup system operated. USACE and regional fish managers have previously developed an emergency operation plan in the event of the loss of a *single* fish turbine unit (USACE 2013). The backup systems and proposed operations considered in this report are *not* intended to supplant the emergency operation plan for the loss of a single unit.

Table 2-1. Adult Pacific Lamprey Migration Dates for The Dalles Dam

Year	Cumulative Percent Passage		
	10%	50%	90%
2002	4-Jul	29-Jul	3-Sep
2003	3-Jul	23-Jul	27-Aug
2004	26-Jun	15-Jul	26-Aug
2005	26-Jun	12-Jul	12-Aug
2006	30-Jun	23-Jul	29-Aug
2007	8-Jul	17-Jul	15-Aug
2008	4-Jul	26-Jul	24-Aug
2009	23-Jun	19-Jul	21-Aug
2010	4-Jul	25-Jul	31-Aug
2011	19-Jul	8-Aug	3-Sep

2.4.1 Fish Passage Plan Criteria for Adult Fishways at The Dalles Dam

The adult fishway criteria discussed below should assume operation of the east entrances of the EFL only (in addition to normal operation of the north fish ladder). Per the 2013 *Fish Passage Plan* (USACE 2013), relevant criteria include:

- Depth over fish ladder weirs: 1.0 foot (± 0.1 foot). During the shad passage season (> 5,000 shad/count station/day at Bonneville Dam): 1.3 feet (± 0.1 foot). The 2013 *Fish Passage Plan* includes exceptions to these criteria:
    - East powerhouse entrance (east entrances): Operate entrance weirs E2 and E3 to maintain gate crest > 8 feet below tailwater, currently operated at 13 feet below tailwater. Weir E1 is to be closed at 81 feet mean sea level (msl), but will remain operational. At lower range of tailwater elevation, weir E1 may be operated manually at any depth to meet entrance differential criteria.

  - o Operate EFL junction pool weir JP6 at the following minimum depths in relation to east entrances tailwater surface elevation: > 7 feet.

- Head on all entrances: 1 to 2 feet (1.5 feet optimum).

- Entrance weir depths: 8 feet or greater below tailwater. Maintain tailwater elevation greater than 70 feet msl to remain in entrance weir criteria operating range, which is regulated by the Reservoir Control Center (RCC).

- Velocity: A water velocity of 1.5 to 4 feet per second (fps) (2 fps optimum) shall be maintained for the full length of the powerhouse collection channel and lower ends of the fish ladders that are below the tailwater. ***Note:*** *For the purposes of this report, it is assumed that these criteria will not apply to the powerhouse collection channel, as the west and south entrances will be closed. The water velocity criteria here will only apply to the lower ladder/junction pool area immediately upstream of the east entrances.*

- Diffuser velocities: AWS diffuser velocity must be < 1.0 fps for vertical diffusers and < 0.5 fps for horizontal diffusers, based on total diffuser panel area. Diffuser velocities should be nearly uniform. Energy dissipation on the upstream side of the diffuser screens will be provided, if needed, to meet this criterion.

- Debris removal: Remove debris as required to maintain head below 0.5 feet on attraction water intakes and trash racks at all ladder exits. Debris shall be removed when significant amounts accumulate.

Discharge from the two operating fish units will be adjusted to maintain criteria at all associated fishway entrances. Discharge volume will be dependent on criteria levels at entrances. ***Note:*** *The AWS system design in this report should provide discharge volume sufficient to maintain entrance criteria at the east entrances only.*

2.4.2 Adult Salmonid Passage Facility Design Criteria

Relevant criteria specified in the *Anadromous Salmonid Passage Facility Design* report (NMFS 2011) that is not already specified above from the 2013 *Fish Passage Plan*:

<u>AWS Diffusers</u>

- Velocity and orientation: The maximum AWS diffuser velocity must be < 1.0 fps for vertical diffusers and 0.5 fps for horizontal diffusers, based on total diffuser panel area. Vertical diffusers should only be used in appropriate orientation to assist in guiding fish within the fishway. Diffuser velocities should be nearly uniform.

- Debris removal: The AWS design must include access for debris for each diffuser, unless the AWS intake is equipped with a juvenile fish screen, as described in Section 11 (NMFS 2011) or if required by Section 4.3.4 (NMFS 2011).

- Edges: All flat bar diffuser edges and surfaces exposed to fish shall be rounded or grounded smooth to the touch, with all edges aligning in a single smooth plane to reduce potential for contact injury.

<u>AWS Fine Trash Racks</u>

As defined by NMFS (2011), a fine trash rack must be provided at the AWS intake with clear space between the vertical flat bars of 7/8 inch or less, and the maximum velocity shall not exceed 1 fps, as calculated by the maximum flow divided by the entire fine trash rack area. The support structure for the fine trash rack must not interfere with cleaning requirements and must provide access for debris raking and removal. Fine trash racks must be installed at a 1:5 (horizontal:vertical) slope (or flatter) for ease of cleaning.

The new AWS system design will include a new fine trash rack with grating criteria of 0.75 inch clear opening to prevent debris from accumulating in the AWS diffuser system and exclude lamprey from the AWS.

- Gages: Staff gages must be installed to indicate head differential across the AWS fine trash rack, and must be located to facilitate observation and in-season cleaning. Head difference across the AWS intake must not exceed 0.3 feet. ***Note**: Due to the potential depth of the AWS intake design, the staff gage criterion may have to be reconsidered or changed, in consultation with regional fish managers.*

- Structural integrity: The AWS intake fine trash racks must be of sufficient structural integrity to avoid permanent deformation associated with maximum occlusion.

<u>Transport Channels</u>

- Dimensions: Transport channels should be a minimum of 5 feet deep.

- Velocity: A water velocity of 1.5 to 4 fps (2 fps optimum) shall be maintained in all channels and at the lower ends of the fish ladder that are below tailwater (already stated as 2013 *Fish Passage Plan* criteria).

<u>Ladder Pools</u>

- Hydraulic drop: The maximum hydraulic drop between fishway pools is 1 foot or less. The maximum hydraulic drop between fishway pools is 1.3 feet during shad season.

- Pool dimensions: Pool dimensions should be a minimum of 5 feet deep.

- Pool volume: The fishway pools shall have a minimum water volume of:

$$V = \frac{\gamma Q i H o}{\left(4 \cdot \frac{ft}{s} \cdot \frac{lbs}{ft^3}\right)}$$

where:
V = Pool volume = depth x width x length (feet^3)
γ = Unit weight of water = 62.4 lbs/feet^3
Qi = Total inflow to pool (cfs)
Ho = Energy head of pool to pool flow (feet)

This pool volume must be provided under all expected design flow conditions, with the entire pool having active flow and contributing to energy dissipation.

2.5 ADULT PACIFIC LAMPREY CRITERIA

Most passage criteria developed for adult Pacific lamprey are not directly relevant to development of AWS backup system alternatives, as they generally address structural design (shape) of fish ladder features, such as overflow weirs. For the purposes of this report, it is assumed that maintaining the adult fish passage criteria described in the 2013 *Fish Passage Plan* (USACE 2013) and by NMFS (2011) will provide the hydraulic targets for the EFL in the event of the loss of both fish turbine units.

The primary concern relative to adult Pacific lamprey is infiltration of AWS backup system intakes, particularly those that are in close proximity to entrances (tailwater) or exits (forebay) of the EFL. Clear openings on AWS backup system intake trash racks shall be no greater than 0.75 inch clear opening to prevent lamprey infiltration.

2.5.1 Anadromous Fish Passage Structure Materials

Materials to be used for the construction of the AWS will be nontoxic stainless and carbon steel and should have no negative effect on adult salmonid and lamprey attraction and passage. A protective coating may be applied to the inside of the AWS conduit between the intake structure and the EFL auxiliary water supply diffuser chamber to prevent corrosion or rusting while dewatered for extended periods of time. The coating will be a material such as the powder coating used on the Bonneville Powerhouse II lamprey flume entrance and is not expected to cause avoidance behavior due to olfactory cues in adult fish; hence, no impact to the EFL adult fish entrance efficiency is expected during operation of the AWS.

2.6 DESIGN IMPLICATIONS FOR ADULT FISH PASSAGE

It is imperative that the EFL have the appropriate attraction flow and entrance depth to effectively attract adult salmonids and lamprey. The AWS design specifications will be appropriate to provide the necessary EFL entrance conditions to eliminate delay and encourage adult salmonids and lamprey to enter. While the EFL AWS design is a fairly benign passage structure for adult fish, any construction project at a dam will have the potential to provide negative impacts on fish passage to some degree.

Adult salmonids migrating upriver and exiting the fishways of dams will occasionally pass back downstream via one of many potential routes, an event referred to as fallback. When exiting fishways and confronting the impounded water of a dam forebay, migrants may be attracted to water passing through spillways, sluiceways, and turbine intakes or may orient with the upstream face of the dam and enter these areas of downstream flow. Fallback rates at The Dalles Dam for adult salmonids have been higher than rates at other mainstem dams (Burke et al. 2005); however, fallback was lower for fish using the EFL (1.1 percent to 1.4 percent) than for those using the north fish ladder (1.8 percent to 5.0 percent). Similarly, fallback of adult Pacific lamprey was lower for those using the EFL (2.6 percent) than the north fish ladder (11.8 percent) (Claybough et al. 2011).

The design elevation and location of this AWS intake is sufficiently low in the water column with velocities low enough to minimize the potential for adult salmonid and lamprey attraction to the structure. Adult salmonids are more likely to remain surface and shoreline oriented as they move away from the fishway exit. Adult lamprey are at a slightly greater risk of interaction with the AWS intake because these fish tend to migrate deeper in the water column than salmonids. While adult fish interactions with the AWS intake structure are likely to be minimal, the entrainment and fallback of adult fish is not possible with this design. Fine trash rack spacing criteria will exclude adult salmonids and lamprey from physically entering the AWS intake. During tests at Bonneville Dam, no adult lamprey were able to pass through grating with ¾-inch spacing (Moser et al. 2007). Adult Pacific lamprey can achieve short-term burst speeds exceeding 12 fps (Moser et al. 2002); therefore, impingement on trash racks is not a concern.

While the potential risks imposed by the AWS intake design are greatest relative to adult salmonid passage delay and fallback, the water delivery from the intake into the diffuser chamber also provides a minor possibility of reducing adult passage efficiency through the EFL. Two 7.5-foot-diameter pipes will extend over the EFL just downstream of the fish lock approach channel, where they will terminate in the auxiliary water supply diffuser chamber. Shading is certain at times of the day as a result of these pipes being installed; however, the potential for this shading to cause delays or other behavioral reactions that may interfere with adult passage is unlikely.

Taking the possibility of adult attraction to the intake structure in the forebay into consideration, the possibility of a minor migration delay is offset by the benefit of having a reliable AWS. This AWS may be operating within hours in the event of the failure of both fish turbine units that currently supplement the EFL AWS entrance. Being operational in such short order will greatly reduce passage delay and ensure that adults will be attracted to the EFL entrance. Overall, the combination of sufficient fishway depth, entrance velocities, fine trash rack criteria applied to the intake, and the rare occasion that this AWS will be operated suggests that this design will provide a benefit to fish passage.

2.7 JUVENILE PASSAGE PERIOD

Turbine units at The Dalles Dam are not screened. Juvenile fish passage facilities consist of the spillway, the ice and trash sluiceway, and one 6-inch orifice in each gatewell. Gatewell orifices allow flow into the sluiceway, providing a potential means of passing fish from the gatewells into the sluiceway. However, it should be recognized that the 6-inch orifices are no longer being operated as part of the juvenile bypass system and are being closed as time and opportunity permit. When any of the sluiceway gates (located in the forebay side of the sluiceway) are opened, water and juvenile migrants are skimmed from the forebay into the sluiceway and deposited in the tailrace downstream of the dam. Approximately 80 percent of juvenile salmonids pass over the spillway (Johnson et al. 2007). Many others pass through the ice and trash sluiceway, with the remainder passing through turbines.

The primary juvenile salmonid passage period is April through November. Because juvenile monitoring is not performed at The Dalles Dam, refer to table 2-2 for John Day Dam (USACE 2013) and add approximately 1 day to the dates for each species to estimate the juvenile salmonid arrival dates at The Dalles Dam.

Although no sampling is conducted at The Dalles Dam, data from John Day Dam indicate that most juvenile lamprey are collected between early April and late June, with some fish collected into September (Fish Passage Center 2011). Many fish likely pass during winter when counting does not take place.

Table 2-2. Juvenile Salmonid Migration Dates for John Day Dam

Yearling Chinook	10 %	50%	90 %	# of Days
2003	May 03	May 19	Jun 02	31
2004	Apr 28	May 16	May 30	33
2005	Apr 25	May 12	May 22	28
2006	Apr 25	May 11	May 24	30
2007	May 02	May 13	May 25	24
2008	May 04	May 22	Jun 01	29
2009	Apr 27	May 17	Jun 01	36
2010	May 01	May 18	Jun 06	37
2011	May 02	May 17	May 28	27
2012	Apr 27	May 06	May 22	26
MEDIAN	**Apr 29**	**May 16**	**May 29**	**31**
MIN	**Apr 25**	**May 06**	**May 22**	**24**
MAX	**May 04**	**May 22**	**Jun 06**	**46**

Subyearling Chinook*	10 %	50%	90 %	# of Days
2003	Jun 06	Jun 27	Jul 30	55
2004	Jun 14	Jun 28	Jul 23	40
2005	Jun 19	Jul 05	Jul 27	39
2006	Jun 14	Jul 03	Jul 18	35
2007	Jun 25	Jul 08	Jul 17	23
2008	Jun 24	Jul 09	Aug 05	43
2009	Jun 17	Jul 01	Jul 17	31
2010	Jun 14	Jul 01	Jul 20	37
2011	Jun 16	Jul 14	Aug 3	49
2012	Jun 27	Jul 13	Jul 29	33
MEDIAN*	**Jun 16**	**Jun 29**	**Jul 28**	**43**
MIN*	**Jun 06**	**Jun 27**	**Jul 20**	**23**
MAX*	**Jun 27**	**Jul 30**	**Aug 22**	**59**

Unclipped Steelhead	10 %	50%	90 %	# of Days
2003	Apr 30	May 28	Jun 04	36
2004	Apr 30	May 23	Jun 02	34
2005	May 01	May 14	May 24	24
2006	Apr 24	May 13	May 29	36
2007	Apr 29	May 13	May 28	30
2008	May 06	May 21	Jun 01	27
2009	Apr 26	May 11	May 28	33
2010	Apr 27	May 12	Jun 08	43
2011	Apr 25	May 19	May 31	37
2012	Apr 25	May 01	May 19	25
MEDIAN	**Apr 28**	**May 13**	**May 30**	**33**
MIN	**Apr 24**	**May 01**	**May 19**	**24**
MAX	**May 06**	**May 28**	**Jun 08**	**51**

Clipped Steelhead	10 %	50%	90 %	# of Days
2003	May 02	May 29	Jun 04	34
2004	May 07	May 20	May 29	23
2005	May 04	May 19	May 26	23
2006	Apr 28	May 10	May 29	32
2007	May 04	May 12	May 26	23
2008	May 07	May 16	May 30	24
2009	Apr 29	May 10	May 27	29
2010	May 03	May 11	Jun 09	38
2011	Apr 19	May 19	May 30	42
2012	Apr 25	May 03	May 15	21
MEDIAN	**May 02**	**May 14**	**May 29**	**28**
MIN	**Apr 19**	**May 03**	**May 15**	**21**
MAX	**May 07**	**May 29**	**Jun 09**	**44**

Coho	10 %	50%	90 %	# of Days
2003	May 09	May 30	Jun 08	31
2004	May 12	May 27	Jun 12	32
2005	May 05	May 16	Jun 03	30
2006	May 10	May 26	Jun 12	27
2007	May 05	May 16	Jun 04	31
2008	May 11	May 25	Jun 06	27
2009	May 16	May 29	Jun 13	29
2010	May 09	Jun 03	Jun 16	39
2011	May 10	May 23	Jun 06	28
2012	May 06	May 21	Jun 05	31
MEDIAN	**May 09**	**May 25**	**Jun 06**	**30**
MIN	**May 05**	**May 16**	**Jun 03**	**24**
MAX	**May 16**	**Jun 03**	**Jun 16**	**90**

Sockeye (Wild + Hatchery)	10 %	50%	90 %	# of Days
2003	May 10	May 19	Jun 02	24
2004	May 20	Jun 01	Jun 12	24
2005	May 16	May 21	May 31	16
2006	May 07	May 20	May 30	24
2007	May 09	May 25	Jun 07	30
2008	May 22	May 29	Jun 06	16
2009	May 10	May 25	Jun 07	29
2010	May 11	May 29	Jun 09	30
2011	May 10	May 22	Jun 02	24
2012	May 02	May 11	May 25	24
MEDIAN	**May 10**	**May 23**	**Jun 04**	**26**
MIN	**May 02**	**May 11**	**May 25**	**16**
MAX	**May 22**	**Jun 01**	**Jun 12**	**41**

* Subyearling Chinook median, min and max values based on data from 1998-2005. Data from 2006-2012 were not included due to potential bias from missed sample days resulting from the implementation of sampling protocols during periods of high water temperature (Appendix K).

2.7.1 Juvenile Fish Passage Criteria

Although National Oceanic and Atmospheric Administration (NOAA) Fisheries typically requires screening on new intake structures, juvenile fish screening is not required for the *forebay* intake of the AWS as described in this report due to the emergency-use-only nature of the project, the limited duration of operation (up to 1 year), intake depth, and the anticipated construction, operation, and maintenance costs of juvenile fish screening (HDR 2012, Appendix J and Appendix K). The primary concern for juvenile salmon and juvenile lamprey with respect to the AWS backup system design discussed in this report is entrainment at the forebay intake. With this in mind, the fine trash rack criteria as detailed above will likely provide exclusion of juvenile salmonids and lamprey to some degree; however, the assumptions regarding the operation of the AWS are as follows:

- 100 percent mortality is assumed for fish entering the AWS backup system. This is a reasonable assumption given potential velocities and pressures that may be experienced within the system. It is also assumed that the AWS backup system will be operated for up to 1 year, and outmigrating juvenile salmonids and lamprey will be exposed to the backup system for that period.

- Entrainment risk is influenced by a number of factors, including location, design discharge, and depth.

2.7.1.1 Juvenile Salmon and Steelhead

Horizontal Distribution in Forebay

Cash et al. (2005) observed a distinct divergence of juvenile salmonids as they approached The Dalles Dam. Juvenile salmonids approach at approximately mid-river and subsequently segregate – a portion of the fish move toward the powerhouse while the remaining fish move directly toward the spillway. Data on first detections within 328 feet (100 meters) of the dam indicate that acoustic-tagged yearling Chinook salmon and steelhead often approach from the east (upstream) end of the powerhouse, but move along the powerhouse toward the west (downstream) end before passing through turbines and the sluiceway (including F1 and F2). Conversely, subyearling Chinook salmon horizontal passage distribution is typically more evenly distributed across the powerhouse (Johnson et al. 2007, 2011). Overall, having the AWS intake located at the east end of the powerhouse will reduce the likelihood of juvenile salmonid entrainment into the system.

Design Discharge

Relative passage route use by outmigrating juvenile salmonids is influenced by the amount of water passing via various routes. This design will deliver at least 1,400 cfs, which was determined to be appropriate flow to maintain fishway entrance criteria (HDR 2012). This discharge is much less (72 percent less) than the 5,000 cfs supplied to the AWS via F1 and F2, and water velocities at the intake are limited by the fine trash rack at approximately 3.0 fps. Studies of burst swimming performance for juvenile Coho salmon estimated maximum burst speed of approximately 3.5 fps for wild Coho (mean standard length 50.5 mm; Taylor and McPhail 1985). The length of juvenile Coho tested was representative of small run-of-river subyearling Chinook and smaller than run-of-river yearling Chinook and steelhead (Skalski et al. 2013). With this in consideration, juvenile salmonids should experience a very low risk of attraction, entrainment or impingement on the AWS intake.

<u>Forebay Intake Depth</u>

Migration and passage depth varies by species, time of day, location, and structure encountered; however, outmigrating juvenile salmonids generally occupy the upper 20 feet or less of the water column, with more than 80 percent migrating within 30 feet of the water surface at a given time throughout spring and summer (Faber et al. 2005). Approximately 3 percent of outmigrating smolts may be migrating deep enough in the forebay to encounter the top of the AWS intake, and up to 2 percent may be deep enough to approach the intake centerline (Faber et al. 2005). Therefore, locating the intake centerline at approximately 116 feet msl elevation (43 feet deep) will submerge the top of the structure approximately 33.5 feet below low forebay elevation at 155 feet msl. This will reduce the probability of juvenile salmonid entrainment as they approach the powerhouse.

2.7.1.2 Juvenile Pacific Lamprey

<u>Horizontal Distribution in Forebay</u>

The horizontal distribution is unknown for juvenile lamprey. Subyearling Chinook salmon can be used as surrogates for horizontal distribution, because both juvenile Pacific lamprey and subyearling Chinook salmon are relatively weak swimmers compared to larger yearling salmonids.

<u>Design Discharge</u>

Relative passage route use by outmigrating juvenile lamprey is influenced by the amount of water passing via various routes and the water velocities encountered at those routes. This AWS design will deliver at least 1,400 cfs, which was determined to be appropriate flow to maintain fishway entrance criteria (HDR 2012). This discharge is much less (72 percent less) than the 5,000 cfs supplied to the AWS via F1 and F2, and water velocities at the intake are limited by the fine trash rack to approximately 3.0 fps. This is greater than the 2.6 fps mean burst swim speed, but equivalent to the 3.5 fps maximum burst swim speed of juvenile Pacific lamprey (Moursund et al. 2003). An unknown proportion of juvenile lamprey may be attracted to the intake as a potential downstream passage route and face potential risk of entrainment or impingement on the AWS intake; however, the maximum burst swimming speed as reported by Moursund et al. (2003) suggests that juvenile lamprey may resist impingement. With these considerations, the proposed AWS intake should result in a neutral impact on attraction, entrainment, and impingement potential for juvenile lamprey.

<u>Forebay Intake Depth</u>

Migration depth of juvenile lamprey is poorly understood, but studies at various dams found that > 70 percent of juvenile lamprey passed below turbine intake screens of juvenile bypass systems (BioAnalysts Inc. 2000; Moursund et al. 2003; Monk et al. 2004; Moursund and Bleich, 2006). The proposed intake depth of the AWS backup system may increase entrainment risk for juvenile lamprey; however, it is expected that other factors such as design intake trash rack criteria and location will generally neutralize this risk.

2.8 DESIGN IMPLICATIONS FOR JUVENILE FISH PASSAGE

Juvenile salmonids and lamprey encounter The Dalles Dam during their downstream migration; therefore, flow through the intake pipes may result in some entrainment. Although approximately 80 percent of juvenile salmonids pass the dam via the spillway (Johnson et al. 2007), fish approaching the dam near the south shore of the Columbia River first pass along the powerhouse and will therefore be vulnerable to entrainment. However, the proposed intake depth and velocities of the AWS are such that entrainment of juvenile salmonids is not expected. Over 80 percent of all juvenile salmonids should be distributed within approximately 30 feet of the water surface (Faber et al. 2005), which is above the ceiling of the intake pipe, assuming a 10-foot-diameter intake pipe with the top of the structure approximately 33.5 feet deep at minimum operating pool.

Turbine and sluiceway passage of yearling Chinook salmon and steelhead is skewed to the west end of the powerhouse and horizontal distribution is more evenly distributed; therefore, location of the intake at the east end of the powerhouse will reduce risk of entrainment relative to the existing system.

Forebay distribution of outmigrating lamprey is unknown; however, they may distribute similarly to subyearling Chinook salmon, or travel slightly deeper, as some studies suggest (BioAnalysts Inc. 2000; Moursund et al. 2003; Monk et al. 2004; Moursund and Bleich 2006). While juvenile lamprey may migrate deeper, it cannot be assumed that they prefer to migrate at depths below that of the juvenile bypass screens (which are not installed at The Dalles, but discussed for depth perspective). It may be assumed that instinctual lamprey behavior may cue juveniles to dive deeper when entering a turbine intake, potentially to avoid shallow water predators. Due to the unknowns of juvenile lamprey migration, the location of the AWS intake in the water column is not expected to provide a great risk of entrainment. Further, given the AWS fine trash rack criteria and low intake velocity, a low risk of entrainment is expected for juvenile lamprey.

While the AWS design imposes minor risks to juvenile salmonids and lamprey, the risks to juvenile fishes are outweighed by the benefit this system will provide to adult passage. The rare use of the system and potential to eliminate serious delays in adult salmonid migration for a duration that may extend to a year prove that this system design is acceptable for an AWS backup system.

2.8.1 Predation

Structures added to the forebay will be limited to an intake pipe bulkhead and trash rack, which will provide little additional habitat for predators or change in conditions that may provide an advantage to predators. Piers will be constructed for bulkhead slots measuring approximately 5 feet deep from pier nose to the dam face. These piers may provide velocity breaks and concealment on the downstream side of the structure where predators may hold. Once constructed, a shroud of steel or piping will be placed along each pier and in the upper portion of the bulkhead slots to close off and eliminate abrupt contour changes along the structure (see appendix H). The shroud should be placed along either pier extending from the water surface down approximately 25-30 feet to reduce the potential for predators to hold and ambush juveniles as they pass by.

2.9 CONSIDERATIONS FOR WHITE STURGEON

Position and depth of the intake should have a negligible effect on white sturgeon. Adult sturgeon will be precluded from entrainment by the trash racks. Young sturgeon are usually found near the bottom in reservoirs, preferring deep (approximately 30 to 125 feet), low velocity areas (Parsley et al. 1993; Parsley and Beckman 1994). During non-winter months, age-0 and juvenile white sturgeon tend to select areas of moderate to high depth (approximately 68 feet) with steep channel slopes (Hatten and Parsley 2009).

2.10 SUMMARY OF DESIGN IMPLICATIONS FOR FISH PASSAGE

The benefits this AWS will provide for adult passage makes the potential risk to juveniles insignificant. The fine trash rack criteria, intake depth, and low intake velocity will exclude fish from entering the system and eliminate any potential for entrainment or impingement for adults and minimize the potential for juveniles. The AWS bulkhead and trash rack installation in the forebay will also be designed to reduce predator habitat. The rare use of this system and expected minor risk to juvenile passage suggests this design will be acceptable to meet the requirements of the AWS with little impact to ESA listed fish.

2.11 IN-WATER WORK WINDOW

The in-water work window (IWWW) for annual maintenance of fish facilities is scheduled from December 1 through February 28 or 29. Work during this period minimizes impacts on both upstream and downstream migrating salmonids. During the in-water work period, one fish ladder (north or east fish ladder) is always operational. Coordination with Northern Wasco People’s Utility District (PUD) is needed prior to scheduling construction because they conduct routine maintenance each year when the north fish ladder is out of service.

CHAPTER 3 – GEOTECHNICAL DESIGN

3.1 GENERAL

This chapter describes expected subsurface and soil conditions and provides preliminary geotechnical design parameters for The Dalles EFL AWS backup system. The information and recommendations presented in this chapter are based on existing references and a brief field visit. Additional information gained through subsurface exploration and laboratory testing is needed and recommended to confirm assumptions and provide a basis for geotechnical design prior to development of plans and specifications.

3.2 REFERENCES

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3.3 SEISMICITIY

There are several faults mapped at, near, and crossing beneath the dam. Three significant faults have been identified at the site. Displacement on these faults range between 50 to 300 feet. The faults have brecciated the rock, forming weak zones where the river has eroded deep channels. These faults include:

- Three Mile Rapids fault, located immediately downstream of the navigation lock.
- Signal Butte fault, located south of the powerhouse.
- Big Eddy fault, which passes beneath the closure dam.

Additionally, there are several minor faults and shear zones throughout the foundation. Most are low-angle faults with displacements of a few inches and no fault breccia.

Complex uplift, shearing, and faulting are described and discussed in the 2013 Seismic Safety Review, which is 95 percent complete. Ground motions and other design considerations for the site are also presented

3.4 GEOLOGIC CONDITIONS

3.4.1 General Geology

The Dalles Lock and Dam is located at the western edge of the Columbia Basin, in the eastern foothills of the Cascade Mountain Range. Geologic conditions are controlled by Columbia River Basalts, which extend downstream all the way to the Pacific Ocean, and the Missoula Floods, which occurred in the Pleistocene (13,000 to 17,000 years ago). These floods involved hundreds of feet of water, carried a tremendous volume of sediment, and scoured the river channel, leaving channeled scabland topography.

The Columbia River Basalt Group consists of multiple flow-on-flow layers with little or no intervening soil horizons. The basalt at the site includes Grande Ronde and Wanapum basalt groups. The foundation of the dam is constructed on Grande Ronde basalt.

Individual basalt flows range from 60 to 100 feet in thickness. Typically, the uppermost zone of a basalt flow cools and solidifies while the material is still moving. The solidified crystalline rock is fractured and disturbed, creating a layer of breccia. Breccia can also form along the bottom surface of a flow, where contact with the ground accelerates cooling and the solidified material is disturbed by flow. Where the hot interior mass of the flow cools after the flow stops, crystalline microstructure and shrinkage cracking create the easily recognized columnar basalt zones.

Columnar basalts are typically more dense, more erosion resistant, and less permeable than breccias. Where fractures are closed or completely in-filled, basalt can be quite strong. In contrast, breccias typically have disturbed particles with closely spaced fractures, and this reduces strength as well as erosion resistance. Gas bubbles that form as molten rock solidifies create vesicles in the solid rock, and these contribute voids that directly reduce rock mass density and strength. Vessicular basalt and breccia can be hard, resistant bedrock, but this usually involves secondary mineralization or other processes that fill cracks and voids.

3.4.2 Bedrock at the Site

The regulated river hides the scabland topography the dam was built on. In March of 1957, when spill gates were closed, Celilo Falls – 13 miles upstream – was submerged within hours. Almost all of the exposed rock of what was previously called “the Dalles of the Columbia” remains submerged. One of the now submerged but once prominent features of the Dalles was the “Long Narrows,” where a segment of riverbed was constricted to approximately 60 yards in width. The 1882 photos below show the view to the southwest from the upstream mouth of the Long Narrows. Both images look across the modern dam site, approximately three miles distant.

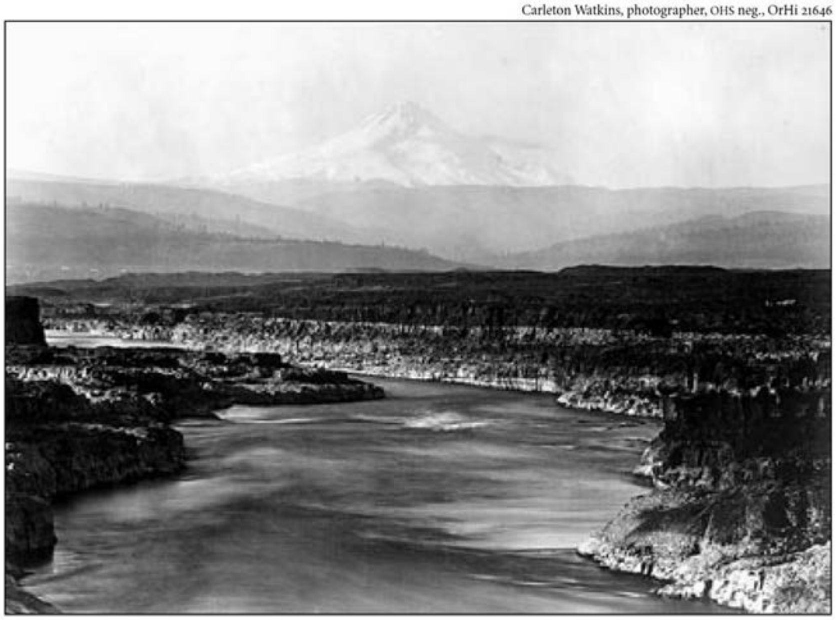
Carleton Watkins, photographer, OHS neg., OrHi 21648

An 1882 photograph by Carlton Watkins, looking west, shows the upstream entrance to the Long Narrows and the flanking "scabland." The Dalles–Celilo Portage Railroad runs through the foreground.

Figure 3-1. 1882 Photo of the Upstream Entrance to the Long Narrows

NOTE: The view is across the dam site. Note the deceptively flat, barren basalt surface that is now submerged. Also note the barely visible Mount Hood 35 miles away on the horizon.

Carleton Watkins, photographer, OHS neg., OrHi 21646



The Columbia River is confined to a gap about sixty yards wide at the entrance to the Long Narrows, shown here in 1882.

Figure 3-2. 1882 Photo Taken on the Bluff above the Upstream Entrance to the Long Narrows

NOTE: The view is across the dam site. Note Mount Hood and buildings in The Dalles in the background.

The dam was built on rugged, eroded basalt of the Grande Ronde formation. The lowland areas now submerged in the forebay were fluted, channeled, and potholed surfaces that formed long anastomosing tracts of scabland separated by islands of softly rounded hills of windblown sand. The "anastomosing tracts" are contiguous areas of the rock surface within a network of incised erosion channels and potholes. It appears that erosion in the river channel cut bedrock to the elevation of a resistant layer in the flow basalt, exposing its relatively flat top surface.

Rare catastrophic flood flows also carved the complex network of channels and scabland topography – and the Long and Short Narrows – by a combination of extreme erosion conditions and zones of variable erosion resistance in the bedrock layers. Exposed breccia and other less resistant materials would have been stripped away. The resulting topography is characterized by the pattern of partially in-filled channels with steep side slopes. It seems likely that in-filled erosion channels were exposed in foundation excavations.

3.5 SOIL CONDITIONS

3.5.1 General

The Missoula Floods created a channeled scabland topography along the river. During receding phases of each flood, scattered irregular deposits of sand, gravels, and boulders were left behind in protected areas.

While zones of cobbles, sandy gravel, and boulders are common – either alluvial or as localized talus – surficial soils are predominantly alluvial and fluvial sands and silty sands. Some of the fine sand deposits are aeolian (windblown). There are also minor amounts of low plasticity sandy materials. Ash fall and other materials deposited prior to catastrophic floods were scoured out.

3.5.2 Riverbed Soils

The irregularly incised river channel still contains boulder, cobble, gravel, and sand deposited as Plestocene floods receded. Generally, these materials would be expected in deeper erosion pits and less active areas along the river. The bed-load materials along the river are expected to be dominated by silty sand with gravel.

3.5.3 Upland Areas

The right bank slopes upward to the north, away from the river, at a net slope on the order of 5 percent. Steeper slopes of 15 percent to 50 percent occur at localized rock outcrops. The steepest areas appear to be along the river. Much of the surface is capped with more than 5 feet of sandy loam and fine to medium sand over the underlying bedrock.

Compared to the right bank, slopes on the left bank are typically steeper, at 5 percent to 25 percent. There are more rock scarps and outcrops, and they are generally more prominent, taller, and steeper, with some vertical rock faces. In general, native soils are less than 5 feet in thickness.

3.5.4 Site Soils

Site soils are fill that varies in depth from 15 to more than 30 feet in depth. The depth to bedrock increases with distance away from the monolith and drops steeply before the alignment extends under the EFL. Based on limited information, the fill is considered sand and gravel with some cobbles. Construction debris, including broken stone waste material as well as wood, metal, and concrete debris could be present, but are not expected.

Excavations for the pipe will extend into the wall backfill zone of the junction pool wall. Only sand and gravel are expected in the wall backfill, but crushed rock could be encountered as well. Boulders and debris are not expected within tens of feet of retaining walls or fish ladder support columns.

Although construction debris and boulders are not expected within the planned excavation area of the 10-foot conduit, additional explorations are needed to confirm soil conditions and depth to bedrock along the pipe alignment.

3.6 ENGINEERING PROPERTIES OF SOIL AND BEDROCK

3.6.1 Overburden Soils (Fill)

Site soils are considered sand and gravel with cobbles placed as fill. Exploration will confirm site soils prior to the development of plans and specifications. Based on surface settlements visible beneath the EFL, 8 to 10 inches of fill compression appears to have occurred. Areas not under the ladder show no similar signs of settlement. This is taken as indication that fill in the paved parking area was well compacted, while fill beneath the ladder is twice as deep and was poorly compacted. Based on granular, non-plastic site soils, the following soil properties are recommended.

Table 3-1. Overburden Soil Parameters

Overburden Soil Parameters				
Property		**Value**	**Units**	
dry unit weight*	γ_d	122	pounds per cubic foot	pcf
friction angle	ϕ	33	degrees	°
cohesion	c	0	pounds per square foot	psf
Equivalent fluid pressure – Active Case		40	pounds per square foot per foot	psf/ft
Equivalent fluid pressure – At Rest Case		60	pounds per square foot per foot	psf/ft
Equivalent fluid pressure – Passive Case		400	pounds per square foot per foot	psf/ft

* In the absence of exploration information, assume a moist unit weight of 130 pcf.

3.6.2 Bedrock Properties

The dam was constructed on basalt bedrock. Results from unconfined compressive strength tests vary from 6,000 to 25,000 psi with an average of 15,000 psi. It is important to recognize that samples selected for compression testing are short segments of intact rock core and are not often representative of the strength of the rock mass. Bedrock in excavations at the site is expected to be hard, resistant basalt. Widely spaced fractures or fully in-filled fractures could result in large blocks of resistant bedrock. Extremely difficult digging conditions could prevail where hard, almost massive rock conditions extend more than 3 feet below the bedrock surface.

Additional explorations are needed to confirm soil and bedrock conditions. It appears that at least one test pit is needed to evaluate use of a hydraulic ram for rock breakup. Consideration should be given to evaluating other attachments for an excavator if they are used locally.

3.7 EXCAVATION CONSIDERATIONS

3.7.1 Overburden Soils

Much of the material excavated for construction of the pipeline will be removed from the site or stockpiled at a designated onsite location. Excavated granular materials may be reused as backfill, provided that it meets requirements. It will be necessary to remove cobbles and boulders more than 9 inches in diameter.

Some crushed rock or processed sand and gravel materials may be encountered in excavations; however, it is expected that volumes will be too low to justify keeping them separate for reuse.

3.7.2 Poorly Compacted Fill

The twin 7.5-foot-diameter pipes extending beneath the fish ladder will be constructed on up to 15 feet of existing fill. Based on surface settlements, fill under the fish ladder was poorly compacted. After 50 years in service, and more than 8 inches of surface subsidence, additional settlements are not expected; however, the pipeline will transition off a thin layer of well compacted fill over bedrock onto more than 12 feet of fill that was poorly compacted. The fill may also be a different material (i.e., wall backfill rather than general fill). During construction, subgrade preparation and compaction prior to fill placement will be critical to confirm that foundation soils provide support and additional settlements are not expected.

With 14 feet of overhead clearance under the fish ladder, borehole explorations using a conventional 22-foot-tall boom would be limited to just outside the edge of the fish ladder. A boring near the side of the fish ladder along the alignment could provide blow-count data to confirm the density of fill that will be beneath the pipe.

3.7.3 Excavated Bedrock

It is anticipated that bedrock materials will be removed from the site.

Blasting would be effective for rock breakup, but will not likely be permitted. Specialized equipment of some kind could potentially be effective for rock breakup and removal. For example, pre-drilling the rock to facilitate breakup could be effective in combination with excavation equipment, or expansive grout could be used to fracture large blocks of bedrock. However, without exploration information, contractors may assume that a large track-mounted hydraulic excavator could be used. Contractors with local experience may bid similarly, though they might expect that bucket teeth fixtures, hydraulic rams, or other attachments would be required to achieve required excavation rates. Based on site geology, the bedrock surface could be resistant enough that use of conventional equipment would yield unsatisfactory excavation rates.

3.8 SUBGRADE PREPARATION

Foundation soils at subgrade elevations are expected to be firm, granular fill materials or hard bedrock that will provide good support.

Required preparation of exposed soil surfaces is limited to surficial compaction. Great care is needed within about 50 feet of the junction pool wall to ensure the deeper fill is dense, well compacted, and will provide good support.

Preparation of bedrock surfaces will involve removal of loose rock and protrusions that intrude within 9 inches of the pipe.

3.9 BEDDING AND BACKFILL

3.9.1 Bedding Material

Imported bedding materials consisting of well graded crushed rock will be needed. A routinely available ¾-inch or ½-inch minus crushed rock product will be suitable. To facilitate compaction of fill below the spring line of the pipe, it will be necessary to overbuild the bedding material and excavate its surface to place the pipe in a trough.

3.9.2 Requirements for Bedding

Bedding should be placed in horizontal lifts to at least 3 feet above the bottom elevation of the pipe. The compacted bedding will then be excavated carefully and fine graded to construct a 5-foot-radius circular trough along the centerline of the bedding material. The 3-foot-deep trough in the bedding avoids the need for compaction effort low on the pipe profile. It also ensures reasonable access for placing backfill along each subsequent fill lift, especially adjacent to the pipe below its spring line, where access is difficult.

Great care will be needed to construct the trough round and at grade, and then place the pipe without disturbance. If pipe segment ends need to be exposed or undermined for weld connections, controlled density fill (CDF) should be used in lieu of bedding. Great care will be needed while placing fluid concrete to ensure it does not cause pipe movement, uplift, or floating.

3.9.3 General Backfill

It is expected that existing granular fill excavated for the pipeline can be reused as general backfill, though it may be necessary to screen the material to remove particles more than 9 inches in diameter.

3.9.4 Surface Pavement Section

The surface pavement section should include a minimum 3-inch thickness of asphalt concrete on a minimum 4-inch thickness of aggregate base material.

The minimum cover requirement for the type of pipe is 15 inches. The current cover depth of 2 feet should be adequate for the anticipated loaded truck traffic. Analysis is needed to confirm the subgrade of the roadway across the top of the pipeline will be stiff enough to limit deflections under traffic loads and provide good pavement service life.

3.10 BURIED UTILITIES

3.10.1 Storm Drains

The existing storm drain system should, to the extent practicable, be reconstructed in its current configuration.

Based on visual observation, it appears the storm drains are up to 6 feet in depth. Prior to developing plans and specifications, the utility survey should be used to confirm that the existing system can be replaced in-kind. It may be necessary to redesign the system, which would change final site grades.

3.10.2 Electrical Power and Control & Indication

Existing electrical and control and indication utilities should be replaced in-kind. It may be necessary to bury utilities crossing over the pipeline in relatively shallow trenches. In this event, conduit should be encased in red-tinted CDF. Splicing could introduce requirements for utility vaults/boxes. If practicable, existing wire and conduit should be routed to minimize the number of vaults/boxes in the roadway.

3.10.3 Gravity Sewer Drains

Plan information indicates that a gravity flow sewer extends across the alignment. If the sewer is not abandoned, it will be necessary to construct a pump station with a grinder and pump sewage over the pipeline. A manhole/drop structure may be needed on the downstream side of the pipeline (or a trench to an existing manhole or cleanout). It will be necessary to design sewer modifications prior to developing plans and specifications. The utility survey will be needed for this effort.

3.10.4 Uplift Drains

It may be prudent to install a drain system in the bedding material of the pipeline. Prior to developing plans and specifications, the potential value of a water collection and drain system should be evaluated. The drain system could discharge through the junction pool wall between the two 7.5-foot-diameter pipes.

3.11 CONSTRUCTION REQUIREMENTS

3.11.1 Fish Ladder Support Columns

Excavations downstream of the wye extend beneath the fish ladder, between successive pairs of concrete columns. If the excavation is not braced to maintain vertical side slopes, portions of the concrete columns will be exposed where side slopes extend away from the trench. The resulting difference in fill height on opposite sides of the columns could create horizontal loads. In the absence of calculations to estimate these loads, the soil surfaces around the columns shall be flat within 5 feet of the columns.

3.11.2 Concrete Monolith Monitoring

Based on visual inspections of the D&G gallery, the face of the monolith, and the pump room walls in the adjacent monolith, concrete of the non-overflow section of the dam is in good condition. These surfaces – especially the ceiling of the D&G gallery – should be indexed and documented with photographs or video before, during, and after the mining for the pipeline.

3.11.3 Fill Placement

All fill shall be placed in loose lifts not exceeding 9 inches in thickness. The materials need to be moisture conditioned to within 3 percent of their optimum moisture content and compacted to 95 percent of their maximum density, per the Modified Proctor Test (ASTM D 1557). Full-time construction monitoring and testing should be required during construction.

Fill placed horizontally within 50 percent of the height of retaining walls shall be compacted to 91-96 percent of its maximum dry density. Great care should be taken to prevent wall displacement or distress due to compaction loads.

3.11.4 Crane Restriction

While the soil cover over the pipeline is adequate for HS-20 truck traffic loads, it is anticipated that outrigger loads for large cranes will cause too much surface deflection and could damage the pipe. The surface within 10 feet of the edges of the pipe should be painted to mark it as a crane exclusion zone.

3.12 EXPLORATION REQUIREMENTS

3.12.1 Drilling

Borehole explorations are needed to confirm the depth to bedrock and confirm the density of fill that will support the pipeline downstream of the wye.

3.12.2 Test Pits

Test pit explorations are needed to identify and evaluate site soils, determine cobble and boulder content, and to evaluate use of a large track-mounted excavator with a hydraulic ram for rock breakup and removal.

CHAPTER 4 – HYDRAULIC DESIGN

4.1 GENERAL

The selected alternative relies on energy dissipation through orifice plates and provides a variable flow of 1,400 to 1,500 cfs of flow, dependant on forebay and tailwater elevation. An intake structure consisting of a trash rack and closure gate on the upstream face of Monolith 5 serves the primary 10-foot-diameter conduit through the dam. After crossing the parking lot, this primary conduit divides into two 7.5-foot-diameter conduits to supply the AWS. Final discharge consists of each 7.5-foot conduit terminating with an orifice manifold into the AWS chamber at diffusers supplying junction pool D. Orifice plates within the 7.5-foot and 10-foot conduits provide energy dissipation, and a butterfly valve in the 10-foot conduit serves as the secondary system closure.

4.2 REFERENCES

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4.3 HYDRAULIC CRITERIA

Under a normal two turbine operating condition, the auxiliary water supply (AWS) operates with flows of up to 5,000 cfs. In an emergency operating scenario where both fish turbine units fail, the proposed backup AWS minimum design discharge is 1,400 cfs (coordinated and approved by USACE and fisheries agencies; see table 4-1). Due to the reduced discharge available, the following operational changes will be made to the system.

- West and south fish entrance weirs will be closed.
- East fish entrance will operate with only two weirs; the third weir will be closed.

Table 4-1. Emergency AWS Discharge Requirements

Emergency AWS Discharge Requirements	
Design Discharge	1,400 cfs
Design Supply Head	89.5 feet

4.3.1 Water Surface Elevations

The design water surface elevations for forebay and tailwater are shown in table 4-2 below. These values were identified in the Juvenile Behavioral Guidance System report (USACE 2006). The AWSC water surface elevations were identified from the design tailwater elevation and the original east fish ladder (EFL) hydraulic design analysis. The exact water surface elevations used for the design of the alternative components are described in the appropriate sections of this report.

Table 4-2. Design Elevations

Design Elevations	
	Feet, msl
Maximum Forebay	160.0
Minimum Forebay	155.0
Maximum Tailwater	86.0
Minimum Tailwater	74.0
Maximum AWSC	89.5
Minimum AWSC	77.5
Maximum Junction Pool WSE	91.3

4.4 HYDRAULIC DESIGN

4.4.1 Inlet Design

The inlet of the supply conduit is set at elevation 116.5 feet, 38.5 feet below minimum forebay water surface elevation and approximately 20 feet off the river bottom, to avoid entrainment of juvenile salmonids and lamprey during operation. The current bathymetric survey indicates a river bottom of approximately 94 feet at the upstream side of the penetration through the dam. The inlet is to be a bell-mouthed circular conduit inlet normal to the dam face with a rounded elliptical geometry of 1.5 feet for the secondary axis and 5 feet for the primary axis.

Trash racks for the intake are sized with a 3 feet-per-second (fps) approach velocity and a flow of 1,400 cfs. Velocity criterion was determined during the EDR phase of design and based on guidance in EM 1110-2-1602. A through-bar velocity of 5 fps is recommended by the Bureau of Reclamation's *Design of Small Dams* (1987) publication. An assumed porosity of 70 percent for the trash rack results in a required gross area of 375 square feet; however, in order to meet the approach velocity, a required gross area of the trash rack is required to be 466 square feet. Trash rack width is set at 22 feet, and the height extends the full depth of the water column to the intake, with an offset of 5 feet from the dam. This allows for uniform localized flow at the intake under clean conditions; as debris loads the trash rack, additional flow capacity is available above the intake elevation. Maximum debris loading design is 50 percent clogging of the open area, resulting in a maximum loading of 42.0 pounds per square foot (psf).

A closure gate slides down over the intake against the dam face to act as the primary means of system operation, as shown in figure 4-1 below. This gate is not intended to operate in a flow throttling capacity, but it will be the primary means of turning the system on or off. This gate will also act as the primary dewatering gate while the emergency auxiliary water supply system is not in operation and during inspection of the conduit and downstream butterfly valve.

An air relief valve is located downstream of the closure gate to supply air during typical dewatering of the conduit or emergency closure.

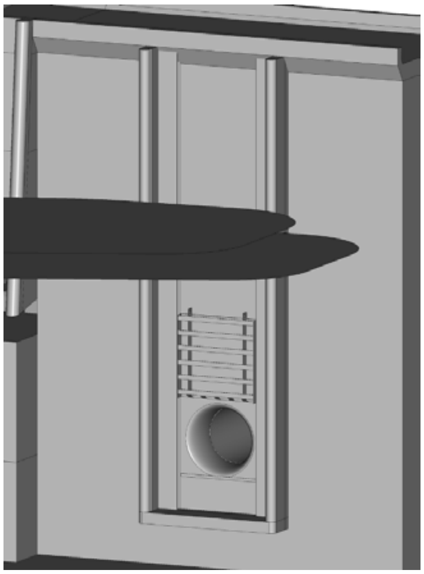

Figure 4-1. Rendering of Proposed Intake Structure Centered on Monolith 5 Illustrating the Piers, Closure Gate, and Elliptical Bell-Mouthed Intake

4.4.2 Main Supply Conduit

Conduit size selection and design were based on head loss, velocity constraints, cavitation potential, and alignment constraints.

Friction losses were based the Darcy-Weisbach friction formula (Equation 1) for a welded steel pipe,

$$h_f = f\frac{L}{D}\frac{V^2}{2g} \quad \text{(Equation 1)}$$

where h_f is the head loss due to friction, *f* is the friction factor, *L* is the length of conduit, *D* is the conduit diameter, *V* is the fluid velocity in the pipe, and *g* is the acceleration due to gravity. The friction factor *f* was developed from the explicit friction factor equation listed below,

$$f = \frac{0.25}{log\left[\frac{k_s}{3.7D}+\frac{5.74}{Re^{0.9}}\right]^2} \quad \text{(Equation 2)}$$

where k_s is the equivalent sand grain roughness of the pipe, and *Re* is the Reynolds number for the fluid passing through the conduit. Equation 2 was developed in the ASCE *Journal of Hydraulics Division* article “Explicit equations for pipe-flow problems.”

Minor losses were based on D.S. Miller’s *Internal Flow Systems* (1990) and consist of an entrance loss, a butterfly valve loss, bend losses, dividing Y losses, energy dissipation orifice losses, exit losses, and friction losses.

The supply conduit selection was primarily governed by the maximum velocity guidance defined in the EDR of 18 fps and site constraints. This drove the selection of a 10-foot-diameter steel conduit for the majority of the alignment and two 7.5-foot-diameter conduits to meet the site constraints entering the AWS chamber. This results in a design flow velocity of 17.9 fps and 15.9 fps and a max flow velocity of 19.2 fps and 17.1 fps in the 10-foot conduit and 7.5-foot conduits, respectively.

The intake centerline is located mid-span of Monolith 5 east of the EFL exit at elevation 116.5 feet. The alignment through the dam sloped at 0.1 percent to provide drainage during non-emergency operation. At the downstream face of the monolith, a 10-foot-diameter butterfly valve provides secondary closure for the emergency AWS. Due to high operating velocities, this valve is to be selected and designed against cavitation potential. The conduit makes two vertical-plane oriented 60 degree bends downstream of the valve to achieve a centerline elevation of 104.5 feet. The bend radii are 10 feet to the centerline of the pipe to ensure negligible cavitation potential. The conduit then continues at a 15.0 percent slope to meet an elevation of 98.3 feet over 120 feet of conduit. Within this reach are two energy dissipation orifices, which are described in the next chapter. The conduit makes a 45 degree horizontal turn and continues at a slope of 0.1 percent for 20 feet to a dividing Y. The total head loss through this conduit is 29.1 to 34.4 feet for low and high forebay conditions, respectively.

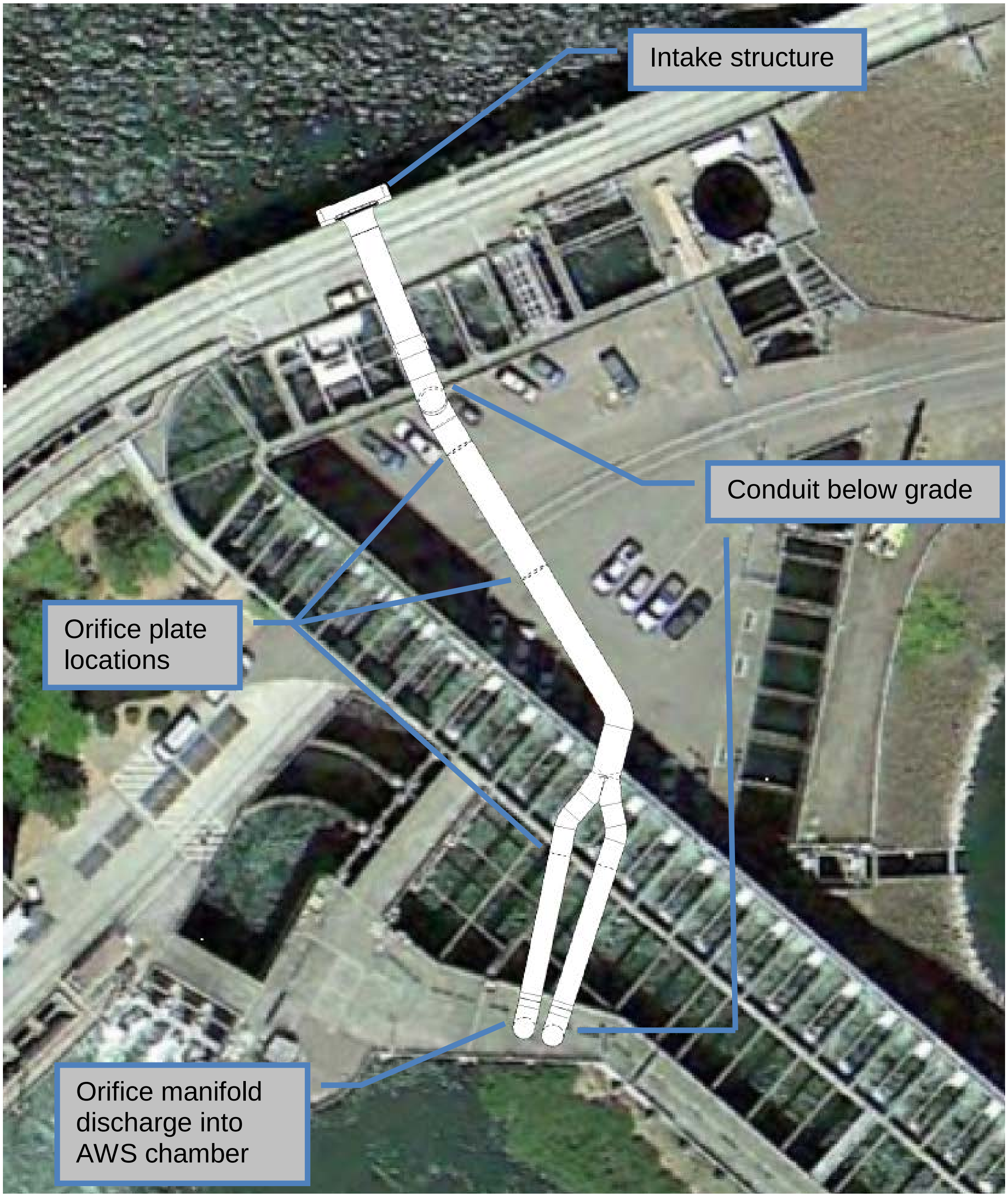

Figure 4-2. Aerial Photo Overlay Showing Proposed Alignment of the Emergency AWS System

The dividing Y equally splits the flow from the 10-foot conduit into two smaller 7.5-foot conduits, as shown in figure 4-2 above. Each conduit makes an approximate 15 degree bend to achieve a straight alignment into the AWS chamber from the diverging Y. Within the straight reach of each of the 7.5-foot-diameter conduits is an additional energy dissipation orifice (see next section). At the termination of each of these conduits, within the AWS chamber, there is a downward-directed elbow and a sharp-crested orifice manifold. The final bend is necessary to ensure the flow does not impact and damage structural elements within the AWS chamber. The orifice manifold is required to diffuse the remaining velocity energy in the chamber (see section 4.4.4). The total head loss through each conduit is 15.1 feet and 17.9 feet for low and high forebay conditions, respectively.

4.4.3 Energy Dissipation

A total head differential range of 65.5 feet to 82.5 feet is available to provide flow through the conduit. Due to the velocity and site constraints, the total hydraulic head cannot be dissipated through the pipe with friction and minor losses. The EDR identified energy dissipation with the use of ported sleeve valves. Concerns for clogging within the valve or valve seizure due to intermittent use prompted investigation into alternative energy dissipation methods better suited for this use. An alternative utilizing a hollow cone-jet valve was selected and developed for the 60 percent DDR submittal.

The 2013 Value Engineering study identified several alternatives, and large single-port orifice plates were selected to act as the primary method of energy dissipation to be placed within the supply conduits. Orifice plates provide a low cost and low maintenance in-line energy dissipation option as well as high flow capacity.

The orifice design is intended to create a significant head loss; however, cavitation is expected to occur downstream of the orifice as a result of the high-velocity rapid expansion. Cavitation is characterized in four different levels: Incipient cavitation, critical cavitation, incipient damage cavitation, and choking cavitation. Incipient cavitation is identified as the initial stages of noise development by cavitation. Critical cavitation is identified as consistent noise from cavitation and negligible to nonexistent cavitation damage in steel conduit. Incipient damage cavitation is identified as potentially objectionable noise and minor damage. Choking cavitation occurs when the average pressure downstream of the orifice achieves liquid vapor pressure. At this stage of cavitation, the orifice loss coefficient is no longer valid and damage to the conduit at the zone of pressure recovery becomes severe. Exceeding the choking cavitation threshold extends the zone of pressure recovery and increases damage potential; however, operating in the incipient damage condition just below choking cavitation causes a condition of maximum vibration.

Two orifice plates are placed in the 10-foot conduit (orifices 1.1 and 1.2, as shown in appendix B) and one orifice plate is placed in each 7.5-foot conduit (orifice 2.1 and 3.1). Design and selection of the orifice plates was intended to minimize cavitation and vibration potential and achieve the design energy loss. The method of orifice plate cavitation and scale effects design presented in the ASCE Journal of Hydraulics Division and detailed in the FEMA Technical Manual: Outlet Works Energy Dissipaters was used as the primary method of orifice plate selection and cavitation characterization due to its application to large scale orifice plate design. Cavitation potential is quantified using the Rahmeyer equation given below to create a cavitation parameter, σ.

$$\sigma = \frac{H_d - H_v}{H_u - H_d} \quad \text{(Equation 3)}$$

Where H_u is the gage pressure head upstream of the orifice, H_v is the gage vapor pressure head of the liquid, and H_d is the gage pressure head downstream of the orifice resulting from the losses through the orifice. The applied method for orifice plate design (FEMA) uses this cavitation parameter in comparison with scale-adjusted empirical data to define the level of cavitation. D.S. Miller's Internal Flow Systems method uses graphical interpretation and has a limited capability for large system design; however, it was deemed pertinent as a secondary check to insure damaging cavitation was not occurring.

Orifice plates 1.1 and 1.2 are each 7.4 feet and 7.5 feet in diameter, respectively. The resulting head loss through each is 11.5 feet and 13.5 feet for low operating forebay and high operating forebay, respectively. These two orifices result in the majority of the head loss in the system and were designed with a cavitation parameter that indicates critical cavitation but no incipient damaging cavitation. Orifice plates 2.1 and 3.1 are intended to act identically, with equal flow distribution. These are intended to dissipate 7.7 feet to 9.0 feet of head loss in parallel under low and high forebay conditions, respectively. These two orifices were designed with a cavitation parameter indicating incipient cavitation occurrence but no critical or damaging cavitation due to the proximity to the fish ladder and potential vibration or sound transmission. Table 4-3 summarizes orifice design details, including the level of cavitation potential.

Table 4-3. Orifice Summary Table

Orifice	Diameter (feet)	Low Head Loss (feet)	High Head Loss (feet)	Cavitation Potential
Orifice 1.1	7.4	12.7	15.0	Incipient Cavitation
Orifice 1.2	7.5	11.5	13.6	Incipient Cavitation
Orifice 2.1	5.5	10.8	12.7	Incipient Cavitation
Orifice 3.1	5.5	10.8	12.7	Incipient Cavitation

4.4.4 AWS Chamber Discharge

The AWS chamber consists of a deep channel aligned with the lower section of the east fish ladder. Within the AWS chamber are diffuser gates and lateral supports that are key to the operation and structural stability of the chamber. The area selected within the AWS chamber for discharge was based on geometry constraints. The bays between frames 15, 16, and 17 provide space for the two 7.5-foot conduits to turn 90 degrees downward without conflicting with the frame cross bracing in figure 4-3 below. The diffuser gate operators for these two bays will require modifications to maintain the ability to operate.

Figure 4-3. Photo of Dewatered AWS Chamber during Site Visit (Dec. 10, 2013)

The discharge of each 7.5-foot-diameter conduit will terminate in a series of sharp-crested orifices in the vertical section of the pipe as shown in figure 4-4 below. The flow and associated force from the emergency AWS system is directed through the final orifice manifold to avoid directly impacting any of these features. There are 12 of these orifices measuring 1.875 feet in diameter, with varying discharges dependent on orifice elevation, AWS chamber water surface submergence, and forebay water surface elevation. The orifices act as an additional energy dissipation feature for the emergency AWS system, but primarily serve to distribute the flow in a diffused pattern within the AWS.

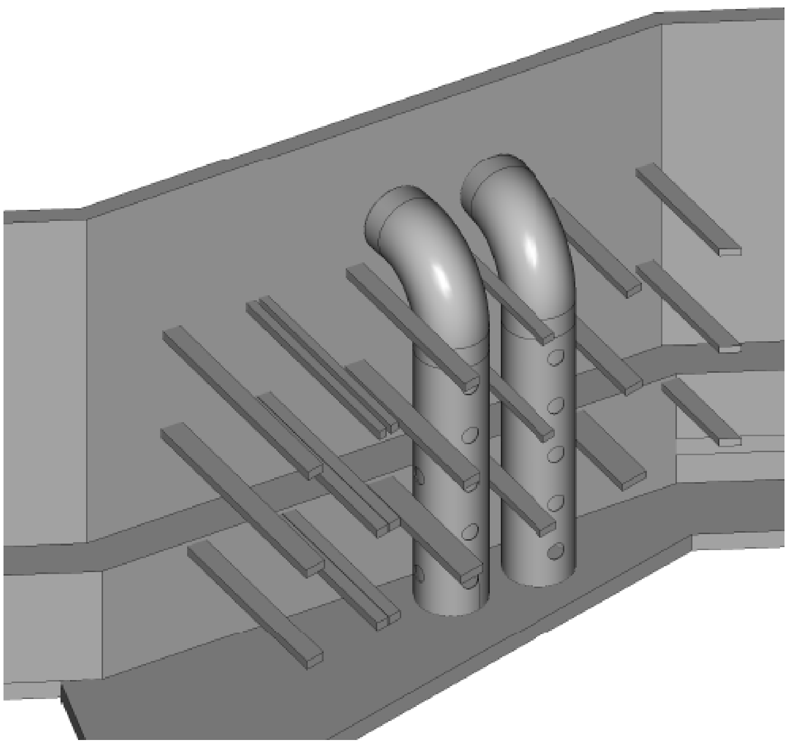

Figure 4-4: Rendering of Orifice Manifold Discharge into AWS Chamber

4.4.5 Forebay Velocity Considerations

Forebay velocities near the proposed intake are largely unknown. Defining the flow conditions in this area is important primarily for construction of the intake. Surface velocity observations show a sheltering effect of the earthen dam protrusion. Active flow appears from the edge of the earthen dam protrusion in the river and tapers back to the dam, as shown in figure 4-5. Eddies shed off of the active flow into the shelter, creating stagnant and sometimes upstream flow at the face of the dam near the proposed intake.

Figure 4-5. Surface Velocity Observation

It is recommended that acoustic doppler current profile (ADCP) data be collected at a minimum of one river flow representative of the working conditions in the winter work window.

CHAPTER 5 – STRUCTURAL DESIGN

5.1 GENERAL

This chapter describes the design for structural features as part of The Dalles east fish ladder backup auxiliary water supply.

5.2 STRUCTURAL DESIGN FEATURES

<u>Guide Slots</u>

- Closure gate guides will be fabricated out of stainless steel plates. After fabrication, the seal surface shall be machined to a smooth uniform surface to remove any distortion caused by welding.

- Trash rack guides will be formed from concrete with stainless steel guides. The guide for the trash rake will be built into the trash rack frame. A steel plate will be fastened from the edge of the guide to the monolith at a 45 degree angle. The steel plate will span from elevation 140 to 160 feet, with the intent to reduce fish predator habitat.

<u>Closure Gate</u>

- Lifting beam will be designed at a later time; not part of this DDR.

- The bottom of the gate is sloped to reduce hydraulic down-pull. The hydraulic design needs to provide exact detail for the best slope configuration to reduce down-pull for final bulkhead design.

- The gate is designed with 10 wheels to raise and lower under service loads. The wheels are designed to transfer the water pressure loads from the gate to the guides.

- The seal system is a center dome seal with Teflon coating. Traditional J-bulb seals were not used due to potential vibration during opening and closing of the gate. The seal is to be installed around the perimeter of the skin plate. There will be a tight tolerance required during fabrication between the skin plate and the seal surface.

- Gate design considerations. The gate is detailed for minimal welds and simple construction. The only fracture critical members on the gate will be the lifting eyes.

<u>Trash Rack</u>

Stainless steel bar grating with ¾-inch clear opening between bars will be used. The grating callout is W15 1-1/4x3/16. The trash rack frame will be 12 feet by 23 feet in overall size, made from stainless steel 4-inch by 10-inch tubes. A guide pin will be required to align each rack vertically. The ends of the grating bars will be beveled to assist the trash rake between the trash rack bars in case of misalignment. The trash racks are sized at 12 feet tall for transport and unstacking. Stainless steel was chosen as the material for reduced maintenance cost. Guides for the trash rake will be added to the trash rack to maintain a tight tolerance. Trash rack loads came from hydraulic pressure on the bar grating with 75 percent open space for normal conditions and 5 feet of head differential for unusual conditions, per EM-1110-2-3104.

<u>Thrust Blocks</u>

Thrust blocks for 10-foot-diameter and 7.5-foot-diameter supply conduits are to be fabricated out of concrete.

<u>Dam Penetration</u>

The penetration hole through the dam is sized at 11 feet in diameter. This will allow for installation of a 10-foot-diameter pipe and provide for a 6-inch grout space.

<u>Inlet Design</u>

The inlet is to be a bell-mouthed circular conduit inlet normal to the dam face with a rounded elliptical geometry of 1.5 feet for the secondary axis and 5 feet for the primary axis. The inlet bell is to be fabricated out of reinforced concrete.

<u>Steel Pipe</u>

- Steel pipe in the dam is sized based on Steel Penstocks 2nd edition criteria, specifically following Amstutz Formulation and Jacobsen Formulation for sizing steel penstocks in concrete dams. A minimum of 5/8-inch steel wall pipe based on Amstutz formulation will meet the required strength, but a ¾-inch steel pipe will be used to account for any corrosion loss over the years. Holes will be drilled into the steel pipe for grouting. The holes will provide grout access ports, air vent holes, and inspection holes. The holes will be plugged by threaded inserts ground flush. This is similar to how Hinze Dam in Australia was modified, based on conversations with Salvatore Todaro from the Risk Management Center (RMC).

- Buried steel pipe is to be ½-inch wall pipe.

- The steel pipe spanning over the fish ladder is sized based on Table 7-1 from AWWA-M11, with a span of 45 feet and a minimum of 120 degree contact saddle supports at each end. A ½-inch wall pipe provides the required structural loading capacity for the span. Bird spikes are to be installed on top of the pipe to prevent bird droppings from damaging the paint system. A large thrust block will be installed around the steel pipe before spanning the fish ladder. The steel pipe will transfer the load from the 90 degree bend in the AWS chamber to the thrust block, thus preventing lateral loads on the AWS wall.

Interior Wall Penetrations

Wall E2, as shown on drawing sheet DDF-1-4-5/V10 (see appendix C), can support the increased load from the 7.5-foot pipes that span over the fish ladder. Wall E2 is the wall that is common between the AWSC and the fish ladder. Wall E2 penetration for the 7.5-foot pipe was analyzed to take the dead load of the pipes and have a slip connection to allow the pipes to expand and contract with temperature without adding lateral loads. It is critical not to destroy the rebar in the frames F14, F15, and F16, as seen in sheet DDF-1-4-5_R1 in appendix C. This can be accomplished by scanning for rebar and adding more prescriptive requirements in the specifications. The AWSC walls E2 appear to be designed by spanning the hydraulic loads horizontally to the frame. The struts in frames F14, F15, and F16 will be protected from high velocities and vibration by the orientation of the orifice plates in the vertical steel pipes. The vertical steel pipes will be bearing on the AWS chamber floor and be tied together to resist movement.

Dewatering Structure

There are two options that were proposed for dewatering the face of the dam to prevent water from entering the construction area. Option 1 is for a contractor designed and installed large steel cofferdam, and Option 2 is for precast concrete piers with bulkheads. Each option has advantages and disadvantages, as outlined below.

1. Contractor designed and installed large cofferdam. In this alternative, the contractor will design and install a large cofferdam that covers the entire work area on the face of the monolith. The steel cofferdam allows for minimal dive time. The cofferdam would be a steel structure with a maximum 17.5-foot radius centered over the pipe opening. The cofferdam would provide the protection required to allow for penetration through the monolith and provide a dry installation of the gate and trash rack guides.

    - Advantage: The cofferdam would have minimal dive time compared to concrete piers. If powerhouse units have to be diverted to allow for appropriate water velocities for diving, this would provide minimal impact.

    - Advantage: The contractor could design platforms, ladders, and other specific fabrication assistance items.

    - Advantage: The cofferdam would provide the contractor a larger work area with more space to access equipment than the alternative pier option.

    - Advantage: The cofferdam allows for a smaller trash rack pier, versus the precast concrete piers designed for dewatering.

    - Disadvantage: The cofferdam would require two separate dives, one to install and one to remove.

- Disadvantage: There is a large lead time for design and fabrication of the cofferdam.

- Disadvantage: The Government does not have as much control over the design and fabrication of the cofferdam. Measures can be taken in the specification to provide the Government more oversight and control during design and fabrication.

2. <u>Precast concrete piers with bulkheads</u>. This alternative uses precast concrete piers that will be installed with divers. After the piers are installed, bulkheads would be used to dewater to allow the installation of the gate guides. The bulkhead guides would double as the trash rack guides during operations.

   - Advantage: This option would provide the Government with bulkheads for future service work of the gate guide.

   - Advantage: The Government would have control over the design and fabrication of the bulkheads. Eight bulkheads would be required, at an approximate total weight of 180,000 pounds.

   - Advantage: Only one dive operation at the beginning of the project would be required.

   - Disadvantage: This alternative requires a lot of dive time to install the anchors for the precast piers.

   - Disadvantage: There will be underwater grouting that requires good quality control to provide uniform bearing surface between the precast piers and the monolith.

   - Disadvantage: There will only be 5 feet of clearance between the bulkhead and the face of the monolith for the contractor to work in. This is a tight space, and it will be challenging for the contractor to get the equipment in to drill and smooth the bell-shaped opening and install the gate guides.

Option 1, the cofferdam, was chosen as the preferred alternative for several reasons. It requires less dive time with divers closer to the dam face, allowing the divers to work in lower velocity conditions. Having the face of the monolith dewatered provides better quality control for fabrication of the trash rack guides and provides adequate construction room for fabricating the gate guide on the face of the dam. The cofferdam also provides adequate work area space, which will provide a safer work environment.

One technique that could be used to install the cofferdam came from a local contractor with experience in fabricating and installing cofferdams. The contractor indicated a preference to design resistance for uplift (buoyancy force) by placing the majority of anchorage to the dam face above the water, if possible. This design reduces anchorage locations below the water, thereby reducing dive time and providing improved quality control. Also, the contractor indicated they may choose to use guides to install the cofferdam. Guides provide the advantage of a smaller structure compared to cofferdam segments, allowing divers increased mobility by staying close to the concrete face where water velocities are slower. With guides, a similar dive technique that is currently being used for fish research trolley pipe installation/removal on powerhouse intake piers at The Dalles dam could be used, employing a crane with a man basket.

Monolith 5 Stability

Monolith 5 stability calculations were run for two loading conditions. The loading conditions are: (1) normal pool with 10-foot pipe installed, and (2) construction with a 35-foot-diameter half cofferdam on face of monolith with a 10-foot-diameter pipe installed. The following assumptions were used in the calculations: base of monolith is at elevation 94 feet, normal high water depth is at 160 feet, and tailwater is below toe of Monolith 5. It was assumed there is no soil behind the toe of the monolith to create passive pressures for sliding or provide additional overturning mass. The calculations do not account for the concrete and steel added on the face of the monolith for the gate and trash rack guides or the weight of the temporary cofferdam; this is conservative. Table 5-1 shows the internal friction angles (phi) and cohesive (c) values used based on information provided from Portland District (NWP). Table 5-2 provides the factors of safety for the two loading conditions investigated. The overturning calculations for both loading conditions had the resultant within the middle 1/3 of the monolith.

Seismic Safety Review (SSR) for The Dalles Dam, dated 27 September 2013, Revision 11-R1 (95% Draft), indicates the increased seismic loading is not expected to alter the conclusion of the original design regarding the stability analysis. This indicates that the stability of the monolith is governed by flood conditions. The mass for the modifications may decrease by up to 1.8 percent. During a seismic event, it is anticipated that tensile stresses may develop around the inlet opening. The inlet opening is to be reinforced with rebar to reduce cracking. Calculations were performed on Monolith 5 based on the Seismic Coefficient Method per EM 1110-2-2100. The minimum factor of safety was 1.7, above the required 1.3 for the seismic loading scenario based on the SSR. Note that the calculations performed do not capture any tensile stress in the face of the concrete.

Drawing DDF-1-4-5/P2 in appendix C for Monolith 5 provides no base elevation. Original calculations have the base elevation at 97 feet. If the grout gallery elevation is used for a reference elevation, the base elevation would be at 94 feet. In both cases, it appears that the grout gallery will act similar to a shear key, creating a low point in the base of the monolith. This can also be seen in Drawing DDF-1-4-5/P2 in appendix C. This key was ignored in all calculations; the monolith was assumed to have a flat base.

Table 5-1. Internal Friction Angles and Cohesive Values

Phi and C Values for Sliding		
Case	**Phi (deg)**	**C (psi)**
Case 1	30	36
Case 2	40	200
Case 3	45	250
Case 4	45	0

Table 5-2. Factor of Safety for Sliding

FOS for Sliding				
Case	**Existing Condition**	**Normal Pool with 10-foot Pipe**	**Construction with Cofferdam and 10-foot Pipe**	**Seismic Coefficient Method**
Case 1	4.11	4.08	3.97	2.49
Case 2	16.04	15.99	15.83	9.77
Case 3	19.91	19.85	19.65	12.12
Case 4	2.88	2.81	2.62	1.72

5.3 GOVERNING DESIGN CODES

- Emergency gate and bulkheads:
  - Engineer Manual (EM) 1110-2-2105, Design of Hydraulic Steel Structures.
  - EM 1110-2-2701, Vertical Lift Gates.
- Steel design – American Institute of Steel Construction (AISC) 360-05 Specification for Structural Steel Buildings – Steel Construction Manual 13th Ed.
- Concrete design:
  - American Concrete Institute (ACI) 318-08, Building Code Requirements for Structural Concrete.
  - EM 1110-2-2104 – Strength Design for Reinforced Concrete Hydraulic Structures – will use load factors from EM, will use ACI 318-08 for design equations.
- American Welding Society (AWS) D1.1-2008, American Welding Society, Structural Welding Code – Steel.
- American Welding Society (AWS) D1.5-2008, American Welding Society, Bridge Welding Code.

- American Welding Society (AWS) D1.6-2007, American Welding Society, Structural Welding Code – Stainless Steel.
- American Society of Civil Engineers (ASCE)-7-05, American Society for Civil Engineers, Minimum Design Loads for Buildings and Other Structures.
- Stability Analysis of Concrete Structures, EM 1110-2-2100.
- Gravity Dam Design, EM 1110-2-2200.
- Structural and Architectural Design of Pumping Stations, EM 1110-2-3104.
- American Water Works Association (AWWA) M11, Steel Water Pipe: A Guide for Design and Installation.
- Steel Penstocks 2nd edition, Bambei Jr., John H., ASCE 2012.
- The Dalles Lock and Dam Columbia River, Oregon-Washington Seismic Safety Review, Dated 27 September 2013 (95% PCCR Draft).

5.4 MATERIAL PROPERTIES

- Existing concrete 28-day compressive strength: f'c = 3,000 psi.
- New concrete 28-day compressive strength: f'c = 4,000 psi.
- Precast concrete 28-day compressive strength: f'c = 6,000 psi.
- Existing reinforcing steel: Grade 40 fy = 40,000 psi.
- New reinforcing steel: American Society for Testing and Materials (ASTM) A615, Grade 60 fy = 60,000 psi.
- Existing structural steel: ASTM A36, fy = 36,000 psi or ASTM A572, fy = 50,000 psi.
- New structural steel:
  - W shapes: ASTM A992, fy = 50,000 psi.
  - M, S, C, MC, and L shapes: ASTM A36, fy = 36,000 psi.
  - Hollow structural sections (HSS):
    - Round – ASTM A500 Grade B, fy = 42,000 psi.
    - Rectangular and Square – ASTM A500 Grade B, fy = 46,000 psi.

- Pipe: ASTM A53 Grade B, fy = 35,000 psi.
- HP shapes: ASTM A572 Grade 50, fy = 50,000 psi.
- Plates and Bars: ASTM A36, fy = 36,000 psi.
- Plates and Bars for HSS: ASTM A 709 Grade 50, fy = 50,000 psi.
- Conventional Structural Bolts: ASTM A325.
- Nuts: ASTM A563.
- Washers: ASTM F436.
- Anchor Rods: ASTM F1554 Grade 36, fy = 36,000 psi, Grade 55, fy = 55,000 psi.
- All-Thread Bar: ASTM A722 fy = 150,000 psi.
- All-Thread Bar Couplings: ASTM A29, Grade C1045.

CHAPTER 6 – MECHANICAL DESIGN

6.1 GENERAL

The addition of emergency backup auxiliary water supply to The Dalles dam is largely composed of structural and geotechnical features. However, there are a handful of features that are mechanical in nature. These features include the trash rake, the operating gate roller wheels, a flexible connection between the pipeline and dam, and the downstream isolation butterfly valve and actuator. These features are described in further detail below. These features will be presented generally in the order that they are encountered by water flowing from upstream to downstream.

6.2 MECHANICAL FEATURES

6.2.1 Trash Rake

A trash rack will be provided as the upstream-most feature in the system. This structure forms a grill of vertical running bar grating that protects the pipeline and downstream features from damage or plugging from debris suspended in the river. In order to ensure that this grating does not become plugged with debris, a trash rake will be provided to enable project personnel to clear debris from the rack.

The trash rake will be designed to push debris downward from the rack surface in order to clear the passageway. The assumed operational procedure for raking trash will be to suspend flow with the downstream isolation valve, then lower the trash rake to clear debris. It is anticipated that this operation would be very infrequent and require less than 1 hour to complete. As a result, it is assumed that a no-flow type of operation is acceptable.

The trash rack is approximately 22 feet wide and will extend from just below the pipeline entrance up to the water surface. The rack width is required to maintain the required water velocity through the bars to reduce the risk of impinging debris and adult fish. The trash rake will be sized to match that width. The height of the trash rake is approximately 7 feet. This height is intended to provide a reasonable aspect ratio that is unlikely to bind in its guide slots. It is also required to develop sufficient weight to push debris downward off the rack. The initial concept for the rake geometry weighs in at approximately 7,000 pounds. The rake geometry is essentially four wide flange beams spanning the width of the rack. The beams are tied together at each end by a pair of vertically mounted channels.

There a couple different concepts that were investigated for the raking tines. The original concept was to connect bar grating on the back side of the wide flange beams running the full height of the rake, arranged so that the bars of the rake would run between the bars on the trash rack. The grating design consisted of ¼-inch bars 2 inches deep, tied together by pins run through the bars at their centerlines. With this configuration, any debris that was pinned to the face of the rack would be pushed downward by the weight of the rake and any debris that was pinned between the rack bars would be either sheared or pushed downward by the nested bars on the rake.

There was one problem with this system. With the trash rack bars spaced at ¾-inch intervals and the rake tines centered between those bars, there will only be ¼ inch of space between the rake tines and the rack bars. As a result, the rake system will be very sensitive to binding if it is not lowered evenly. A 1/16th-inch difference in the elevation between either end of the rake would cause the rake bars to bind against the rack bars.

This condition could be mitigated by ensuring tight clearances between the gate and the guide; however, that would require less than ¼ inch of play between the rake and guides over the full travel of the rack.

It was assumed that these tolerances were likely not achievable and would likely cause operational hardship. As a result, an alternative tine design was considered. Instead of running the bar grating the full height of the rake, only the leading 6 inches or so would have rake tines. These small-length tines would have enough strength to push though any debris that may be built up on the rack, but be small enough to allow some misalignment in the rake guides. The bars that form the tines would be “bull nosed” on both the top and bottom in order to guide between any minor offsets that may be present between the trash rack panels.

The rake guides would be part of the trash rack panel so that the rake is always aligned with the rack instead of having the rake being aligned with the guide structure, which may or may not be aligned with the trash rack. This should further mitigate any alignment issues that may come up.

While it is assumed that there will be a no-flow condition when the rake is lowered, the initial concept provides for the ability to rake under flow. The beams are sized to take the drag of the water flowing through the tines and the wheels are provided to allow for the rake to roll under flow. The leading edge of the rake will form a ramp away from the rack surface, so that as the rake encounters debris it will lift debris off the rack surface and force it downward.

The rake will typically be dogged off above the water surface. If it is determined that trash has built up on the racks, a mobile crane will be required to lift the rake off the dogs and lower it to clear debris.

6.2.2 Emergency Gate

The dam safety criteria for the emergency gate have one requirement in particular that pertains to mechanical design. That requirement is that the gate be deployable under flow. This suggests some kind of gate end roller to eliminate or mitigate the amount of sliding friction between the gate structure and the gate guides while the gate is moving through flowing water.

6.2.3 Gate Wheels

The emergency gate is approximately 14.5 feet square in order to cover the 10-foot-diameter pipe. This area would have a 50-foot water head applied to it, resulting in a total normal force of approximately 650,000 pounds. This is the load that would need to be carried by the end rollers. It was initially assumed that the gate would have self-lubricating, self-aligning, spherical track rollers similar to the closure gate wheel on the John Day top spillway weir (TSW). However, this type of roller is essentially a sliding roller, where an internal ball slides on an external race separated by a self-lubricating liner. This type of roller can lower the frictional sliding at the interface, but not remove it entirely. Under the given load, the force required to move the gate with this type of wheel would be approximately 42,000 pounds. This is more than double the gate weight of approximately 20,000 pounds. As a result, the gate would not be able to close under its own weight. Rather, it would require some type of closing actuator. This would add expense and complexity to the system.

As a result of this analysis, three alternative end rolling systems were evaluated: (1) the spherical plain roller described above; (2) a roller chain system similar to that on powerhouse head gates; and (3) a spherical roller bearing based wheel similar to the spillway lift gates at McNary Dam.

The roller chain is essentially a chain that encircles either end of the gate. The idea is that the load is transferred from the gate structure through the rollers and into the guides. As the gate is lowered under load, it rolls along these rollers. As the gate lowers, the roller chain rolls around the end of the gate as new rollers at the bottom are brought in to take up bearing and rollers at the top are removed from bearing.

A spherical roller is similar to the spherical plane bearing except that the spherical element does not slide, but rather rolls on a series of rollers arranged in a circle around the spherical element. It is essentially a roller chain that encircles each gate axle instead of the entire gate end.

A list of pros and cons were developed for each option to facilitate the selection of the most appropriate roller type.

<u>Spherical Plane Bearing Analysis</u>

The benefits of the spherical plane bearing are as follows. First, there are very few moving parts; only the outer race that rotates around a solid ball. Because the bearing is self lubricating, there is no potential for grease to enter the river. While a gate operator would be required to force the gate downward, that operator could be configured for push button operation, eliminating the need to bring in a crane to lower the gate. Finally, the spherical geometry of the bearings allows the gate to deflect while maintaining good contact between the wheel and guide. However, there are several negative aspects to this type of bearing. Primary among them is that a gate operator would be required. This adds cost and complexity to the system. The operator would likely consist of a hydraulic system, which would require additional maintenance and introduce the potential for oil entering into the river. The presence of a standalone operator would require a dedicated electrical system to be installed in the area, again adding cost to the project. Another detriment to a wheel-on-axle type roller is that it imposes a point load on the guide structure.

<u>Roller Chain System Analysis</u>

One benefit of a roller chain system is that the gate could be deployed by crane without the need for a standalone operator. The roller chain system is not lubricated, so there is no potential for grease to enter the river. Finally, due to the large number or rollers, the load on the gate is spread out more evenly onto the guide structure. However, there are several drawbacks to this system. There are a large number of moving parts – each roller consists of a roller, axle, and link bar. A failure of any one of those parts could cripple the system. Typically, to allow these items to roll freely without worry of seizure due to corrosion, the chains are made from stainless steel. This large volume of stainless steel contacting the carbon steel gate would result in the need to have a cathodic protection system, most likely sacrificial anodes. The chains themselves are heavy and unwieldy. Also, the chains do not compensate well for gate deflection.

<u>Spherical Roller Bearing Analysis (Selected Design)</u>

The benefits of this system are that with this system the gate could be lowered under flow without the need of a dedicated operator. The roller bearings have several moving parts, but they are contained and protected within the wheel structure. The spherical geometry allows the wheel to compensate for gate deflection while still maintaining good contact between the wheel and the guide. There are, however, a few drawbacks to this system. The spherical roller bearing is a grease-packed bearing, and as such there is potential for grease to enter the river. This would require additional maintenance to periodically monitor and re-pack the bearings. And, finally, the individual wheel imposes a point load on the guide structure.

The spherical roller bearing system is the selected design. The primary concern is to simplify the system, and the need to have a dedicated gate operator would create an overly complex system. The maintenance and grease potential were strikes against this system; however, the maintenance requirement is infrequent and the grease is thick and behind seals, so the likelihood of grease escaping is minimal. This type of system has been operating on the McNary spillway lift gates for 50 years without much of a problem. The McNary spillway lift gates are currently being rehabilitated, and the majority of these wheels are still in good shape.

The gate geometry provided for ten wheels, five on either side. The wheels have an approximately 10-inch spherical element diameter and a 16-inch-diameter tread. The wheel axle is about 6 inches in diameter to accommodate the bending generated by cantilevering out from the end of the gate. The wheel tread and axle will be fabricated from 17-4 PH stainless steel. The amount of stainless steel in contact with the carbon steel gate is low and as such will not require a galvanic protection system beyond the paint coating on the gate.

6.2.4 Pipeline Venting

A 6-inch pipe vent will be provided immediately downstream of the operating gate in order to relieve negative pressures developed by operation of the gate. The vent will tie into the top of the 10-foot-diameter pipe. The 10-foot pipe starts approximately 5 feet downstream of the dam face. This is to allow room for a formed entrance bell. The vent pipe cannot run entirely along the face of the dam because the operating gate sealing surface and trash rack guides are in the way. To avoid these features, the vent pipe will have to run embedded within the concrete until it is outside of these features, at which point the pipe can emerge from the face of the dam and run vertically upward along the dam face up to an elevation above the high forebay elevation. The pipe will terminate in a “candy cane” vent. In order to route the vent pipe in this manner, a vertical trench will need to be excavated to access the top of the 10-foot pipe. The pipe would be routed to allow free movement of air using 45 degree bends with no purely horizontal runs of pipe.

6.2.5 Operating Gate Hydraulic Operators

The original concept called for the emergency gate to be supported against flow using wheels mounted on plain spherical bearings. As discussed above, this would not completely eliminate the sliding friction as the gate is lowered into place. The remaining friction could not be overcome by the weight of the gate itself, so some means to push the gate closed would be required. This would have been accomplished using hydraulic cylinders and a hydraulic power unit. However, since spherical roller bearings are being used instead of plain bearings, the gate will be able to lower under its own weight. As such, hydraulic operators will not be required.

6.2.6 Downstream Isolation Valve

A 10-foot-diameter butterfly valve will be provided immediately downstream of the dam as the pipe daylights, but prior to the pipeline becoming buried. This valve will act as a secondary isolation point if for some reason the operating gate could not be closed. This valve will be anchored into the dam so that in a seismic event where the dam and ground do not move together, the pipe would break downstream of the valve. This would guarantee that there are always two isolation points in the pipeline.

The valve will be flange connected to the pipe that extends downstream through the dam. Concrete will be formed up between the downstream slope of the dam and the face of the mounting flange. Concrete anchors will be used to fasten the flange connection, thus tying the valve directly to the concrete structure.

This valve is to be motor operated, and as such, coordination with electrical design will be required. Valve operating equipment will include a worm gear operator mounted to the valve shaft. This will reduce the torque required from the motor operator and provide a self-locking valve closure where the torque on the valve cannot reverse-turn the motor. The motor operator will be a multi-turn valve operator similar to a Limitorque

MX series operator. This operator will allow push-button operation as well as valve position feedback.

This feature was originally included, but was removed from the 60% DDR. However, the current system concept does not have an energy dissipation valve to act as secondary isolation. In order to provide the required two isolation points, this valve is now required.

6.2.7 Pipeline

The pipeline itself will be a 10-foot-diameter (¾-inch wall within the dam monolith and ½-inch wall downstream of the monolith) welded steel pipe. Connections to valves and specialty fittings will be done using flanged joints. The pipeline will be lined and coated with an epoxy coating system in accordance with AWWA C210 to mitigate corrosion. To accommodate relative motion between the ground and structure resulting from seismic conditions, a restrained harness pipe connection, similar to Dresser style 63, will be located between the butterfly valve and the point where the pipe becomes buried.

6.2.8 Expansion Joints

Because the pipe is almost completely buried, it is assumed that dedicated expansion joints will not be necessary. Any minor movements that may develop are assumed to be accommodated though the harness joint at the butterfly valve.

6.3 DESIGN CODE REFERENCES

The design will conform to the following pertinent mechanical criteria and applicable standards and codes.

6.3.1 General Standards

- American Society of Mechanical Engineers, 2004. ASME B31.1, Power Piping.
- American Welding Society, 2008. AWS D1.1, Structural Welding Code – Steel.
- American Welding Society, 1999. AWS D1.6, Structural Welding Code – Stainless Steel.
- International Code Council, 2012. International Plumbing Code.

6.3.2 Water Control Gates

- Maximum effort on crank or hand wheel: 40 pounds.
- Centerline height of crank or hand wheel: 36 inches.

- Stem covers: Clear butyrate plastic with Mylar open/close indicator. Maximum allowable leakage rate: 0.1 gallons per minute (gpm) per foot of seat perimeter.

6.3.3 Piping

- AWWA C200, Standard for Steel Water Pipe: 6 inches (150 mm) and larger.
- AWWA C206, Standard for Field Welding of Steel Water Pipe.
- AWWA C207, Standard for Steel Pipe Flanges for Waterworks Service – Sizes 4-inch through 144-inch.
- AWWA C208, Standard for Dimensions for Fabricated Steel Water Pipe Fittings.
- AWWA C210, Standard for Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines.
- AWWA M11, Steel Water Pipe: A Guide for Design and Installation.

6.3.4 Valves

- AWWA C515, Standards for Reduced-Wall, Resilient-Seated Gate Valves for Water.
- AWWA C504, Rubber Seated Butterfly Valves.
- AWWA C540, Standard for Power-Actuating Devices for Valves and Slide Gates.
- AWWA C550, Standard for Protective Epoxy Interior Coatings for Valves and Hydrants.

CHAPTER 7 – ELECTRICAL DESIGN

7.1 GENERAL

The primary electrical work to be provided is listed below.

1. Valve actuator motor and control panel for 10-foot pipe:
   - Electrical power – load 480V/3PH/3HP/10A.
   - Control – combination reversible motor starter with pushbuttons (CLOSED and OPEN).
   - Manual mechanical position indication on valve actuator.
2. Pipe instrumentation and sensors to measure and monitor pressure and flow with remote indication and alarms in control room.
3. Determine and design the maintenance lights and receptacles needed at the valve actuator.
4. Relocate existing electrical, control and monitoring equipment, devices, and conduit in the construction area.
5. No remote or automatic control expected.

7.2 ELECTRIC VALVE ACTUATORS

The 10-foot pipe valve actuator will be opened and closed with an electric motor. The valve actuator includes an electric motor, gear box, built-in control switches, adjustable limit switches, manual lock, manual hand wheel, and mechanical position (open/closed) indication. The valve actuators will be controlled by hand switches on or near the actuator. It is assumed the valve actuator needs a motor in the range of 1 to 5 horsepower (hp). A lockable disconnect switch will be provided.

7.2.1 Electrical Power

Provide electrical power for the valve actuator from one of the unused fish lock ladder gate operator circuits (i.e. FCQ7-q1-AW3). Sheet E-101 in appendix H shows the location of the fish lock actuator (FCQ7-q1-AW3) that may be used for the pipe valve actuator power.

- Identify the gate operator on the fish lock ladder that can be re-circuited and extended to provide power to the pipe valve actuator.
- Determine how to update and reconfigure the “FCQ7-q” bucket to provide power to the valve actuator.

- Label and update as-built drawings to abandoned and reused circuits.

7.2.2 Control

The electric valve actuator motor control will be built-in factory switches (CLOSED and OPEN) with a local lockable disconnect.

There are no automatic or remote controls associated with the operation of this equipment. The electrical valve actuator will be manually operated.

7.3 PIPE FLOW AND PRESSURE INSTRUMENTATION AND ANNUNCIATION

Required instrumentation will be determined during plans and specifications. Instrumentation in concert with annunciation may be considered to monitor and alarm dangerous conditions. Project personnel indicate that current monitoring of flow depth over the fish ladder entrance weirs could be used to determine operational condition of the backup AWS. If further forms of instrumentation are pursued, the following tasks could be performed:

- Identify the unused gate operator on the fish lock ladder that can be recircuited and extended for pipe pressure and flow indication and alarms.
- Determine how to update and reconfigure the “FCQ7-u” buckets to monitor pipe flow and pressure.
- The existing water level sensors in the fish ladder are assumed to be adequate to indicate water levels and alarm conditions.
- Sheet E-101 shows the location of fish lock actuator indicator conduit (FCQ7-u1-AW3) that may be used for the pipe flow and pressure indication and alarm circuits.
- Label and update as-built drawings to show abandoned and reused circuits.

7.4 RELOCATE EXISTING CONDUIT, DEVICES, AND EQUIPMENT IN CONSTRUCTION ZONE

- Survey existing drawings and locate existing conduit, devices, and equipment impacted by construction. Existing site drawings have been reviewed; Sheet E-101 shows conduits that need to be relocated.
- Locate site survey to find existing conduit, devices, and equipment in the construction area. This “locate” survey will be used to further identify buried conduits that will need to be relocated. Coordinate survey with as-built site drawings.
- Determine electrical equipment, devices, and conduits that need relocation.

- Develop plan for relocating electrical items located in the construction area.

7.5 MAINTENANCE LIGHTING AND RECEPTACLES

Design work should include maintenance lighting and receptacles near the pipe valve actuator. This will involve providing 120VAC power circuits for lights and receptacles.

7.6 DESIGN REFERENCES

The designs of alternatives will conform to the following pertinent electrical criteria and applicable standards and codes.

<u>National Codes</u>

- National Fire Protection Association (NFPA) 70 – National Electrical Code.
- NFPA 79 – Electrical Standard for Industrial Control.
- American National Standards Institute (ANSI) C2 2012 – National Electric Safety Code

<u>U.S. Army Corp of Engineers</u>

- Unified Facilities Criteria (UFC) 3-501-01 – Electrical Engineering.

<u>Valve Actuators, Electrical</u>

- International Society of Automation (ISA) 96.02.01-2007 – Guidelines for the Specification of Electric Valve Actuators.

CHAPTER 8 – ENVIRONMENTAL AND CULTURAL RESOURCES

This chapter outlines the environmental and cultural resources and permitting requirements as they may apply to providing a backup auxiliary water system for The Dalles EFL. During plans and specifications, the design will be further refined. Typically, it is during this phase that environmental clearance documents are prepared to satisfy the various environmental laws and regulations that U.S. Army Corps of Engineers (USACE) must comply with prior to constructing the facilities or modifying operations to improve the adult fish facilities operation. USACE is required to comply with numerous Federal laws, rules, and regulations, as well as potential additional requirements under state and/or local jurisdictions.

All Federal actions that are funded, constructed, or permitted must comply with the National Environmental Policy Act (NEPA). The NWP District Commander is the USACE NEPA official responsible for compliance with NEPA for actions within District boundaries. Typically, under NEPA, the District will prepare a Categorical Exclusion for O&M activities, or an Environmental Assessment (EA) for larger construction projects. An EA is a brief document that provides sufficient information to the District Commander on potential environmental effects of the proposed action, if appropriate, and its alternatives. The EA review also determines whether an Environmental Impact Statement (EIS) or a Finding of No Significant Impact (FONSI) needs to be prepared. In the case where project impacts are known to be major, USACE may decide to proceed to an EIS without conducting the EA/FONSI.

Consultation with appropriate Federal, State, and tribal agencies regarding potential environmental effects is coordinated by CENWP-PM-E. Compliance and consultation includes all permitting activities associated with the Clean Water Act (CWA) including Sections 401, 402, and 404. Under Section 401 of the CWA, water quality certification will be requested from the State of Oregon. Cultural resource clearance will be required for construction sites, other areas disturbed to facilitate construction (access roads, staging areas, etc.), or otherwise affected by operational changes. Endangered Species Act (ESA) compliance will include interagency consultation with the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) on all threatened, endangered, and proposed species and/or designated critical habitat, including terrestrial and aquatic plants and animals.

The consultation process may also encompass sections of the Fish and Wildlife Coordination Act; Magnuson-Stevens Act (Essential Fish Habitat); Bald and Golden Eagle Protection Act; several cultural resource laws including the National Historic Preservation Act; Archaeological Resources Protection Act; Native American Grave Protection and Repatriation Act; Antiquities Act; Archaeological and Historic Preservation Act; Executive Order 11988, Flood Plain Management; Executive Order 11990, Protection of Wetlands; Executive Order 13514, Federal Leadership in Environmental, Energy, and Economic Performance; Comprehensive Environmental Response, Compensation, and Liability Act; Resource Conservation and Recovery Act; Toxic Substances Control Act; Federal Insecticide, Fungicide, and Rodenticide Act; and Migratory Bird Treaty Act.

CHAPTER 9 – OPERATIONS AND MAINTENANCE

9.1 OPERATIONS

The emergency AWS chamber is operated by two primary means of closure – the intake closure gate and the butterfly valve on the downstream side of the monolith penetration. When the system is turned on, the butterfly valve should be set to the open position prior to opening the intake gate. The intake gate will be opened with the mobile crane, the 10-foot and 7.5-foot conduits will be flooded, and the system will be delivering flow to the AWS chamber. During shutdown of the system, the butterfly valve will be closed, shutting off flow. The intake gate will then be lowered into place with the mobile crane. The butterfly valve provides an unassisted means of flow closure and may be closed prior to positioning the mobile crane for intake gate operation. Butterfly valve operation is coordinated to result in negligible transient effects during closure.

Since debris will likely build up on the trash rack, a debris removal schedule will need to be developed. The schedule will be based on project observation; raking will be conducted on a more aggressive schedule compared to the existing fish unit raking. The butterfly valve should be used to stop flow before raking to increase the potential for debris to drop off the trash rack and have sweeping flow move the debris downstream. Once raking is completed, the butterfly valve can be opened to reestablish flow.

9.2 MAINTENANCE REQUIREMENTS

Maintenance requirements for this system should be relatively minor. The trash rake should not require much maintenance outside of periodically inspecting the rake tines for damage or wedged debris. The operating gate roller wheels will also require only periodic inspection to make sure they remain free and that the wheel bearings have not lost any grease. The operating gate itself will require addition to the Hydraulic Steel Structures Inspection program. The gate will remain continuously submerged, so in order to inspect it and its wheels, it will be required to flood the pipeline up to the butterfly valve, as the gate is removed. The inspection sequence should be set up so that the butterfly valve and pipeline have been inspected prior to removing the operating gate. The butterfly valve should also only require periodic inspection. The seats and trunnions should be inspected periodically and the valve cycled to ensure that everything is working properly. The valve operator should not require any special maintenance. The inside of the pipeline itself should be inspected every 5 years or so, perhaps as part of the dam safety periodic inspection.

CHAPTER 10 – COST ESTIMATE

10.1 COST EVALUATION

This chapter presents the construction cost estimate for The Dalles east fish ladder auxiliary water supply (AWS) as described in this DDR. Two options were estimated. See appendix G for cost estimates, schedules, and analyses of these two options.

Option 1 entails the construction of a temporary cofferdam at the face of the dam prior to tunneling through the dam. The cofferdam would be installed with divers during the in-water work window (IWWW), between December 1 and February 28. The cofferdam would be removed during the following season's IWWW.

Option 2 entails the installation of pre-cast piers at the face of the dam with integral guides for installation of bulkheads to enable the upstream portion of the tunnel to be dewatered. With Option 2, the bulkheads would remain with the Government, benefitting future maintenance work, and will eliminate the need to work in the second season IWWW to remove the cofferdam. However, Option 2 requires significantly more dive time and has additional risks over and above Option 1.

Based on price and risk, Option 1 was determined to be the preferable option. See Chapter 5, Structural Design, for detailed discussions of advantages and disadvantages of each option.

The estimated construction cost, including contingency and escalation, is $11,037,000 for Option 1 and $12,458,000 for Option 2.

The total project cost including planning, engineering and design, and construction management is $14,531,000 for Option 1 and $16,400,000 for Option 2.

10.2 REFERENCES

a. U.S. Army Corps of Engineers (USACE) Engineering Regulation (ER) 1110-2-1302, September 15, 2008, Civil Works Cost Engineering.

b. Davis-Bacon Act Wage Decision: OR 11/01/2013 OR79, State: Oregon, Construction Type: Heavy, County: Wasco County in Oregon.

c. U.S. Army Corps of Engineers (USACE) Engineer Pamphlet (EP) 1110-1-8, Volume EP11R08, 2011 Construction Equipment Ownership and Operating Expense Schedule, Region 8.

ER 1110-2-1302, Engineering and Design Civil Works Cost Engineering, provides policy, guidance, and procedures for cost engineering for all civil works projects for USACE. The cost estimating methods used establish reasonable costs to support a planning evaluation process. The design is at a preliminary level and the cost estimate is at a similar level.

10.3 BASIS OF COST ESTIMATE

The cost estimates are based on the analyses in this 90 percent DDR. The estimates have been prepared in Micro Computer Cost Estimating System (MCACES) MII Version 4.2.

10.4 CONSTRUCTION SCHEDULE

It is anticipated that the construction schedule for Option 1 will be approximately 20 months from notice to proceed (NTP) to project closeout (see appendix G).

10.4.1 Construction Work Windows

The construction schedule is primarily driven by the IWWW from December 1 to February 28. During the first season IWWW, the contractor will install a cofferdam. The cofferdam will remain in place until the second season IWWW. Additionally, installation of the 7.5-foot-diameter piping across the junction pool and the orifice manifolds in the AWS chamber must be conducted during the IWWW, when they can be dewatered.

Option 2 would eliminate the need to work in the second season IWWW because there would be no cofferdam to remove.

10.4.2 Overtime

The estimates assumed a 40-hour work week.

10.4.3 Acquisition Plan

The estimates were developed assuming the project will be competitively bid with full and open competition.

10.5 SUBCONTRACTING PLAN

The cost estimates were based on the work being accomplished by a general construction contractor with marine construction expertise.

The following key specialty subcontractors are anticipated:

- Concrete Mining Subcontractor.
- Concrete Saw-cutting Subcontractor.
- Industrial Coating Subcontractor.
- Electrical Subcontractor.
- Paving Subcontractor.

10.6 PROJECT CONSTRUCTION

10.6.1 Site Access

The project site is located at The Dalles Lock and Dam. The project site can be accessed by an exit from Interstate 84. There is also barge access through the Columbia River Navigation Lock System. It is anticipated that the cofferdam will be installed and removed from a barge on the forebay side of the dam.

10.6.2 Materials and Offsite Fabrication

Items to be fabricated offsite include the temporary cofferdam, the trash rack panels, the trash rake, and emergency closure gate. Additionally, the large diameter pipe (10-foot and 7.5-foot-diameter), large diameter mitered pipe bends, and 10-foot by 7.5-foot wye will be custom fabrication items for the project.

The cofferdam will require Government approval of a contractor provided design and several week of offsite fabrication time. The cofferdam must be fabricated and delivered to the project for installation during the first season IWWW.

The 10-foot-diameter butterfly valve will be a special order item, requiring 6 to 8 months to manufacture. The contractor may choose to install a temporary spacer so that they can proceed with construction of the pipeline, then install the butterfly valve later in the project. The 10-foot-diameter expansion joint will likely also be a special order item, requiring a long lead item.

10.6.3 Borrow Area

The borrow sources for materials will be commercially purchased. It is assumed that sources are located locally.

10.6.4 Unusual Conditions (Soil, Water, Weather)

Rock is expected to be encountered with the trenching of the 10-foot-diameter pipeline. The estimate assumed that bedrock will be encountered at elevation 105 feet near the monolith (STA 0+75), and drop to elevation 100 feet at STA 2+10. See Chapter 3, Geotechnical Design, for recommendations for additional geotechnical investigations to identify the rock excavation quantities.

Use of explosives at the project site will likely not be permitted. Therefore, the cost estimate was based on the use of expansive grout to fracture the rock prior to removal with a hydraulic excavator.

Ground water may be encountered during the excavation work. The proximity of the project to the river and fish ladder will require stringent measures to prevent spills, sediment, and debris from entering the river.

10.6.5 Construction Methodology

10.6.5.1 Cofferdam Construction

Construction of the conduit through the Monolith 5 will require installation of a 35-foot-diameter cofferdam estimated to have a weight of 270 kips. The specific design of the cofferdam will be the responsibility of the contractor.

The cofferdam will require divers for installation. Discussions with a local contractor have indicated that the contractor may choose to employ a technique of placing the majority of the anchors required to resist buoyancy forces above the water line in order to reduce the required dive time.

Once the cofferdam is constructed and dewatered, the contractor will commence with tunneling operations. The cofferdam will stay in place during construction of the trash rack guides, installation of the trash rack and trash rake, and installation of the emergency closure gate.

10.6.5.2 Concrete Tunneling

The cost of concrete tunneling through Monolith 5 was estimated based on methods and productivity data from NWP's Dorena Lake Hydroelectric Project, which utilized an F16A Alpine Miner Roadheader machine.

10.6.5.3 Underwater Construction

Underwater construction by divers is required for installation and removal of the cofferdam at the upstream face of Monolith 5. Option 2 would require significantly more dive time for installation of precast pier sections, but would eliminate the need for a second mobilization of the divers to remove the cofferdam.

10.6.5.4 AWS Chamber Discharge Piping

Work in the AWS chamber will require the installation of temporary platforms, scaffolding, and special rigging to assemble the sections of the discharge piping orifice manifolds. There is a 4-foot by 4-foot hatch immediately above the discharge piping. The hatch can be used for access and for lowering materials and tools into the AWS chamber. However, the large diameter discharge piping and large equipment and materials will need to be lowered into the chamber through another access point.

There are removable slabs approximately 60 feet upstream from the discharge pipes that would be utilized for lowering the 7.5-foot-diameter orifice discharge manifolds into the AWS chamber. Immediately below the removable slabs is an up-well into the AWS chamber. It is anticipated that a temporary platform would be installed over the up-well so that manifold sections could be dropped into the AWS chamber, and then be moved on casters on the floor of the AWS chamber. The manifold sections will then be lifted into position with hoists for welded or bolted connections. The 7.5-foot-diameter orifice manifolds will likely need to be fabricated into 8-foot to 10-foot sections to be practically handled within the AWS chamber. The estimates assumed additional field welds to assemble the manifolds within the AWS chamber.

10.6.5.5 Installation of the Buried Pipeline

It was assumed that the installation of the 10-foot-diameter pipeline will be done in two phases to allow for road access to the powerhouse. The first phase would be completely backfilled and brought up to grade before starting the second phase.

10.6.5.6 Site Utilities

Several underground utilities will likely be affected by the excavation for the 10-foot-diameter pipeline. General assumptions were made about the cost impact for repairing/restoring the affected utilities. Refinements to the estimate will be made once a utility survey accurately determines the location and status of the underground utilities.

10.6.6 Equipment/Labor Availability and Distance Traveled

Labor and equipment are available within a 100-mile radius of the project, which includes Portland, Oregon, and Vancouver, Washington.

10.6.7 Overhead, Profit, Bond, Contingency, and Escalation

Table 10-1 summarizes the markups applied to the construction cost estimate.

Table 10-1. Markup Summary

Markup	Percentage
Prime Contractor Job Site Overhead	15%
Prime Contractor Home Office	15%
Profit	10%
Subcontractor Job Site Overhead	15%
Subcontractor Overhead Home Office	15%
Subcontractor Profit	10%
Mobilization	4% of Direct Cost
Bond	2%
Escalation from CWCCIS an 3Q16 index	4.88%
Contingency Based on the Abbreviated Risk Analysis*	
Option 1 – Cofferdam	26.5%
Option 2 – Install Precast Pier with Divers	30.7%

* See appendix G for the Abbreviated Risk Analysis for both options

10.7 COST BASIS

Labor rates were based on General Decision Number: OR130079 11/01/2013 OR79 State: Oregon. Construction Type: Heavy County: Wasco County in Oregon.

Equipment rates used are from Engineer Pamphlet 1110-1-8, Volume EP11R08, Region 8, 2011.

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The Dalles East Fish Ladder Auxiliary Water Backup System

90 Percent Design Documentation Report

APPENDIX A

USACE Memorandum for Estimated Minimum Discharge

CENWP-EC-HD 21 January 2011

MEMORANDUM FOR Randy Lee, CENWP-EC-HD

SUBJECT: The Dalles East Fish Ladder Emergency Backup for the Auxiliary Water Supply System–Minimum Discharge

Objective:

1. This memo will present the rationale for choosing 1400 cfs as the minimum discharge target for emergency backup flow to the Auxiliary Water System (AWS) at The Dalles East Fish Ladder (TDEFL) for the purpose of initial alternatives brainstorming by HDR and USACE Portland District (NWP).

Background:

2. The AWS at TDEFL supplies water to the east, west, and south fish ladder entrances, the fish ladder itself, as well as the transportation and collection channels in order to attract and transport upstream migrating adult fish. Water is currently supplied to the AWS by two fish unit turbines located on the west end of the powerhouse. The AWS normally operates with a total flow of up to 5,000 cfs (2,500 cfs per turbine unit). If both turbines were to fail at the same time, water supplied to the AWS would be severely limited or eliminated.

3. Previous studies have been undertaken to find alternatives to provide a backup supply of water to the AWS for a one-year duration in the event that both fish units fail. For these studies, alternatives have been evaluated assuming that at least 3400 cfs is required to allow the ladder system (including east, west and south entrances) to meet fisheries criteria. Estimated costs for the alternatives that were deemed most promising turned out to be very expensive and consequently impractical.

4. A special Fish Facilities Design Review Work Group (FFDRWG) meeting was held on 2 November 2010 in part for the purpose of discussing the possible reduction of operational constraints for a one-year emergency situation where both fish turbine units were unavailable. Based on discussions at this meeting, it was agreed that the minimum acceptable one-year emergency operation would be to use TDEFL east entrance exclusively.

5. The relative importance of various design criteria was also discussed at the FFDRWG meeting and is shown below in relative order of priority:
   a. Maintain 1.5 ft. of head differential over the entrance weir(s).
   b. Assume operation of two of the three weirs (however, there was additional interest in considering a variable width vertical entrance structure instead with the goal of improved downstream attraction flow properties).
   c. Maintain at least 8 ft. depth at entrance weir(s) (depth from tailwater elevation to top of the weir)

Other operational criterion that were not discussed but need to be considered include:

d. Water velocity of 1.5 to 4 fps (2 fps optimum) maintained for the full length of the lower end of the fish ladder that is affected by tailwater elevation.
e. Water depth over fish ladder weirs: 1.0 ft. +/- 0.1 ft. and 1.3 ft, +/- 0.1 ft, during shad season.
f. Maximum diffuser velocity = 0.5 ft/s

Discussion:

6. Calculations of a single weir discharge at the TDEFL east entrance were made for a range of tailwater elevations with the following equations, criteria, assumptions and constants:
   - Villamonte Equation for Submergence:
     - Q = (1 – (H2/H1)^1.5)^0.385*CwLH1^1.5
     - H1 = depth from water surface elevation (WSE) to top of weir;
     - H2 = depth from tailwater elevation (TW) to top of weir
   - Rehbock Equation for Weir Coefficient:
     - Cw = 3.22 + 0.44 H/P
     - H = H1; P = weir height
   - Entrance weir head (WSE – TW) at entrance weir(s) of 1.5 ft.
   - Depth of weir (H2) minimum of 8 ft.
   - Entrance weir width of 8.67 ft.
   - Invert elevation at entrance of 60 ft.
   - Entrance channel width just upstream of weir of 34 ft.
   - No pier or contraction losses were used to allow for a more conservative discharge (ie: higher acceptable minimum emergency flow).

7. Tailwater (TW) elevation used in the above equations can markedly influence the estimated minimum flow. Therefore it was necessary to choose a reasonable range for this analysis. Both stage and flow duration curves for the period of record (1974-1999) were used to compile a range of tailwater elevations of note at The Dalles Dam (Table 1). As seen in the table, the forebay of Bonneville Dam can influence the tailrace elevation of The Dalles Dam such that there is a range of possible tailwater levels for any given total river flow. A range of probable flow operations within the fish passage season would be banded by the higher flows in May/June and the lower flows in September/October. For the upper tailwater limit in May/June the 5% exceedance TW elevation range is 85.4 to 86.6 ft. Additionally, within the range of high flows, there is a peak where river flow conditions are such that adult fish will hold rather than travel upstream. Until a more defined estimate can be identified using existing fish passage data, it is estimated that this river discharge is around 400 to 450 kcfs, The corresponding TW elevation range (based on Bonneville forebay) for this condition is 84.7-88.6 ft. or an average of 86.6 ft which coincides with the 5% exceedance for June. Therefore, 86.6 ft. was chosen as the upper TW elevation limit for this analysis. Focusing on lower TW levels, the range of 95% exceedance for September and October is 74.0 to 74.2 ft. These values fall within the TW elevation range for the minimum powerhouse flow of 50,000 cfs (72.6 to 77.6 ft.). Therefore the 95% exceedance TW elevation for October (74.0 ft.) was chosen for the lower TW elevation limit for this analysis.

8. Using the criteria deemed most critical for an emergency operation (the ability to maintain 1.5 ft. entrance weir differential head and a minimum of 8 ft. weir depth) through the range of TW elevations 74.0 to 86.6 ft. results in design flows of 1200 cfs and 1000 cfs respectively. However, if minimum channel velocities are to be maintained at the downstream end of the east entrance, more flow would be needed at the higher TW elevation limit of 86.6 ft. If 1.5 fps (minimum channel velocity criteria) is required at the entrance then the flow would need to be 1400 cfs. For the purposes of this analysis, the upper flow of 1400 cfs has been chosen for the minimum allowable emergency flow for TDEFL east entrance-only condition. When the inflow from the upper ladder flow control section (80-120 cfs) is subtracted, the actual total AWS flow required would be 1320 to 1280 cfs. However, for this level of analysis a conservative AWS discharge of 1400 cfs has been chosen.

9. Considerations that could help maintain and/or reduce the minimum allowable emergency flow required for TDEFL include the potential for reduction of the forebay elevation at Bonneville dam during the higher TW period of an emergency operation. Also, further analyses should include the development of an operational logic for the full range of design TW elevations (ie: prescribing weir depth as a function of TW) as the weir height is pivotal to keeping within the minimum discharge needed for emergency operations.

<u>Conclusions:</u>

10. For this initial analysis, 1400 cfs is determined to be a minimum allowable emergency backup flow for TDEFL based on meeting ladder entrance head and 8 feet of passage depth over 2 of the 3 East entrance weirs. A range of TW elevation conditions were defined and flows approximated given certain fisheries criteria. Ultimately, for future alternative analyses, the hydraulics throughout the ladder system will need to be analyzed to ensure that all internal hydraulic criteria are met in order to maximize fish passage success. Also, as studies progress to a recommended design solution, the impact of system operations (such as the elevation of the Bonneville forebay) on an emergency ladder operation should be discussed and possible emergency operations to improve adult movement should be defined.

<u>Recommendations:</u>

11. For this phase of the comparison of alternatives for supplying emergency backup water to the Auxiliary Water Supply System for The Dalles East Fish Ladder in the case where both fish units are unable to function, we recommend using 1400 cfs.

Karen Kuhn
Hydraulic Engineer

REVIEW PROCESS:

HD – Steve Schlenker

CF:
CENWP-EC-HD - Randy Lee
CENWP-EC-HD – Kyle McCune
CENWP-PM-E – Sean Tackley

Table 1 - Range of Significant River Discharge and Tailwater Conditions for The Dalles Dam*

Condition	Discharge	Approximate Tailwater Range at Powerhouse by Flow **		TW at Powerhouse by Exceedance***
	kcfs	ft	ft	ft
100 year event	680	95.6	97.0	
Maximum Tailwater				92.2
5% Exceedance June***				***86.6***
Max Q for Adult Movement****	400-450	84.7	88.6	
5 % Exceedance May***				85.4
Max Ph w/ 40% spill	430	85.3	88.0	
Max Ph	270	77.8	81.3	
Discharge 100kcfs (92% Flow Exceedance)	100	73.5	78.2	
Min Ph w/40% Spill	85	73.3	78.0	
Min Ph	50	72.6	77.6	
95% Exceedance Sept***				74.2
95% Exceedance Oct***				***74.0***
Minimum Operating Tailwater*****				70.0

*Data Source: Stage exceedance, stage/discharge relationships, and tailwater ranges for the period of record (1974-1999) developed by CENWP-EC-HY October 2000.
**Tailwater range based on forebay fluctuations at Bonneville Dam from 71.5-76.5 ft. Tailwater elevations were adjusted from RM 188.95 to location at TDEFL powerhouse (RM 192.43) using relationships developed in Oct. 2000 study.
***Based on hourly readings at Powerhouse gage.
****Estimate to be verified with fish passage data.
*****From Fish Passage Plan 2010

Note: Highlighted values used in final selection of minimum emergency flow analysis.

The Dalles East Fish Ladder Auxiliary Water Backup System

90 Percent Design Documentation Report

APPENDIX B

Hydraulic

Table of Contents

Project Title: Dalles EFL Emergency AWS - Intake Design	12/19/2013	By: Logan Negherbon Check by: Ryan Laughery

Intake Design

The scope of this document is to develop dimensions for the trashrack and intake system. Due to the oversizing of the trashrack, the loss developed at design dischrage will be assumed constant at all flows for the purposes of this submission. See Energy Dissipation and Hydraulic Transient Analysis for supporting hydraulic calculations.

Project Title: Dalles EFL Emergency AWS - Intake Design	12/19/2013	By: Logan Negherbon Check by: Ryan Laughery

Units definition

$cfs := ft^3 \cdot s^{-1}$ cubic feet per second

$fps := ft \cdot s^{-1}$ feet per second

Hydraulic Properties

$\rho := 1000 \frac{kg}{m^3}$ Fluid density

Assumed temperature deg. F

$T_f := 50$ $T_c := (T_f - 32) \cdot \frac{5}{9}$ $T_c = 10$ Temp. deg. C

$$\nu := \frac{1.792 \cdot 10^{-6}}{1.0 + \left(0.0337 \cdot T_c + 0.000221 \cdot T_c^{2}\right)} \cdot \frac{m^2}{s}$$

$\nu = 1.319 \times 10^{-6} \cdot \frac{m^2}{s}$ Kinematic viscosity of water from temp. relationship

Project Title: Dalles EFL Emergency AWS - Intake Design	12/19/2013	By: Logan Negherbon Check by: Ryan Laughery

Design Parameters

$Q := 1400\text{cfs}$ — Design flow rate

$V := 3\text{fps}$ — Velocity limitation for trashrack approach velocity - EM 1110-2-1602

$V_{thr} := 5\text{fps}$ — Recommended thru velocity maximum for cleaning accessible trashracks from Bureau of Reclamation - Design of Small Dams

$A_{req} := \frac{Q}{V}$ — $A_{req} = 466.667\ \text{ft}^2$ — Area required to meet trashrack approach velocity limitation

$h_t = K_t \cdot \frac{v_n^2}{2 \cdot g}$ — $K_t = 1.45 - 0.45 \cdot \frac{a_n}{a_g} - \left(\frac{a_n}{a_g}\right)^2$ — Equation 11, Design of Small Dams - BoR

$a_n := 0.75\text{in}$ — Design bar spacing per EDR

$a_g := \frac{5}{16}\text{in} + a_n$ — Assummed unit thickness for bar and space

$\frac{a_n}{a_g} = 0.706$ — Resultant porosity

$v_n := V_{thr}$ — Thru velocity for head loss differential

$A_{req} := \frac{Q}{v_n} \cdot \frac{a_g}{a_n}$ — $A_{req} = 396.667\ \text{ft}^2$ — Based on thru velocity limitations — $A_{req} := 466\text{ft}^2$ — Area required based on approach velocity limitations - Controlling

Required trashrack height based on 15 foot width

$H := \frac{A_{req}}{15\text{ft}}$ — $H = 31.067\ \text{ft}$

Required trashrack height based on 20 foot width

$H := \frac{A_{req}}{20\text{ft}}$ — $H = 23.3\ \text{ft}$

Project Title: Dalles EFL Emergency AWS - Intake Design	12/19/2013	By: Logan Negherbon Check by: Ryan Laughery

Trashracks for the intake are sized with a 3 fps approach velocity and a flow of 1400 cfs. Velocity criterion was determined during the EDR phase of design and based off of EM 1110-2-1602. A through bar velocity of 5 fps is recommended by the Bureau of Reclamation *Design of Small Dams* publication. An assumed porosity of 70 percent for the trashrack results in a required gross area of 350 square feet; however, in order to meet the approach velocity a required gross area of trashrack is required to be 466 square feet.

$K_t := 1.45 - 0.45 \cdot \frac{a_n}{a_g} - \left(\frac{a_n}{a_g}\right)^2$ $\quad K_t = 0.634$ $\quad$ Resultant loss coefficient

$h_t := K_t \cdot \frac{v_n^2}{2 \cdot g}$ $\quad h_t = 0.246\,ft$ $\quad$ Resultant head differential

$A_{req} = 466\,ft^2$

$R_h := 160ft$ $\quad R_l := 155ft$ $\quad CL := 116.5ft$ $\quad p_t := h_t \cdot \rho \cdot g$ $\quad p_t = 0.107\,psi$

$P_1 := (R_h - CL) \cdot g \cdot \rho$ $\quad P_1 = 18.858\,psi$ $\quad p_1 := R_h - CL$

$P_2 := P_1 - p_t$ $\quad P_2 = 18.752\,psi$ $\quad p_2 := p_1 - h_t$

$\beta := 100\%$ $\quad$ Debris blockage factor (% open area)

$V_1 := V = 3\,\frac{ft}{s}$ $\quad V_2 := \frac{Q}{\beta\, A_{req} \cdot \frac{a_n}{a_g}} = 4.256\,\frac{ft}{s}$

$F_r := (P_1 - P_2) \cdot A_{req} \cdot \left(1 - \beta \frac{a_n}{a_g}\right) + \rho \cdot Q \cdot (V_2 - V_1)$ $\quad$ Equation for force imparted by momentum and pressure differential

$F_r = 5.52 \cdot kip$ $\quad$ Resultant force from momentum and pressure differential

$\frac{F_r}{A_{req}} = 11.845 \cdot psf$ $\quad$ Resultant pressure resistance from momentum and pressure differential

Project Title: Dalles EFL Emergency AWS - Intake Design	12/19/2013	By: Logan Negherbon Check by: Ryan Laughery

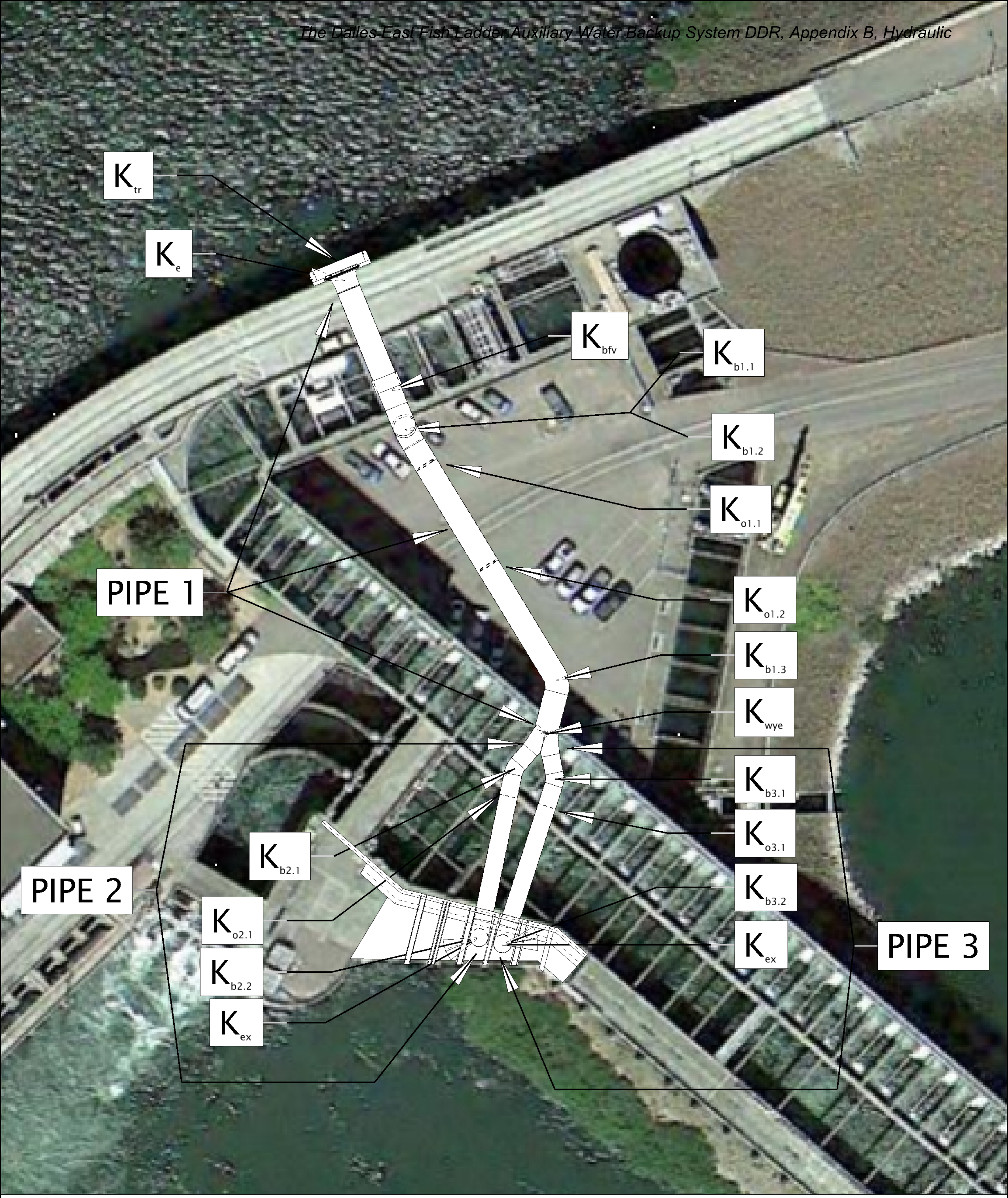
$\beta := 50\%$ Debris blockage factor (% open area)

$V_1 := V = 3\,\frac{ft}{s}$ $V_2 := \frac{Q}{\beta\,A_{req}\cdot\frac{a_n}{a_g}} = 8.512\,\frac{ft}{s}$

$F_r := (P_1 - P_2)\cdot A_{req}\cdot\left(1 - \beta\frac{a_n}{a_g}\right) + \rho\cdot Q\cdot(V_2 - V_1)$ Equation for force imparted by momentum and pressure differential

$F_r = 19.611\cdot kip$ Resultant force from momentum and pressure differential

$\frac{F_r}{A_{req}} = 42.083\cdot psf$ Resultant pressure resistance from momentum and pressure differential



K_{tr}
K_e
K_{bfv}
$K_{b1.1}$
$K_{b1.2}$
$K_{o1.1}$
PIPE 1
$K_{o1.2}$
$K_{b1.3}$
K_{wye}
$K_{b3.1}$
$K_{b2.1}$
$K_{o3.1}$
PIPE 2
$K_{b3.2}$
$K_{o2.1}$
K_{ex}
PIPE 3
$K_{b2.2}$
K_{ex}

Pipe Losses

Project Title: Dalles EFL Emergency AWS - Energy Dissipation	12/19/2013	By: Logan Negherbon Checked By: Ryan Laughery

Energy Dissipation

The scope of this document is to develop a one dimensional pipe network design model of the energy dissipation of the backup AWS system from intake to discharge. This will include flow rates based on available hydraulic head, frictional headloss as a function of flow rate, minor headlosses as a function of geometry and flow rates, thrust forces based on flow rates and pressure, cavitation potential of minor losses based on flow rates. Manual calculations were deemed preferable to commercial pipe network model analysis due to the simplicity of the pipe network and the complexity of the orifice and caviation analysis. Sensitivities factors are included in minor loss definition and equivalent sand grain roughness for friction through out the document. Common variables are listed on the following page and a design summary is avaliable at the end of the document. Use the Pipe Losses aerial overlay of the design for references to losses and loss locations. Intake design is available in the Intake worksheet and hydraulic transient analysis is available in the Hydraulic Transient worksheet.

Project Title: Dalles EFL Emergency AWS - Energy Dissipation	12/19/2013	By: Logan Negherbon Checked By: Ryan Laughery

Common variables

T	Temperature	K	Minor loss coefficient
D	Diameter	ρ	Density
A	Area	γ	Unit weight
g	Gravitational constant	P	Pressure
V	Velocity	eH	Energy gradeline
Q	Flowrate	H	Hydraulic gradeline
L	Length	HV	Velocity head
f	Friction factor	Fr	Froude number
Re	Reynolds number	θ	Area ratio/bend angle
ν	Kinematic viscosity	C	Contraction/Discharge coefficient

Common Subscripts

$-o$	Orifice
$-us$	Upstream
$-ds$	Downstream
$-1.\_$	Pipe #
$-\_.1$	Loss ID on Pipe _
$-b$	Bend
$-vc$	Vena contracta
$-c$	Centigrade
$-f$	Fahrenheit

Project Title: Dalles EFL Emergency AWS - Energy Dissipation	12/19/2013	By: Logan Negherbon Checked By: Ryan Laughery

Custom Units Definition

$fps := ft \cdot s^{-1}$ feet per second

$cfs := ft^2 \cdot fps$ cubic feet per second

Fluid Properties

$\rho := 1000 \frac{kg}{m^3}$ Density of water

$\gamma := 62.41 \frac{lbf}{ft^3}$ Unit weight of water

Assumed temperature deg. F

$T_f := 50$

$T_c := (T_f - 32) \cdot \frac{5}{9}$

$T_c = 10$ Temp. deg. C

$$\nu := \frac{1.792 \cdot 10^{-6}}{1.0 + (0.0337 \cdot T_c + 0.000221 \cdot T_c^2)} \cdot \frac{m^2}{s}$$

$\nu = 1.32 \times 10^{-6} \cdot \frac{m^2}{s}$ Kinematic viscosity of water from temp. relationship

Vapor pressure input matrix (values [Tf, psia] from Prasuhn)

$$Data := \begin{pmatrix} 32 & 0.087 \\ 40 & 0.12 \\ 50 & 0.18 \\ 60 & 0.26 \\ 70 & 0.36 \\ 80 & 0.51 \\ 90 & 0.70 \end{pmatrix}$$

$data := csort(Data, 1)$

$S := cspline(Tf, Pv)$

Temp deg F

$Tf := data^{\langle 0 \rangle}$

Pressure psia

$Pv := data^{\langle 1 \rangle}$

Vapor pressure as function of temp, psia

$Pv(x) := interp(S, Tf, Pv, x)\, psi$

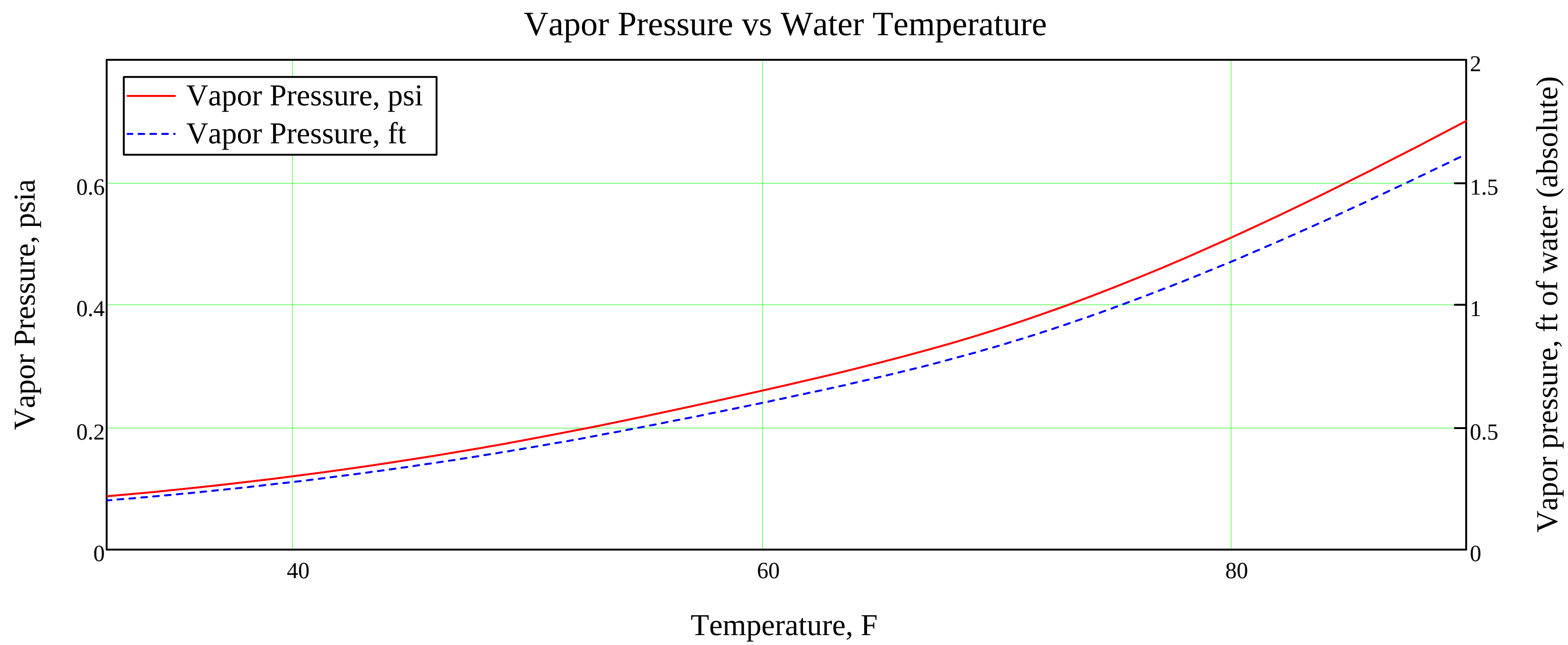
$Pv(T_f) = 0.18\, psi$

Vapor pressure as function of temp, psig

$Pvg(T_f) := Pv(T_f) - 1atm$

$Pvg(T_f) = -14.52\, psi$

$x := 32, 33 .. 90$



Geometric Functions   Area function   Reynolds number   Average velocity

For circular conduit

$$A_c(d) := \frac{\pi d^2}{4} \qquad Re_c(Q,d) := \frac{Q \cdot d}{A_c(d) \cdot \nu} \qquad V_c(Q,d) := \frac{Q}{A_c(d)}$$

Jain's explicit equation for friction factor

Ref: Swamee and Jain, 1976, "Explicit equations for pipe-flow problems," Journal of Hydr. Div. ASCE, Vol. 102, No. HY5, pp. 657-664

$$f_c(Q,d,k_s) := \frac{0.25}{\log\left(\frac{k_s}{3.7 \cdot d} + \frac{5.74}{Re_c(Q,d)^{0.9}}\right)^2}$$

friction factor for circular conduit

Project Title: Dalles EFL Emergency AWS - Energy Dissipation	12/19/2013	By: Logan Negherbon Checked By: Ryan Laughery

Design Parameters

$Q_t := 1500cfs$ Design flow rate from intake (high forebay flowrate selected for initial loss calculations)

$Q_{t2} := \frac{Q_t}{2}$ Assumed branching flow to pipe 2 at bifurcation

$Q_{t3} := Q_t - Q_{t2}$ $Q_{t3} = 750 \cdot cfs$ Assumed branching flow to pipe 3 at bifurcation

	Diameter	Length	
Pipe 1	$D_1 := 10ft$	$L_1 := 190ft$	Section from dam to bifurcation
Pipe 2	$D_2 := 7.5ft$	$L_2 := 110ft$	New section of pipe from bifurcation to AWS Chamber
Pipe 3	$D_3 := 7.5ft$	$L_3 := 110ft$	Section from bifurcation to contraction

Sensitivities

- 10% increase minor losses
- 10% decrease minor losses
- 10x increase in relative roughness
- 0.1x decrease in relative roughness

$\alpha_k := 1.0$ minor loss sensitivity coeff.

$\alpha_f := 1.0$ friction loss sensitivity coeff.

10 degree temperature increase/decrease makes negligible changes and is not varried in sensitivity matrix

Factors of 1.0 indicate assumed losses

Roughness - Assumed epoxy coating

$k := \alpha_f \cdot 0.025mm$ Through new pipe with friction loss sensitivity coefficient (Miller Table 8.1 - New Smooth Pipe)

$k_{sr} := 0.025mm$ Rough (Miller Table 8.1- no lining)

$k_{ss} := 0mm$ Fully smooth

Project Title: Dalles EFL Emergency AWS - Energy Dissipation	12/19/2013	By: Logan Negherbon Checked By: Ryan Laughery

Summary of Losses

Pipe 1
- Trash Rack Loss
- Entrance Loss
- Butterfly Valve Loss
- Bend Loss 1 (59 deg ~ 60 deg)
- Bend Loss 2 (59 deg ~ 60 deg)
- Orifice Loss 1.1
- Orifice Loss 1.2
- Bend Loss 3 (45 deg)
- Friction Loss

Pipe 2
- Wye Loss (10-ft to 7.5-ft)
- Bend Loss 2.1 (30 deg)
- Orifice Loss 2.1
- Bend Loss 2.2 (deg)
- Exit Loss
- Friction Loss

Pipe 3
- Wye Loss (10-ft to 7.5-ft)
- Bend Loss 3.1 (30 deg)
- Orifice Loss 3.1
- Bend Loss 3.2 (90 deg)
- Exit Loss
- Friction Loss

Operating Conditions

High Forebay & High Tailwater (FB:160ft & TW:86ft [AWS:89.8ft] => HD:70.2ft)
High Forebay & Low Tailwater (FB:160ft & TW:76.4ft [AWS:78.4ft] => HD:81.6ft)
Low Forebay & High Tailwater (FB:155ft & TW:86ft [AWS:89.8ft] => HD:65.2ft)
Low Forebay & Low Tailwater (FB:155ft & TW:76.4ft [AWS:78.4ft]=> HD:76.6ft)

Key Elevations

Intake Elevation CL: 116.5 ft

$FB_h := 160ft$ High forebay

$FB_l := 155ft$ Low forebay

$AWSC_h := 89.5ft$ High AWSC WSE

$AWSC_l := 78.4ft$ Low AWSC WSE

$Ele_{top1.1} := 109.5ft$ Top of pipe at orifice 1.1

$Ele_{top1.2} := 109.5ft$ Top of pipe at orifice 1.2

$Ele_{top2.1} := 104.5ft$ Top of pipe at orifice 2.1

$Ele_{top3.1} := 104.5ft$ Top of pipe at orifice 3.1

$FB_d := FB_h$

$AWSC_d := AWSC_l$

$FLC_{cl} := 98.5ft$ Fishladder crossing centerline elevation

$Ele_{bop2} := FLC_{cl} - \frac{D_2}{2}$ $Ele_{bop2} = 94.75\,ft$ Elevation of bottom of pipe into AWSC

$Ele_{bop3} := FLC_{cl} - \frac{D_3}{2}$ $Ele_{bop3} = 94.75\,ft$ Elevation of bottom of pipe into AWSC

Maximum ydraulic head through Pipe 1 and 2

$HP_{H12} := FB_h - AWSC_l = 81.6\,ft$

$HP_{L12} := FB_l - AWSC_h = 65.5\,ft$

Minimum hydraulic head through Pipe 1 and 3

$HP_{H13} := FB_h - AWSC_l = 81.6\,ft$

$HP_{L13} := FB_l - AWSC_h = 65.5\,ft$

Pipe 1 Losses

$Re_c(Q_t, D_1) = 1.3 \times 10^7$ Reynolds number

$HV_1 := \frac{V_c(Q_t, D_1)^2}{2 \cdot g}$ $HV_1 = 5.67\,ft$ Velocity head thru Pipe 1

$hv_1(Q) := \frac{V_c(Q, D_1)^2}{2 \cdot g}$

Trash Rack Loss from Intake worksheet $K_t := 0.634$ ---> $h_t := 0.246\,ft$

Entrance Loss $K_e := 0.16$ Assumed loss based on guidance from EM 1110-2-1602 (Section 3-7)

Butterfly Valve Loss

$K_{bfv} := \alpha_k \cdot 0.2$ From Miller Fig. 14.19

Assumed lentil shaped butterfly valve oriented with a veritcal axis such that the disc does not act as a flow vane near the following bends.

Bend Loss 1 (59 deg ~ 60 deg)

$\frac{r}{d} = 1$

$Ele_{b1.1} := 116.5ft$ Elevation at centerline of bend

$\theta_{b1.1} := -60deg$ Angle of deflection of bend

$k'_b := 0.15$ From Miller Fig. 9.10

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 1.0$ No outlet, Miller Fig. 9.4

$C_f := \frac{f_c(Q_t, D_1, k_{sr})}{f_c(Q_t, D_1, k_{ss})}$ $C_f = 1.12$ From Miller Eq. 9.3

$K_{b1.1} := \alpha_k \cdot k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b1.1} = 0.17$ From Miller Eq. 9.4

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Bend Loss 2 (59 deg ~ 60 deg)

$K_{b1.2} := K_{b1.1}$

$Ele_{b1.2} := 104.5ft$ Elevation at centerline of bend

$K_{b1.2} = 0.17$ Angle is reflected to achieve near zero slope within pipe, loss is identical to previous

$\theta_{b1.2} := 60deg$ Angle of deflection of bend

Corrected Bend Loss 1 & 2 Proximity

$L_s := 2.5ft$ $\quad \frac{L_s}{D_1} = 0.25$

Close proximity allows for reduction in bend loss. L_s denotes the staight length of pipe between bends.

$C_{b\_b} := 0.95$

From Miller Fig 10.3

$K_{b\_b1} := C_{b\_b} \cdot (K_{b1.1} + K_{b1.2})$ $\quad K_{b\_b1} = 0.32$

Bend 1 & 2 Cavitation Potential

for 1.1 $h_u := \left[FB_d - h_t - \left(K_e + K_{bfv} + f_c(Q_t, D_1, k) \cdot \frac{50ft}{D_1}\right) \cdot hv_1(Q_t) - Ele_{b1.1} - HV_1\right] \cdot \gamma$ $\quad h_u = 15.3 psi$

$\sigma_b := \frac{h_u - Pv(T_f)}{\gamma \cdot \frac{V_c(Q_t, D_1)^2}{2 \cdot g}}$ $\quad \sigma_b = 6.15$

Cavitation parameter is greater than incipient cavitation for r/d = 1

$\sigma_{bi} := 2.2$

Incipient cavitation parameter from Miller Fig 6.10 with r/d = 1

$bendcav_{1.1} :=$ | "Incipient cavitation initiated" if $\sigma_b < \sigma_{bi}$
| "Bend radius ok"

$bendcav_{1.1} =$ "Bend radius ok"

for 1.2 $h_u := \left[FB_d - h_t - \left(K_e + K_{bfv} + K_{b1.1} + f_c(Q_t, D_1, k) \cdot \frac{50ft}{D_1}\right) \cdot hv_1(Q_t) - Ele_{b1.2} - HV_1\right] \cdot \gamma$ $\quad h_u = 20.09 psi$

$\sigma_b := \frac{h_u - Pv(T_f)}{\gamma \cdot \frac{V_c(Q_t, D_1)^2}{2 \cdot g}}$ $\quad \sigma_b = 8.1$

Cavitation parameter is greater than incipient cavitation for r/d = 1

$\sigma_{bi} = 2.2$

Incipient cavitation parameter from Miller Fig 6.10 with r/d = 1

$bendcav_{1.2} :=$ | "Incipient cavitation initiated" if $\sigma_b < \sigma_{bi}$
| "Bend radius ok"

$bendcav_{1.2} =$ "Bend radius ok"

Thrust at bends 1 and 2

for 1.1 $P_1 := \left[FB_d - h_t - \left(K_e + K_{bfv} + f_c(Q_t, D_1, k)\cdot\frac{50ft}{D_1}\right)\cdot hv_1(Q_t) - Ele_{b1.1} - HV_1\right]\cdot\gamma$

$P_1 = 15.3\,psi$ Pressure at point 1 $\theta := \theta_{b1.1}$ Set bend to bend 1.2 angle

$P_{1x} := P_1$ $P_{1y} := 0psi$ X and Y components of pressure vectors at control volume surface point 1

$A_1 := A_c(D_1)$ Area of control volume on which the pressure 1 acts on

$A_1 = 78.54\,ft^2$

$V_1 := V_c(Q_t, D_1)$ $V_1 = 19.1\cdot fps$

$V_{1x} := V_1$ Velocity in X direction at point 1

$V_{1x} = 19.1\cdot fps$

$V_{1y} := 0fps$ Velocity in Y direction at point 1

$P_2 := \left[FB_d - h_t - \left(K_e + K_{bfv} + K_{b1.1} + f_c(Q_t, D_1, k)\cdot\frac{50ft}{D_1}\right)\cdot hv_1(Q_t) - Ele_{b1.1} - HV_1\right]\cdot\gamma$ $P_2 = 14.89\,psi$

$P_{2x} := P_2\cdot\cos(\theta)$ X and Y components of pressure vectors at control volume surface point 2

$P_{2y} := P_2\cdot\sin(\theta)$

$A_2 := A_1$ Area of control volume on which the pressure 2 acts on

$V_{2x} := V_1\cdot\cos(\theta)$ Velocity in X direction at point 2 $V_{2x} = 9.55\cdot fps$

$V_{2y} := V_1\cdot\sin(\theta)$ Velocity in Y direction at point 2 $V_{2y} = -16.54\cdot fps$

$F_{b1.1x} := P_{1x}\cdot A_1 - P_{2x}\cdot A_2 - \rho\cdot Q_t\cdot(V_{2x} - V_{1x})$ $P_{1x}\cdot A_1 - P_{2x}\cdot A_2 = 88.83\cdot kip$ $-\rho\cdot Q_t\cdot(V_{2x} - V_{1x}) = 27.79\cdot kip$

$F_{b1.1x} = 116.63\cdot kip$ Reactionary force in X direction

$F_{b1.1y} := P_{1y}\cdot A_1 + P_{2y}\cdot A_2 + \rho\cdot Q_t\cdot(V_{2y} - V_{1y})$ $P_{1y}\cdot A_1 + P_{2y}\cdot A_2 = -145.81\cdot kip$ $\rho\cdot Q_t\cdot(V_{2y} - V_{1y}) = -48.14\cdot kip$

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$F_{b1.1y} = -193.95 \cdot kip$ Reactionary for in Y direction

$F_{B1.1} := \sqrt{F_{b1.1x}^2 + F_{b1.1y}^2}$ $F_{B1.1} = 226.31 \cdot kip$ Resultant force

for 1.2 $P_1 := \left[FB_d - h_t - \left(K_e + K_{bfv} + K_{b1.1} + f_c(Q_t, D_1, k) \cdot \frac{50ft}{D_1}\right) \cdot hv_1(Q_t) - Ele_{b1.2} - HV_1\right] \cdot \gamma$

$P_1 = 20.09\ psi$ Pressure at point 1 $\theta := \theta_{b1.2}$ Set bend to bend 1.2 angle

$P_{1x} := P_1$ $P_{1y} := 0psi$ X and Y components of pressure vectors at control volume surface point 1

$A_1 := A_c(D_1)$ Area of control volume on which the pressure 1 acts on

$A_1 = 78.54\ ft^2$

$V_1 := V_c(Q_t, D_1)$ $V_1 = 19.1 \cdot fps$

$V_{1x} := V_1$ Velocity in X direction at point 1

$V_{1x} = 19.1 \cdot fps$

$V_{1y} := 0fps$ Velocity in Y direction at point 1

$P_2 := \left[FB_d - h_t - \left(K_e + K_{bfv} + K_{b\_b1} + f_c(Q_t, D_1, k) \cdot \frac{50ft}{D_1}\right) \cdot hv_1(Q_t) - Ele_{b1.2} - HV_1\right] \cdot \gamma$ $P_2 = 19.72\ psi$

$P_{2x} := P_2 \cdot \cos(\theta)$ X and Y components of pressure vectors at control volume surface point 2

$P_{2y} := P_2 \cdot \sin(\theta)$

$A_2 := A_1$ Area of control volume on which the pressure 2 acts on

$V_{2x} := V_1 \cdot \cos(\theta)$ Velocity in X direction at point 2 $V_{2x} = 9.55 \cdot fps$

$V_{2y} := V_1 \cdot \sin(\theta)$ Velocity in Y direction at point 2 $V_{2y} = 16.54 \cdot fps$

$F_{b1.2x} := P_{1x} \cdot A_1 - P_{2x} \cdot A_2 - \rho \cdot Q_t \cdot (V_{2x} - V_{1x})$ $P_{1x} \cdot A_1 - P_{2x} \cdot A_2 = 115.69 \cdot kip$ $-\rho \cdot Q_t \cdot (V_{2x} - V_{1x}) = 27.79 \cdot kip$

$F_{b1.2x} = 143.48 \cdot kip$ Reactionary force in X direction

$F_{b1.2y} := P_{1y} \cdot A_1 + P_{2y} \cdot A_2 + \rho \cdot Q_t \cdot (V_{2y} - V_{1y})$ $P_{1y} \cdot A_1 + P_{2y} \cdot A_2 = 193.12 \cdot kip$ $\rho \cdot Q_t \cdot (V_{2y} - V_{1y}) = 48.14 \cdot kip$

$F_{b1.2y} = 241.26 \cdot kip$ Reactionary for in Y direction

$F_{B1.2} := \sqrt{F_{b1.2x}^2 + F_{b1.2y}^2}$ $F_{B1.1} = 226.31 \cdot kip$ Resultant force

Orifice Loss 1.1

$D_{o1.1} := 7.4ft$ Orifice Diameter

$L_{o1.1} := 100ft$ Length of 10-ft diameter pipe to first orifice

$\theta := \left(\frac{D_{o1.1}}{D_1}\right)^2$ $\theta = 0.55$ Area ratio of inline orifice and inside pipe diameter (FEMA Eq. 17a)

$C_c := 3.1341 \cdot \theta^5 - 5.8809 \cdot \theta^4 + 3.8307 \cdot \theta^3 - 0.879 \cdot \theta^2 + 0.1851 \cdot \theta + 0.61$ $C_c = 0.7$ Vena Contracta Coefficient (FEMA Eq. 17)

$V_{vc}(Q) := \frac{Q}{C_c \cdot 0.25 \cdot \pi \cdot D_{o1.1}^2}$ $V_{vc}(Q_t) = 49.66 \frac{ft}{s}$ Vena contracta velocity

$C_v := 0.98$ Velocity coefficient for Reynolds number > 10^5 (FEMA)

$CD_o := \frac{C_c \cdot C_v}{\sqrt{1 - C_c^2 \cdot \frac{A_c(D_{o1.1})^2}{A_c(D_1)^2}}}$ $CD_o = 0.75$ Orifice discharge coefficient for vena contracta calcs (FEMA Eq. 20)

$\beta := \frac{D_{o1.1}}{D_1}$ $\beta = 0.74$ Diameter ratio of inline orifice and inside pipe diameter

$K_{o1.1} := \alpha_k \cdot 4890 \cdot e^{-10.18 \cdot \beta}$	$K_{o1.1} = 2.62$	Loss coefficient (FEMA Eq. 23)
$h_{o1.1}(Q) := \left(\frac{Q}{A_c(D_1)}\right)^2 \cdot \frac{K_{o1.1}}{2 \cdot g}$	$h_{o1.1}(Q_t) = 14.83\ \text{ft}$	Head loss associated with design discharge
$f_{o1.1}(Q) := f_c(Q, D_1, k) \cdot \frac{L_{o1.1}}{D_1}$		Friction loss to orifice from intake
$eh_{uso1.1}(Q) := h_t + \left(K_e + K_{bfv} + K_{b\_b1} + f_{o1.1}(Q_t)\right) \cdot hv_1(Q)$		Head loss from entrance to upstream side of orifice
$eh_{uso1.1}(Q_t) = 4.58\ \text{ft}$		
$eH_{uso1.1}(Q_t) := FB_d - eh_{uso1.1}(Q_t)$	$eH_{uso1.1}(Q_t) = 155.42\ \text{ft}$	Energy gradeline at upstream side of orifice
$H_{uso1.1}(Q_t) := eH_{uso1.1}(Q_t) - HV_1$	$H_{uso1.1}(Q_t) = 149.75\ \text{ft}$	Hydraulic gradeline at upstream side of orifice
$P_{uso1.1}(Q_t) := \left(H_{uso1.1}(Q_t) - Ele_{top1.1}\right) \cdot \gamma$	$P_{uso1.1}(Q_t) = 17.44\ \text{psi}$	Pressure at upstream side of orifice at top of pipe
$eh_{dso1.1}(Q_t) := eh_{uso1.1}(Q_t) + h_{o1.1}(Q_t)$		Head loss from entrance to downstream side of orifice
$Q = CD_o \cdot A_o \cdot \sqrt{2 \cdot g \cdot \left(\frac{P_1}{\gamma} - \frac{P_{vc}}{\gamma}\right)}$		Discharge as a function of headloss from upstream side orifice to downstream side at vena contracta (FEMA Eq. 18)
$P_{vc}(Q_t) := P_{uso1.1}(Q_t) - \gamma \cdot \frac{V_c(Q_t, D_{o1.1})^2}{CD_o^{\ 2} \cdot 2 \cdot g}$	$P_{vc}(Q_t) = 2.71\ \text{psi}$	Pressure at vena contracta
	$Pvg(T_f) = -14.52\ \text{psi}$	Vapor pressure of water at assume temp
$H_{vc}(Q_t) := H_{uso1.1}(Q_t) - \frac{V_c(Q_t, D_{o1.1})^2}{CD_o^{\ 2} \cdot 2 \cdot g}$	$H_{vc}(Q_t) = 115.75\ \text{ft}$	Hydraulic gradeline at vena contracta

$eH_{dso1.1}(Q_t) := FB_d - eh_{dso1.1}(Q_t)$ $eH_{dso1.1}(Q_t) = 140.59\ ft$ Energy gradeline downstream of orifice

$H_{dso1.1}(Q_t) := eH_{dso1.1}(Q_t) - HV_1$ $H_{dso1.1}(Q_t) = 134.92\ ft$ Hydraulic gradeline downstream of orifice

$P_{dso1.1}(Q_t) := (H_{dso1.1}(Q_t) - Ele_{top1.1})\cdot\gamma$ $P_{dso1.1}(Q_t) = 11.02\ psi$ Pressure at downstream side of orifice at top of pipe

$Pvg(T_f) = -14.52\ psi$ Vapor pressure of water at assumed temp

$\sigma := \dfrac{P_{dso1.1}(Q_t) - Pvg(T_f)}{P_{uso1.1}(Q_t) - P_{dso1.1}(Q_t)}$ $\sigma = 3.97$ Cavitation parameter (Rahmeyer Eq 10)

$\sigma_{o1.1} := \sigma$ Setting cavitation parameter for later output

Tullis Cavitation Method Check

$CD := 0.019 + 0.083\cdot\beta - 0.203\cdot\beta^2 + 1.35\cdot\beta^3$ $CD = 0.52$ Discharge coefficient based on orifice/pipe diameter ratio (FEMA Eq. 27)

$CD := \dfrac{1}{\sqrt{K_{o1.1} + 1}}$ $CD = 0.53$ Discharge coefficient based on orifice loss calculated previously (FEMA Eq. 28)

Conservative CD chosen for further calculations

$\sigma_{im} := 0.62 + 4.4\cdot CD + 6.6CD^2 + 1.3CD^3$ $\sigma_{im} = 4.95$ Reference incipient cavitation from Tullis lab tests (FEMA Eq. 30)

$D_p := D_1$ Prototype orifice sise

$D_m := 3in$ Lab model orifice size (Tullis)

$Y := 0.3\cdot K_{o1.1}^{\ 0.25}$ Conversion exponent (FEMA Eq. 32)

$SSE := \left(\dfrac{D_p}{D_m}\right)^Y$ Size scale effect from reference lab results (FEMA Eq. 31)

$\sigma_i := SSE \cdot \sigma_{im}$ — $\sigma_i = 20.22$ — Incipient cavitation parmeter (FEMA Eq. 29)

$check\_\sigma_{i\_1.1} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_i \\ \text{"check next"} & \text{otherwise} \end{cases}$ — $check\_\sigma_{i\_1.1} = \text{"check next"}$

$\sigma_{cm} := 0.78 + 0.77 \cdot CD + 0.89 \cdot CD^2 - 4.16 \cdot CD^3$ — $\sigma_{cm} = 0.83$ — Reference critical cavitation from Tullis lab tests (FEMA Eq. 34)

$\sigma_{cr} := SSE \cdot \sigma_{cm}$ — $\sigma = 3.97$ — $\sigma_{cr} = 3.38$ — Critical cavitation parameter (FEMA Eq. 33)

$check\_\sigma_{cr\_1.1} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_{cr} \\ \text{"check next"} & \text{otherwise} \end{cases}$ — $check\_\sigma_{cr\_1.1} = \text{"ok"}$

$\sigma_{idm} := 0.11 + 6.5 \cdot CD - 7.9 \cdot CD^2 + 8.8 \cdot CD^3$ — Reference incipient damage cavitation from Tullis tests (FEMA Eq. 36)

$P_{1m} := 90psi \qquad P_{vgm} := -12.2psi$ — Reference Tullis lab pressure and vapor pressure

$Pvg(T_f) = -14.52\ psi$ — Vapor pressure of river water at assumed temperature

$$PSE := \left(\frac{P_{dso1.1}(Q_t) - Pvg(T_f)}{P_{1m} - P_{vgm}} \right)^{0.16}$$

$PSE = 0.8$ — Pressure scale effect from reference lab test (FEMA Eq. 37

$\sigma_{id} := \sigma_{idm} \cdot PSE$ — $\sigma_{id} = 2.1$ — Incipient damage caviation parameter (FEMA Eq. 35)

$check\_\sigma_{id\_1.1} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_{id} \\ \text{"resize orifice"} & \text{otherwise} \end{cases}$ — $check\_\sigma_{id\_1.1} = \text{"ok"}$

$\sigma_{ch} := 0.15 + 1.2CD - 0.31 \cdot CD^2 + 3.3 \cdot CD^3$ — $\sigma_{ch} = 1.18$ — Choking cavitation parameter (FEMA Eq. 38)

$check\_\sigma_{ch\_1.1} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_{ch} \\ \text{"resize orifice"} & \text{otherwise} \end{cases}$ — $check\_\sigma_{ch\_1.1} = \text{"ok"}$

Miller Cavitation Check

- Miller's cavitation check was included for additional verification of the Tullis method ensuring no incipient caviation but is not to be considered primary design method of orifice due to it's inherent size limitation.

$\frac{D_{o1.1}}{D_1} = 0.74$ — Orifice/pipe diameter ratio (beta)

$V_c(Q_t, D_1) = 5.82 \cdot \frac{m}{s}$ — Approach velocity at orifice

$C_1 := 0.5$ — Miller Fig. 6.17

$H_{uso1.1}(Q_t) = 45.64 \cdot m$ — Approach pressure head at orifice

$Hvg(T_f) := \frac{Pvg(T_f)}{\gamma} + Ele_{top1.1}$ — Vapor pressure head at orifice (top of pipe, gage)

$Hvg(T_f) = 23.17 \cdot m$

Input matrix for incipient cavitation (Miller Fig. 6.16)

$$Data := \begin{pmatrix} 0.4 & 2.9 \\ 0.49 & 4 \\ 0.6 & 5.8 \\ 0.66 & 7 \\ 0.7 & 8 \\ 0.77 & 10 \\ 0.8 & 11.5 \end{pmatrix}$$

$data := csort(Data, 1)$ $\quad dD := data^{\langle 0 \rangle}$ $\quad ui := data^{\langle 1 \rangle}$

$S := cspline(dD, ui)$ $\quad Uir(x) := interp(S, dD, ui, x) \frac{m}{s}$

Input matrix for critical incipient cavitation (Miller Fig. 6.16)

$$Data := \begin{pmatrix} 0.4 & 3 \\ 0.47 & 4 \\ 0.56 & 6 \\ 0.64 & 8 \\ 0.7 & 10 \\ 0.75 & 12 \\ 0.79 & 14 \end{pmatrix}$$

$data := csort(Data, 1)$ $\quad dD_{cr} := data^{\langle 0 \rangle}$ $\quad ucr := data^{\langle 1 \rangle}$

$S := cspline(dD_{cr}, ucr)$ $\quad Ucr(x) := interp(S, dD_{cr}, ucr, x) \frac{m}{s}$

Input matrix for incipient damaging cavitation (Miller Fig. 6.16)

$$Data := \begin{pmatrix} 0.4 & 3.4 \\ 0.44 & 4 \\ 0.54 & 6 \\ 0.6 & 7.5 \\ 0.62 & 8 \\ 0.68 & 10 \\ 0.72 & 12 \\ 0.77 & 14 \\ 0.8 & 15.7 \end{pmatrix}$$

$data := csort(Data, 1)$ $\qquad dD_{dr} := data^{\langle 0 \rangle}$ $\qquad uidr := data^{\langle 1 \rangle}$

$S := cspline(dD_{dr}, uidr)$ $\qquad Uidr(x) := interp(S, dD_{dr}, uidr, x)\,\frac{m}{s}$

$$Uir\left(\frac{D_{o1.1}}{D_1}\right) = 9 \cdot \frac{m}{s}$$

$$U_c := C_1 \cdot Uir\left(\frac{D_{o1.1}}{D_1}\right) \cdot \left(\frac{H_{uso1.1}(Q_t) - Hvg(T_f)}{71.6m}\right)^{0.5}$$

$$check\_o1_{1\_u.c} := \begin{cases} \text{"incipient cavitation initiated"} & \text{if } U_c < V_c(Q_t, D_1) \\ \text{"no cavitation"} & \text{otherwise} \end{cases}$$

$$U_c = 2.52 \cdot \frac{m}{s}$$

$check\_o1_{1\_u.c}$ = "incipient cavitation initiated"

$$Ucr\left(\frac{D_{o1.1}}{D_1}\right) = 11.57 \cdot \frac{m}{s}$$

$$U_{cr} := C_1 \cdot Ucr\left(\frac{D_{o1.1}}{D_1}\right) \cdot \left(\frac{H_{uso1.1}(Q_t) - Hvg(T_f)}{71.6m}\right)^{0.5}$$

$$check\_o1_{1\_u.cr} := \begin{cases} \text{"critical cavitation initiated"} & \text{if } U_{cr} < V_c(Q_t, D_1) \\ \text{"non critical cavitation"} & \text{otherwise} \end{cases}$$

$$U_{cr} = 3.24 \cdot \frac{m}{s}$$

$check\_o1_{1\_u.cr}$ = "critical cavitation initiated"

$$Uidr\left(\frac{D_{o1.1}}{D_1}\right) = 12.82 \cdot \frac{m}{s}$$

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$$U_{id} := Uidr\left(\frac{D_{o1.1}}{D_1}\right)\cdot\left(\frac{H_{uso1.1}(Q_t) - Hvg(T_f)}{71.6m}\right)^{0.45}$$

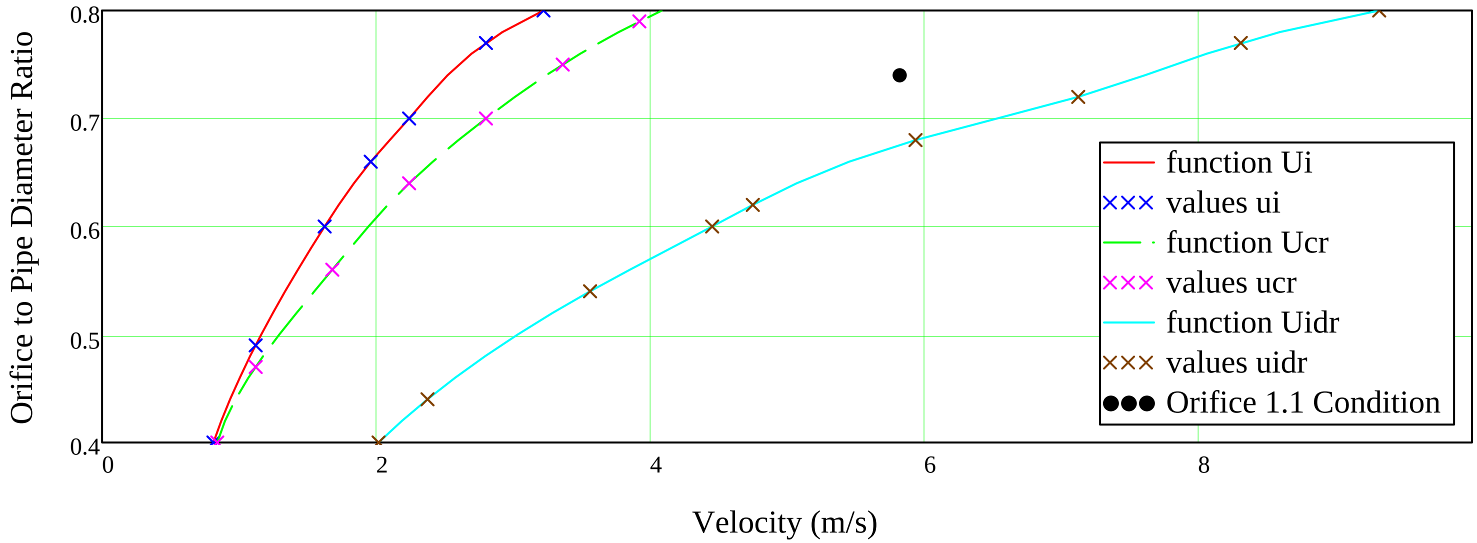
$$U_{id} = 7.61\cdot\frac{m}{s}$$

$$x := 0.4, 0.42 .. 0.8$$

$$check\_o1_{1\_u.id} := \begin{cases} \text{"damaging incipient cavitation initiated"} & \text{if } U_{id} < V_c(Q_t, D_1) \\ \text{"non damaging"} & \text{otherwise} \end{cases}$$

$$check\_o1_{1\_u.id} = \text{"non damaging"}$$

Factored Miller Fig 6.16 for Prototype Conditions



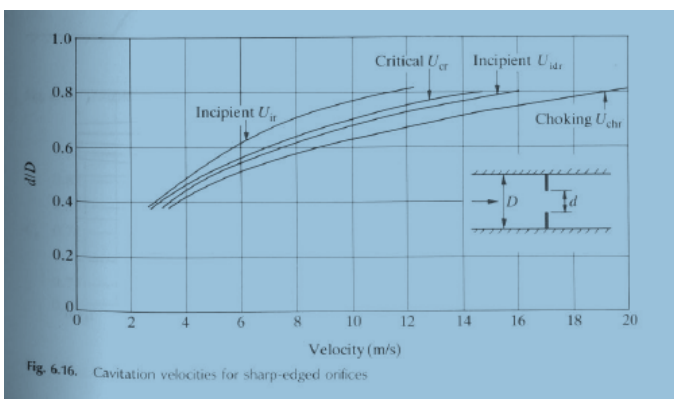


Fig. 6.16. Cavitation velocities for sharp-edged orifices

Original Miller Fig 6.16

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Thrust at Orifice 1.1

Thrust on the orifice will be assumed equal to that of a square edged contraction to a pipe the size of the orifice. This is a conservative measure that ensures that momentum is accounted including pressure reduction through the orifice.

$P_1 := P_{uso1.1}(Q_t)$ $\quad P_1 = 17.44\ psi$

$P_2 := P_{dso1.1}(Q_t)$ $\quad P_2 = 11.02\ psi$

$A_1 := A_c(D_1)$ $\quad A_1 = 78.54\ ft^2$

$A_2 := A_c(D_{o1.1})$ $\quad A_2 = 43.01\ ft^2$

$V_1 := \frac{Q_t}{A_1}$ $\quad V_1 = 19.1\ \frac{ft}{s}$

$V_2 := \frac{Q_t}{A_2}$ $\quad V_2 = 34.88\ \frac{ft}{s}$

$F_{o1.1} := P_1 \cdot A_1 - P_2 \cdot A_2 + \rho \cdot Q_t \cdot (V_2 - V_1)$ $\quad P_1 \cdot A_1 - P_2 \cdot A_2 = 129.06 \cdot kip$ $\quad \rho \cdot Q_t \cdot (V_2 - V_1) = 45.92 \cdot kip$

$F_{o1.1} = 174.98 \cdot kip$

Orifice Loss 1.2

$D_{o1.2} := 7.5ft$ Orifice Diameter

$L_{o1.2} := 140ft$

$\theta := \left(\frac{D_{o1.2}}{D_1}\right)^2$ $\quad \theta = 0.56$ Area ratio of inline orifice and inside pipe diameter (FEMA Eq. 17a)

$C_c := 3.1341 \cdot \theta^5 - 5.8809 \cdot \theta^4 + 3.8307 \cdot \theta^3 - 0.879 \cdot \theta^2 + 0.1851 \cdot \theta + 0.61$ $\quad C_c = 0.71$ Vena Contracta Coefficient (FEMA Eq. 17)

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$V_{vc}(Q) := \frac{Q}{C_c \cdot 0.25 \cdot \pi \cdot D_{o1.2}{}^2}$ $\quad V_{vc}(Q_t) = 48.12 \frac{ft}{s}$ — Vena contracta velocity

$C_v := 0.98$ — Velocity coefficient for Reynolds number > 10^5 (FEMA)

$CD_o := \frac{C_c \cdot C_v}{\sqrt{1 - C_c{}^2 \cdot \frac{A_c(D_{o1.2})^2}{A_c(D_1)^2}}}$ $\quad CD_o = 0.75$ — Orifice discharge coefficient for vena contracta calcs (FEMA Eq. 20)

$\beta := \frac{D_{o1.2}}{D_1}$ $\quad \beta = 0.75$ — Diameter ratio of inline orifice and inside pipe diameter

$K_{o1.2} := \alpha_k \cdot 4890 \cdot e^{-10.18 \cdot \beta}$ $\quad K_{o1.2} = 2.36$ — Loss coefficient (FEMA Eq. 23)

$h_{o1.2}(Q) := \left(\frac{Q}{A_c(D_1)}\right)^2 \cdot \frac{K_{o1.2}}{2 \cdot g}$ $\quad h_{o1.2}(Q_t) = 13.39\ ft$ — Head loss associated with design discharge

$f_{o1.2}(Q) := f_c(Q, D_1, k) \cdot \frac{L_{o1.2}}{D_1}$ — Friction loss to orifice from intake

$eh_{uso1.2}(Q) := h_t + (K_e + K_{bfv} + K_{b\_b1} + K_{o1.1} + f_{o1.2}(Q)) \cdot hv_1(Q)$ — Head loss from entrance to upstream side of orifice

$eh_{uso1.2}(Q_t) = 19.61\ ft$

$eH_{uso1.2}(Q_t) := FB_d - eh_{uso1.2}(Q_t)$ $\quad eH_{uso1.2}(Q_t) = 140.39\ ft$ — Energy gradeline at upstream side of orifice

$H_{uso1.2}(Q_t) := eH_{uso1.2}(Q_t) - HV_1$ $\quad H_{uso1.2}(Q_t) = 134.72\ ft$ — Hydraulic gradeline at upstream side of orifice

$P_{uso1.2}(Q_t) := (H_{uso1.2}(Q_t) - Ele_{top1.2}) \cdot \gamma$ $\quad P_{uso1.2}(Q_t) = 10.93\ psi$ — Pressure at upstream side of orifice at top of pipe

$eh_{dso1.2}(Q_t) := eh_{uso1.2}(Q_t) + h_{o1.2}(Q_t)$ — Head loss from entrance to downstream side of orifice

$$Q = CD_o \cdot A_o \cdot \sqrt{2 \cdot g \cdot \left(\frac{P_1}{\gamma} - \frac{P_{vc}}{\gamma} \right)}$$

Discharge as a function of headloss from upstream side orifice to downstream side at vena contracta (FEMA Eq. 18)

$$P_{vc}(Q_t) := P_{uso1.2}(Q_t) - \gamma \cdot \frac{V_c(Q_t, D_{o1.2})^2}{CD_o^{\,2} \cdot 2 \cdot g} \qquad P_{vc}(Q_t) = -2.75\,\text{psi}$$

Pressure at vena contracta

$$Pvg(T_f) = -14.52\,\text{psi}$$

Vapor pressure of water at assume temp

$$H_{vc}(Q_t) := H_{uso1.2}(Q_t) - \frac{V_c(Q_t, D_{o1.2})^2}{CD_o^{\,2} \cdot 2 \cdot g} \qquad H_{vc}(Q_t) = 103.15\,\text{ft}$$

Hydraulic gradeline at vena contracta

$$eH_{dso1.2}(Q_t) := FB_d - eh_{dso1.2}(Q_t) \qquad eH_{dso1.2}(Q_t) = 126.99\,\text{ft}$$

Energy gradeline downstream of orifice

$$H_{dso1.2}(Q_t) := eH_{dso1.2}(Q_t) - HV_1 \qquad H_{dso1.2}(Q_t) = 121.32\,\text{ft}$$

Hydraulic gradeline downstream of orifice

$$P_{dso1.2}(Q_t) := \left(H_{dso1.2}(Q_t) - Ele_{top1.2}\right) \cdot \gamma \qquad P_{dso1.2}(Q_t) = 5.12\,\text{psi}$$

Pressure at downstream side of orifice at top of pipe

$$Pvg(T_f) = -14.52\,\text{psi}$$

Vapor pressure of water at assumed temp

$$\sigma := \frac{P_{dso1.2}(Q_t) - Pvg(T_f)}{P_{uso1.2}(Q_t) - P_{dso1.2}(Q_t)} \qquad \sigma = 3.38$$

Cavitation parameter (Rahmeyer Eq 10)

$\sigma_{o1.2} := \sigma$ Setting cavitation parameter for later output

Tullis Cavitation Method Check

$$CD := 0.019 + 0.083 \cdot \beta - 0.203 \cdot \beta^2 + 1.35 \cdot \beta^3 \qquad CD = 0.54$$

Discharge coefficient based on orifice/pipe diameter ratio (FEMA Eq. 27)

$$CD := \frac{1}{\sqrt{K_{o1.2} + 1}} \qquad CD = 0.55$$

Discharge coefficient based on orifice loss calculated previously (FEMA Eq. 28)

Conservative CD chosen for further calculations

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$\sigma_{im} := 0.62 + 4.4 \cdot CD + 6.6CD^2 + 1.3CD^3$	$\sigma_{im} = 5.19$	Reference incipient cavitation from Tullis lab tests (FEMA Eq. 30)
$D_p := D_1$		Prototype pipe sise
$D_m := 3in$		Lab model pipe size
$Y := 0.3 \cdot K_{o1.2}{}^{0.25}$		Conversion exponent (FEMA Eq. 32)
$SSE := \left(\frac{D_p}{D_m}\right)^Y$		Size scale effect from reference lab results (FEMA Eq. 31
$\sigma_i := SSE \cdot \sigma_{im}$	$\sigma_i = 20.48$	Incipient cavitation parmeter (FEMA Eq. 29)
$check\_\sigma_{i\_1.2} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_i \\ \text{"check next"} & \text{otherwise} \end{cases}$	$check\_\sigma_{i\_1.2} = \text{"check next"}$	
$\sigma_{cm} := 0.78 + 0.77 \cdot CD + 0.89 \cdot CD^2 - 4.16 \cdot CD^3$	$\sigma_{cm} = 0.79$	Reference critical cavitation from Tullis lab tests (FEMA Eq. 34)
$\sigma_{cr} := SSE \cdot \sigma_{cm}$	$\sigma_{cr} = 3.12$	Critical cavitation parameter (FEMA Eq. 33)
$check\_\sigma_{cr\_1.2} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_{cr} \\ \text{"check next"} & \text{otherwise} \end{cases}$	$check\_\sigma_{cr\_1.2} = \text{"ok"}$	
$\sigma_{idm} := 0.11 + 6.5 \cdot CD - 7.9 \cdot CD^2 + 8.8 \cdot CD^3$		Reference incipient damage cavitation from Tullis tests (FEMA Eq. 36)
$P_{1m} := 90psi \quad P_{vgm} := -12.2psi$		Reference Tullis lab pressure and vapor pressure
$Pvg(T_f) = -14.52\ psi$		Vapor pressure of river water at assumed temperature

$$PSE := \left(\frac{P_{dso1.2}(Q_t) - Pvg(T_f)}{P_{1m} - P_{vgm}}\right)^{0.16}$$ $PSE = 0.77$ Pressure scale effect from reference lab test (FEMA Eq. 37

$\sigma_{id} := \sigma_{idm} \cdot PSE$ $\sigma_{id} = 2.1$ Incipient damage caviation parameter (FEMA Eq. 35)

$$check\_\sigma_{id\_1.2} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_{id} \\ \text{"resize orifice"} & \text{otherwise} \end{cases}$$

$check\_\sigma_{id\_1.2} = \text{"ok"}$

$\sigma_{ch} := 0.15 + 1.2CD - 0.31 \cdot CD^2 + 3.3 \cdot CD^3$ $\sigma_{ch} = 1.25$ Choking cavitation parameter (FEMA Eq. 38)

$$check\_\sigma_{ch\_1.2} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_{ch} \\ \text{"resize orifice"} & \text{otherwise} \end{cases}$$

$check\_\sigma_{ch\_1.2} = \text{"ok"}$

Miller Cavitation Check

$\frac{D_{o1.2}}{D_1} = 0.75$ Orifice/pipe diameter ratio (beta)

$V_c(Q_t, D_1) = 5.82 \cdot \frac{m}{s}$ Approach velocity at orifice

$C_1 := 0.5$ Miller Fig. 6.17

$H_{uso1.2}(Q_t) = 41.06 \cdot m$ Approach pressure head at orifice

$Hvg(T_f) = 23.17 \cdot m$ Vapor pressure head at orifice (top of pipe, gage)

$$U_c := C_1 \cdot Uir\left(\frac{D_{o1.2}}{D_1}\right) \cdot \left(\frac{H_{uso1.2}(Q_t) - Hvg(T_f)}{71.6m}\right)^{0.5}$$

$$check\_o1_{2\_u.c} := \begin{cases} \text{"incipient cavitation initiated"} & \text{if } U_c < V_c(Q_t, D_1) \\ \text{"no cavitation"} & \text{otherwise} \end{cases}$$

$U_c = 2.32 \cdot \frac{m}{s}$

$check\_o1_{2\_u.c} = \text{"incipient cavitation initiated"}$

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$$U_{cr} := C_1 \cdot Ucr\left(\frac{D_{o1.2}}{D_1}\right) \cdot \left(\frac{H_{uso1.2}(Q_t) - Hvg(T_f)}{71.6m}\right)^{0.5}$$

$$check\_o1_{2\_u.cr} := \begin{cases} \text{"critical cavitation initiated"} & \text{if } U_{cr} < V_c(Q_t, D_1) \\ \text{"non critical cavitation"} & \text{otherwise} \end{cases}$$

$$U_{cr} = 3 \cdot \frac{m}{s}$$

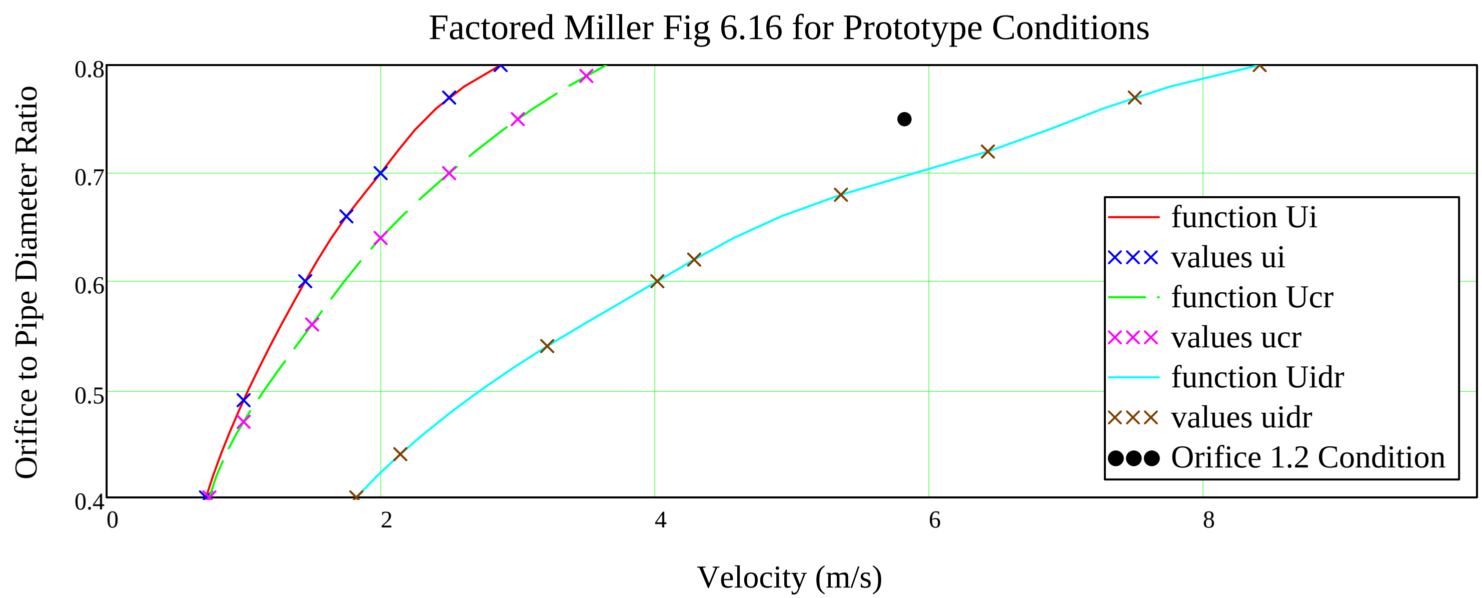
$check\_o1_{2\_u.cr}$ = "critical cavitation initiated"

$$U_{id} := Uidr\left(\frac{D_{o1.2}}{D_1}\right) \cdot \left(\frac{H_{uso1.2}(Q_t) - Hvg(T_f)}{71.6m}\right)^{0.45}$$

$$check\_o1_{2\_u.id} := \begin{cases} \text{"damaging incipient cavitation initiated"} & \text{if } U_{id} < V_c(Q_t, D_1) \\ \text{"non damaging"} & \text{otherwise} \end{cases}$$

$check\_o1_{2\_u.id}$ = "non damaging"

$$U_{id} = 7.07 \cdot \frac{m}{s}$$



$$K_{o1.2} = 2.36$$

Thrust at Orifice 1.2

Thrust on the orifice will be assumed equal to that of a square edged contraction to a pipe the size of the orifice. This is a conservative measure that ensures that momentum is accounted including pressure reduction through the orifice.

$P_1 := P_{uso1.2}(Q_t)$ $P_1 = 10.93\,psi$

$P_2 := P_{dso1.2}(Q_t)$ $P_2 = 5.12\,psi$

$A_1 := A_c(D_1)$ $A_1 = 78.54\,ft^2$

$A_2 := A_c(D_{o1.2})$ $A_2 = 44.18\,ft^2$

$V_1 := \frac{Q_t}{A_1}$ $V_1 = 19.1\,\frac{ft}{s}$

$V_2 := \frac{Q_t}{A_2}$ $V_2 = 33.95\,\frac{ft}{s}$

$F_{o1.2} := P_1 \cdot A_1 - P_2 \cdot A_2 + \rho \cdot Q_t \cdot (V_2 - V_1)$ $P_1 \cdot A_1 - P_2 \cdot A_2 = 91.01 \cdot kip$ $\rho \cdot Q_t \cdot (V_2 - V_1) = 43.23 \cdot kip$

$F_{o1.2} = 134.25 \cdot kip$

Bend Loss 3 (45 deg)

$\frac{r}{d} = 1$ $Ele_{b1.3} := 101.5ft$

$k'_b := 0.1$ From Miller Fig. 9.10 $\theta_{b1.3} := -45deg$

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 1.0$ No outlet, Miller Fig. 9.4

$C_f := \frac{f_c(Q_t, D_1, k_{sr})}{f_c(Q_t, D_1, k_{ss})}$ $C_f = 1.12$ From Miller Eq. 9.3

$K_{b1.3} := \alpha_k \cdot k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b1.3} = 0.11$ From Miller Eq. 9.4

Bend Cavitation Potential

for 1.3 $h_u := \left[FB_d - \left(K_t + K_e + K_{bfv} + K_{b\_b1} + K_{o1.1} + K_{o1.2} + f_c(Q_t, D_1, k) \cdot \frac{220ft}{D_1}\right) \cdot hv_1(Q_t) - Ele_{b1.3} - HV_1\right] \cdot \gamma$ $h_u = 6.97\,psi$

$\sigma_b := \dfrac{h_u - Pv(T_f)}{\gamma \cdot \dfrac{V_c(Q_t, D_1)^2}{2 \cdot g}}$ $\sigma_b = 2.76$ Cavitation parameter is greater than incipient cavitation for r/d = 1

$\sigma_{bi} := 1.2$ Incipient cavitation parameter from Miller Fig 6.10 with r/d = 1.5

$bendcav_{1.3} :=$ | "Incipient cavitation initiated" if $\sigma_b < 0.8 \cdot \sigma_{bi}$
| "Bend radius ok" otherwise

$bendcav_{1.3} =$ "Bend radius ok"

Last been in 10-ft diameter pipe must be 15-ft in radius to avoid initiating incipient cavitation. Due to the low angle of deflection (45 degrees) a reducing factor of 0.8 is applied to the cavitation parameter from Miller Fig 6.10.

Thrust for Bend 3

for 1.3 $P_1 := \left[FB_d - h_t - \left(K_e + K_{bfv} + K_{b\_b1} + K_{o1.1} + K_{o1.2} + f_c(Q_t, D_1, k) \cdot \frac{220ft}{D_1}\right) \cdot hv_1(Q_t) - Ele_{b1.3} - HV_1\right] \cdot \gamma$

$P_1 = 8.42\,psi$ Pressure at point 1

$\theta := \theta_{b1.3}$ Set bend to bend 1.3 angle

$P_{1x} := P_1$ $P_{1y} := 0psi$ X and Y components of pressure vectors at control volume surface point 1

$A_1 := A_c(D_1)$ Area of control volume on which the pressure 1 acts on

$A_1 = 78.54\,ft^2$

$V_1 := V_c(Q_t, D_1)$ $V_1 = 19.1 \cdot fps$

$V_{1x} := V_1$ Velocity in X direction at point 1

$V_{1x} = 19.1 \cdot fps$

$V_{1y} := 0fps$ Velocity in Y direction at point 1

$$P_2 := \left[FB_d - h_t - \left(K_e + K_{bfv} + K_{b\_b1} + K_{o1.1} + K_{o1.2} + f_c(Q_t, D_1, k)\cdot\frac{220ft}{D_1}\right)\cdot hv_1(Q_t) - Ele_{b1.3} - HV_1\right]\cdot\gamma$$

$P_2 = 8.42\,psi$

$P_{2x} := P_2\cdot\cos(\theta)$ — X and Y components of pressure vectors at control volume surface point 2

$P_{2y} := P_2\cdot\sin(\theta)$

$A_2 := A_1$ — Area of control volume on which the pressure 2 acts on

$V_{2x} := V_1\cdot\cos(\theta)$ — Velocity in X direction at point 2 — $V_{2x} = 13.5\cdot fps$

$V_{2y} := V_1\cdot\sin(\theta)$ — Velocity in Y direction at point 2 — $V_{2y} = -13.5\cdot fps$

$F_{b1.3x} := P_{1x}\cdot A_1 - P_{2x}\cdot A_2 - \rho\cdot Q_t\cdot(V_{2x} - V_{1x})$ — $P_{1x}\cdot A_1 - P_{2x}\cdot A_2 = 27.89\cdot kip$ — $-\rho\cdot Q_t\cdot(V_{2x} - V_{1x}) = 16.28\cdot kip$

$F_{b1.3x} = 44.17\cdot kip$ — Reactionary force in X direction

$F_{b1.3y} := P_{1y}\cdot A_1 + P_{2y}\cdot A_2 + \rho\cdot Q_t\cdot(V_{2y} - V_{1y})$ — $P_{1y}\cdot A_1 + P_{2y}\cdot A_2 = -67.34\cdot kip$ — $\rho\cdot Q_t\cdot(V_{2y} - V_{1y}) = -39.31\cdot kip$

$F_{b1.3y} = -106.65\cdot kip$ — Reactionary for in Y direction

$F_{B1.3} := \sqrt{F_{b1.3x}^2 + F_{b1.3y}^2}$ — $F_{B1.3} = 115.43\cdot kip$ — Resultant force

Friction Loss

$$f_1(Q) := f_c(Q, D_1, k)\cdot\frac{L_1}{D_1}$$

$h_{f1}(Q) := f_c(Q, D_1, k)\cdot\frac{L_1}{D_1}\cdot hv_1(Q)$ — $h_{f1}(Q_t) = 0.94\,ft$ — friction loss head at design discharge

Pipe 1 total losses

$$H_1(Q) := h_t + \left(K_e + K_{bfv} + K_{b\_b1} + K_{o1.1} + K_{o1.2} + K_{b1.3} + f_1(Q)\right)\cdot hv_1(Q)$$

$$H_1\left(Q_t\right) = 33.89\,ft$$

$$h_t = 0.25\,ft$$

$$K_e\cdot hv_1\left(Q_t\right) = 0.91\,ft$$

$$K_{bfv}\cdot hv_1\left(Q_t\right) = 1.13\,ft$$

$$K_{b\_b1}\cdot hv_1\left(Q_t\right) = 1.8\,ft$$

$$K_{o1.1}\cdot hv_1\left(Q_t\right) = 14.83\,ft$$

$$K_{o1.2}\cdot hv_1\left(Q_t\right) = 13.39\,ft$$

$$K_{b1.3}\cdot hv_1\left(Q_t\right) = 0.63\,ft$$

$$f_1\left(Q_t\right)\cdot hv_1\left(Q_t\right) = 0.9391\,ft$$

Pipe 2 Losses

$Q_{t2} = 750\cdot cfs$ Trial split (assume equal distribution) $V_c\left(Q_{t2}, D_2\right) = 16.98\,\frac{ft}{s}$

$L_2 = 110\,ft$

$HV_2 := \frac{V_c\left(Q_{t2}, D_2\right)^2}{2\cdot g}$ $HV_2 = 4.48\,ft$ Velocity head thru Pipe 2

$$hv_2(Q) := \frac{V_c\left(Q, D_2\right)^2}{2\cdot g}$$

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Wye Loss

$\frac{Q_1}{Q_3} = \frac{700}{1400}$ $\qquad \frac{700}{1400} = 0.5$ $\qquad Q_R := 0.5$ $\qquad Ele_{wye} := Ele_{b1.3}$ $\qquad \theta := 30deg$

Tee loss assigned assuming 45 degree angled branching flow

$\frac{A_1}{A_3} = 0.5$ $\qquad \frac{A_c(D_2)}{A_c(D_1)} = 0.56$ $\qquad A_R := 0.563$

$K_{31} := \alpha_k \cdot 0.15$ From Miller Fig. 13.28

Thrust at Wye

$$P_1 := \left(FB_d - H_1(Q_t) - Ele_{wye} - HV_1\right) \cdot \gamma$$

$P_1 = 8.21\,psi$

$$P_2 := \left[FB_d - H_1(Q_t) - \left(K_{31} + f_c(Q_{t2}, D_2, k) \cdot \frac{20ft}{D_2}\right) \cdot hv_2(Q_{t2}) - Ele_{wye} - HV_2\right] \cdot \gamma$$

$P_2 = 8.39\,psi$

$A_1 := A_c(D_1) \qquad A_1 = 78.54\,ft^2$

$A_2 := A_c(D_2) \qquad A_2 = 44.18\,ft^2$

$V_{1x} := \frac{Q_t}{A_1} \qquad V_{1x} = 19.1\,\frac{ft}{s}$

$V_{2x} := \frac{Q_{t2}}{A_2} \cdot \cos(\theta) \qquad V_{2x} = 14.7\,\frac{ft}{s}$

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$$F_{wye} := P_1 \cdot A_1 - 2 \cdot P_2 \cdot A_2 - \rho \cdot Q_t \cdot (V_{2x} - V_{1x})$$

$$F_{wye} = -1.06 \cdot kip$$

Since flow is equally distributed between the wye branches at opposing angles, force in the lateral direction (y-axis) are assumed equal.

Bend Loss 2.1 (30 deg)

$\frac{r}{d} = 1$

$Ele_{b2.1} := 101.1ft$ Elevation of bend

$L_{b2.1} := 20ft$ Length of pipe 2 to bend

$\theta_{b2.1} := 30deg$ Bend angle

$k'_b := 0.06$ From Miller Fig. 9.10

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 1.0$ No outlet, Miller Fig. 9.4

$C_f := \frac{f_c(Q_{t3}, D_2, k_{sr})}{f_c(Q_{t3}, D_2, k_{ss})}$ $C_f = 1.11$ From Miller Eq. 9.3

$K_{b2.1} := \alpha_k \cdot k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b2.1} = 0.07$ From Miller Eq. 9.4

Corrected Bend Loss 1 & Wye Proximity

$L_s := 20ft$ $\frac{L_s}{D_2} = 2.67$ Close proximity allows for reduction in bend loss. L_s denotes the staight length of pipe between bends.

$C_{b\_b} := 0.775$ From Miller Fig 10.3

$K_{b\_b2.1} := C_{b\_b} \cdot (K_{b2.1})$ $K_{b\_b2.1} = 0.05$

Bend Cavitation Potential

for 2.1 $h_u := \left[FB_d - H_1(Q_t) - \left(K_{31} + f_c(Q_{t2}, D_2, k) \cdot \frac{L_{b2.1}}{D_2}\right) \cdot hv_2(Q_{t2}) - Ele_{b2.1} - HV_2\right] \cdot \gamma$ $h_u = 8.56\,psi$

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$$\sigma_b := \frac{h_u - Pv(T_f)}{\gamma \cdot \frac{V_c(Q_{t2}, D_2)^2}{2 \cdot g}} \quad \sigma_b = 4.32$$

Cavitation parameter is greater than incipient cavitation for r/d = 1

$\sigma_{bi} := 2.2$

Incipient cavitation parameter from Miller Fig 6.10 with r/d = 1.0

bend less than 45 degrees allows for a reduction factor of 0.8 to be applied (Miller)

$$\text{bendcav}_{2.1} := \begin{cases} \text{"Incipient cavitation initiated"} & \text{if } \sigma_b < 0.8 \cdot \sigma_{bi} \\ \text{"Bend radius ok"} & \text{otherwise} \end{cases}$$

$\text{bendcav}_{2.1} = \text{"Bend radius ok"}$

Thrust at bend

$$P_1 := \left[FB_d - H_1(Q_t) - \left(K_{31} + f_c(Q_{t2}, D_2, k) \cdot \frac{L_{b2.1}}{D_2}\right) \cdot hv_2(Q_{t2}) - Ele_{b2.1} - HV_2\right] \cdot \gamma$$

$P_1 = 8.56\,psi$ — Pressure at point 1

$P_{1x} := P_1 \quad P_{1y} := 0psi$ — X and Y components of pressure vectors at control volume surface point 1

$A_1 := A_c(D_2)$ — Area of control volume on which the pressure 1 acts on

$A_1 = 44.18\,ft^2$

$V_1 := V_c(Q_{t2}, D_2)$

$V_{1x} := V_1$ — Velocity in X direction at point 1

$V_{1x} = 16.98 \cdot fps$

$V_{1y} := 0fps$ — Velocity in Y direction at point 1

$$P_2 := \left[FB_d - H_1(Q_t) - \left(K_{31} + K_{b\_b2.1} + f_c(Q_{t2}, D_2, k) \cdot \frac{L_{b2.1}}{D_2}\right) \cdot hv_2(Q_{t2}) - Ele_{b2.1} - HV_2\right] \cdot \gamma$$

$P_{2x} := P_2 \cdot \cos(\theta_{b2.1})$ — X and Y components of pressure vectors at control volume surface point 2

$P_{2y} := P_2 \cdot \sin(\theta_{b2.1})$

$A_2 := A_1$ — Area of control volume on which the pressure 2 acts on

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$V_{2x} := V_1 \cdot \cos(\theta_{b2.1})$ Velocity in X direction at point 2

$V_{2y} := V_1 \cdot \sin(\theta_{b2.1})$ Velocity in Y direction at point 2

$F_{b2.1x} := P_{1x} \cdot A_1 - P_{2x} \cdot A_2 - \rho \cdot Q_{t2} \cdot (V_{2x} - V_{1x})$ $P_{1x} \cdot A_1 - P_{2x} \cdot A_2 = 7.85 \cdot kip$ $-\rho \cdot Q_{t2} \cdot (V_{2x} - V_{1x}) = 3.31 \cdot kip$

$F_{b2.1x} = 11.16 \cdot kip$ Reactionary force in X direction

$F_{b2.1y} := P_{1y} \cdot A_1 + P_{2y} \cdot A_2 + \rho \cdot Q_{t2} \cdot (V_{2y} - V_{1y})$ $P_{1y} \cdot A_1 + P_{2y} \cdot A_2 = 26.91 \cdot kip$ $\rho \cdot Q_{t2} \cdot (V_{2y} - V_{1y}) = 12.35 \cdot kip$

$F_{b2.1y} = 39.26 \cdot kip$ Reactionary for in Y direction

$F_{b2.1} := \sqrt{F_{b2.1x}^2 + F_{b2.1y}^2}$ $F_{b2.1} = 40.82 \cdot kip$ Resultant force

Orifice Loss 2.1

$D_{o2.1} := 5.5ft$ Orifice Diameter

$L_{o2.1} := 45ft$

$\theta := \left(\frac{D_{o2.1}}{D_2}\right)^2$ $\theta = 0.54$ Area ratio of inline orifice and inside pipe diameter (FEMA Eq. 17a)

$C_c := 3.1341 \cdot \theta^5 - 5.8809 \cdot \theta^4 + 3.8307 \cdot \theta^3 - 0.879 \cdot \theta^2 + 0.1851 \cdot \theta + 0.61$ $C_c = 0.7$ Vena Contracta Coefficient (FEMA Eq. 17)

$V_{vc}(Q) := \frac{Q}{C_c \cdot 0.25 \cdot \pi \cdot D_{o2.1}^2}$ $V_{vc}(Q_{t2}) = 45.08 \frac{ft}{s}$ Vena contracta velocity

$C_v := 0.98$ Velocity coefficient for Reynolds number > 10^5 (FEMA)

$CD_o := \frac{C_c \cdot C_v}{\sqrt{1 - C_c^2 \cdot \frac{A_c(D_{o2.1})^2}{A_c(D_2)^2}}}$ $CD_o = 0.74$ Orifice discharge coefficient for vena contracta calcs (FEMA Eq. 20)

$\beta := \frac{D_{o2.1}}{D_2}$ $\beta = 0.73$ Diameter ratio of inline orifice and inside pipe diameter

$K_{o2.1} := \alpha_k \cdot 4890 \cdot e^{-10.18 \cdot \beta}$ $K_{o2.1} = 2.8$ Loss coefficient (FEMA Eq. 23)

$h_{o2.1}(Q) := \left(\frac{Q}{A_c(D_2)}\right)^2 \cdot \frac{K_{o2.1}}{2 \cdot g}$ $h_{o2.1}(Q_{t2}) = 12.54\ ft$ Head loss associated with design discharge

$f_{o2.1}(Q) := f_c(Q, D_2, k) \cdot \frac{L_{o2.1}}{D_2}$ Friction loss to orifice from intake

$eh_{uso2.1}(Q) := H_1(Q_t) + (K_{b\_b2.1} + K_{31} + f_{o2.1}(Q)) \cdot hv_2(Q)$ Head loss from entrance to upstream side of orifice

$eh_{uso2.1}(Q_{t2}) = 35.04\ ft$

$eH_{uso2.1}(Q) := FB_d - eh_{uso2.1}(Q)$ $eH_{uso2.1}(Q_{t2}) = 124.96\ ft$ Energy gradeline at upstream side of orifice

$H_{uso2.1}(Q) := eH_{uso2.1}(Q) - HV_1$ $H_{uso2.1}(Q_{t2}) = 119.29\ ft$ Hydraulic gradeline at upstream side of orifice

$P_{uso2.1}(Q) := (H_{uso2.1}(Q) - Ele_{top2.1}) \cdot \gamma$ $P_{uso2.1}(Q_{t2}) = 6.41\ psi$ Pressure at upstream side of orifice at top of pipe

$eh_{dso2.1}(Q) := eh_{uso2.1}(Q) + h_{o2.1}(Q)$ Head loss from entrance to downstream side of orifice

$Q = CD_o \cdot A_o \cdot \sqrt{2 \cdot g \cdot \left(\frac{P_1}{\gamma} - \frac{P_{vc}}{\gamma}\right)}$ Discharge as a function of headloss from upstream side orifice to downstream side at vena contracta (FEMA Eq. 18)

$P_{vc}(Q) := P_{uso2.1}(Q) - \gamma \cdot \frac{V_c(Q, D_{o2.1})^2}{CD_o^{\,2} \cdot 2 \cdot g}$ $P_{vc}(Q_{t2}) = -5.82\ psi$ Pressure at vena contracta

$Pvg(T_f) = -14.52\ psi$ Vapor pressure of water at assume temp

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$H_{vc}(Q) := H_{uso2.1}(Q) - \frac{V_c(Q, D_{o2.1})^2}{CD_o^{\ 2} \cdot 2 \cdot g}$ $H_{vc}(Q_{t2}) = 91.07\,ft$ Hydraulic gradeline at vena contracta

$eH_{dso2.1}(Q) := FB_d - eh_{dso2.1}(Q)$ $eH_{dso2.1}(Q_{t2}) = 112.42\,ft$ Energy gradeline downstream of orifice

$H_{dso2.1}(Q) := eH_{dso2.1}(Q) - HV_2$ $H_{dso2.1}(Q_{t2}) = 107.94\,ft$ Hydraulic gradeline downstream of orifice

$P_{dso2.1}(Q) := (H_{dso2.1}(Q) - Ele_{top2.1}) \cdot \gamma$ $P_{dso2.1}(Q_{t2}) = 1.49\,psi$ Pressure at downstream side of orifice at top of pipe

$\sigma := \frac{P_{dso2.1}(Q_{t2}) - Pvg(T_f)}{P_{uso2.1}(Q_{t2}) - P_{dso2.1}(Q_{t2})}$ $\sigma = 3.25$ Cavitation parameter (Rahmeyer Eq 10)

$\sigma_{o2.1} := \sigma$ Setting cavitation parameter for later output

Tullis Cavitation Method Check

$CD := 0.019 + 0.083 \cdot \beta - 0.203 \cdot \beta^2 + 1.35 \cdot \beta^3$ $CD = 0.5$ Discharge coefficient based on orifice/pipe diameter ratio (FEMA Eq. 27)

$CD := \frac{1}{\sqrt{K_{o2.1} + 1}}$ $CD = 0.51$ Discharge coefficient based on orifice loss calculated previously (FEMA Eq. 28)

Conservative CD chosen for further calculations

$\sigma_{im} := 0.62 + 4.4 \cdot CD + 6.6CD^2 + 1.3CD^3$ $\sigma_{im} = 4.79$ Reference incipient cavitation from Tullis lab tests (FEMA Eq. 30)

$D_p := D_2$ Prototype pipe sise

$D_m := 3in$ Lab model pipe size

$Y := 0.3 \cdot K_{o2.1}^{\ 0.25}$ Conversion exponent (FEMA Eq. 32)

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$SSE := \left(\frac{D_p}{D_m}\right)^Y$ — Size scale effect from reference lab results (FEMA Eq. 31

$\sigma_i := SSE \cdot \sigma_{im}$ — $\sigma_i = 17.93$ — Incipient cavitation parmeter (FEMA Eq. 29)

$check\_\sigma_{i\_2.1} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_i \\ \text{"check next"} & \text{otherwise} \end{cases}$ — $check\_\sigma_{i\_2.1} = \text{"check next"}$

$\sigma_{cm} := 0.78 + 0.77 \cdot CD + 0.89 \cdot CD^2 - 4.16 \cdot CD^3$ — $\sigma_{cm} = 0.85$ — Reference critical cavitation from Tullis lab tests (FEMA Eq. 34)

$\sigma_{cr} := SSE \cdot \sigma_{cm}$ — $\sigma_{cr} = 3.17$ — Critical cavitation parameter (FEMA Eq. 33)

$check\_\sigma_{cr\_2.1} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_{cr} \\ \text{"check next"} & \text{otherwise} \end{cases}$ — $check\_\sigma_{cr\_2.1} = \text{"ok"}$

$\sigma_{idm} := 0.11 + 6.5 \cdot CD - 7.9 \cdot CD^2 + 8.8 \cdot CD^3$ — Reference incipient damage cavitation from Tullis tests (FEMA Eq. 36)

$P_{1m} := 90psi \qquad P_{vgm} := -12.2psi$ — Reference Tullis lab pressure and vapor pressure

$Pvg(T_f) = -14.52\ psi$ — Vapor pressure of river water at assumed temperature

$PSE := \left(\frac{P_{dso2.1}(Q_{t2}) - Pvg(T_f)}{P_{1m} - P_{vgm}}\right)^{0.16}$ — $PSE = 0.74$ — Pressure scale effect from reference lab test (FEMA Eq. 37

$\sigma_{id} := \sigma_{idm} \cdot PSE$ — $\sigma_{id} = 1.9$ — Incipient damage caviation parameter (FEMA Eq. 35)

$check\_\sigma_{id\_2.1} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_{id} \\ \text{"resize orifice"} & \text{otherwise} \end{cases}$ — $check\_\sigma_{id\_2.1} = \text{"ok"}$

$\sigma_{ch} := 0.15 + 1.2CD - 0.31 \cdot CD^2 + 3.3 \cdot CD^3$ — $\sigma_{ch} = 1.13$ — Choking cavitation parameter (FEMA Eq. 38)

$check\_\sigma_{ch\_2.1} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_{ch} \\ \text{"resize orifice"} & \text{otherwise} \end{cases}$ — $check\_\sigma_{ch\_2.1} = \text{"ok"}$

Miller Cavitation Check

$\frac{D_{o2.1}}{D_2} = 0.73$ Orifice/pipe diameter ratio

$V_c(Q_{t2}, D_2) = 5.17 \cdot \frac{m}{s}$ Approach velocity to orifice

$C_1 := 0.5$ Miller Fig. 6.17

$H_{uso2.1}(Q_{t2}) = 36.36 \cdot m$ Approach pressure head at orifice

$Hvg(T_f) = 23.17 \cdot m$ Vapor pressure head at orifice (top of pipe, gage)

$$U_c := C_1 \cdot Uir\left(\frac{D_{o2.1}}{D_2}\right) \cdot \left(\frac{H_{uso2.1}(Q_{t2}) - Hvg(T_f)}{71.6m}\right)^{0.5}$$

$U_c = 1.89 \cdot \frac{m}{s}$

check_o2$_{1_u.c}$:= | "incipient cavitation initiated" if $U_c < V_c(Q_{t2}, D_2)$ | "no cavitation" otherwise

check_o2$_{1_u.c}$ = "incipient cavitation initiated"

$$U_{cr} := C_1 \cdot Ucr\left(\frac{D_{o2.1}}{D_2}\right) \cdot \left(\frac{H_{uso2.1}(Q_{t2}) - Hvg(T_f)}{71.6m}\right)^{0.5}$$

$U_{cr} = 2.42 \cdot \frac{m}{s}$

check_o2$_{1_u.cr}$:= | "critical cavitation initiated" if $U_{cr} < V_c(Q_{t2}, D_2)$ | "non critical cavitation" otherwise

check_o2$_{1_u.cr}$ = "critical cavitation initiated"

$$U_{id} := Uidr\left(\frac{D_{o2.1}}{D_2}\right) \cdot \left(\frac{H_{uso2.1}(Q_{t2}) - Hvg(T_f)}{71.6m}\right)^{0.45}$$

$U_{id} = 5.87 \cdot \frac{m}{s}$

check_o2$_{1_u.id}$:= | "damaging incipient cavitation initiated" if $U_{id} < V_c(Q_{t2}, D_2)$ | "non damaging" otherwise

check_o2$_{1_u.id}$ = "non damaging"

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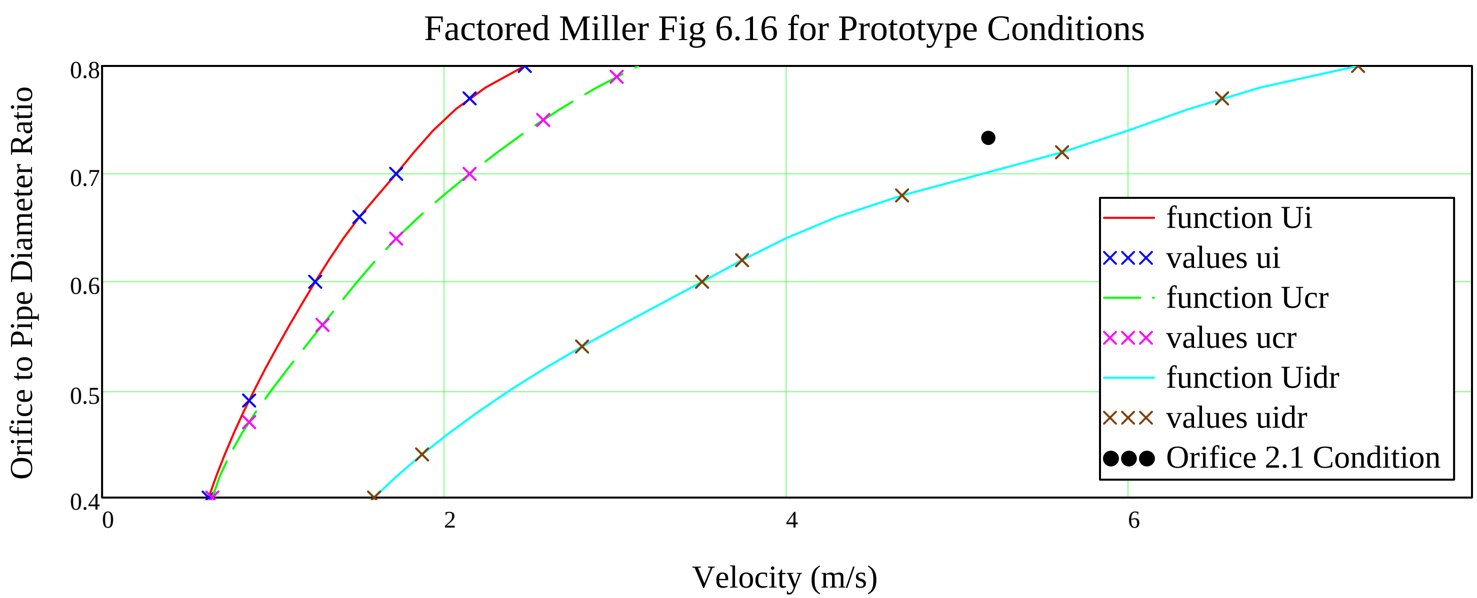

Thrust at Orifice 2.1

Thrust on the orifice will be assumed equal to that of a square edged contraction to a pipe the size of the orifice. This is a conservative measure that ensures that momentum is accounted including pressure reduction through the orifice.

$P_1 := P_{uso2.1}(Q_{t2})$ $\quad P_1 = 6.41\ psi$

$P_2 := P_{dso2.1}(Q_{t2})$ $\quad P_2 = 1.49\ psi$

$A_1 := A_c(D_2)$ $\quad A_1 = 44.18\ ft^2$

$A_2 := A_c(D_{o2.1})$ $\quad A_2 = 23.76\ ft^2$

$V_1 := \frac{Q_{t2}}{A_1}$ $\quad V_1 = 16.98\ \frac{ft}{s}$

$V_2 := \frac{Q_{t2}}{A_2}$ $\quad V_2 = 31.57\ \frac{ft}{s}$

$F_{o2.1} := P_1 \cdot A_1 - P_2 \cdot A_2 + \rho \cdot Q_{t2} \cdot (V_2 - V_1)$ $\quad P_1 \cdot A_1 - P_2 \cdot A_2 = 35.68 \cdot kip$ $\quad \rho \cdot Q_{t2} \cdot (V_2 - V_1) = 21.23 \cdot kip$

$F_{o2.1} = 56.92 \cdot kip$

$K_{o2.1} = 2.8$

Bend Loss 2.2 (90 deg)

$\frac{r}{d} = 1$

$Ele_{b2.2} := 101.1 ft$ Elevation of bend

$L_{b2.2} := 75 ft$ Length of pipe 2 to bend

$\theta_{b2.2} := 90 deg$ Bend angle

$k'_b := 0.26$ From Miller Fig. 9.10

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 2.75$ No outlet, Miller Fig. 9.4

$C_f := \frac{f_c(Q_{t2}, D_2, k_{sr})}{f_c(Q_{t2}, D_2, k_{ss})}$ $\quad C_f = 1.11$ From Miller Eq. 9.3

$K_{b2.2} := \alpha_k \cdot k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $\quad K_{b2.2} = 0.8$ From Miller Eq. 9.4

Bend Cavitation Potential

for 2.2 $h_u := \left[FB_d - H_1(Q_t) - \left(K_{31} + K_{b\_b2.1} + K_{o2.1} + f_c(Q_{t2}, D_2, k) \cdot \frac{L_{b2.2}}{D_2} \right) \cdot hv_2(Q_{t2}) - Ele_{b2.2} - HV_2 \right] \cdot \gamma$ $\quad h_u = 2.89\, psi$

$\sigma_b := \frac{h_u - Pv(T_f)}{\gamma \cdot \frac{V_c(Q_{t2}, D_2)^2}{2 \cdot g}}$ $\quad \sigma_b = 1.4$

Cavitation parameter is greater than incipient cavitation for r/d = 1

$\sigma_{bi} := 2.2$ Incipient cavitation parameter from Miller Fig 6.10 with r/d = 1.0

$bendcav_{2.2} :=$ "Incipient cavitation initiated" if $\sigma_b < \sigma_{bi}$
"Bend radius ok" otherwise

$bendcav_{2.2} =$ "Incipient cavitation initiated"

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Thrust at bend

$$P_1 := \left[FB_d - H_1(Q_t) - \left(K_{31} + K_{b\_b2.1} + K_{o2.1} + f_c(Q_{t2}, D_2, k) \cdot \frac{L_{b2.2}}{D_2}\right) \cdot hv_2(Q_{t2}) - Ele_{b2.2} - HV_2\right] \cdot \gamma$$

$P_1 = 2.89\,psi$ Pressure at point 1

$P_{1x} := P_1$

$P_{1y} := 0psi$ X and Y components of pressure vectors at control volume surface point 1

$A_1 := A_c(D_2)$ Area of control volume on which the pressure 1 acts on

$A_1 = 44.18\,ft^2$

$V_{1x} := V_c(Q_{t2}, D_2)$ Velocity in X direction at point 1

$V_{1x} = 16.98 \cdot fps$

$V_{1y} := 0fps$ Velocity in Y direction at point 1

$P_2 := 0psi$

$P_{2x} := P_2$ $P_{2y} := P_{1x}$ X and Y components of pressure vectors at control volume surface point 2

$A_2 := A_1$ Area of control volume on which the pressure 2 acts on

$V_{2x} := 0fps$ Velocity in X direction at point 2

$V_{2y} := -V_{1x}$ Velocity in Y direction at point 2

$F_{b2.2x} := P_{1x} \cdot A_1 - P_{2x} \cdot A_2 - \rho \cdot Q_{t2} \cdot (V_{2x} - V_{1x})$ $P_{1x} \cdot A_1 - P_{2x} \cdot A_2 = 18.41 \cdot kip$ $-\rho \cdot Q_{t2} \cdot (V_{2x} - V_{1x}) = 24.7 \cdot kip$

$F_{b2.2x} = 43.12 \cdot kip$ Reactionary force in X direction

$F_{b2.2y} := -P_{1y} \cdot A_1 + P_{2y} \cdot A_2 - \rho \cdot Q_{t2} \cdot (V_{2y} - V_{1y})$ $-P_{1y} \cdot A_1 + P_{2y} \cdot A_2 = 18.41 \cdot kip$ $-\rho \cdot Q_{t2} \cdot (V_{2y} - V_{1y}) = 24.7 \cdot kip$

$F_{b2.2y} = 43.12 \cdot kip$ Reactionary for in Y direction

$F_{b2.2} := \sqrt{F_{b2.2x}^2 + F_{b2.2y}^2}$ $F_{b2.2} = 60.98 \cdot kip$ Resultant force

$45ft \cdot A_1 \cdot \gamma = 124.07 \cdot kip$ Weight of water in pipe spanning the fish ladder

$$Fr_2(Q) := \frac{V_c(Q, D_2)}{\sqrt{g \cdot D_2}}$$ $Fr_2(Q_{t2}) = 1.09$

Friction Loss

$$f_2(Q) := f_c(Q, D_2, k) \cdot \frac{L_2}{D_2}$$

$$h_{f2}(Q) := f_c(Q, D_2, k) \cdot \frac{L_2}{D_2} \cdot hv_2(Q)$$ $h_{f2}(Q_{t2}) = 0.6\,ft$ friction loss head at design discharge

Pipe 2 total losses

$$H_2(Q) := \left(K_{31} + K_{b\_b2.1} + K_{o2.1} + K_{b2.2} + f_2(Q)\right) \cdot hv_2(Q)$$

$$H_2\left(Q_{t2}\right) = 17.61\ \text{ft}$$

$$K_{31} \cdot hv_2\left(Q_{t2}\right) = 0.67\ \text{ft}$$

$$K_{b\_b2.1} \cdot hv_2\left(Q_{t2}\right) = 0.23\ \text{ft}$$

$$K_{o2.1} \cdot hv_2\left(Q_{t2}\right) = 12.54\ \text{ft}$$

$$f_2\left(Q_{t2}\right) \cdot hv_2\left(Q_{t2}\right) = 0.6\ \text{ft}$$

$$hv_2\left(Q_{t2}\right) = 4.48\ \text{ft}$$

Pipe 2 Manifold/Orifice Details

Input matrix for manifold orifice discharge (Miller Fig. 13.55)

$$Data := \begin{pmatrix} 0.01 & 0.6 \\ 0.02 & 0.595 \\ 0.03 & 0.59 \\ 0.04 & 0.585 \\ 0.05 & 0.578 \\ 0.06 & 0.57 \\ 0.07 & 0.564 \\ 0.08 & 0.555 \\ 0.09 & 0.547 \\ 0.1 & 0.54 \\ 0.2 & 0.475 \\ 0.3 & 0.419 \\ 0.4 & 0.36 \\ 0.5 & 0.3 \end{pmatrix}$$

$data := csort(Data, 0)$ $R := data^{\langle 0 \rangle}$ $cd := data^{\langle 1 \rangle}$

$S := cspline(R, cd)$ $Cdm2(x) := interp(S, R, cd, x)$ Sharp crested orifice manifold

$xe := 0.01, 0.02 .. 0.5$

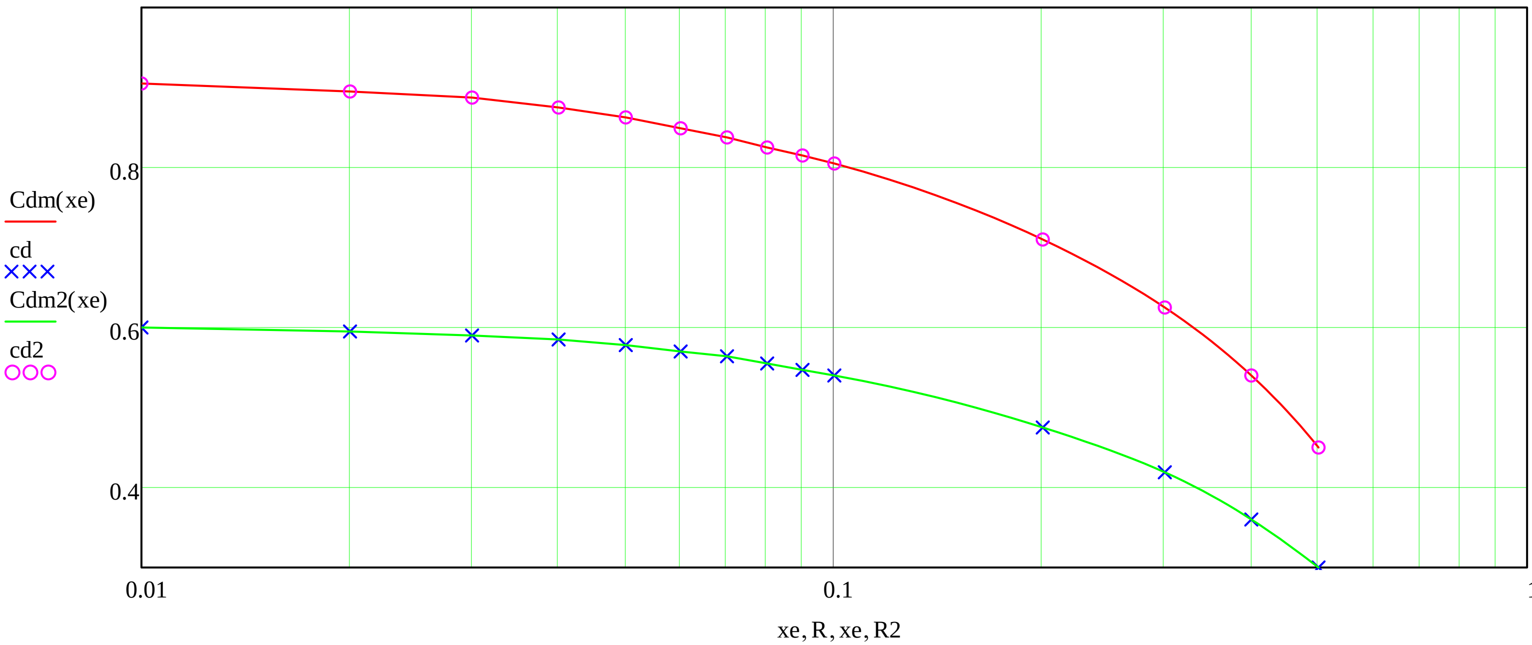
$$Data2 := \begin{pmatrix} 0.01 & 0.905 \\ 0.02 & 0.895 \\ 0.03 & 0.8875 \\ 0.04 & 0.875 \\ 0.05 & 0.8625 \\ 0.06 & 0.849 \\ 0.07 & 0.8375 \\ 0.08 & 0.825 \\ 0.09 & 0.815 \\ 0.1 & 0.805 \\ 0.2 & 0.71 \\ 0.3 & 0.625 \\ 0.4 & 0.54 \\ 0.5 & 0.45 \end{pmatrix}$$

$data2 := csort(Data2, 0)$ $R2 := data2^{\langle 0 \rangle}$ $cd2 := data2^{\langle 1 \rangle}$

$S2 := cspline(R2, cd2)$ $Cdm(xe) := interp(S2, R2, cd2, xe)$

Bell mouthed orifice manifold

$xe := 0.01, 0.02 .. 0.5$



$D_e := 1.875ft$ Diameter of manifold orifices

$\beta := \frac{D_e}{D_2}$ $\beta = 0.25$ Diameter ratio of manifold orifice to pipe diameter

$Ele_{e2.1} := 88ft$ — Outlet elevation for orifice 1

$eH_{use2.1}(Q_t, Q_{t2}) := FB_d - H_1(Q_t) - H_2(Q_{t2})$ — Energy Gradeline Upstream of 1st Orifice Exit

$eH_{use2.1}(Q_t, Q_{t2}) = 108.5\ ft$

$E_{use2.1}(Q_t, Q_{t2}) := \left(eH_{use2.1}(Q_t, Q_{t2}) - Ele_{e2.1}\right)$ — Energy Head on Orifice 1

$E_{use2.1}(Q_t, Q_{t2}) = 20.5\ ft$

$e_{2.1} := 0.03$ — Flow ratio of orifice discharge to total flow of pipe 2

$$mR_{use2.1}(Q_t, Q_{t2}) := \frac{\frac{V_c(Q_{t2}, D_2)^2}{2g}}{E_{use2.1}(Q_t, Q_{t2})}$$

Velocity/Energy head ratio at manifold orifice

$Cdm2(mR_{use2.1}(Q_t, Q_{t2})) = 0.46$ — Coefficitent of disharge of orifice based on velocity head to energy head

$$K_{e2.1}(Q_t, Q_{t2}) := \frac{\alpha_k}{Cdm2(mR_{use2.1}(Q_t, Q_{t2}))^2}$$

$K_{e2.1}(Q_t, Q_{t2}) = 4.64$ — Loss coefficient conversion

$Q_{e2.1} := e_{2.1} \cdot Q_{t2}$ — Discharge from orifice 1

$$hv_{e2.1}(Q_{e2.1}) := \frac{Q_{e2.1}{}^2}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e2.1}}{A_c(D_e)} = 8.15\ \frac{ft}{s}$$

$hv_{e2.1}(Q_{e2.1}) = 1.03\ ft$ — Velocity head thru orifice 1

$H_{e2.1}(Q_t, Q_{t2}, e_{2.1}) := K_{e2.1}(Q_t, Q_{t2}) \cdot hv_{e2.1}(e_{2.1} \cdot Q_{t2})$

$H_{e2.1}(Q_t, Q_{t2}, e_{2.1}) = 4.79\ ft$ — Head loss for trial flow distribution

$E_{use2.1}(Q_t, Q_{t2}) = 20.5\ ft$

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$Ele_{e2.2} := Ele_{e2.1}$ — Outlet elevation for orifice 2

$eH_{use2.2}(Q_t, Q_{t2}) := FB_d - H_1(Q_t) - H_2(Q_{t2})$ — Energy Gradeline Upstream of 2nd Orifice Exit

$eH_{use2.2}(Q_t, Q_{t2}) = 108.5\ ft$

$E_{use2.2}(Q_t, Q_{t2}) := (eH_{use2.2}(Q_t, Q_{t2}) - Ele_{e2.2})$ — Energy Head on Orifice 2

$E_{use2.2}(Q_t, Q_{t2}) = 20.5\ ft$

$e_{2.2} := e_{2.1}$ — Flow ratio of orifice discharge to total flow of pipe 2

$$mR_{use2.2}(Q_t, Q_{t2}) := \frac{\frac{V_c(Q_{t2}, D_2)^2}{2g}}{E_{use2.2}(Q_t, Q_{t2})}$$

Velocity/Energy head ratio at manifold orifice

$Cdm2(mR_{use2.2}(Q_t, Q_{t2})) = 0.46$ — Coefficitent of disharge of orifice based on velocity head to energy head

$$K_{e2.2}(Q_t, Q_{t2}) := \frac{\alpha_k}{Cdm2(mR_{use2.2}(Q_t, Q_{t2}))^2}$$

$K_{e2.2}(Q_t, Q_{t2}) = 4.64$ — Loss coefficient conversion

$Q_{e2.2} := e_{2.2} \cdot Q_{t2}$ — Discharge from orifice 2

$$hv_{e2.2}(Q_{e2.2}) := \frac{Q_{e2.2}^{\ 2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e2.2}}{A_c(D_e)} = 8.15\ \frac{ft}{s}$$

$hv_{e2.2}(Q_{e2.2}) = 1.03\ ft$ — Velocity head thru orifice 2

$H_{e2.2}(Q_t, Q_{t2}, e_{2.2}) := K_{e2.2}(Q_t, Q_{t2}) \cdot hv_{e2.2}(e_{2.2} \cdot Q_{t2})$

$H_{e2.2}(Q_t, Q_{t2}, e_{2.2}) = 4.79\ ft$ — Head loss for trial flow distribution

$E_{use2.2}(Q_t, Q_{t2}) = 20.5\ ft$

$e_{2.1} + e_{2.2} = 0.06$ $\quad K_{e1.32} := 0.05$ Miller 13.31

$Q_{m2.1}(Q_{t2}) := Q_{t2} \cdot (1 - e_{2.1} - e_{2.2})$ Resulting thru flow downstream of Manifold Orifices 1 and 2

$Ele_{e2.3} := 82ft$ Outlet elevation for orifice 3

$eH_{use2.3}(Q_t, Q_{t2}) := eH_{use2.2}(Q_t, Q_{t2}) - K_{e1.32} \cdot hv_2(Q_{m2.1}(Q_{t2}))$ Energy Gradeline Upstream of 3rd Orifice Exit

$eH_{use2.3}(Q_t, Q_{t2}) = 108.3\ ft$

$E_{use2.3}(Q_t, Q_{t2}) := (eH_{use2.3}(Q_t, Q_{t2}) - Ele_{e2.3})$

$E_{use2.3}(Q_t, Q_{t2}) = 26.3\ ft$

$e_{2.3} := 0.068$ Flow ratio of orifice discharge to total flow of pipe 2

$$mR_{use2.3}(Q_t, Q_{t2}) := \frac{\dfrac{V_c(Q_{m2.1}(Q_{t2}), D_2)^2}{2g}}{E_{use2.3}(Q_t, Q_{t2})}$$

Velocity/Energy head ratio at manifold orifice

$Cdm2(mR_{use2.3}(Q_t, Q_{t2})) = 0.51$ Coefficitent of disharge of orifice based on velocity head to energy head

$$K_{e2.3}(Q_t, Q_{t2}) := \frac{\alpha_k}{Cdm2(mR_{use2.3}(Q_t, Q_{t2}))^2}$$

$K_{e2.3}(Q_t, Q_{t2}) = 3.9$ Loss coefficient conversion

$Q_{e2.3} := e_{2.3} \cdot Q_{t2}$ Discharge from orifice 3

$$hv_{e2.3}(Q_{e2.3}) := \frac{Q_{e2.3}^{\ 2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e2.3}}{A_c(D_e)} = 18.47\ \frac{ft}{s}$$

$hv_{e2.3}(Q_{e2.3}) = 5.3\ ft$ Velocity head thru orifice 3

$H_{e2.3}(Q_t, Q_{t2}, e_{2.3}) := K_{e2.3}(Q_t, Q_{t2}) \cdot hv_{e2.3}(e_{2.3} \cdot Q_{t2})$

$H_{e2.3}(Q_t, Q_{t2}, e_{2.3}) = 20.7\ ft$ Head loss for trial flow distribution

$E_{use2.3}(Q_t, Q_{t2}) = 26.3\ ft$

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$Ele_{e2.4} := Ele_{e2.3}$ — Outlet elevation for orifice 3

$eH_{use2.4}(Q_t, Q_{t2}) := eH_{use2.3}(Q_t, Q_{t2})$ — Energy Gradeline Upstream of 3rd Orifice Exit

$eH_{use2.4}(Q_t, Q_{t2}) = 108.3\,ft$

$e_{2.4} := e_{2.3}$

$E_{use2.4}(Q_t, Q_{t2}) := (eH_{use2.4}(Q_t, Q_{t2}) - Ele_{e2.4})$

$E_{use2.4}(Q_t, Q_{t2}) = 26.3\,ft$

$$mR_{use2.4}(Q_t, Q_{t2}) := \frac{\frac{V_c(Q_{m2.1}(Q_{t2}), D_2)^2}{2g}}{E_{use2.4}(Q_t, Q_{t2})}$$

Velocity/Energy head ratio at manifold orifice

$Cdm2(mR_{use2.4}(Q_t, Q_{t2})) = 0.51$ — Coefficitent of disharge of orifice based on velocity head to energy head

$$K_{e2.4}(Q_t, Q_{t2}) := \frac{\alpha_k}{Cdm2(mR_{use2.4}(Q_t, Q_{t2}))^2}$$

$K_{e2.4}(Q_t, Q_{t2}) = 3.9$ — Loss coefficient conversion

$Q_{e2.4} := e_{2.4} \cdot Q_{t2}$ — Discharge from orifice

$$hv_{e2.4}(Q_{e2.4}) := \frac{{Q_{e2.4}}^2}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e2.4}}{A_c(D_e)} = 18.47\,\frac{ft}{s}$$

$hv_{e2.4}(Q_{e2.4}) = 5.3\,ft$ — Velocity head thru orifice

$H_{e2.4}(Q_t, Q_{t2}, e_{2.4}) := K_{e2.4}(Q_t, Q_{t2}) \cdot hv_{e2.4}(e_{2.4} \cdot Q_{t2})$

$H_{e2.4}(Q_t, Q_{t2}, e_{2.4}) = 20.7\,ft$ — Head loss for trial flow distribution

$E_{use2.4}(Q_t, Q_{t2}) = 26.3\,ft$

$$\frac{e_{2.3} \cdot Q_{t2}}{Q_{m2.1}(Q_{t2})} = 0.07$$

$K_{e2.32} := 0$ — Miller 13.23

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$$Q_{m2.2}(Q_{t2}) := Q_{m2.1}(Q_{t2}) - (e_{2.3} + e_{2.4}) \cdot Q_{t2}$$

$$Ele_{e2.5} := 76ft$$

$$eH_{use2.5}(Q_t, Q_{t2}) := eH_{use2.4}(Q_t, Q_{t2}) - K_{e2.32} \cdot hv_2(Q_{m2.2}(Q_{t2}))$$

$$eH_{use2.5}(Q_t, Q_{t2}) = 108.3\ ft$$

$$E_{use2.5}(Q_t, Q_{t2}) := (eH_{use2.5}(Q_t, Q_{t2}) - Ele_{e2.5})$$

$$E_{use2.5}(Q_t, Q_{t2}) = 32.3\ ft$$

$$e_{2.5} := 0.092$$

$$mR_{use2.5}(Q_t, Q_{t2}) := \frac{\dfrac{V_c(Q_{m2.2}(Q_{t2}), D_2)^2}{2g}}{E_{use2.5}(Q_t, Q_{t2})}$$

$$Cdm2(mR_{use2.5}(Q_t, Q_{t2})) = 0.55$$

$$K_{e2.5}(Q_t, Q_{t2}) := \frac{\alpha_k}{Cdm2(mR_{use2.5}(Q_t, Q_{t2}))^2}$$

$$K_{e2.5}(Q_t, Q_{t2}) = 3.34$$

$$Q_{e2.5} := e_{2.5} \cdot Q_{t2}$$

$$hv_{e2.5}(Q_{e2.5}) := \frac{Q_{e2.5}^{\ 2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e2.5}}{A_c(D_e)} = 24.99\ \frac{ft}{s}$$

$$hv_{e2.5}(Q_{e2.5}) = 9.7\ ft$$

$$H_{e2.5}(Q_t, Q_{t2}, e_{2.5}) := K_{e2.5}(Q_t, Q_{t2}) \cdot hv_{e2.5}(e_{2.5} \cdot Q_{t2})$$

$$H_{e2.5}(Q_t, Q_{t2}, e_{2.5}) = 32.4\ ft$$

$$eH_{use2.5}(Q_t, Q_{t2}) - AWSC_d = 29.9\ ft$$

$Ele_{e2.6} := Ele_{e2.5}$

$eH_{use2.6}(Q_t, Q_{t2}) := eH_{use2.5}(Q_t, Q_{t2})$

Energy Gradeline Upstream of 6th Orifice Exit

$eH_{use2.6}(Q_t, Q_{t2}) = 108.3\ ft$

$E_{use2.6}(Q_t, Q_{t2}) := (eH_{use2.6}(Q_t, Q_{t2}) - Ele_{e2.6})$

$e_{2.6} := e_{2.5}$

$E_{use2.6}(Q_t, Q_{t2}) = 32.3\ ft$

$$mR_{use2.6}(Q_t, Q_{t2}) := \frac{\frac{V_c(Q_{m2.2}(Q_{t2}), D_2)^2}{2g}}{E_{use2.6}(Q_t, Q_{t2})}$$

$Cdm2(mR_{use2.6}(Q_t, Q_{t2})) = 0.55$

$$K_{e2.6}(Q_t, Q_{t2}) := \frac{\alpha_k}{Cdm2(mR_{use2.6}(Q_t, Q_{t2}))^2}$$

$K_{e2.6}(Q_t, Q_{t2}) = 3.34$

$Q_{e2.6} := e_{2.6} \cdot Q_{t2}$

$$hv_{e2.6}(Q_{e2.6}) := \frac{Q_{e2.6}^{\ 2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e2.6}}{A_c(D_e)} = 24.99\ \frac{ft}{s}$$

$hv_{e2.6}(Q_{e2.6}) = 9.7\ ft$

$H_{e2.6}(Q_t, Q_{t2}, e_{2.6}) := K_{e2.6}(Q_t, Q_{t2}) \cdot hv_{e2.6}(e_{2.6} \cdot Q_{t2})$

$H_{e2.6}(Q_t, Q_{t2}, e_{2.6}) = 32.4\ ft$

$eH_{use2.6}(Q_t, Q_{t2}) - AWSC_d = 29.9\ ft$

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$Ele_{e2.7} := Ele_{e2.6}$

$eH_{use2.7}(Q_t, Q_{t2}) := eH_{use2.6}(Q_t, Q_{t2})$ Energy Gradeline Upstream of 7th Orifice Exit

$eH_{use2.7}(Q_t, Q_{t2}) = 108.3\ ft$

$E_{use2.7}(Q_t, Q_{t2}) := (eH_{use2.7}(Q_t, Q_{t2}) - Ele_{e2.7})$ $e_{2.7} := e_{2.6}$

$E_{use2.7}(Q_t, Q_{t2}) = 32.3\ ft$

$$mR_{use2.7}(Q_t, Q_{t2}) := \frac{\frac{V_c(Q_{m2.2}(Q_{t2}), D_2)^2}{2g}}{E_{use2.7}(Q_t, Q_{t2})}$$

$Cdm2(mR_{use2.7}(Q_t, Q_{t2})) = 0.55$

$$K_{e2.7}(Q_t, Q_{t2}) := \frac{\alpha_k}{Cdm2(mR_{use2.7}(Q_t, Q_{t2}))^2}$$

$K_{e2.7}(Q_t, Q_{t2}) = 3.34$

$Q_{e2.7} := e_{2.7} \cdot Q_{t2}$

$$hv_{e2.7}(Q_{e2.7}) := \frac{Q_{e2.7}^{\ 2}}{A_c(D_e)^2 \cdot 2g} \qquad \frac{Q_{e2.7}}{A_c(D_e)} = 24.99\ \frac{ft}{s}$$

$hv_{e2.7}(Q_{e2.7}) = 9.7\ ft$

$H_{e2.7}(Q_t, Q_{t2}, e_{2.7}) := K_{e2.7}(Q_t, Q_{t2}) \cdot hv_{e2.7}(e_{2.7} \cdot Q_{t2})$

$H_{e2.7}(Q_t, Q_{t2}, e_{2.7}) = 32.4\ ft$

$eH_{use2.7}(Q_t, Q_{t2}) - AWSC_d = 29.9\ ft$

$$\frac{e_{2.5} \cdot Q_{t2}}{Q_{m2.2}(Q_{t2})} = 0.11$$

$K_{e3.32} := 0.05$ Miller 13.23

$Q_{m2.3}(Q_{t2}) := Q_{m2.2}(Q_{t2}) - (e_{2.5} + e_{2.6} + e_{2.7}) \cdot Q_{t2}$

$Ele_{e2.8} := 68.0ft$

$eH_{use2.8}(Q_t, Q_{t2}) := eH_{use2.7}(Q_t, Q_{t2}) - K_{e3.32} \cdot hv_2(Q_{m2.3}(Q_{t2}))$ Energy Gradeline Upstream of 8th Orifice Exit

$eH_{use2.8}(Q_t, Q_{t2}) = 108.24\ ft$

$E_{use2.8}(Q_t, Q_{t2}) := (eH_{use2.8}(Q_t, Q_{t2}) - Ele_{e2.8})$ $e_{2.8} := 0.105$

$E_{use2.8}(Q_t, Q_{t2}) = 40.24\ ft$

$$mR_{use2.8}(Q_t, Q_{t2}) := \frac{\frac{V_c(Q_{m2.3}(Q_{t2}), D_2)^2}{2g}}{E_{use2.8}(Q_t, Q_{t2})}$$

$Cdm2(mR_{use2.8}(Q_t, Q_{t2})) = 0.59$

$$K_{e2.8}(Q_t, Q_{t2}) := \frac{\alpha_k}{Cdm2(mR_{use2.8}(Q_t, Q_{t2}))^2}$$

$K_{e2.8}(Q_t, Q_{t2}) = 2.88$

$Q_{e2.8} := e_{2.8} \cdot Q_{t2}$

$$hv_{e2.8}(Q_{e2.8}) := \frac{Q_{e2.8}^{\ 2}}{A_c(D_e)^2 \cdot 2g}$$ $$\frac{Q_{e2.8}}{A_c(D_e)} = 28.52\ \frac{ft}{s}$$

$hv_{e2.8}(Q_{e2.8}) = 12.64\ ft$

$H_{e2.8}(Q_t, Q_{t2}, e_{2.8}) := K_{e2.8}(Q_t, Q_{t2}) \cdot hv_{e2.8}(e_{2.8} \cdot Q_{t2})$

$H_{e2.8}(Q_t, Q_{t2}, e_{2.8}) = 36.37\ ft$

$eH_{use2.8}(Q_t, Q_{t2}) - AWSC_d = 29.84\ ft$

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$Ele_{e2.9} := Ele_{e2.8}$

$eH_{use2.9}(Q_t, Q_{t2}) := eH_{use2.8}(Q_t, Q_{t2})$ — Energy Gradeline Upstream of 9th Orifice Exit

$eH_{use2.9}(Q_t, Q_{t2}) = 108.24\ ft$

$E_{use2.9}(Q_t, Q_{t2}) := \left(eH_{use2.9}(Q_t, Q_{t2}) - Ele_{e2.9}\right)$ — $e_{2.9} := e_{2.8}$

$E_{use2.9}(Q_t, Q_{t2}) = 40.24\ ft$

$$mR_{use2.9}(Q_t, Q_{t2}) := \frac{\dfrac{V_c\left(Q_{m2.3}(Q_{t2}), D_2\right)^2}{2g}}{E_{use2.9}(Q_t, Q_{t2})}$$

$Cdm2\left(mR_{use2.9}(Q_t, Q_{t2})\right) = 0.59$

$$K_{e2.9}(Q_t, Q_{t2}) := \frac{\alpha_k}{Cdm2\left(mR_{use2.9}(Q_t, Q_{t2})\right)^2}$$

$K_{e2.9}(Q_t, Q_{t2}) = 2.88$

$Q_{e2.9} := e_{2.9} \cdot Q_{t2}$

$$hv_{e2.9}(Q_{e2.9}) := \frac{{Q_{e2.9}}^2}{A_c(D_e)^2 \cdot 2g} \qquad \frac{Q_{e2.9}}{A_c(D_e)} = 28.52\ \frac{ft}{s}$$

$hv_{e2.9}(Q_{e2.9}) = 12.64\ ft$

$H_{e2.9}(Q_t, Q_{t2}, e_{2.9}) := K_{e2.9}(Q_t, Q_{t2}) \cdot hv_{e2.9}(e_{2.9} \cdot Q_{t2})$

$H_{e2.9}(Q_t, Q_{t2}, e_{2.9}) = 36.37\ ft$

$eH_{use2.9}(Q_t, Q_{t2}) - AWSC_d = 29.84\ ft$

$$\frac{e_{2.9} \cdot Q_{t2}}{Q_{m2.3}(Q_{t2})} = 0.2 \qquad K_{e4.32} := 0.05 \quad \text{Miller 13.23}$$

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$Q_{m2.4}(Q_{t2}) := Q_{m2.3}(Q_{t2}) - (e_{2.8} + e_{2.9}) \cdot Q_{t2}$

$Ele_{e2.10} := 62.0ft$

$eH_{use2.10}(Q_t, Q_{t2}) := eH_{use2.9}(Q_t, Q_{t2}) - K_{e4.32} \cdot hv_2(Q_{m2.4}(Q_{t2}))$ Energy Gradeline Upstream of 10th Orifice Exit

$eH_{use2.10}(Q_t, Q_{t2}) = 108.22\ ft$

$E_{use2.10}(Q_t, Q_{t2}) := (eH_{use2.10}(Q_t, Q_{t2}) - Ele_{e2.10})$

$e_{2.10} := 0.109$

$E_{use2.10}(Q_t, Q_{t2}) = 46.22\ ft$

$$mR_{use2.10}(Q_t, Q_{t2}) := \frac{\frac{V_c(Q_{m2.4}(Q_{t2}), D_2)^2}{2g}}{E_{use2.10}(Q_t, Q_{t2})}$$

$Cdm2(mR_{use2.10}(Q_t, Q_{t2})) = 0.6$

$$K_{e2.10}(Q_t, Q_{t2}) := \frac{\alpha_k}{Cdm2(mR_{use2.10}(Q_t, Q_{t2}))^2}$$

$K_{e2.10}(Q_t, Q_{t2}) = 2.78$

$Q_{e2.10} := e_{2.10} \cdot Q_{t2}$

$$hv_{e2.10}(Q_{e2.10}) := \frac{Q_{e2.10}{}^2}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e2.10}}{A_c(D_e)} = 29.61\ \frac{ft}{s}$$

$hv_{e2.10}(Q_{e2.10}) = 13.62\ ft$

$H_{e2.10}(Q_t, Q_{t2}, e_{2.10}) := K_{e2.10}(Q_t, Q_{t2}) \cdot hv_{e2.10}(e_{2.10} \cdot Q_{t2})$

$H_{e2.10}(Q_t, Q_{t2}, e_{2.10}) = 37.83\ ft$

$eH_{use2.10}(Q_t, Q_{t2}) - AWSC_d = 29.82\ ft$

$Ele_{e2.11} := 62.0ft$

$eH_{use2.11}(Q_t, Q_{t2}) := eH_{use2.10}(Q_t, Q_{t2})$

Energy Gradeline Upstream of 11th Orifice Exit

$eH_{use2.11}(Q_t, Q_{t2}) = 108.22\ ft$

$E_{use2.11}(Q_t, Q_{t2}) := (eH_{use2.11}(Q_t, Q_{t2}) - Ele_{e2.11})$

$e_{2.11} := e_{2.10}$

$E_{use2.11}(Q_t, Q_{t2}) = 46.22\ ft$

$$mR_{use2.11}(Q_t, Q_{t2}) := \frac{\dfrac{V_c(Q_{m2.4}(Q_{t2}), D_2)^2}{2g}}{E_{use2.11}(Q_t, Q_{t2})}$$

$Cdm2(mR_{use2.11}(Q_t, Q_{t2})) = 0.6$

$$K_{e2.11}(Q_t, Q_{t2}) := \frac{\alpha_k}{Cdm2(mR_{use2.11}(Q_t, Q_{t2}))^2}$$

$K_{e2.11}(Q_t, Q_{t2}) = 2.78$

$Q_{e2.11} := e_{2.11} \cdot Q_{t2}$

$$hv_{e2.11}(Q_{e2.11}) := \frac{Q_{e2.11}{}^2}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e2.11}}{A_c(D_e)} = 29.61\ \frac{ft}{s}$$

$hv_{e2.11}(Q_{e2.11}) = 13.62\ ft$

$H_{e2.11}(Q_t, Q_{t2}, e_{2.11}) := K_{e2.11}(Q_t, Q_{t2}) \cdot hv_{e2.11}(e_{2.11} \cdot Q_{t2})$

$H_{e2.11}(Q_t, Q_{t2}, e_{2.11}) = 37.83\ ft$

$eH_{use2.11}(Q_t, Q_{t2}) - AWSC_d = 29.82\ ft$

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$Ele_{e2.12} := 62.0ft$

$eH_{use2.12}(Q_t, Q_{t2}) := eH_{use2.11}(Q_t, Q_{t2})$

Energy Gradeline Upstream of 12th Orifice Exit

$eH_{use2.12}(Q_t, Q_{t2}) = 108.22\ ft$

$E_{use2.12}(Q_t, Q_{t2}) := (eH_{use2.12}(Q_t, Q_{t2}) - Ele_{e2.12})$

$e_{2.12} := e_{2.11}$

$E_{use2.12}(Q_t, Q_{t2}) = 46.22\ ft$

$$mR_{use2.12}(Q_t, Q_{t2}) := \frac{\frac{V_c(Q_{m2.4}(Q_{t2}), D_2)^2}{2g}}{E_{use2.12}(Q_t, Q_{t2})}$$

$Cdm2(mR_{use2.12}(Q_t, Q_{t2})) = 0.6$

$$K_{e2.12}(Q_t, Q_{t2}) := \frac{\alpha_k}{Cdm2(mR_{use2.12}(Q_t, Q_{t2}))^2}$$

$K_{e2.12}(Q_t, Q_{t2}) = 2.78$

$Q_{e2.12} := e_{2.12} \cdot Q_{t2}$

$$hv_{e2.12}(Q_{e2.12}) := \frac{Q_{e2.12}{}^2}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e2.12}}{A_c(D_e)} = 29.61\ \frac{ft}{s}$$

$hv_{e2.12}(Q_{e2.12}) = 13.62\ ft$

$H_{e2.12}(Q_t, Q_{t2}, e_{2.12}) := K_{e2.12}(Q_t, Q_{t2}) \cdot hv_{e2.12}(e_{2.12} \cdot Q_{t2})$

$H_{e2.12}(Q_t, Q_{t2}, e_{2.12}) = 37.83\ ft$

$eH_{use2.12}(Q_t, Q_{t2}) - AWSC_d = 29.82\ ft$

$$1 - (e_{2.1} + e_{2.2} + e_{2.3} + e_{2.4} + e_{2.5} + e_{2.6} + e_{2.7} + e_{2.8} + e_{2.9} + e_{2.10} + e_{2.11} + e_{2.12}) = -9 \times 10^{-3}$$

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Pipe 3 Losses

$Q_{t3} = 750 \cdot cfs$ Trial split (assume equal distribution) $V_c(Q_{t3}, D_3) = 16.98 \frac{ft}{s}$

$L_3 = 110\,ft$

$HV_3 := \frac{V_c(Q_{t3}, D_3)^2}{2 \cdot g}$ $HV_3 = 4.48\,ft$ Velocity head thru Pipe 3

$hv_3(Q) := \frac{V_c(Q, D_3)^2}{2 \cdot g}$

Wye Loss

$\frac{Q_1}{Q_3} = \frac{700}{1400}$ $\frac{700}{1400} = 0.5$ $Q_R := 0.5$ $\frac{Q_1}{Q_3} = \frac{700}{1400}$ $\frac{700}{1400} = 0.5$ $Q_R := 0.5$

Tee loss assigned assuming 30 degree angled branching flow

$\frac{A_1}{A_3} = 05$ $\frac{A_c(D_3)}{A_c(D_1)} = 0.56$ $A_R := 0.563$

$K_{31} := \alpha_k \cdot 0.15$ From Miller Fig. 13.28

Bend Loss 1 (30 deg)

$\frac{r}{d} = 1$

$k'_b := 0.06$ From Miller Fig. 9.10 $Ele_{b3.1} := 101.1ft$ Elevation of bend

$C_{Re} := 1.0$ From Miller Fig. 9.3 $L_{b3.1} := 20ft$ Length of pipe 2 to bend

$C_o := 1.0$ No outlet, Miller Fig. 9.4 $\theta_{b3.1} := -30deg$ Bend angle

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$C_f := \frac{f_c(Q_{t3}, D_3, k_{sr})}{f_c(Q_{t3}, D_3, k_{ss})}$ $C_f = 1.11$ From Miller Eq. 9.3

$K_{b3.1} := \alpha_k \cdot k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b3.1} = 0.07$ From Miller Eq. 9.4

Corrected Bend Loss Wye & 3.1 Proximity

$L_s := 20ft$ $\frac{L_s}{D_3} = 2.67$ Close proximity allows for reduction in bend loss. L_s denotes the staight length of pipe between bends.

$C_{b\_b} := 0.775$ From Miller Fig 10.3

$K_{b\_b3.1} := C_{b\_b} \cdot (K_{b3.1})$ $K_{b\_b3.1} = 0.05$

Bend Cavitation Potential

for 3.1 $h_u := \left[FB_d - H_1(Q_t) - \left(K_{31} + f_c(Q_{t3}, D_3, k) \cdot \frac{L_{b3.1}}{D_3}\right) \cdot hv_3(Q_{t3}) - Ele_{b3.1} - HV_3\right] \cdot \gamma$ $h_u = 8.56\,psi$

$\sigma_b := \frac{h_u - Pv(T_f)}{\gamma \cdot \frac{V_c(Q_{t2}, D_2)^2}{2 \cdot g}}$ $\sigma_b = 4.32$ Cavitation parameter is greater than incipient cavitation for r/d = 1

$\sigma_{bi} := 2.2$ Incipient cavitation parameter from Miller Fig 6.10 with r/d = 1.0

bend less than 45 degrees allows for a reduction factor of 0.8 to be applied (Miller)

$bendcav_{3.1} :=$ "Incipient cavitation initiated" if $\sigma_b < 0.8 \cdot \sigma_{bi}$
"Bend radius ok" otherwise

$bendcav_{3.1} =$ "Bend radius ok"

Thrust at bend

$$P_1 := \left[FB_d - H_1(Q_t) - \left(K_{31} + f_c(Q_{t3}, D_3, k)\cdot\frac{L_{b3.1}}{D_3}\right)\cdot hv_3(Q_{t3}) - Ele_{b3.1} - HV_3\right]\cdot\gamma$$

$P_1 = 8.56\,psi$ Pressure at point 1

$P_{1x} := P_1$ $P_{1y} := 0psi$ X and Y components of pressure vectors at control volume surface point 1

$A_1 := A_c(D_3)$ Area of control volume on which the pressure 1 acts on

$A_1 = 44.18\,ft^2$

$V_1 := V_c(Q_{t3}, D_3)$

$V_{1x} := V_1$ Velocity in X direction at point 1

$V_{1x} = 16.98\cdot fps$

$V_{1y} := 0fps$ Velocity in Y direction at point 1

$$P_2 := \left[FB_d - H_1(Q_t) - \left(K_{31} + K_{b\_b3.1} + f_c(Q_{t3}, D_3, k)\cdot\frac{L_{b3.1}}{D_3}\right)\cdot hv_3(Q_{t3}) - Ele_{b3.1} - HV_3\right]\cdot\gamma$$

$P_{2x} := P_2\cdot\cos(\theta_{b3.1})$ X and Y components of pressure vectors at control volume surface point 2

$P_{2y} := P_2\cdot\sin(\theta_{b3.1})$

$A_2 := A_1$ Area of control volume on which the pressure 2 acts on

$V_{2x} := V_1\cdot\cos(\theta_{b3.1})$ Velocity in X direction at point 2

$V_{2y} := V_1\cdot\sin(\theta_{b3.1})$ Velocity in Y direction at point 2

$F_{b3.1x} := P_{1x}\cdot A_1 - P_{2x}\cdot A_2 - \rho\cdot Q_{t2}\cdot(V_{2x} - V_{1x})$ $P_{1x}\cdot A_1 - P_{2x}\cdot A_2 = 7.85\cdot kip$ $-\rho\cdot Q_{t2}\cdot(V_{2x} - V_{1x}) = 3.31\cdot kip$

$F_{b3.1x} = 11.16\cdot kip$ Reactionary force in X direction

$F_{b3.1y} := -\left[P_{1y}\cdot A_1 - P_{2y}\cdot A_2 - \rho\cdot Q_{t2}\cdot\left(V_{2y} - V_{1y}\right)\right]$ $\quad -\left(P_{1y}\cdot A_1\right) - P_{2y}\cdot A_2 = 26.91\cdot kip \quad \rho\cdot Q_{t2}\cdot\left(V_{2y} - V_{1y}\right) = -12.35\cdot kip$

$F_{b3.1y} = -39.26\cdot kip$ Reactionary for in Y direction

$F_{b3.1} := \sqrt{F_{b3.1x}^2 + F_{b3.1y}^2}$ $\quad F_{b3.1} = 40.82\cdot kip$ Resultant force

Orifice Loss 3.1

$D_{o3.1} := D_{o2.1}$ Orifice Diameter

$L_{o3.1} := 45ft$

$\theta := \left(\frac{D_{o3.1}}{D_2}\right)^2$ $\quad \theta = 0.54$ — Area ratio of inline orifice and inside pipe diameter (FEMA Eq. 17a)

$C_c := 3.1341\cdot\theta^5 - 5.8809\cdot\theta^4 + 3.8307\cdot\theta^3 - 0.879\cdot\theta^2 + 0.1851\cdot\theta + 0.61$ $\quad C_c = 0.7$ — Vena Contracta Coefficient (FEMA Eq. 17)

$V_{vc}(Q) := \frac{Q}{C_c\cdot 0.25\cdot\pi\cdot D_{o3.1}^2}$ $\quad V_{vc}\left(Q_{t3}\right) = 45.08\frac{ft}{s}$ — Vena contracta velocity

$C_v := 0.98$ — Velocity coefficient for Reynolds number > 10^5 (FEMA)

$CD_o := \frac{C_c\cdot C_v}{\sqrt{1 - C_c^2\cdot\frac{A_c\left(D_{o3.1}\right)^2}{A_c\left(D_3\right)^2}}}$ $\quad CD_o = 0.74$ — Orifice discharge coefficient for vena contracta calcs (FEMA Eq. 20)

$\beta := \frac{D_{o3.1}}{D_3}$ $\quad \beta = 0.73$ — Diameter ratio of inline orifice and inside pipe diameter

$K_{o3.1} := \alpha_k\cdot 4890\cdot e^{-10.18\cdot\beta}$ $\quad K_{o3.1} = 2.8$ — Loss coefficient (FEMA Eq. 23)

$h_{o3.1}(Q) := \left(\frac{Q}{A_c(D_3)}\right)^2 \cdot \frac{K_{o3.1}}{2 \cdot g}$ $\quad h_{o3.1}(Q_{t3}) = 12.54\ ft$ $\quad$ Head loss associated with design discharge

$F_{o3.1} := \left(A_c(D_3) - A_c(D_{o3.1})\right) \cdot h_{o3.1}(Q_{t3}) \cdot \gamma$

$F_{o3.1} = 15.98 \cdot kip$ $\quad \left(A_c(D_3) - A_c(D_{o3.1})\right) = 20.42\ ft^2$

$f_{o3.1}(Q) := f_c(Q, D_3, k) \cdot \frac{L_{o3.1}}{D_3}$ $\quad$ Friction loss to orifice from intake

$eh_{uso3.1}(Q) := H_1(Q_t) + \left(K_{b\_b3.1} + K_{31} + f_{o3.1}(Q)\right) \cdot hv_2(Q)$ $\quad$ Head loss from entrance to upstream side of orifice

$eh_{uso3.1}(Q_{t3}) = 35.04\ ft$

$eH_{uso3.1}(Q) := FB_d - eh_{uso3.1}(Q)$ $\quad eH_{uso3.1}(Q_{t3}) = 124.96\ ft$ $\quad$ Energy gradeline at upstream side of orifice

$H_{uso3.1}(Q) := eH_{uso3.1}(Q) - HV_1$ $\quad H_{uso3.1}(Q_{t3}) = 119.29\ ft$ $\quad$ Hydraulic gradeline at upstream side of orifice

$P_{uso3.1}(Q) := \left(H_{uso3.1}(Q) - Ele_{top3.1}\right) \cdot \gamma$ $\quad P_{uso3.1}(Q_{t3}) = 6.41\ psi$ $\quad$ Pressure at upstream side of orifice at top of pipe

$eh_{dso3.1}(Q) := eh_{uso3.1}(Q) + h_{o3.1}(Q)$ $\quad$ Head loss from entrance to downstream side of orifice

$Q = CD_o \cdot A_o \cdot \sqrt{2 \cdot g \cdot \left(\frac{P_1}{\gamma} - \frac{P_{vc}}{\gamma}\right)}$ $\quad$ Discharge as a function of headloss from upstream side orifice to downstream side at vena contracta (FEMA Eq. 18)

$P_{vc}(Q) := P_{uso3.1}(Q) - \gamma \cdot \frac{V_c(Q, D_{o3.1})^2}{CD_o^2 \cdot 2 \cdot g}$ $\quad P_{vc}(Q_{t3}) = -5.82\ psi$ $\quad$ Pressure at vena contracta

$Pvg(T_f) = -14.52\ psi$ $\quad$ Vapor pressure of water at assume temp

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$H_{vc}(Q) := H_{uso3.1}(Q) - \frac{V_c(Q, D_{o3.1})^2}{CD_o^{\,2} \cdot 2 \cdot g}$ $\quad H_{vc}(Q_{t3}) = 91.07\ ft$ $\quad$ Hydraulic gradeline at vena contracta

$eH_{dso3.1}(Q) := FB_d - eh_{dso3.1}(Q)$ $\quad eH_{dso3.1}(Q_{t3}) = 112.42\ ft$ $\quad$ Energy gradeline downstream of orifice

$H_{dso3.1}(Q) := eH_{dso3.1}(Q) - HV_2$ $\quad H_{dso3.1}(Q_{t3}) = 107.94\ ft$ $\quad$ Hydraulic gradeline downstream of orifice

$P_{dso3.1}(Q) := (H_{dso3.1}(Q) - Ele_{top3.1}) \cdot \gamma$ $\quad P_{dso3.1}(Q_{t3}) = 1.49\ psi$ $\quad$ Pressure at downstream side of orifice at top of pipe

$\sigma := \frac{P_{dso3.1}(Q_{t3}) - Pvg(T_f)}{P_{uso3.1}(Q_{t3}) - P_{dso3.1}(Q_{t3})}$ $\quad \sigma = 3.25$ $\quad$ Cavitation parameter (Rahmeyer Eq 10)

$\sigma_{o3.1} := \sigma$ $\quad$ Setting cavitation parameter for later output

Tullis Cavitation Method Check

$CD := 0.019 + 0.083 \cdot \beta - 0.203 \cdot \beta^2 + 1.35 \cdot \beta^3$ $\quad CD = 0.5$ $\quad$ Discharge coefficient based on orifice/pipe diameter ratio (FEMA Eq. 27)

$CD := \frac{1}{\sqrt{K_{o3.1} + 1}}$ $\quad CD = 0.51$ $\quad$ Discharge coefficient based on orifice loss calculated previously (FEMA Eq. 28)

Conservative CD chosen for further calculations

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$\sigma_{im} := 0.62 + 4.4 \cdot CD + 6.6CD^2 + 1.3CD^3$	$\sigma_{im} = 4.79$	Reference incipient cavitation from Tullis lab tests (FEMA Eq. 30)
$D_p := D_3$		Prototype pipe sise
$D_m := 3in$		Lab model pipe size
$Y := 0.3 \cdot K_{o3.1}{}^{0.25}$		Conversion exponent (FEMA Eq. 32)
$SSE := \left(\frac{D_p}{D_m}\right)^Y$		Size scale effect from reference lab results (FEMA Eq. 31
$\sigma_i := SSE \cdot \sigma_{im}$	$\sigma_i = 17.93$	Incipient cavitation parmeter (FEMA Eq. 29)
$check\_\sigma_{i\_3.1} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_i \\ \text{"check next"} & \text{otherwise} \end{cases}$	$check\_\sigma_{i\_3.1} = \text{"check next"}$	
$\sigma_{cm} := 0.78 + 0.77 \cdot CD + 0.89 \cdot CD^2 - 4.16 \cdot CD^3$	$\sigma_{cm} = 0.85$	Reference critical cavitation from Tullis lab tests (FEMA Eq. 34)
$\sigma_{cr} := SSE \cdot \sigma_{cm}$	$\sigma_{cr} = 3.17$	Critical cavitation parameter (FEMA Eq. 33)
$check\_\sigma_{cr\_3.1} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_{cr} \\ \text{"check next"} & \text{otherwise} \end{cases}$	$check\_\sigma_{cr\_3.1} = \text{"ok"}$	
$\sigma_{idm} := 0.11 + 6.5 \cdot CD - 7.9 \cdot CD^2 + 8.8 \cdot CD^3$		Reference incipient damage cavitation from Tullis tests (FEMA Eq. 36)
$P_{1m} := 90psi$ $\quad P_{vgm} := -12.2psi$		Reference Tullis lab pressure and vapor pressure
$Pvg(T_f) = -14.52\ psi$		Vapor pressure of river water at assumed temperature

$PSE := \left(\frac{P_{dso3.1}(Q_{t3}) - Pvg(T_f)}{P_{1m} - P_{vgm}}\right)^{0.16}$ $PSE = 0.74$ Pressure scale effect from reference lab test (FEMA Eq. 37)

$\sigma_{id} := \sigma_{idm} \cdot PSE$ $\sigma_{id} = 1.9$ Incipient damage caviation parameter (FEMA Eq. 35)

$check\_\sigma_{id\_3.1} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_{id} \\ \text{"resize orifice"} & \text{otherwise} \end{cases}$ $check\_\sigma_{id\_3.1} = \text{"ok"}$

$\sigma_{ch} := 0.15 + 1.2CD - 0.31 \cdot CD^2 + 3.3 \cdot CD^3$ $\sigma_{ch} = 1.13$ Choking cavitation parameter (FEMA Eq. 38)

$check\_\sigma_{ch\_3.1} := \begin{cases} \text{"ok"} & \text{if } \sigma > \sigma_{ch} \\ \text{"resize orifice"} & \text{otherwise} \end{cases}$ $check\_\sigma_{ch\_3.1} = \text{"ok"}$

Miller Cavitation Check

$\frac{D_{o3.1}}{D_3} = 0.73$ Orifice/pipe diameter ratio

$V_c(Q_{t3}, D_3) = 5.17 \cdot \frac{m}{s}$ Approach velocity to orifice

$C_1 := 0.5$ Miller Fig. 6.17

$H_{uso3.1}(Q_{t3}) = 36.36 \cdot m$ Approach pressure head at orifice

$Hvg(T_f) = 23.17 \cdot m$ Vapor pressure head at orifice (top of pipe, gage)

$U_c := C_1 \cdot Uir\left(\frac{D_{o3.1}}{D_3}\right) \cdot \left(\frac{H_{uso3.1}(Q_{t3}) - Hvg(T_f)}{71.6m}\right)^{0.5}$

$check\_o3_{1\_u.c} := \begin{cases} \text{"incipient cavitation initiated"} & \text{if } U_c < V_c(Q_{t3}, D_3) \\ \text{"no cavitation"} & \text{otherwise} \end{cases}$

$U_c = 1.89 \cdot \frac{m}{s}$

check_o3$_{1_u.c}$ = "incipient cavitation initiated"

$$U_{cr} := C_1 \cdot Ucr\left(\frac{D_{o3.1}}{D_3}\right) \cdot \left(\frac{H_{uso3.1}(Q_{t3}) - Hvg(T_f)}{71.6m}\right)^{0.5}$$

check_o3$_{1_u.cr}$:= | "critical cavitation initiated" if $U_{cr} < V_c(Q_{t3}, D_3)$
| "non critical cavitation" otherwise

$U_{cr} = 2.42 \cdot \frac{m}{s}$

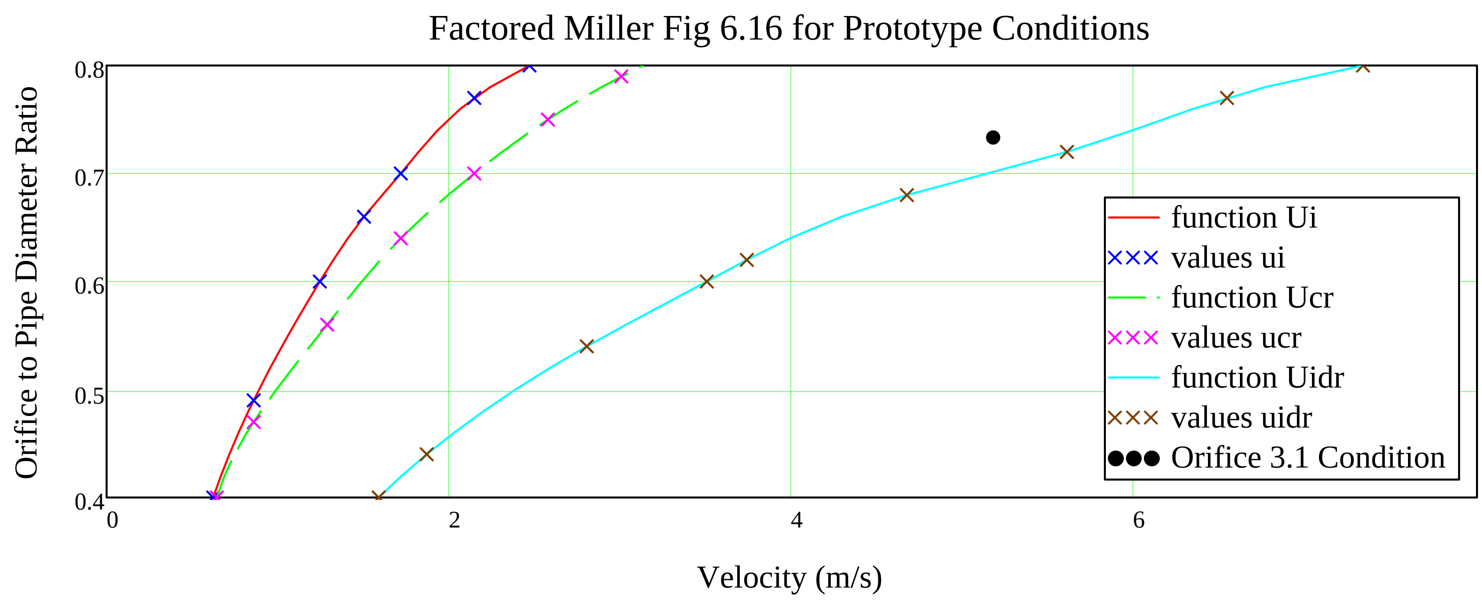
check_o3$_{1_u.cr}$ = "critical cavitation initiated"

$$U_{id} := Uidr\left(\frac{D_{o3.1}}{D_3}\right) \cdot \left(\frac{H_{uso3.1}(Q_{t3}) - Hvg(T_f)}{71.6m}\right)^{0.45}$$

check_o3$_{1_u.id}$:= | "damaging incipient cavitation initiated" if $U_{id} < V_c(Q_{t3}, D_3)$
| "non damaging" otherwise

$U_{id} = 5.87 \cdot \frac{m}{s}$

check_o3$_{1_u.id}$ = "non damaging"



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Thrust at Orifice 2.1

Thrust on the orifice will be assumed equal to that of a square edged contraction to a pipe the size of the orifice. This is a conservative measure that ensures that momentum is accounted including pressure reduction through the orifice.

$P_1 := P_{uso3.1}(Q_{t3})$ $\quad P_1 = 6.41\,psi$

$P_2 := P_{dso3.1}(Q_{t3})$ $\quad P_2 = 1.49\,psi$

$A_1 := A_c(D_3)$ $\quad A_1 = 44.18\,ft^2$

$A_2 := A_c(D_{o3.1})$ $\quad A_2 = 23.76\,ft^2$

$V_1 := \frac{Q_{t2}}{A_1}$ $\quad V_1 = 16.98\,\frac{ft}{s}$

$V_2 := \frac{Q_{t2}}{A_2}$ $\quad V_2 = 31.57\,\frac{ft}{s}$

$F_{o3.1} := P_1 \cdot A_1 - P_2 \cdot A_2 + \rho \cdot Q_{t2} \cdot (V_2 - V_1)$ $\quad P_1 \cdot A_1 - P_2 \cdot A_2 = 35.68 \cdot kip$ $\quad \rho \cdot Q_{t2} \cdot (V_2 - V_1) = 21.23 \cdot kip$

$F_{o3.1} = 56.92 \cdot kip$

$K_{o3.1} = 2.8$

Bend Loss 3.2 (90 deg)

$Ele_{b3.2} := 101.1\,ft$ $\quad L_{b3.2} := 75\,ft$

$\frac{r}{d} = 1$

$k'_b := 0.26$ From Miller Fig. 9.10

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 2.75$ No outlet, Miller Fig. 9.4

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$C_f := \frac{f_c(Q_{t3}, D_3, k_{sr})}{f_c(Q_{t3}, D_3, k_{ss})}$ $C_f = 1.11$ From Miller Eq. 9.3

$K_{b3.2} := \alpha_k \cdot k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b3.2} = 0.8$ From Miller Eq. 9.4

Bend Cavitation Potential

for 3.2 $h_u := \left[FB_d - H_1(Q_t) - \left(K_{31} + K_{b\_b2.1} + K_{o3.1} + f_c(Q_{t3}, D_3, k) \cdot \frac{L_{b3.2}}{D_3}\right) \cdot hv_3(Q_{t3}) - Ele_{b3.2} - HV_3\right] \cdot \gamma$ $h_u = 2.89\,psi$

$\sigma_b := \frac{h_u - Pv(T_f)}{\gamma \cdot \frac{V_c(Q_{t2}, D_2)^2}{2 \cdot g}}$ $\sigma_b = 1.4$

$\sigma_{bi} := 2.2$ Incipient cavitation parameter from Miller Fig 6.10 with r/d = 1.0

Cavitation parameter is greater than incipient cavitation for r/d = 1

$bendcav_{3.2} :=$ "Incipient cavitation initiated" if $\sigma_b < \sigma_{bi}$; "Bend radius ok" otherwise

$bendcav_{3.2} =$ "Incipient cavitation initiated"

Thrust at bend

$P_1 := \left[FB_d - H_1(Q_t) - \left(K_{31} + K_{b\_b3.1} + K_{o3.1} + f_c(Q_{t3}, D_3, k) \cdot \frac{L_3}{D_3}\right) \cdot hv_3(Q_{t3}) - Ele_{b3.2} - HV_3\right] \cdot \gamma$

$P_1 = 2.81\,psi$ Pressure at point 1 at high discharge

$P_{1x} := P_1$

$P_{1y} := 0psi$ X and Y components of pressure vectors at control volume surface point 1

$A_1 := A_c(D_3)$ Area of control volume on which the pressure 1 acts on

$A_1 = 44.18\,ft^2$

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$V_{1x} := V_c(Q_{t3}, D_3)$ Velocity in X direction at point 1

$V_{1x} = 16.98 \cdot fps$

$V_{1y} := 0fps$ Velocity in Y direction at point 1

$P_2 := 0psi$

$P_{2x} := P_2$ $P_{2y} := P_{1x}$ X and Y components of pressure vectors at control volume surface point 2

$A_2 := A_1$ Area of control volume on which the pressure 2 acts on

$V_{2x} := 0fps$ Velocity in X direction at point 2

$V_{2y} := -V_{1x}$ Velocity in Y direction at point 2

$F_{b3.2x} := P_{1x} \cdot A_1 - P_{2x} \cdot A_2 - \rho \cdot Q_{t3} \cdot (V_{2x} - V_{1x})$

$F_{b3.2x} = 42.59 \cdot kip$ Reactionary force in X direction

$F_{b3.2y} := P_{1y} \cdot A_1 - P_{2y} \cdot A_2 - \rho \cdot Q_{t3} \cdot (V_{2y} - V_{1y})$

$F_{b3.2y} = 6.82 \cdot kip$ Reactionary for in Y direction

$F_{b3.2} := \sqrt{F_{b3.2x}^2 + F_{b3.2y}^2}$ $F_{b3.2} = 43.13 \cdot kip$ Resultant force

$45ft \cdot A_1 \cdot \gamma = 124.07 \cdot kip$ Weight of water in pipe spanning the fish ladder

$Fr_3(Q) := \frac{V_c(Q, D_3)}{\sqrt{g \cdot D_3}}$ $Fr_3(Q_{t3}) = 1.09$ Froude number of pipe 3

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Friction Loss

$$f_3(Q) := f_c(Q, D_3, k) \cdot \frac{L_3}{D_3}$$

$$h_{f3}(Q) := f_c(Q, D_3, k) \cdot \frac{L_3}{D_3} \cdot hv_3(Q) \qquad h_{f3}(Q_{t3}) = 0.6\,ft$$

friction loss head at design discharge

Control check for horizontal discharge and potential open channel flow within Pipe 3

$D := D_3 \qquad Q := Q_{t3}$

$n := 0.010$ Mannings roughness coefficient

$C_u := 1.486\,\sqrt[3]{ft} \cdot s^{-1}$ Units factor for Mannings equation

$S_o := 0.001\,\frac{ft}{ft}$ Slope of pipe crossing fishladder

Angle Functions $\theta(y) := 2 \cdot acos\left(1 - 2 \cdot \frac{y}{D}\right)$

Area Functions $A(\theta) := \frac{D^2}{8} \cdot (\theta - \sin(\theta))$

Perimeter Functions $P(\theta) := \frac{D}{2} \cdot (\theta)$

Hydraulic Radius $R_H(\theta) := A(\theta) \cdot P(\theta)^{-1}$

Top Width $T(\theta) := D \cdot \sin\left(\frac{\theta}{2}\right)$

Full Pipe Condition

$y_f := 0.90D \qquad y_f = 6.75\,ft \qquad \theta_f := 2 \cdot acos\left(1 - 2\,\frac{y_f}{D}\right) \qquad \theta_f = 5 \qquad A_f := \frac{\pi \cdot D^2}{4}$

Critical Flow Depth Computations

$Z_c := \frac{Q^2}{g} \qquad Z_c = 1.75 \times 10^4\,ft^5$ Critical Section Factor

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$\theta := 1.1\pi$ Trial value for flow angle

Given Solve block for critical depth angle

$\frac{A(\theta)^3}{T(\theta)} = Z_c$ $\theta_c := \text{Find}(\theta)$ $\theta_c = 5.06$

$\theta_c := \begin{cases} (2\cdot\pi) & \text{if } \theta_c > 2\cdot\pi \\ \theta_c & \text{otherwise} \end{cases}$ $\theta_c = 5.06$

$y_c := \begin{cases} D & \text{if } \theta_c > \theta_f \\ \frac{D}{2}\cdot\left(1 - \cos\left(\frac{\theta_c}{2}\right)\right) & \text{otherwise} \end{cases}$ $y_c = 7.5\,ft$ Critical Depth

Critical flow

$R_H(\theta_c) = 2.22\,ft$ Hydraulic Radius

$Per_{full}(y) := \frac{y}{D}$ $Per_{full}(y_c) = 100\cdot\%$ Percent Full

$V_{cr} := Q\cdot A(\theta_c)^{-1}$ $V_{cr} = 17.77\,\frac{ft}{s}$ Critical Velocity

$T(\theta_c) = 4.3\,ft$ Top Width

$S_c := \frac{Q^2\cdot n^2}{C_u^{\,2}\cdot A(\theta_c)^2\cdot\sqrt[3]{R_H(\theta_c)^4}}$ $S_c = 0.49\cdot\%$ Critical Slope

Inlet Condition Factor $N := \frac{Q\cdot cfs^{-1}}{A_f\cdot ft^{-2}\cdot\sqrt{D\cdot ft^{-1}}}$ $N = 6.2$

Specific Head at Critical Depth

$H_c := y_c + \frac{V_{cr}^{\,2}}{2\cdot g}$ $H_c = 12.41\,ft$

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Normal Depth Computation

Trial depth angle $\theta := 1.5\pi$

Given $Q = \frac{C_u}{n} \cdot A(\theta) \cdot R_H(\theta)^{\frac{2}{3}} \cdot \sqrt{S_o}$ $\theta_n := \text{Find}(\theta)$ $\theta_n = 15.41$

$$\theta_n := \begin{cases} (2\cdot\pi) & \text{if } \theta_n > 2\cdot\pi \\ \theta_n & \text{otherwise} \end{cases}$$ $\theta_n = 6.28$

Normal Depth	Critical Depth
$y_n = 7.5\,\text{ft}$	$y_c = 7.5\,\text{ft}$

$$y_n := \begin{cases} D & \text{if } \theta_n > \theta_f \\ \frac{D}{2}\cdot\left(1 - \cos\left(\frac{\theta_n}{2}\right)\right) & \text{otherwise} \end{cases}$$

Flow Area $A(\theta_n) = 44.18\,\text{ft}^2$

Hydraulic Radius $R_H(\theta_n) = 1.88\,\text{ft}$

Percent Full $Per_{full}(y_n) = 100\cdot\%$

Velocity $V_n := Q \cdot A(\theta_n)^{-1}$ $V_n = 16.98\,\frac{\text{ft}}{\text{s}}$

Top Width $T(\theta_n) = 0\,\text{ft}$

Hydraulic Depth $D_{hn} := \frac{A(\theta_n)}{T(\theta_n)}$ $D_{hn} = 4.81 \times 10^{16}\,\text{ft}$

Pipe 3 total losses

$$H_3(Q) := \left(K_{31} + K_{b\_b3.1} + K_{o3.1} + K_{b3.2} + f_3(Q)\right)\cdot hv_3(Q)$$

$$H_3\left(Q_{t3}\right) = 17.61\ ft$$

$$K_{31}\cdot hv_3\left(Q_{t3}\right) = 0.67\ ft$$

$$K_{b\_b3.1}\cdot hv_3\left(Q_{t3}\right) = 0.23\ ft$$

$$K_{o3.1}\cdot hv_3\left(Q_{t3}\right) = 12.54\ ft$$

$$K_{b3.2}\cdot hv_3\left(Q_{t3}\right) = 3.56\ ft$$

$$f_3(Q)\cdot hv_3\left(Q_{t3}\right) = 0.6\ ft$$

$$hv_3\left(Q_{t3}\right) = 4.48\ ft$$

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$D_e = 1.875\ \text{ft}$ Diameter of manifold orifices $\beta := \frac{D_e}{D_2}$ $\beta = 0.25$ Diameter ratio of manifold orifice to pipe diameter

$Ele_{e3.1} := 88\text{ft}$ Outlet elevation for orifice 1

$eH_{use3.1}(Q_t, Q_{t3}) := FB_d - H_1(Q_t) - H_3(Q_{t3})$ Energy Gradeline Upstream of 1st Orifice Exit

$eH_{use3.1}(Q_t, Q_{t3}) = 108.5\ \text{ft}$

$E_{use3.1}(Q_t, Q_{t3}) := (eH_{use3.1}(Q_t, Q_{t3}) - Ele_{e3.1})$ Energy Head on Orifice 1

$E_{use3.1}(Q_t, Q_{t3}) = 20.5\ \text{ft}$

$e_{3.1} := 0.03$ Flow ratio of orifice discharge to total flow of pipe 3

$$mR_{use3.1}(Q_t, Q_{t3}) := \frac{\frac{V_c(Q_{t3}, D_2)^2}{2g}}{E_{use3.1}(Q_t, Q_{t3})}$$

$Cdm2(mR_{use3.1}(Q_t, Q_{t3})) = 0.46$ Coefficitent of disharge of orifice based on velocity head to energy head

$$K_{e3.1}(Q_t, Q_{t3}) := \frac{\alpha_k}{Cdm2(mR_{use3.1}(Q_t, Q_{t3}))^2}$$

$K_{e3.1}(Q_t, Q_{t3}) = 4.64$ Loss coefficient conversion

$Q_{e3.1} := e_{3.1} \cdot Q_{t3}$ Discharge from orifice 1

$$hv_{e3.1}(Q_{e3.1}) := \frac{Q_{e3.1}^{\ 2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e3.1}}{A_c(D_e)} = 8.15\ \frac{\text{ft}}{\text{s}}$$

$hv_{e3.1}(Q_{e3.1}) = 1.03\ \text{ft}$ Velocity head thru orifice 1

$H_{e3.1}(Q_t, Q_{t3}, e_{3.1}) := K_{e3.1}(Q_t, Q_{t3}) \cdot hv_{e3.1}(e_{3.1} \cdot Q_{t3})$

$H_{e3.1}(Q_t, Q_{t3}, e_{3.1}) = 4.79\ \text{ft}$ Head loss for trial flow distribution

$E_{use3.1}(Q_t, Q_{t3}) = 20.5\ \text{ft}$

$Ele_{e3.2} := Ele_{e3.1}$ — Outlet elevation for orifice 2

$eH_{use3.2}(Q_t, Q_{t3}) := FB_d - H_1(Q_t) - H_3(Q_{t3})$ — Energy Gradeline Upstream of 2nd Orifice Exit

$eH_{use3.2}(Q_t, Q_{t3}) = 108.5\ ft$

$E_{use3.2}(Q_t, Q_{t3}) := (eH_{use3.2}(Q_t, Q_{t3}) - Ele_{e3.2})$ — Energy Head on Orifice 2

$E_{use3.2}(Q_t, Q_{t3}) = 20.5\ ft$

$$mR_{use3.2}(Q_t, Q_{t3}) := \frac{\frac{V_c(Q_{t3}, D_2)^2}{2g}}{E_{use3.2}(Q_t, Q_{t3})}$$

$e_{3.2} := e_{3.1}$ — Flow ratio of orifice discharge to total flow of pipe 3

$Cdm2(mR_{use3.2}(Q_t, Q_{t3})) = 0.46$ — Coefficitent of disharge of orifice based on velocity head to energy head

$$K_{e3.2}(Q_t, Q_{t3}) := \frac{\alpha_k}{Cdm2(mR_{use3.2}(Q_t, Q_{t3}))^2}$$

$K_{e3.2}(Q_t, Q_{t3}) = 4.64$ — Loss coefficient conversion

$Q_{e3.2} := e_{3.2} \cdot Q_{t3}$ — Discharge from orifice 2

$$hv_{e3.2}(Q_{e3.2}) := \frac{Q_{e3.2}^{\ 2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e3.2}}{A_c(D_e)} = 8.15\ \frac{ft}{s}$$

$hv_{e3.2}(Q_{e3.2}) = 1.03\ ft$ — Velocity head thru orifice 2

$H_{e3.2}(Q_t, Q_{t3}, e_{3.2}) := K_{e3.2}(Q_t, Q_{t3}) \cdot hv_{e3.2}(e_{3.2} \cdot Q_{t3})$

$H_{e3.2}(Q_t, Q_{t3}, e_{3.2}) = 4.79\ ft$ — Head loss for trial flow distribution

$E_{use3.2}(Q_t, Q_{t3}) = 20.5\ ft$

$e_{3.1} + e_{3.2} = 0.06$

$K_{e1.32} := 0.05$ Miller 13.31

$$Q_{m2.1}(Q_{t3}) := Q_{t3} \cdot (1 - e_{3.1} - e_{3.2})$$

$$Ele_{e3.3} := 82ft$$ Outlet elevation for orifice 3

$$eH_{use3.3}(Q_t, Q_{t3}) := eH_{use3.2}(Q_t, Q_{t3}) - K_{e1.32} \cdot hv_2(Q_{m2.1}(Q_{t3}))$$ Energy Gradeline Upstream of 3rd Orifice Exit

$$eH_{use3.3}(Q_t, Q_{t3}) = 108.3\ ft$$

$$E_{use3.3}(Q_t, Q_{t3}) := (eH_{use3.3}(Q_t, Q_{t3}) - Ele_{e3.3})$$

$$E_{use3.3}(Q_t, Q_{t3}) = 26.3\ ft$$

$$e_{3.3} := 0.068$$ Flow ratio of orifice discharge to total flow of pipe 3

$$mR_{use3.3}(Q_t, Q_{t3}) := \frac{\frac{V_c(Q_{m2.1}(Q_{t3}), D_2)^2}{2g}}{E_{use3.3}(Q_t, Q_{t3})}$$

$$Cdm2(mR_{use3.3}(Q_t, Q_{t3})) = 0.51$$

$$K_{e3.3}(Q_t, Q_{t3}) := \frac{\alpha_k}{Cdm2(mR_{use3.3}(Q_t, Q_{t3}))^2}$$

$$K_{e3.3}(Q_t, Q_{t3}) = 3.9$$

$$Q_{e3.3} := e_{3.3} \cdot Q_{t3}$$

$$hv_{e3.3}(Q_{e3.3}) := \frac{Q_{e3.3}^{\ 2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e3.3}}{A_c(D_e)} = 18.47\ \frac{ft}{s}$$

$$hv_{e3.3}(Q_{e3.3}) = 5.3\ ft$$

$$H_{e3.3}(Q_t, Q_{t3}, e_{3.3}) := K_{e3.3}(Q_t, Q_{t3}) \cdot hv_{e3.3}(e_{3.3} \cdot Q_{t3})$$

$$H_{e3.3}(Q_t, Q_{t3}, e_{3.3}) = 20.7\ ft$$

$$E_{use3.3}(Q_t, Q_{t3}) = 26.3\ ft$$

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$Ele_{e3.4} := Ele_{e3.3}$

$eH_{use3.4}(Q_t, Q_{t3}) := eH_{use3.3}(Q_t, Q_{t3})$

Energy Gradeline Upstream of 4th Orifice Exit

$eH_{use3.4}(Q_t, Q_{t3}) = 108.3\,ft$

$E_{use3.4}(Q_t, Q_{t3}) := \left(eH_{use3.4}(Q_t, Q_{t3}) - Ele_{e3.4}\right)$

$E_{use3.4}(Q_t, Q_{t3}) = 26.3\,ft$

$e_{3.4} := e_{3.3}$

$$mR_{use3.4}(Q_t, Q_{t3}) := \frac{\frac{V_c\left(Q_{m2.1}(Q_{t3}), D_2\right)^2}{2g}}{E_{use3.4}(Q_t, Q_{t3})}$$

$Cdm2\left(mR_{use3.4}(Q_t, Q_{t3})\right) = 0.51$

$$K_{e3.4}(Q_t, Q_{t3}) := \frac{\alpha_k}{Cdm2\left(mR_{use3.4}(Q_t, Q_{t3})\right)^2}$$

$K_{e3.4}(Q_t, Q_{t3}) = 3.9$

$Q_{e3.4} := e_{3.4} \cdot Q_{t3}$

$$hv_{e3.4}(Q_{e3.4}) := \frac{Q_{e3.4}^{\;2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e3.4}}{A_c(D_e)} = 18.47\,\frac{ft}{s}$$

$hv_{e3.4}(Q_{e3.4}) = 5.3\,ft$

$H_{e3.4}(Q_t, Q_{t3}, e_{3.4}) := K_{e3.4}(Q_t, Q_{t3}) \cdot hv_{e3.4}(e_{3.4} \cdot Q_{t3})$

$H_{e3.4}(Q_t, Q_{t3}, e_{3.4}) = 20.7\,ft$

$E_{use3.4}(Q_t, Q_{t3}) = 26.3\,ft$

$$\frac{e_{3.3} \cdot Q_{t3}}{Q_{m2.1}(Q_{t3})} = 0.07$$ $K_{e2.32} := 0$ Miller 13.23

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$Q_{m2.2}(Q_{t3}) := Q_{m2.1}(Q_{t3}) - (e_{3.3} + e_{3.4}) \cdot Q_{t3}$

$Ele_{e3.5} := 76ft$

$eH_{use3.5}(Q_t, Q_{t3}) := eH_{use3.4}(Q_t, Q_{t3}) - K_{e2.32} \cdot hv_2(Q_{m2.2}(Q_{t3}))$

Energy Gradeline Upstream of 5th Orifice Exit

$eH_{use3.5}(Q_t, Q_{t3}) = 108.3\ ft$

$E_{use3.5}(Q_t, Q_{t3}) := (eH_{use3.5}(Q_t, Q_{t3}) - Ele_{e3.5})$

$E_{use3.5}(Q_t, Q_{t3}) = 32.3\ ft$

$e_{3.5} := 0.092$

$$mR_{use3.5}(Q_t, Q_{t3}) := \frac{\frac{V_c(Q_{m2.2}(Q_{t3}), D_2)^2}{2g}}{E_{use3.5}(Q_t, Q_{t3})}$$

$Cdm2(mR_{use3.5}(Q_t, Q_{t3})) = 0.55$

$$K_{e3.5}(Q_t, Q_{t3}) := \frac{\alpha_k}{Cdm2(mR_{use3.5}(Q_t, Q_{t3}))^2}$$

$K_{e3.5}(Q_t, Q_{t3}) = 3.34$

$Q_{e3.5} := e_{3.5} \cdot Q_{t3}$

$$hv_{e3.5}(Q_{e3.5}) := \frac{Q_{e3.5}^{\ 2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e3.5}}{A_c(D_e)} = 24.99\ \frac{ft}{s}$$

$hv_{e3.5}(Q_{e3.5}) = 9.7\ ft$

$H_{e3.5}(Q_t, Q_{t3}, e_{3.5}) := K_{e3.5}(Q_t, Q_{t3}) \cdot hv_{e3.5}(e_{3.5} \cdot Q_{t3})$

$H_{e3.5}(Q_t, Q_{t3}, e_{3.5}) = 32.4\ ft$

$eH_{use3.5}(Q_t, Q_{t3}) - AWSC_d = 29.9\ ft$

$Ele_{e3.6} := Ele_{e3.5}$

$eH_{use3.6}(Q_t, Q_{t3}) := eH_{use3.5}(Q_t, Q_{t3})$

Energy Gradeline Upstream of 6th Orifice Exit

$eH_{use3.6}(Q_t, Q_{t3}) = 108.3 \text{ ft}$

$E_{use3.6}(Q_t, Q_{t3}) := (eH_{use3.6}(Q_t, Q_{t3}) - Ele_{e3.6})$

$e_{3.6} := e_{3.5}$

$E_{use3.6}(Q_t, Q_{t3}) = 32.3 \text{ ft}$

$$mR_{use3.6}(Q_t, Q_{t3}) := \frac{\frac{V_c(Q_{m2.2}(Q_{t3}), D_2)^2}{2g}}{E_{use3.6}(Q_t, Q_{t3})}$$

$Cdm2(mR_{use3.6}(Q_t, Q_{t3})) = 0.55$

$$K_{e3.6}(Q_t, Q_{t3}) := \frac{\alpha_k}{Cdm2(mR_{use3.6}(Q_t, Q_{t3}))^2}$$

$e_{3.1} + e_{3.2} + e_{3.3} + e_{3.4} + e_{3.5} + e_{3.6} = 0.38$

$K_{e3.6}(Q_t, Q_{t3}) = 3.34$

$Q_{e3.6} := e_{3.6} \cdot Q_{t3}$

$$hv_{e3.6}(Q_{e3.6}) := \frac{Q_{e3.6}^{\,2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e3.6}}{A_c(D_e)} = 24.99 \frac{\text{ft}}{\text{s}}$$

$hv_{e3.6}(Q_{e3.6}) = 9.7 \text{ ft}$

$H_{e3.6}(Q_t, Q_{t3}, e_{3.6}) := K_{e3.6}(Q_t, Q_{t3}) \cdot hv_{e3.6}(e_{3.6} \cdot Q_{t3})$

$H_{e3.6}(Q_t, Q_{t3}, e_{3.6}) = 32.4 \text{ ft}$

$eH_{use3.6}(Q_t, Q_{t3}) - AWSC_d = 29.9 \text{ ft}$

$Ele_{e3.7} := Ele_{e3.6}$

$eH_{use3.7}(Q_t, Q_{t3}) := eH_{use3.6}(Q_t, Q_{t3})$

Energy Gradeline Upstream of 7th Orifice Exit

$eH_{use3.7}(Q_t, Q_{t3}) = 108.3\ ft$

$E_{use3.7}(Q_t, Q_{t3}) := (eH_{use3.7}(Q_t, Q_{t3}) - Ele_{e3.7})$

$e_{3.7} := e_{3.6}$

$E_{use3.7}(Q_t, Q_{t3}) = 32.3\ ft$

$$mR_{use3.7}(Q_t, Q_{t3}) := \frac{\frac{V_c(Q_{m2.2}(Q_{t3}), D_2)^2}{2g}}{E_{use3.7}(Q_t, Q_{t3})}$$

$Cdm2(mR_{use3.7}(Q_t, Q_{t3})) = 0.55$

$$K_{e3.7}(Q_t, Q_{t3}) := \frac{\alpha_k}{Cdm2(mR_{use3.7}(Q_t, Q_{t3}))^2}$$

$e_{3.1} + e_{3.2} + e_{3.3} + e_{3.4} + e_{3.5} + e_{3.6} + e_{3.7} = 0.47$

$K_{e3.7}(Q_t, Q_{t3}) = 3.34$

$Q_{e3.7} := e_{3.7} \cdot Q_{t3}$

$$hv_{e3.7}(Q_{e3.7}) := \frac{{Q_{e3.7}}^2}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e3.7}}{A_c(D_e)} = 24.99\ \frac{ft}{s}$$

$hv_{e3.7}(Q_{e3.7}) = 9.7\ ft$

$H_{e3.7}(Q_t, Q_{t3}, e_{3.7}) := K_{e3.7}(Q_t, Q_{t3}) \cdot hv_{e3.7}(e_{3.7} \cdot Q_{t3})$

$H_{e3.7}(Q_t, Q_{t3}, e_{3.7}) = 32.4\ ft$

$eH_{use3.7}(Q_t, Q_{t3}) - AWSC_d = 29.9\ ft$

$\frac{e_{3.5} \cdot Q_{t3}}{Q_{m2.2}(Q_{t3})} = 0.11$ $K_{e3.32} := 0.05$ Miller 13.23

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$$Q_{m2.3}(Q_{t3}) := Q_{m2.2}(Q_{t3}) - (e_{3.5} + e_{3.6} + e_{3.7}) \cdot Q_{t3}$$

$$Ele_{e3.8} := 68.0ft$$

$$eH_{use3.8}(Q_t, Q_{t3}) := eH_{use3.7}(Q_t, Q_{t3}) - K_{e3.32} \cdot hv_2(Q_{m2.3}(Q_{t3}))$$

Energy Gradeline Upstream of 8th Orifice Exit

$$eH_{use3.8}(Q_t, Q_{t3}) = 108.24\,ft$$

$$E_{use3.8}(Q_t, Q_{t3}) := (eH_{use3.8}(Q_t, Q_{t3}) - Ele_{e3.8})$$

$$e_{3.8} := 0.105$$

$$E_{use3.8}(Q_t, Q_{t3}) = 40.24\,ft$$

$$mR_{use3.8}(Q_t, Q_{t3}) := \frac{\frac{V_c(Q_{m2.3}(Q_{t3}), D_2)^2}{2g}}{E_{use3.8}(Q_t, Q_{t3})}$$

$$Cdm2(mR_{use3.8}(Q_t, Q_{t3})) = 0.59$$

$$K_{e3.8}(Q_t, Q_{t3}) := \frac{\alpha_k}{Cdm2(mR_{use3.8}(Q_t, Q_{t3}))^2}$$

$$e_{3.1} + e_{3.2} + e_{3.3} + e_{3.4} + e_{3.5} + e_{3.6} + e_{3.7} = 0.47$$

$$K_{e3.8}(Q_t, Q_{t3}) = 2.88$$

$$Q_{e3.8} := e_{3.8} \cdot Q_{t3}$$

$$hv_{e3.8}(Q_{e3.8}) := \frac{Q_{e3.8}^{\,2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e3.8}}{A_c(D_e)} = 28.52\,\frac{ft}{s}$$

$$hv_{e3.8}(Q_{e3.8}) = 12.64\,ft$$

$$H_{e3.8}(Q_t, Q_{t3}, e_{3.8}) := K_{e3.8}(Q_t, Q_{t3}) \cdot hv_{e3.8}(e_{3.8} \cdot Q_{t3})$$

$$H_{e3.8}(Q_t, Q_{t3}, e_{3.8}) = 36.37\,ft$$

$$eH_{use3.8}(Q_t, Q_{t3}) - AWSC_d = 29.84\,ft$$

$Ele_{e3.9} := Ele_{e3.8}$

$eH_{use3.9}(Q_t, Q_{t3}) := eH_{use3.8}(Q_t, Q_{t3})$ Energy Gradeline Upstream of 9th Orifice Exit

$eH_{use3.9}(Q_t, Q_{t3}) = 108.24\ ft$

$E_{use3.9}(Q_t, Q_{t3}) := (eH_{use3.9}(Q_t, Q_{t3}) - Ele_{e3.9})$

$e_{3.9} := e_{3.8}$

$E_{use3.9}(Q_t, Q_{t3}) = 40.24\ ft$

$$mR_{use3.9}(Q_t, Q_{t3}) := \frac{\frac{V_c(Q_{m2.3}(Q_{t3}), D_2)^2}{2g}}{E_{use3.9}(Q_t, Q_{t3})}$$

$Cdm2(mR_{use3.9}(Q_t, Q_{t3})) = 0.59$

$$K_{e3.9}(Q_t, Q_{t3}) := \frac{\alpha_k}{Cdm2(mR_{use3.9}(Q_t, Q_{t3}))^2}$$

$e_{3.1} + e_{3.2} + e_{3.3} + e_{3.4} + e_{3.5} + e_{3.6} + e_{3.7} = 0.47$

$K_{e3.9}(Q_t, Q_{t3}) = 2.88$

$Q_{e3.9} := e_{3.9} \cdot Q_{t3}$

$$hv_{e3.9}(Q_{e3.9}) := \frac{Q_{e3.9}^{\ 2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e3.9}}{A_c(D_e)} = 28.52\ \frac{ft}{s}$$

$hv_{e3.9}(Q_{e3.9}) = 12.64\ ft$

$H_{e3.9}(Q_t, Q_{t3}, e_{3.9}) := K_{e3.9}(Q_t, Q_{t3}) \cdot hv_{e3.9}(e_{3.9} \cdot Q_{t3})$

$H_{e3.9}(Q_t, Q_{t3}, e_{3.9}) = 36.37\ ft$

$eH_{use3.9}(Q_t, Q_{t3}) - AWSC_d = 29.84\ ft$

$$\frac{e_{3.9} \cdot Q_{t3}}{Q_{m2.3}(Q_{t3})} = 0.2$$

$K_{e4.32} := 0.05$ Miller 13.23

$Q_{m2.4}(Q_{t3}) := Q_{m2.3}(Q_{t3}) - (e_{3.8} + e_{3.9}) \cdot Q_{t3}$

$Ele_{e3.10} := 62.0ft$

$eH_{use3.10}(Q_t, Q_{t3}) := eH_{use3.9}(Q_t, Q_{t3}) - K_{e4.32} \cdot hv_2(Q_{m2.4}(Q_{t3}))$

Energy Gradeline Upstream of 10th Orifice Exit

$eH_{use3.10}(Q_t, Q_{t3}) = 108.22\ ft$

$E_{use3.10}(Q_t, Q_{t3}) := (eH_{use3.10}(Q_t, Q_{t3}) - Ele_{e3.10})$

$e_{3.10} := 0.109$

$E_{use3.10}(Q_t, Q_{t3}) = 46.22\ ft$

$$mR_{use3.10}(Q_t, Q_{t3}) := \frac{\frac{V_c(Q_{m2.4}(Q_{t3}), D_2)^2}{2g}}{E_{use3.10}(Q_t, Q_{t3})}$$

$Cdm2(mR_{use3.10}(Q_t, Q_{t3})) = 0.6$

$$K_{e3.10}(Q_t, Q_{t3}) := \frac{\alpha_k}{Cdm2(mR_{use3.10}(Q_t, Q_{t3}))^2}$$

$e_{3.1} + e_{3.2} + e_{3.3} + e_{3.4} + e_{3.5} + e_{3.6} + e_{3.7} = 0.47$

$K_{e3.10}(Q_t, Q_{t3}) = 2.78$

$Q_{e3.10} := e_{3.10} \cdot Q_{t3}$

$$hv_{e3.10}(Q_{e3.10}) := \frac{Q_{e3.10}^{\ 2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e3.10}}{A_c(D_e)} = 29.61\ \frac{ft}{s}$$

$hv_{e3.10}(Q_{e3.10}) = 13.62\ ft$

$H_{e3.10}(Q_t, Q_{t3}, e_{3.10}) := K_{e3.10}(Q_t, Q_{t3}) \cdot hv_{e3.10}(e_{3.10} \cdot Q_{t3})$

$H_{e3.10}(Q_t, Q_{t3}, e_{3.10}) = 37.83\ ft$

$eH_{use3.10}(Q_t, Q_{t3}) - AWSC_d = 29.82\ ft$

$Ele_{e3.11} := 62.0ft$

Energy Gradeline Upstream of 11th Orifice Exit

$eH_{use3.11}(Q_t, Q_{t3}) := eH_{use3.10}(Q_t, Q_{t3})$

$eH_{use3.11}(Q_t, Q_{t3}) = 108.22\ ft$

$E_{use3.11}(Q_t, Q_{t3}) := (eH_{use3.11}(Q_t, Q_{t3}) - Ele_{e3.11})$

$e_{3.11} := e_{3.10}$

$E_{use3.11}(Q_t, Q_{t3}) = 46.22\ ft$

$$mR_{use3.11}(Q_t, Q_{t3}) := \frac{\frac{V_c(Q_{m2.4}(Q_{t3}), D_2)^2}{2g}}{E_{use3.11}(Q_t, Q_{t3})}$$

$Cdm2(mR_{use3.11}(Q_t, Q_{t3})) = 0.6$

$$K_{e3.11}(Q_t, Q_{t3}) := \frac{\alpha_k}{Cdm2(mR_{use3.11}(Q_t, Q_{t3}))^2}$$

$e_{3.1} + e_{3.2} + e_{3.3} + e_{3.4} + e_{3.5} + e_{3.6} + e_{3.7} = 0.47$

$K_{e3.11}(Q_t, Q_{t3}) = 2.78$

$Q_{e3.11} := e_{3.11} \cdot Q_{t3}$

$$hv_{e3.11}(Q_{e3.11}) := \frac{Q_{e3.11}^{\ 2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e3.11}}{A_c(D_e)} = 29.61\ \frac{ft}{s}$$

$hv_{e3.11}(Q_{e3.11}) = 13.62\ ft$

$H_{e3.11}(Q_t, Q_{t3}, e_{3.11}) := K_{e3.11}(Q_t, Q_{t3}) \cdot hv_{e3.11}(e_{3.11} \cdot Q_{t3})$

$H_{e3.11}(Q_t, Q_{t3}, e_{3.11}) = 37.83\ ft$

$eH_{use3.11}(Q_t, Q_{t3}) - AWSC_d = 29.82\ ft$

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$Ele_{e3.12} := 62.0ft$

$eH_{use3.12}(Q_t, Q_{t3}) := eH_{use3.11}(Q_t, Q_{t3})$ Energy Gradeline Upstream of 12th Orifice Exit

$eH_{use3.12}(Q_t, Q_{t3}) = 108.22\ ft$

$E_{use3.12}(Q_t, Q_{t3}) := (eH_{use3.12}(Q_t, Q_{t3}) - Ele_{e3.12})$

$e_{3.12} := e_{3.11}$

$E_{use3.12}(Q_t, Q_{t3}) = 46.22\ ft$

$$mR_{use3.12}(Q_t, Q_{t3}) := \frac{\dfrac{V_c(Q_{m2.4}(Q_{t3}), D_2)^2}{2g}}{E_{use3.12}(Q_t, Q_{t3})}$$

$Cdm2(mR_{use3.12}(Q_t, Q_{t3})) = 0.6$

$$K_{e3.12}(Q_t, Q_{t3}) := \frac{\alpha_k}{Cdm2(mR_{use3.12}(Q_t, Q_{t3}))^2}$$

$K_{e3.12}(Q_t, Q_{t3}) = 2.78$

$Q_{e3.12} := e_{3.12} \cdot Q_{t3}$

$$hv_{e3.12}(Q_{e3.12}) := \frac{Q_{e3.12}^{\ 2}}{A_c(D_e)^2 \cdot 2g}$$

$$\frac{Q_{e3.12}}{A_c(D_e)} = 29.61\ \frac{ft}{s}$$

$hv_{e3.12}(Q_{e3.12}) = 13.62\ ft$

$H_{e3.12}(Q_t, Q_{t3}, e_{3.12}) := K_{e3.12}(Q_t, Q_{t3}) \cdot hv_{e3.12}(e_{3.12} \cdot Q_{t3})$

$H_{e3.12}(Q_t, Q_{t3}, e_{3.12}) = 37.83\ ft$

$eH_{use3.12}(Q_t, Q_{t3}) - AWSC_d = 29.82\ ft$

$1 - (e_{3.1} + e_{3.2} + e_{3.3} + e_{3.4} + e_{3.5} + e_{3.6} + e_{3.7} + e_{3.8} + e_{3.9} + e_{3.10} + e_{3.11} + e_{3.12}) = -9 \times 10^{-3}$ Check for total flow distribution

Flow Solver

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2 \cdot g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2 \cdot g} + z_2 + h_L$$

Bernoulli equation with Point 1 taken in the forebay at the water surface assuming negligible velocity head and Point 2 taken at the outlet of one of the 7.5 ft diameter conduits emptying into the AWSC.

$\frac{P_1}{\gamma} = 0\text{ft}$ Pressure at surface is atmospheric

$\frac{V_1^2}{2 \cdot g} = 0\text{ft}$ Velocity head at surface assumed negligible

$z_1 = FB_l \text{ or } z_1 = FB_h$ Elevation of water surface in forebay

$\frac{P_2}{\gamma} = 0\text{ft}$ Pressure at outlet is atmospheric

$\frac{V_2^2}{2 \cdot g} = hv_2(Q_{t2})$ Velocity head of water exiting outlet

$z_2 = AWSC_{el}$ Elevation of AWSC water surface

$z_2 = Ele_e$ Elevation of centerline of outlet

$h_L = H_1(Q_t) + H_2(Q_{t2})$ Headloss through pipe 1 and pipe 2

Loop Check

$H_1(Q_t) + H_2(Q_{t2}) + hv_2(Q_{t2}) = 55.98\text{ ft}$ Check to see if assumed flow distribution at the Y equalizes head loss through both branches.

$H_1(Q_t) + H_3(Q_{t3}) + hv_3(Q_{t3}) = 55.98\text{ ft}$

For Low Driving Head Conditions (Low Forebay - High Tailwater)

Given

Bernoulli equation rewriten with losses as a function of flowrate with an iterative solve block to converge on total and split flow rates.

$$FB_l = AWSC_h + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.1}(Q_t, Q_{t2}, e_{2.1})$$
$$FB_l = AWSC_h + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.2}(Q_t, Q_{t2}, e_{2.2})$$
$$FB_l = AWSC_h + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.3}(Q_t, Q_{t2}, e_{2.3})$$
$$FB_l = AWSC_h + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.4}(Q_t, Q_{t2}, e_{2.4})$$
$$FB_l = AWSC_h + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.5}(Q_t, Q_{t2}, e_{2.5})$$
$$FB_l = AWSC_h + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.6}(Q_t, Q_{t2}, e_{2.6})$$
$$FB_l = AWSC_h + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.7}(Q_t, Q_{t2}, e_{2.7})$$
$$FB_l = AWSC_h + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.8}(Q_t, Q_{t2}, e_{2.8})$$
$$FB_l = AWSC_h + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.9}(Q_t, Q_{t2}, e_{2.9})$$
$$FB_l = AWSC_h + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.10}(Q_t, Q_{t2}, e_{2.10})$$
$$FB_l = AWSC_h + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.11}(Q_t, Q_{t2}, e_{2.11})$$
$$FB_l = AWSC_h + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.12}(Q_t, Q_{t2}, e_{2.12})$$

$$FB_l = AWSC_h + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.1}(Q_t, Q_{t2}, e_{3.1})$$
$$FB_l = AWSC_h + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.2}(Q_t, Q_{t2}, e_{3.2})$$
$$FB_l = AWSC_h + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.3}(Q_t, Q_{t2}, e_{3.3})$$
$$FB_l = AWSC_h + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.4}(Q_t, Q_{t2}, e_{3.4})$$
$$FB_l = AWSC_h + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.5}(Q_t, Q_{t2}, e_{3.5})$$
$$FB_l = AWSC_h + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.6}(Q_t, Q_{t2}, e_{3.6})$$
$$FB_l = AWSC_h + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.7}(Q_t, Q_{t2}, e_{3.7})$$
$$FB_l = AWSC_h + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.8}(Q_t, Q_{t2}, e_{3.8})$$
$$FB_l = AWSC_h + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.9}(Q_t, Q_{t2}, e_{3.9})$$
$$FB_l = AWSC_h + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.10}(Q_t, Q_{t2}, e_{3.10})$$
$$FB_l = AWSC_h + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.11}(Q_t, Q_{t2}, e_{3.11})$$
$$FB_l = AWSC_h + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.12}(Q_t, Q_{t2}, e_{3.12})$$

$$1 = e_{2.1} + e_{2.2} + e_{2.3} + e_{2.4} + e_{2.5} + e_{2.6} + e_{2.7} + e_{2.8} + e_{2.9} + e_{2.10} + e_{2.11} + e_{2.12}$$

$$1 = e_{3.1} + e_{3.2} + e_{3.3} + e_{3.4} + e_{3.5} + e_{3.6} + e_{3.7} + e_{3.8} + e_{3.9} + e_{3.10} + e_{3.11} + e_{3.12}$$

$$Q_t = Q_{t2} + Q_{t3}$$

$$\begin{pmatrix} e_{2.1} \\ e_{2.2} \\ e_{2.3} \\ e_{2.4} \\ e_{2.5} \\ e_{2.6} \\ e_{2.7} \\ e_{2.8} \\ e_{2.9} \\ e_{2.10} \\ e_{2.11} \\ e_{2.12} \\ Q_{d2} \\ e_{3.1} \\ e_{3.2} \\ e_{3.3} \\ e_{3.4} \\ e_{3.5} \\ e_{3.6} \\ e_{3.7} \\ e_{3.8} \\ e_{3.9} \end{pmatrix} := \mathrm{Find}\left(e_{2.1}, e_{2.2}, e_{2.3}, e_{2.4}, e_{2.5}, e_{2.6}, e_{2.7}, e_{2.8}, e_{2.9}, e_{2.10}, e_{2.11}, e_{2.12}, Q_{t2}, e_{3.1}, e_{3.2}, e_{3.3}, e_{3.4}, e_{3.5}, e_{3.6}, e_{3.7}, e_{3.8}, e_{3.9}, e_{3.10}, e_{3.11}, e_{3.12}, Q_{t3}, Q_t\right)$$

$$\begin{pmatrix} e_{3.10} \\ e_{3.11} \\ e_{3.12} \\ Q_{d3} \\ Q_{d1} \end{pmatrix}$$

$$e_{2.1} + e_{2.2} + e_{2.3} + e_{2.4} + e_{2.5} + e_{2.6} + e_{2.7} + e_{2.8} + e_{2.9} + e_{2.10} + e_{2.11} + e_{2.12} = 1$$

$$e_{3.1} + e_{3.2} + e_{3.3} + e_{3.4} + e_{3.5} + e_{3.6} + e_{3.7} + e_{3.8} + e_{3.9} + e_{3.10} + e_{3.11} + e_{3.12} = 1$$

$Q_{d1} = 1390 \cdot cfs$ Total deliver flowed $V_c(Q_{d1}, D_1) = 17.69 \frac{ft}{s}$ Velocity in pipe 1

$Q_{d2} = 695 \cdot cfs$ Flow rate thru pipe 2 $V_c(Q_{d2}, D_2) = 15.73 \frac{ft}{s}$ Velocity in pipe 2

$Q_{d3} = 695 \cdot cfs$ Flow rate thru pipe 3 $V_c(Q_{d3}, D_3) = 15.73 \frac{ft}{s}$ Velocity in pipe 3

For High Driving Head Conditions (Low Forebay - High Tailwater)

Given

Bernoulli equation rewriten with losses as a function of flowrate with an iterative solve block to converge on total and split flow rates.

$$FB_h = Ele_{e2.1} + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.1}(Q_t, Q_{t2}, e_{2.1})$$
$$FB_h = Ele_{e2.2} + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.2}(Q_t, Q_{t2}, e_{2.2})$$
$$FB_h = Ele_{e2.3} + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.3}(Q_t, Q_{t2}, e_{2.3})$$
$$FB_h = Ele_{e2.4} + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.4}(Q_t, Q_{t2}, e_{2.4})$$
$$FB_h = AWSC_l + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.5}(Q_t, Q_{t2}, e_{2.5})$$
$$FB_h = AWSC_l + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.6}(Q_t, Q_{t2}, e_{2.6})$$
$$FB_h = AWSC_l + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.7}(Q_t, Q_{t2}, e_{2.7})$$
$$FB_h = AWSC_l + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.8}(Q_t, Q_{t2}, e_{2.8})$$
$$FB_h = AWSC_l + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.9}(Q_t, Q_{t2}, e_{2.9})$$
$$FB_h = AWSC_l + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.10}(Q_t, Q_{t2}, e_{2.10})$$
$$FB_h = AWSC_l + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.11}(Q_t, Q_{t2}, e_{2.11})$$
$$FB_h = AWSC_l + \left(H_2(Q_{t2}) + H_1(Q_t)\right) + H_{e2.12}(Q_t, Q_{t2}, e_{2.12})$$

$$FB_h = Ele_{e3.1} + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.1}(Q_t, Q_{t2}, e_{3.1})$$
$$FB_h = Ele_{e3.2} + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.2}(Q_t, Q_{t2}, e_{3.2})$$
$$FB_h = Ele_{e3.3} + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.3}(Q_t, Q_{t2}, e_{3.3})$$
$$FB_h = Ele_{e3.4} + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.4}(Q_t, Q_{t2}, e_{3.4})$$
$$FB_h = AWSC_l + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.5}(Q_t, Q_{t2}, e_{3.5})$$
$$FB_h = AWSC_l + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.6}(Q_t, Q_{t2}, e_{3.6})$$
$$FB_h = AWSC_l + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.7}(Q_t, Q_{t2}, e_{3.7})$$
$$FB_h = AWSC_l + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.8}(Q_t, Q_{t2}, e_{3.8})$$
$$FB_h = AWSC_l + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.9}(Q_t, Q_{t2}, e_{3.9})$$
$$FB_h = AWSC_l + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.10}(Q_t, Q_{t2}, e_{3.10})$$
$$FB_h = AWSC_l + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.11}(Q_t, Q_{t2}, e_{3.11})$$
$$FB_h = AWSC_l + \left(H_3(Q_{t3}) + H_1(Q_t)\right) + H_{e3.12}(Q_t, Q_{t2}, e_{3.12})$$

$$1 = e_{2.1} + e_{2.2} + e_{2.3} + e_{2.4} + e_{2.5} + e_{2.6} + e_{2.7} + e_{2.8} + e_{2.9} + e_{2.10} + e_{2.11} + e_{2.12}$$

$$1 = e_{3.1} + e_{3.2} + e_{3.3} + e_{3.4} + e_{3.5} + e_{3.6} + e_{3.7} + e_{3.8} + e_{3.9} + e_{3.10} + e_{3.11} + e_{3.12}$$

$$Q_t = Q_{t2} + Q_{t3}$$

$$\begin{pmatrix} e_{2.1} \\ e_{2.2} \\ e_{2.3} \\ e_{2.4} \\ e_{2.5} \\ e_{2.6} \\ e_{2.7} \\ e_{2.8} \\ e_{2.9} \\ e_{2.10} \\ e_{2.11} \\ e_{2.12} \\ Q_{m2} \\ e_{3.1} \\ e_{3.2} \\ e_{3.3} \\ e_{3.4} \\ e_{3.5} \\ e_{3.6} \\ e_{3.7} \\ e_{3.8} \\ e_{3.9} \end{pmatrix} := \text{Find}\left(e_{2.1}, e_{2.2}, e_{2.3}, e_{2.4}, e_{2.5}, e_{2.6}, e_{2.7}, e_{2.8}, e_{2.9}, e_{2.10}, e_{2.11}, e_{2.12}, Q_{t2}, e_{3.1}, e_{3.2}, e_{3.3}, e_{3.4}, e_{3.5}, e_{3.6}, e_{3.7}, e_{3.8}, e_{3.9}, e_{3.10}, e_{3.11}, e_{3.12}, Q_{t3}, Q_t\right)$$

$$\begin{pmatrix} e_{3.10} \\ e_{3.11} \\ e_{3.12} \\ Q_{m3} \\ Q_{m1} \end{pmatrix}$$

$$e_{2.1} + e_{2.2} + e_{2.3} + e_{2.4} + e_{2.5} + e_{2.6} + e_{2.7} + e_{2.8} + e_{2.9} + e_{2.10} + e_{2.11} + e_{2.12} = 1$$

$$e_{3.1} + e_{3.2} + e_{3.3} + e_{3.4} + e_{3.5} + e_{3.6} + e_{3.7} + e_{3.8} + e_{3.9} + e_{3.10} + e_{3.11} + e_{3.12} = 1$$

$Q_{m1} = 1511 \cdot cfs$ Total deliver flowed $V_c(Q_{m1}, D_1) = 19.24 \frac{ft}{s}$ Velocity in pipe 1

$Q_{m2} = 756 \cdot cfs$ Flow rate thru pipe 2 $V_c(Q_{m2}, D_2) = 17.11 \frac{ft}{s}$ Velocity in pipe 2

$Q_{m3} = 756 \cdot cfs$ Flow rate thru pipe 3 $V_c(Q_{m3}, D_3) = 17.11 \frac{ft}{s}$ Velocity in pipe 3

Exit Trajectory Analysis For Horizontal Discharge

The purpose of this section is to demonstate the flow path of a horizontal discharge from the 7.5-ft pipes into the AWSC. This shows that low tailwater would result in an impact on the far wall of the AWS chamber, potentially causing scour damage demonstrating the need for the orifice manifold at the end of the discharge.

$EL_{imp\_min} := 74.0ft$ Minimum Depth in AWSC (assuming an equalization of AWSC water surface and fishladder and tailrace with no initial flow)

$EL_{imp\_max} := 90.0ft$ Maximum Depth in AWSC

$FLC_{cl} = 98.5\,ft$ Outlet centerline

$y_{imp\_max} := FLC_{cl} - EL_{imp\_min}$ Maximum fall distance from centerline

$y_{imp\_max} = 24.5\,ft$

$y_{imp\_min} := FLC_{cl} - EL_{imp\_max}$ Minimum fall distance from centerline

$y_{imp\_min} = 8.5\,ft$

$t_{max} := \sqrt{\frac{y_{imp\_max} \cdot 2}{g}}$ Time to impact for low tailwater

$t_{max} = 1.23\,s$

$t_{min} := \sqrt{\frac{y_{imp\_min} \cdot 2}{g}}$ Time to impact for high tail water

$t_{min} = 0.73\,s$

$x(t) := V_c(Q_{m2}, D_2) \cdot t$ $x(t_{max}) = 21.11\,ft$ Maximum horizontal distance to impact from centerline

$x(t_{min}) = 12.43\,ft$ Minimum horizontal distance to impact form centerline

$y(t) := -g \cdot \frac{t^2}{2}$

$v_y(t) := -g \cdot t$ $\quad v_y(t_{max}) = -39.71 \frac{ft}{s}$ Velocity in the vertical direction at impact during low tailwater conditions

$v_y(t_{min}) = -23.39 \frac{ft}{s}$ Velocity in the vertical direction at impact during high tailwater conditions

$v_x := V_c(Q_{m2}, D_2)$

$\theta_{imp\_min} := \operatorname{atan}\left(\frac{v_y(t_{min})}{v_x}\right)$ $\quad \theta_{imp\_min} = -53.82 \cdot deg$ Impact angle (from horizontal) of water jet during high tailwater conditions

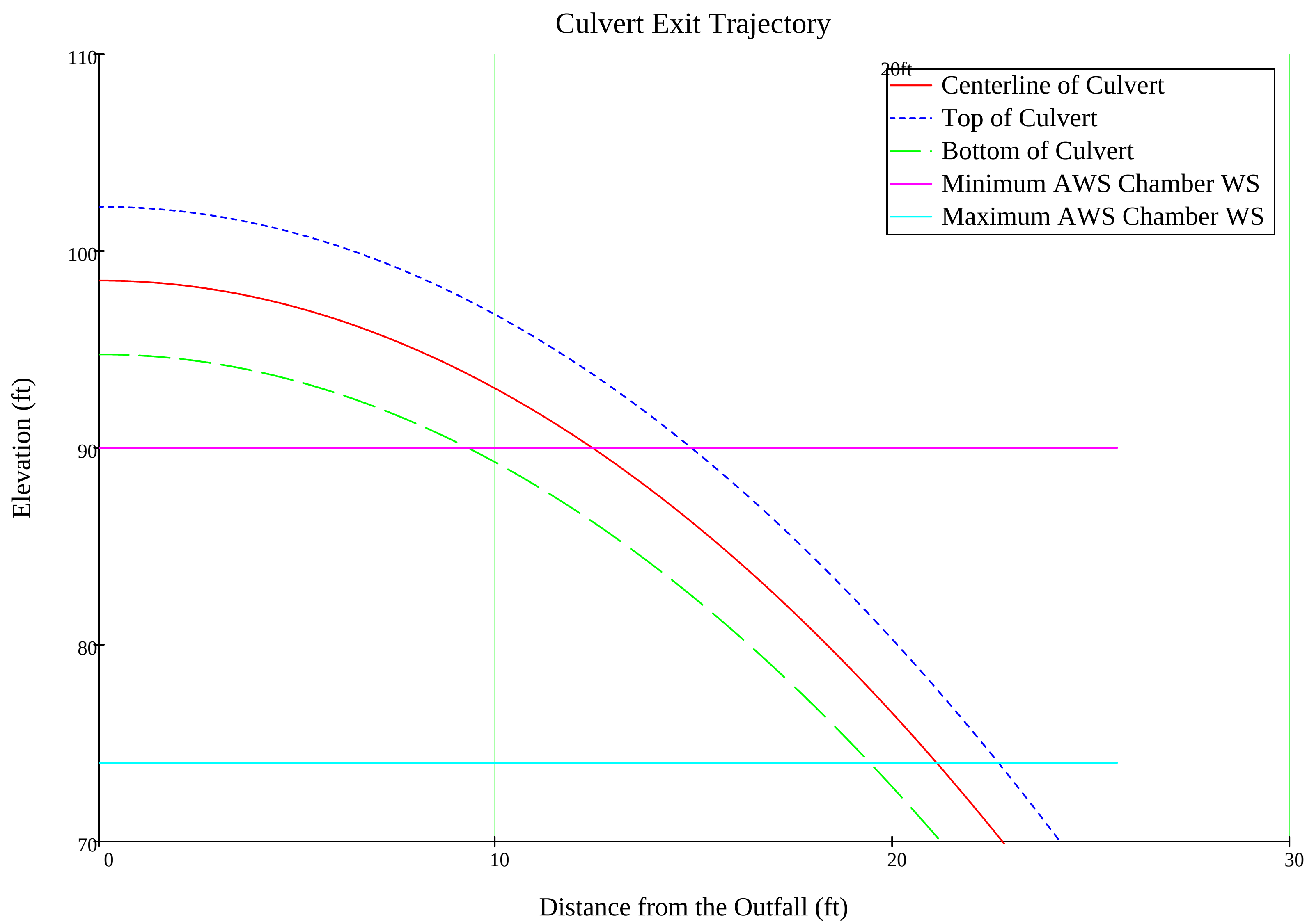
$\theta_{imp\_max} := \operatorname{atan}\left(\frac{v_y(t_{max})}{v_x}\right)$ $\quad \theta_{imp\_max} = -66.69 \cdot deg$ Impact angle (from horizontal) of water jet during low tailwater conditions

$v_{max} := \sqrt{v_y(t_{max})^2 + v_x^2}$ $\quad v_{max} = 43.23 \frac{ft}{s}$ Velocity at impact during low tailwater condition

$v_{min} := \sqrt{v_y(t_{min})^2 + v_x^2}$ $\quad v_{min} = 28.98 \frac{ft}{s}$ Veloctiy at impact during high tailwater condition

$t := 0s, 0.001s .. 1.5s$

Project Title: Dalles EFL Emergency AWS - Energy Dissipation	12/19/2013	By: Logan Negherbon Checked By: Ryan Laughery



$F_x := Q_{m2} \cdot \rho \cdot v_{max} \cdot \cos(\theta_{imp\_max})$ $\qquad F_x = 25.08 \cdot kip$

$F_y := Q_{m2} \cdot \rho \cdot (v_{max} - v_{max} \cdot \sin(\theta_{imp\_max}))$ $\qquad F_y = 121.62 \cdot kip$

Based on impact potential on exterior wall of the AWSC, it was not recommended to discharge at a horizontal orientation into the AWSC. An elbow and vertical orientation was chosen to alleviate this issue.

Hydraulic Design Summary

Entrance Bell

Concentric eliptical bell entrance with a 5-ft primary radius and 1.5-ft secondary entrance base on guidance from EM 1110-2-1602 (Section 3-7)

Conduit

Steel, lined against corrosion with cavitation resistant material.

$k = 0.000082\,ft$ Design equivalent sand grain roughness

$D_1 = 10\,ft$	Diameter of Pipe 1	$L_1 = 190\,ft$	Length of Pipe 1
$D_2 = 7.5\,ft$	Diameter of Pipe 2	$L_2 = 110\,ft$	Length of Pipe 2
$D_3 = 7.5\,ft$	Diameter of Pipe 3	$L_3 = 110\,ft$	Length of Pipe 3

Appurtenances

Valves

One 10 ft butterfly valve (concentric) will be used at the downstream face of the dam as secondary flow closure.

Orifices

Orifices shall have openings at the invert of the pipe to allow for drainage of conduit during system shutdown.

$D_{o1.1} = 7.4\,ft$	Orifice 1.1 (Orifice 1 on Pipe 1)	$L_{o1.1} = 100\,ft$	Station of Orifice 1.1 on Pipe 1
$D_{o1.2} = 7.5\,ft$	Orifice 1.2 (Orifice 2 on Pipe 1)	$L_{o1.2} = 140\,ft$	Station of Orifice 1.2 on Pipe 1
$D_{o2.1} = 5.5\,ft$	Orifice 2.1 (Orifice 1 on Pipe 2)	$L_{o2.1} = 45\,ft$	Station of Orifce 2.1 on Pipe 2
$D_{o3.1} = 5.5\,ft$	Orifce 3.1 (Orifice 1 on Pipe 3)	$L_{o3.1} = 45\,ft$	Station of Orifice 3.1 on Pipe 3

Air Inlets

Air inlets shall be installed downstream of orifices. To be designed.

Bends

Bends shall have a radius of bending to diameter of pipe ratio equal to or greater than 1.0 except for bend 1.3 which requires a bend ratio of 1.5. Bends shall not be mitered if possible. If mitered bends are determined necessary, maximum number of miters constructably feasible are desired.

Sensitivity Factors $\alpha_k = 1$ Minor loss factor $\alpha_f = 1$ Equivalent sand grain roughness factor

Flowrates

$Q_{d1} = 1390 \cdot cfs$	Design flow rate (low forebay) - Pipe 1	$Q_{m1} = 1511 \cdot cfs$	Max flow rate (high forebay) - Pipe 1
$Q_{d2} = 695\,cfs$	Design flow rate (low forebay) - Pipe 2	$Q_{m2} = 756 \cdot cfs$	Max flow rate (high forebay) - Pipe 2
$Q_{d3} = 695 \cdot cfs$	Design flow rate (low forebay) - Pipe 3	$Q_{m3} = 756 \cdot cfs$	Max flow rate (high forebay) - Pipe 3

Headlosses

Pipe 1

Design Flow	Max Flow	
$H_1(Q_{d1}) = 29.12\,ft$	$H_1(Q_{m1}) = 34.4\,ft$	Total losses thru Pipe 1
$h_t = 0.25\,ft$	$h_t = 0.25\,ft$	Trashrack loss
$K_e \cdot hv_1(Q_{d1}) = 0.78\,ft$	$K_e \cdot hv_1(Q_{m1}) = 0.92\,ft$	Entrance loss
$K_{bfv} \cdot hv_1(Q_{d1}) = 0.97\,ft$	$K_{bfv} \cdot hv_1(Q_{m1}) = 1.15\,ft$	Butterfly valve loss
$K_{b\_b1} \cdot hv_1(Q_{d1}) = 1.55\,ft$	$K_{b\_b1} \cdot hv_1(Q_{m1}) = 1.83\,ft$	Combinded bend loss
$K_{o1.1} \cdot hv_1(Q_{d1}) = 12.73\,ft$	$K_{o1.1} \cdot hv_1(Q_{m1}) = 15.06\,ft$	Orifice loss 1.1
$K_{o1.2} \cdot hv_1(Q_{d1}) = 11.5\,ft$	$K_{o1.2} \cdot hv_1(Q_{m1}) = 13.6\,ft$	Orifice loss 1.2
$K_{b1.3} \cdot hv_1(Q_{d1}) = 0.54\,ft$	$K_{b1.3} \cdot hv_1(Q_{m1}) = 0.64\,ft$	Bend loss 1.3
$f_1(Q_{d1}) \cdot hv_1(Q_{d1}) = 0.8105\,ft$	$f_1(Q_{m1}) \cdot hv_1(Q_{m1}) = 0.9529\,ft$	Total frictional loss
$hv_1(Q_{d1}) = 4.86\,ft$	$hv_1(Q_{m1}) = 5.76\,ft$	Velocity head within the pipe

Pipe 2

Design Flow	Max Flow	
$H_2(Q_{d2}) = 15.12\,ft$	$H_2(Q_{m2}) = 17.88\,ft$	Total head loss in Pipe 2
$K_{31} \cdot hv_2(Q_{d2}) = 0.58\,ft$	$K_{31} \cdot hv_2(Q_{m2}) = 0.68\,ft$	Y loss to Pipe 2
$K_{b\_b2.1} \cdot hv_2(Q_{d2}) = 0.2\,ft$	$K_{b\_b2.1} \cdot hv_2(Q_{m2}) = 0.24\,ft$	Combined bend loss
$K_{o2.1} \cdot hv_2(Q_{d2}) = 10.76\,ft$	$K_{o2.1} \cdot hv_2(Q_{m2}) = 12.73\,ft$	Orifice loss 2.1
$K_{b2.2} \cdot hv_2(Q_{d2}) = 3.06\,ft$	$K_{b2.2} \cdot hv_2(Q_{m2}) = 3.62\,ft$	Bend loss 2.2
$f_2(Q_{d2}) \cdot hv_2(Q_{d2}) = 0.52\,ft$	$f_2(Q_{m2}) \cdot hv_2(Q_{m2}) = 0.61\,ft$	Total friction loss for Pipe 2
$hv_2(Q_{d2}) = 3.84\,ft$	$hv_2(Q_{m2}) = 4.55\,ft$	Velocity head within the pipe
$Fr_2(Q_{d2}) = 1.01$	$Fr_2(Q_{m2}) = 1.1$	Froude exiting pipe 2

Pipe 3

Design Flow	Max Flow	
$H_3(Q_{d3}) = 15.12\,ft$	$H_3(Q_{m3}) = 17.88\,ft$	Total head loss in Pipe 3
$K_{31} \cdot hv_3(Q_{d3}) = 0.58\,ft$	$K_{31} \cdot hv_3(Q_{m3}) = 0.68\,ft$	Y loss to Pipe 3
$K_{b\_b3.1} \cdot hv_3(Q_{d3}) = 0.2\,ft$	$K_{b\_b3.1} \cdot hv_3(Q_{m3}) = 0.24\,ft$	Combined bend loss
$K_{o3.1} \cdot hv_3(Q_{d3}) = 10.76\,ft$	$K_{o3.1} \cdot hv_3(Q_{m3}) = 12.73\,ft$	Orifice loss 3.1
$K_{b3.2} \cdot hv_3(Q_{d3}) = 3.06\,ft$	$K_{b3.2} \cdot hv_3(Q_{m3}) = 3.62\,ft$	Bend loss 3.2
$f_3(Q) \cdot hv_3(Q_{d3}) = 0.52\,ft$	$f_3(Q) \cdot hv_3(Q_{m3}) = 0.61\,ft$	Total friction loss for Pipe 3
$hv_3(Q_{d3}) = 3.84\,ft$	$hv_3(Q_{m3}) = 4.55\,ft$	Velocity head within the pipe
$Fr_3(Q_{d3}) = 1.01$	$Fr_3(Q_{m3}) = 1.1$	Froude exiting pipe 3

Reactionary Forces

Forces in X direction as shown	Forces in flow direction as shown	Forces in Y direction as shown	
$F_{b1.1x} = 116.63 \cdot kip$		$F_{b1.1y} = -193.95 \cdot kip$	Bend 1.1
$F_{b1.2x} = 143.48 \cdot kip$		$F_{b1.2y} = 241.26 \cdot kip$	Bend 1.2
	$F_{o1.1} = 174.98 \cdot kip$		Orifice 1.1
	$F_{o1.2} = 134.25 \cdot kip$		Orifice 1.2
$F_{b1.3x} = 44.17 \cdot kip$		$F_{b1.3y} = -106.65 \cdot kip$	Bend 1.3
	$F_{wye} = -1.06 \cdot kip$		Wye - Note that force is considered in the X direction only
$F_{b2.1x} = 11.16 \cdot kip$		$F_{b2.1y} = 39.26 \cdot kip$	Bend 2.1
	$F_{o2.1} = 56.92 \cdot kip$		Orifice 2.1
$F_{b2.2x} = 43.12 \cdot kip$		$F_{b2.2y} = 43.12 \cdot kip$	Bend 2.2
$F_{b3.1x} = 11.16 \cdot kip$		$F_{b3.1y} = -39.26 \cdot kip$	Bend 3.1
	$F_{o3.1} = 56.92 \cdot kip$		Orifice 3.1
$F_{b3.2x} = 42.59 \cdot kip$		$F_{b3.2y} = 6.82 \cdot kip$	Bend 3.2

Cavitation Potential Summary

$bendcav_{1.1}$ = "Bend radius ok"

$bendcav_{1.2}$ = "Bend radius ok"

$bendcav_{1.3}$ = "Bend radius ok"

$bendcav_{2.1}$ = "Bend radius ok"

$bendcav_{2.2}$ = "Incipient cavitation initiated"

Bend 2.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$bendcav_{3.1}$ = "Bend radius ok"

$bendcav_{3.2}$ = "Incipient cavitation initiated"

Bend 3.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$check\_\sigma_{i\_1.1}$ = "check next"

Orifice 1.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.1}$ = "ok"

$check\_\sigma_{id\_1.1}$ = "ok"

$check\_\sigma_{ch\_1.1}$ = "ok"

$check\_\sigma_{i\_1.2}$ = "check next"

Orifice 1.2 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.2}$ = "ok"

$check\_\sigma_{id\_1.2}$ = "ok"

$check\_\sigma_{ch\_1.2}$ = "ok"

$check\_\sigma_{i\_2.1}$ = "check next"

Orifice 2.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_2.1}$ = "ok"

$check\_\sigma_{id\_2.1}$ = "ok"

$check\_\sigma_{ch\_2.1}$ = "ok"

$check\_\sigma_{i\_3.1}$ = "check next"

Orifice 3.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_3.1}$ = "ok"

$check\_\sigma_{id\_3.1}$ = "ok"

$check\_\sigma_{ch\_3.1}$ = "ok"

Clearances

$Ele_{bop2} = 94.75\,ft$ Elevation of the bottom of pipe 2 at fishladder crossing

$Ele_{bop3} = 94.75\,ft$ Elevation of the bottom of pipe 3 at fishladder crossing

$\Delta EFL_{ent} := 1.3ft$ Maximum differential at fish ladder entrance

$\Delta EFL_{diff} := 2.2ft$ Maximum head on diffusers from AWSC

$TW_{min} := 74.0ft$ Minimum tailwater at which the backup AWS operates

$TW_{high} := 86.0ft$ Maximum tailwater at which the backup AWS operates

$TW_{max} := 90.0ft$ Maximum tailwater at which EFL maintains criteria

$Ele_{bop2} - TW_{high} - \Delta EFL_{ent} = 7.45\,ft$ Clearance of water in fishladder to bottom of pipe 2 at emergency AWS backup high tailwater operation

$Ele_{bop2} - TW_{max} - \Delta EFL_{ent} = 3.45\,ft$ Clearance of water in fishladder to bottom of pipe 2 at max tailwater EFL operation point

REFERENCES

a. U.S. Army Corps of Engineers (USACE). Engineering Manual (EM) 1110-2-1602, Hydraulic Design of Reservoir Outlet Works.

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Hydraulic Design Summary

Entrance Bell

Concentric eliptical bell entrance with a 5-ft primary radius and 1.5-ft secondary entrance base on guidance from EM 1110-2-1602 (Section 3-7)

Conduit

Steel, lined against corrosion with cavitation resistant material.

$k = 0.00082\,ft$	Design equivalent sand grain roughness		
$D_1 = 10\,ft$	Diameter of Pipe 1	$L_1 = 190\,ft$	Length of Pipe 1
$D_2 = 7.5\,ft$	Diameter of Pipe 2	$L_2 = 110\,ft$	Length of Pipe 2
$D_3 = 7.5\,ft$	Diameter of Pipe 3	$L_3 = 110\,ft$	Length of Pipe 3

Appurtenances

Valves

One 10 ft butterfly valve (concentric) will be used at the downstream face of the dam as secondary flow closure.

Orifices

Orifices shall have openings at the invert of the pipe to allow for drainage of conduit during system shutdown.

$D_{o1.1} = 7.4\,ft$	Orifice 1.1 (Orifice 1 on Pipe 1)	$L_{o1.1} = 100\,ft$	Station of Orifice 1.1 on Pipe 1
$D_{o1.2} = 7.5\,ft$	Orifice 1.2 (Orifice 2 on Pipe 1)	$L_{o1.2} = 140\,ft$	Station of Orifice 1.2 on Pipe 1
$D_{o2.1} = 5.5\,ft$	Orifice 2.1 (Orifice 1 on Pipe 2)	$L_{o2.1} = 45\,ft$	Station of Orifce 2.1 on Pipe 2
$D_{o3.1} = 5.5\,ft$	Orifce 3.1 (Orifice 1 on Pipe 3)	$L_{o3.1} = 45\,ft$	Station of Orifice 3.1 on Pipe 3

Air Inlets

Air inlets shall be installed downstream of orifices. To be designed.

Bends

Bends shall have a radius of bending to diameter of pipe ratio equal to or greater than 1.0 except for bend 1.3 which requires a bend ratio of 1.5. Bends shall not be mitered if possible. If mitered bends are determined necessary, maximum number of miters constructably feasible are desired.

Sensitivity Factors $\alpha_k = 1.1$ Minor loss factor $\alpha_f = 10$ Equivalent sand grain roughness factor

Flowrates

$Q_{d1} = 1325 \cdot cfs$	Design flow rate (low forebay) - Pipe 1	$Q_{m1} = 1442 \cdot cfs$	Max flow rate (high forebay) - Pipe 1
$Q_{d2} = 663\,cfs$	Design flow rate (low forebay) - Pipe 2	$Q_{m2} = 721 \cdot cfs$	Max flow rate (high forebay) - Pipe 2
$Q_{d3} = 663 \cdot cfs$	Design flow rate (low forebay) - Pipe 3	$Q_{m3} = 721 \cdot cfs$	Max flow rate (high forebay) - Pipe 3

Headlosses

Pipe 1

Design Flow	Max Flow	
$H_1(Q_{d1}) = 29.24\,ft$	$H_1(Q_{m1}) = 34.6\,ft$	Total losses thru Pipe 1
$h_t = 0.25\,ft$	$h_t = 0.25\,ft$	Trashrack loss
$K_e \cdot hv_1(Q_{d1}) = 0.71\,ft$	$K_e \cdot hv_1(Q_{m1}) = 0.84\,ft$	Entrance loss
$K_{bfv} \cdot hv_1(Q_{d1}) = 0.97\,ft$	$K_{bfv} \cdot hv_1(Q_{m1}) = 1.15\,ft$	Butterfly valve loss
$K_{b\_b1} \cdot hv_1(Q_{d1}) = 1.55\,ft$	$K_{b\_b1} \cdot hv_1(Q_{m1}) = 1.83\,ft$	Combinded bend loss
$K_{o1.1} \cdot hv_1(Q_{d1}) = 12.73\,ft$	$K_{o1.1} \cdot hv_1(Q_{m1}) = 15.09\,ft$	Orifice loss 1.1
$K_{o1.2} \cdot hv_1(Q_{d1}) = 11.5\,ft$	$K_{o1.2} \cdot hv_1(Q_{m1}) = 13.63\,ft$	Orifice loss 1.2
$K_{b1.3} \cdot hv_1(Q_{d1}) = 0.54\,ft$	$K_{b1.3} \cdot hv_1(Q_{m1}) = 0.64\,ft$	Bend loss 1.3
$f_1(Q_{d1}) \cdot hv_1(Q_{d1}) = 0.9895\,ft$	$f_1(Q_{m1}) \cdot hv_1(Q_{m1}) = 1.1708\,ft$	Total frictional loss
$hv_1(Q_{d1}) = 4.42\,ft$	$hv_1(Q_{m1}) = 5.24\,ft$	Velocity head within the pipe

Pipe 2

Design Flow	Max Flow	
$H_2(Q_{d2}) = 15.24\ ft$	$H_2(Q_{m2}) = 18.06\ ft$	Total head loss in Pipe 2
$K_{31} \cdot hv_2(Q_{d2}) = 0.58\ ft$	$K_{31} \cdot hv_2(Q_{m2}) = 0.68\ ft$	Y loss to Pipe 2
$K_{b\_b2.1} \cdot hv_2(Q_{d2}) = 0.2\ ft$	$K_{b\_b2.1} \cdot hv_2(Q_{m2}) = 0.24\ ft$	Combined bend loss
$K_{o2.1} \cdot hv_2(Q_{d2}) = 10.77\ ft$	$K_{o2.1} \cdot hv_2(Q_{m2}) = 12.76\ ft$	Orifice loss 2.1
$K_{b2.2} \cdot hv_2(Q_{d2}) = 3.06\ ft$	$K_{b2.2} \cdot hv_2(Q_{m2}) = 3.62\ ft$	Bend loss 2.2
$f_2(Q_{d2}) \cdot hv_2(Q_{d2}) = 0.64\ ft$	$f_2(Q_{m2}) \cdot hv_2(Q_{m2}) = 0.76\ ft$	Total friction loss for Pipe 2
$hv_2(Q_{d2}) = 3.5\ ft$	$hv_2(Q_{m2}) = 4.14\ ft$	Velocity head within the pipe
$Fr_2(Q_{d2}) = 0.97$	$Fr_2(Q_{m2}) = 1.05$	Froude exiting pipe 2

Pipe 3

Design Flow	Max Flow	
$H_3(Q_{d3}) = 15.24\ ft$	$H_3(Q_{m3}) = 18.06\ ft$	Total head loss in Pipe 3
$K_{31} \cdot hv_3(Q_{d3}) = 0.58\ ft$	$K_{31} \cdot hv_3(Q_{m3}) = 0.68\ ft$	Y loss to Pipe 3
$K_{b\_b3.1} \cdot hv_3(Q_{d3}) = 0.2\ ft$	$K_{b\_b3.1} \cdot hv_3(Q_{m3}) = 0.24\ ft$	Combined bend loss
$K_{o3.1} \cdot hv_3(Q_{d3}) = 10.77\ ft$	$K_{o3.1} \cdot hv_3(Q_{m3}) = 12.76\ ft$	Orifice loss 3.1
$K_{b3.2} \cdot hv_3(Q_{d3}) = 3.06\ ft$	$K_{b3.2} \cdot hv_3(Q_{m3}) = 3.62\ ft$	Bend loss 3.2
$f_3(Q) \cdot hv_3(Q_{d3}) = 0.64\ ft$	$f_3(Q) \cdot hv_3(Q_{m3}) = 0.75\ ft$	Total friction loss for Pipe 3
$hv_3(Q_{d3}) = 3.5\ ft$	$hv_3(Q_{m3}) = 4.14\ ft$	Velocity head within the pipe
$Fr_3(Q_{d3}) = 0.97$	$Fr_3(Q_{m3}) = 1.05$	Froude exiting pipe 3

Project Title: Dalles EFL Emergency AWS - Energy Dissipation	12/19/2013	By: Logan Negherbon Checked By: Ryan Laughery

Reactionary Forces

Forces in X direction as shown	Forces in flow direction as shown	Forces in Y direction as shown	
$F_{b1.1x} = 116.37 \cdot kip$		$F_{b1.1y} = -192.7 \cdot kip$	Bend 1.1
$F_{b1.2x} = 142.97 \cdot kip$		$F_{b1.2y} = 239.65 \cdot kip$	Bend 1.2
	$F_{o1.1} = 177.93 \cdot kip$		Orifice 1.1
	$F_{o1.2} = 133.62 \cdot kip$		Orifice 1.2
$F_{b1.3x} = 39.16 \cdot kip$		$F_{b1.3y} = -94.54 \cdot kip$	Bend 1.3
	$F_{wye} = 1.67 \cdot kip$		Wye - Note that force is considered in the X direction only
$F_{b2.1x} = 9.88 \cdot kip$		$F_{b2.1y} = 34.25 \cdot kip$	Bend 2.1
	$F_{o2.1} = 54.08 \cdot kip$		Orifice 2.1
$F_{b2.2x} = 29.35 \cdot kip$		$F_{b2.2y} = 29.35 \cdot kip$	Bend 2.2
$F_{b3.1x} = 9.88 \cdot kip$		$F_{b3.1y} = -34.25 \cdot kip$	Bend 3.1
	$F_{o3.1} = 54.08 \cdot kip$		Orifice 3.1
$F_{b3.2x} = 28.63 \cdot kip$		$F_{b3.2y} = 20.78 \cdot kip$	Bend 3.2

Project Title: Dalles EFL Emergency AWS - Energy Dissipation	12/19/2013	By: Logan Negherbon Checked By: Ryan Laughery

Cavitation Potential Summary

$\text{bendcav}_{1.1}$ = "Bend radius ok"

$\text{bendcav}_{1.2}$ = "Bend radius ok"

$\text{bendcav}_{1.3}$ = "Bend radius ok"

$\text{bendcav}_{2.1}$ = "Bend radius ok"

$\text{bendcav}_{2.2}$ = "Incipient cavitation initiated"

Bend 2.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$\text{bendcav}_{3.1}$ = "Bend radius ok"

$\text{bendcav}_{3.2}$ = "Incipient cavitation initiated"

Bend 3.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$\text{check\_}\sigma_{i\_1.1}$ = "check next"

Orifice 1.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$\text{check\_}\sigma_{cr\_1.1}$ = "check next"

$\text{check\_}\sigma_{id\_1.1}$ = "ok"

$\text{check\_}\sigma_{ch\_1.1}$ = "ok"

$\text{check\_}\sigma_{i\_1.2}$ = "check next"

Orifice 1.2 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$\text{check\_}\sigma_{cr\_1.2}$ = "check next"

$\text{check\_}\sigma_{id\_1.2}$ = "ok"

$\text{check\_}\sigma_{ch\_1.2}$ = "ok"

$check\_\sigma_{i\_2.1}$ = "check next"

$check\_\sigma_{cr\_2.1}$ = "check next"

$check\_\sigma_{id\_2.1}$ = "ok"

$check\_\sigma_{ch\_2.1}$ = "ok"

Orifice 2.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{i\_3.1}$ = "check next"

$check\_\sigma_{cr\_3.1}$ = "check next"

$check\_\sigma_{id\_3.1}$ = "ok"

$check\_\sigma_{ch\_3.1}$ = "ok"

Orifice 3.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

Clearances

$Ele_{bop2} = 94.75\ ft$ Elevation of the bottom of pipe 2 at fishladder crossing

$Ele_{bop3} = 94.75\ ft$ Elevation of the bottom of pipe 3 at fishladder crossing

$\Delta EFL_{ent} := 1.3ft$ Maximum differential at fish ladder entrance

$\Delta EFL_{diff} := 2.2ft$ Maximum head on diffusers from AWSC

$TW_{min} := 74.0ft$ Minimum tailwater at which the backup AWS operates

$TW_{high} := 86.0ft$ Maximum tailwater at which the backup AWS operates

$TW_{max} := 90.0ft$ Maximum tailwater at which EFL maintains criteria

$Ele_{bop2} - TW_{high} - \Delta EFL_{ent} = 7.45\ ft$ Clearance of water in fishladder to bottom of pipe 2 at emergency AWS backup high tailwater operation

$Ele_{bop2} - TW_{max} - \Delta EFL_{ent} = 3.45\ ft$ Clearance of water in fishladder to bottom of pipe 2 at max tailwater EFL operation point

Hydraulic Design Summary

Entrance Bell

Concentric eliptical bell entrance with a 5-ft primary radius and 1.5-ft secondary entrance base on guidance from EM 1110-2-1602 (Section 3-7)

Conduit

Steel, lined against corrosion with cavitation resistant material.

$k = 0.000082\,ft$ Design equivalent sand grain roughness

$D_1 = 10\,ft$	Diameter of Pipe 1	$L_1 = 190\,ft$	Length of Pipe 1
$D_2 = 7.5\,ft$	Diameter of Pipe 2	$L_2 = 110\,ft$	Length of Pipe 2
$D_3 = 7.5\,ft$	Diameter of Pipe 3	$L_3 = 110\,ft$	Length of Pipe 3

Appurtenances

Valves

One 10 ft butterfly valve (concentric) will be used at the downstream face of the dam as secondary flow closure.

Orifices

Orifices shall have openings at the invert of the pipe to allow for drainage of conduit during system shutdown.

$D_{o1.1} = 7.4\,ft$	Orifice 1.1 (Orifice 1 on Pipe 1)	$L_{o1.1} = 100\,ft$	Station of Orifice 1.1 on Pipe 1
$D_{o1.2} = 7.5\,ft$	Orifice 1.2 (Orifice 2 on Pipe 1)	$L_{o1.2} = 140\,ft$	Station of Orifice 1.2 on Pipe 1
$D_{o2.1} = 5.5\,ft$	Orifice 2.1 (Orifice 1 on Pipe 2)	$L_{o2.1} = 45\,ft$	Station of Orifce 2.1 on Pipe 2
$D_{o3.1} = 5.5\,ft$	Orifce 3.1 (Orifice 1 on Pipe 3)	$L_{o3.1} = 45\,ft$	Station of Orifice 3.1 on Pipe 3

Air Inlets

Air inlets shall be installed downstream of orifices. To be designed.

Bends

Bends shall have a radius of bending to diameter of pipe ratio equal to or greater than 1.0 except for bend 1.3 which requires a bend ratio of 1.5. Bends shall not be mitered if possible. If mitered bends are determined necessary, maximum number of miters constructably feasible are desired.

Sensitivity Factors $\alpha_k = 1.1$ Minor loss factor $\alpha_f = 1$ Equivalent sand grain roughness factor

Flowrates

$Q_{d1} = 1329 \cdot cfs$	Design flow rate (low forebay) - Pipe 1	$Q_{m1} = 1447 \cdot cfs$	Max flow rate (high forebay) - Pipe 1
$Q_{d2} = 665\, cfs$	Design flow rate (low forebay) - Pipe 2	$Q_{m2} = 724 \cdot cfs$	Max flow rate (high forebay) - Pipe 2
$Q_{d3} = 665 \cdot cfs$	Design flow rate (low forebay) - Pipe 3	$Q_{m3} = 724 \cdot cfs$	Max flow rate (high forebay) - Pipe 3

Headlosses

Pipe 1

Design Flow	Max Flow	
$H_1(Q_{d1}) = 29.17\, ft$	$H_1(Q_{m1}) = 34.51\, ft$	Total losses thru Pipe 1
$h_t = 0.25\, ft$	$h_t = 0.25\, ft$	Trashrack loss
$K_e \cdot hv_1(Q_{d1}) = 0.71\, ft$	$K_e \cdot hv_1(Q_{m1}) = 0.84\, ft$	Entrance loss
$K_{bfv} \cdot hv_1(Q_{d1}) = 0.98\, ft$	$K_{bfv} \cdot hv_1(Q_{m1}) = 1.16\, ft$	Butterfly valve loss
$K_{b\_b1} \cdot hv_1(Q_{d1}) = 1.56\, ft$	$K_{b\_b1} \cdot hv_1(Q_{m1}) = 1.85\, ft$	Combinded bend loss
$K_{o1.1} \cdot hv_1(Q_{d1}) = 12.81\, ft$	$K_{o1.1} \cdot hv_1(Q_{m1}) = 15.18\, ft$	Orifice loss 1.1
$K_{o1.2} \cdot hv_1(Q_{d1}) = 11.57\, ft$	$K_{o1.2} \cdot hv_1(Q_{m1}) = 13.71\, ft$	Orifice loss 1.2
$K_{b1.3} \cdot hv_1(Q_{d1}) = 0.55\, ft$	$K_{b1.3} \cdot hv_1(Q_{m1}) = 0.65\, ft$	Bend loss 1.3
$f_1(Q_{d1}) \cdot hv_1(Q_{d1}) = 0.7442\, ft$	$f_1(Q_{m1}) \cdot hv_1(Q_{m1}) = 0.8762\, ft$	Total frictional loss
$hv_1(Q_{d1}) = 4.45\, ft$	$hv_1(Q_{m1}) = 5.28\, ft$	Velocity head within the pipe

Pipe 2

Design Flow	Max Flow	
$H_2(Q_{d2}) = 15.17\ ft$	$H_2(Q_{m2}) = 17.97\ ft$	Total head loss in Pipe 2
$K_{31} \cdot hv_2(Q_{d2}) = 0.58\ ft$	$K_{31} \cdot hv_2(Q_{m2}) = 0.69\ ft$	Y loss to Pipe 2
$K_{b\_b2.1} \cdot hv_2(Q_{d2}) = 0.2\ ft$	$K_{b\_b2.1} \cdot hv_2(Q_{m2}) = 0.24\ ft$	Combined bend loss
$K_{o2.1} \cdot hv_2(Q_{d2}) = 10.83\ ft$	$K_{o2.1} \cdot hv_2(Q_{m2}) = 12.84\ ft$	Orifice loss 2.1
$K_{b2.2} \cdot hv_2(Q_{d2}) = 3.08\ ft$	$K_{b2.2} \cdot hv_2(Q_{m2}) = 3.65\ ft$	Bend loss 2.2
$f_2(Q_{d2}) \cdot hv_2(Q_{d2}) = 0.48\ ft$	$f_2(Q_{m2}) \cdot hv_2(Q_{m2}) = 0.56\ ft$	Total friction loss for Pipe 2
$hv_2(Q_{d2}) = 3.52\ ft$	$hv_2(Q_{m2}) = 4.17\ ft$	Velocity head within the pipe
$Fr_2(Q_{d2}) = 0.97$	$Fr_2(Q_{m2}) = 1.05$	Froude exiting pipe 2

Pipe 3

Design Flow	Max Flow	
$H_3(Q_{d3}) = 15.17\ ft$	$H_3(Q_{m3}) = 17.97\ ft$	Total head loss in Pipe 3
$K_{31} \cdot hv_3(Q_{d3}) = 0.58\ ft$	$K_{31} \cdot hv_3(Q_{m3}) = 0.69\ ft$	Y loss to Pipe 3
$K_{b\_b3.1} \cdot hv_3(Q_{d3}) = 0.2\ ft$	$K_{b\_b3.1} \cdot hv_3(Q_{m3}) = 0.24\ ft$	Combined bend loss
$K_{o3.1} \cdot hv_3(Q_{d3}) = 10.83\ ft$	$K_{o3.1} \cdot hv_3(Q_{m3}) = 12.84\ ft$	Orifice loss 3.1
$K_{b3.2} \cdot hv_3(Q_{d3}) = 3.08\ ft$	$K_{b3.2} \cdot hv_3(Q_{m3}) = 3.65\ ft$	Bend loss 3.2
$f_3(Q) \cdot hv_3(Q_{d3}) = 0.47\ ft$	$f_3(Q) \cdot hv_3(Q_{m3}) = 0.56\ ft$	Total friction loss for Pipe 3
$hv_3(Q_{d3}) = 3.52\ ft$	$hv_3(Q_{m3}) = 4.17\ ft$	Velocity head within the pipe
$Fr_3(Q_{d3}) = 0.97$	$Fr_3(Q_{m3}) = 1.05$	Froude exiting pipe 3

Reactionary Forces

Forces in X direction as shown	Forces in flow direction as shown	Forces in Y direction as shown	
$F_{b1.1x} = 116.58 \cdot kip$		$F_{b1.1y} = -193.06 \cdot kip$	Bend 1.1
$F_{b1.2x} = 143.18 \cdot kip$		$F_{b1.2y} = 240.02 \cdot kip$	Bend 1.2
	$F_{o1.1} = 178.31 \cdot kip$		Orifice 1.1
	$F_{o1.2} = 134.13 \cdot kip$		Orifice 1.2
$F_{b1.3x} = 39.7 \cdot kip$		$F_{b1.3y} = -95.85 \cdot kip$	Bend 1.3
	$F_{wye} = 1.26 \cdot kip$		Wye - Note that force is considered in the X direction only
$F_{b2.1x} = 10.02 \cdot kip$		$F_{b2.1y} = 34.76 \cdot kip$	Bend 2.1
	$F_{o2.1} = 54.61 \cdot kip$		Orifice 2.1
$F_{b2.2x} = 30.65 \cdot kip$		$F_{b2.2y} = 30.65 \cdot kip$	Bend 2.2
$F_{b3.1x} = 10.02 \cdot kip$		$F_{b3.1y} = -34.76 \cdot kip$	Bend 3.1
	$F_{o3.1} = 54.61 \cdot kip$		Orifice 3.1
$F_{b3.2x} = 30.11 \cdot kip$		$F_{b3.2y} = 19.3 \cdot kip$	Bend 3.2

Cavitation Potential Summary

$bendcav_{1.1}$ = "Bend radius ok"

$bendcav_{1.2}$ = "Bend radius ok"

$bendcav_{1.3}$ = "Bend radius ok"

$bendcav_{2.1}$ = "Bend radius ok"

$bendcav_{2.2}$ = "Incipient cavitation initiated"

Bend 2.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$bendcav_{3.1}$ = "Bend radius ok"

$bendcav_{3.2}$ = "Incipient cavitation initiated"

Bend 3.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$check\_\sigma_{i\_1.1}$ = "check next"

Orifice 1.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.1}$ = "check next"

$check\_\sigma_{id\_1.1}$ = "ok"

$check\_\sigma_{ch\_1.1}$ = "ok"

$check\_\sigma_{i\_1.2}$ = "check next"

Orifice 1.2 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.2}$ = "check next"

$check\_\sigma_{id\_1.2}$ = "ok"

$check\_\sigma_{ch\_1.2}$ = "ok"

$check\_\sigma_{i\_2.1}$ = "check next"

Orifice 2.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_2.1}$ = "check next"

$check\_\sigma_{id\_2.1}$ = "ok"

$check\_\sigma_{ch\_2.1}$ = "ok"

$check\_\sigma_{i\_3.1}$ = "check next"

Orifice 3.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_3.1}$ = "check next"

$check\_\sigma_{id\_3.1}$ = "ok"

$check\_\sigma_{ch\_3.1}$ = "ok"

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Clearances

$Ele_{bop2} = 94.75\,ft$ Elevation of the bottom of pipe 2 at fishladder crossing

$Ele_{bop3} = 94.75\,ft$ Elevation of the bottom of pipe 3 at fishladder crossing

$\Delta EFL_{ent} := 1.3ft$ Maximum differential at fish ladder entrance

$\Delta EFL_{diff} := 2.2ft$ Maximum head on diffusers from AWSC

$TW_{min} := 74.0ft$ Minimum tailwater at which the backup AWS operates

$TW_{high} := 86.0ft$ Maximum tailwater at which the backup AWS operates

$TW_{max} := 90.0ft$ Maximum tailwater at which EFL maintains criteria

$Ele_{bop2} - TW_{high} - \Delta EFL_{ent} = 7.45\,ft$ Clearance of water in fishladder to bottom of pipe 2 at emergency AWS backup high tailwater operation

$Ele_{bop2} - TW_{max} - \Delta EFL_{ent} = 3.45\,ft$ Clearance of water in fishladder to bottom of pipe 2 at max tailwater EFL operation point

Hydraulic Design Summary

Entrance Bell

Concentric eliptical bell entrance with a 5-ft primary radius and 1.5-ft secondary entrance base on guidance from EM 1110-2-1602 (Section 3-7)

Conduit

Steel, lined against corrosion with cavitation resistant material.

$k = 0.000008\,ft$ Design equivalent sand grain roughness

$D_1 = 10\,ft$	Diameter of Pipe 1	$L_1 = 190\,ft$	Length of Pipe 1
$D_2 = 7.5\,ft$	Diameter of Pipe 2	$L_2 = 110\,ft$	Length of Pipe 2
$D_3 = 7.5\,ft$	Diameter of Pipe 3	$L_3 = 110\,ft$	Length of Pipe 3

Appurtenances

Valves

One 10 ft butterfly valve (concentric) will be used at the downstream face of the dam as secondary flow closure.

Orifices

Orifices shall have openings at the invert of the pipe to allow for drainage of conduit during system shutdown.

$D_{o1.1} = 7.4\,ft$	Orifice 1.1 (Orifice 1 on Pipe 1)	$L_{o1.1} = 100\,ft$	Station of Orifice 1.1 on Pipe 1
$D_{o1.2} = 7.5\,ft$	Orifice 1.2 (Orifice 2 on Pipe 1)	$L_{o1.2} = 140\,ft$	Station of Orifice 1.2 on Pipe 1
$D_{o2.1} = 5.5\,ft$	Orifice 2.1 (Orifice 1 on Pipe 2)	$L_{o2.1} = 45\,ft$	Station of Orifce 2.1 on Pipe 2
$D_{o3.1} = 5.5\,ft$	Orifce 3.1 (Orifice 1 on Pipe 3)	$L_{o3.1} = 45\,ft$	Station of Orifice 3.1 on Pipe 3

Air Inlets

Air inlets shall be installed downstream of orifices. To be designed.

Bends

Bends shall have a radius of bending to diameter of pipe ratio equal to or greater than 1.0 except for bend 1.3 which requires a bend ratio of 1.5. Bends shall not be mitered if possible. If mitered bends are determined necessary, maximum number of miters constructably feasible are desired.

Sensitivity Factors $\alpha_k = 1.1$ Minor loss factor $\alpha_f = 0.1$ Equivalent sand grain roughness factor

Flowrates

$Q_{d1} = 1330 \cdot cfs$	Design flow rate (low forebay) - Pipe 1	$Q_{m1} = 1448 \cdot cfs$	Max flow rate (high forebay) - Pipe 1
$Q_{d2} = 665\,cfs$	Design flow rate (low forebay) - Pipe 2	$Q_{m2} = 724 \cdot cfs$	Max flow rate (high forebay) - Pipe 2
$Q_{d3} = 665 \cdot cfs$	Design flow rate (low forebay) - Pipe 3	$Q_{m3} = 724 \cdot cfs$	Max flow rate (high forebay) - Pipe 3

Headlosses

Pipe 1

Design Flow	Max Flow	
$H_1(Q_{d1}) = 29.15\,ft$	$H_1(Q_{m1}) = 34.49\,ft$	Total losses thru Pipe 1
$h_t = 0.25\,ft$	$h_t = 0.25\,ft$	Trashrack loss
$K_e \cdot hv_1(Q_{d1}) = 0.71\,ft$	$K_e \cdot hv_1(Q_{m1}) = 0.85\,ft$	Entrance loss
$K_{bfv} \cdot hv_1(Q_{d1}) = 0.98\,ft$	$K_{bfv} \cdot hv_1(Q_{m1}) = 1.16\,ft$	Butterfly valve loss
$K_{b\_b1} \cdot hv_1(Q_{d1}) = 1.56\,ft$	$K_{b\_b1} \cdot hv_1(Q_{m1}) = 1.85\,ft$	Combinded bend loss
$K_{o1.1} \cdot hv_1(Q_{d1}) = 12.83\,ft$	$K_{o1.1} \cdot hv_1(Q_{m1}) = 15.21\,ft$	Orifice loss 1.1
$K_{o1.2} \cdot hv_1(Q_{d1}) = 11.59\,ft$	$K_{o1.2} \cdot hv_1(Q_{m1}) = 13.73\,ft$	Orifice loss 1.2
$K_{b1.3} \cdot hv_1(Q_{d1}) = 0.55\,ft$	$K_{b1.3} \cdot hv_1(Q_{m1}) = 0.65\,ft$	Bend loss 1.3
$f_1(Q_{d1}) \cdot hv_1(Q_{d1}) = 0.682\,ft$	$f_1(Q_{m1}) \cdot hv_1(Q_{m1}) = 0.7995\,ft$	Total frictional loss
$hv_1(Q_{d1}) = 4.46\,ft$	$hv_1(Q_{m1}) = 5.28\,ft$	Velocity head within the pipe

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Pipe 2

Design Flow	Max Flow	
$H_2(Q_{d2}) = 15.16\,ft$	$H_2(Q_{m2}) = 17.95\,ft$	Total head loss in Pipe 2
$K_{31} \cdot hv_2(Q_{d2}) = 0.58\,ft$	$K_{31} \cdot hv_2(Q_{m2}) = 0.69\,ft$	Y loss to Pipe 2
$K_{b\_b2.1} \cdot hv_2(Q_{d2}) = 0.2\,ft$	$K_{b\_b2.1} \cdot hv_2(Q_{m2}) = 0.24\,ft$	Combined bend loss
$K_{o2.1} \cdot hv_2(Q_{d2}) = 10.85\,ft$	$K_{o2.1} \cdot hv_2(Q_{m2}) = 12.86\,ft$	Orifice loss 2.1
$K_{b2.2} \cdot hv_2(Q_{d2}) = 3.08\,ft$	$K_{b2.2} \cdot hv_2(Q_{m2}) = 3.65\,ft$	Bend loss 2.2
$f_2(Q_{d2}) \cdot hv_2(Q_{d2}) = 0.44\,ft$	$f_2(Q_{m2}) \cdot hv_2(Q_{m2}) = 0.52\,ft$	Total friction loss for Pipe 2
$hv_2(Q_{d2}) = 3.52\,ft$	$hv_2(Q_{m2}) = 4.17\,ft$	Velocity head within the pipe
$Fr_2(Q_{d2}) = 0.97$	$Fr_2(Q_{m2}) = 1.06$	Froude exiting pipe 2

Pipe 3

Design Flow	Max Flow	
$H_3(Q_{d3}) = 15.16\,ft$	$H_3(Q_{m3}) = 17.95\,ft$	Total head loss in Pipe 3
$K_{31} \cdot hv_3(Q_{d3}) = 0.58\,ft$	$K_{31} \cdot hv_3(Q_{m3}) = 0.69\,ft$	Y loss to Pipe 3
$K_{b\_b3.1} \cdot hv_3(Q_{d3}) = 0.2\,ft$	$K_{b\_b3.1} \cdot hv_3(Q_{m3}) = 0.24\,ft$	Combined bend loss
$K_{o3.1} \cdot hv_3(Q_{d3}) = 10.85\,ft$	$K_{o3.1} \cdot hv_3(Q_{m3}) = 12.86\,ft$	Orifice loss 3.1
$K_{b3.2} \cdot hv_3(Q_{d3}) = 3.08\,ft$	$K_{b3.2} \cdot hv_3(Q_{m3}) = 3.65\,ft$	Bend loss 3.2
$f_3(Q) \cdot hv_3(Q_{d3}) = 0.43\,ft$	$f_3(Q) \cdot hv_3(Q_{m3}) = 0.51\,ft$	Total friction loss for Pipe 3
$hv_3(Q_{d3}) = 3.52\,ft$	$hv_3(Q_{m3}) = 4.17\,ft$	Velocity head within the pipe
$Fr_3(Q_{d3}) = 0.97$	$Fr_3(Q_{m3}) = 1.06$	Froude exiting pipe 3

Reactionary Forces

Forces in X direction as shown	Forces in flow direction as shown	Forces in Y direction as shown	
$F_{b1.1x} = 116.64 \cdot kip$		$F_{b1.1y} = -193.16 \cdot kip$	Bend 1.1
$F_{b1.2x} = 143.23 \cdot kip$		$F_{b1.2y} = 240.11 \cdot kip$	Bend 1.2
	$F_{o1.1} = 178.41 \cdot kip$		Orifice 1.1
	$F_{o1.2} = 134.27 \cdot kip$		Orifice 1.2
$F_{b1.3x} = 39.84 \cdot kip$		$F_{b1.3y} = -96.19 \cdot kip$	Bend 1.3
	$F_{wye} = 1.15 \cdot kip$		Wye - Note that force is considered in the X direction only
$F_{b2.1x} = 10.05 \cdot kip$		$F_{b2.1y} = 34.89 \cdot kip$	Bend 2.1
	$F_{o2.1} = 54.75 \cdot kip$		Orifice 2.1
$F_{b2.2x} = 30.98 \cdot kip$		$F_{b2.2y} = 30.98 \cdot kip$	Bend 2.2
$F_{b3.1x} = 10.05 \cdot kip$		$F_{b3.1y} = -34.89 \cdot kip$	Bend 3.1
	$F_{o3.1} = 54.75 \cdot kip$		Orifice 3.1
$F_{b3.2x} = 30.5 \cdot kip$		$F_{b3.2y} = 18.91 \cdot kip$	Bend 3.2

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Cavitation Potential Summary

$bendcav_{1.1}$ = "Bend radius ok"

$bendcav_{1.2}$ = "Bend radius ok"

$bendcav_{1.3}$ = "Bend radius ok"

$bendcav_{2.1}$ = "Bend radius ok"

$bendcav_{2.2}$ = "Incipient cavitation initiated"

Bend 2.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$bendcav_{3.1}$ = "Bend radius ok"

$bendcav_{3.2}$ = "Incipient cavitation initiated"

Bend 3.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$check\_\sigma_{i\_1.1}$ = "check next"

Orifice 1.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.1}$ = "check next"

$check\_\sigma_{id\_1.1}$ = "ok"

$check\_\sigma_{ch\_1.1}$ = "ok"

$check\_\sigma_{i\_1.2}$ = "check next"

Orifice 1.2 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.2}$ = "check next"

$check\_\sigma_{id\_1.2}$ = "ok"

$check\_\sigma_{ch\_1.2}$ = "ok"

$check\_\sigma_{i\_2.1}$ = "check next"

Orifice 2.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_2.1}$ = "check next"

$check\_\sigma_{id\_2.1}$ = "ok"

$check\_\sigma_{ch\_2.1}$ = "ok"

$check\_\sigma_{i\_3.1}$ = "check next"

Orifice 3.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_3.1}$ = "check next"

$check\_\sigma_{id\_3.1}$ = "ok"

$check\_\sigma_{ch\_3.1}$ = "ok"

Clearances

$Ele_{bop2} = 94.75\ ft$ Elevation of the bottom of pipe 2 at fishladder crossing

$Ele_{bop3} = 94.75\ ft$ Elevation of the bottom of pipe 3 at fishladder crossing

$\Delta EFL_{ent} := 1.3ft$ Maximum differential at fish ladder entrance

$\Delta EFL_{diff} := 2.2ft$ Maximum head on diffusers from AWSC

$TW_{min} := 74.0ft$ Minimum tailwater at which the backup AWS operates

$TW_{high} := 86.0ft$ Maximum tailwater at which the backup AWS operates

$TW_{max} := 90.0ft$ Maximum tailwater at which EFL maintains criteria

$Ele_{bop2} - TW_{high} - \Delta EFL_{ent} = 7.45\ ft$ Clearance of water in fishladder to bottom of pipe 2 at emergency AWS backup high tailwater operation

$Ele_{bop2} - TW_{max} - \Delta EFL_{ent} = 3.45\ ft$ Clearance of water in fishladder to bottom of pipe 2 at max tailwater EFL operation point

<u>Hydraulic Design Summary</u>

Entrance Bell

Concentric eliptical bell entrance with a 5-ft primary radius and 1.5-ft secondary entrance base on guidance from EM 1110-2-1602 (Section 3-7)

Conduit

Steel, lined against corrosion with cavitation resistant material.

$k = 0.00082\,ft$ Design equivalent sand grain roughness

$D_1 = 10\,ft$	Diameter of Pipe 1	$L_1 = 190\,ft$	Length of Pipe 1
$D_2 = 7.5\,ft$	Diameter of Pipe 2	$L_2 = 110\,ft$	Length of Pipe 2
$D_3 = 7.5\,ft$	Diameter of Pipe 3	$L_3 = 110\,ft$	Length of Pipe 3

Appurtenances

Valves

One 10 ft butterfly valve (concentric) will be used at the downstream face of the dam as secondary flow closure.

Orifices

Orifices shall have openings at the invert of the pipe to allow for drainage of conduit during system shutdown.

$D_{o1.1} = 7.4\,ft$	Orifice 1.1 (Orifice 1 on Pipe 1)	$L_{o1.1} = 100\,ft$	Station of Orifice 1.1 on Pipe 1
$D_{o1.2} = 7.5\,ft$	Orifice 1.2 (Orifice 2 on Pipe 1)	$L_{o1.2} = 140\,ft$	Station of Orifice 1.2 on Pipe 1
$D_{o2.1} = 5.5\,ft$	Orifice 2.1 (Orifice 1 on Pipe 2)	$L_{o2.1} = 45\,ft$	Station of Orifce 2.1 on Pipe 2
$D_{o3.1} = 5.5\,ft$	Orifce 3.1 (Orifice 1 on Pipe 3)	$L_{o3.1} = 45\,ft$	Station of Orifice 3.1 on Pipe 3

Air Inlets

Air inlets shall be installed downstream of orifices. To be designed.

Bends

Bends shall have a radius of bending to diameter of pipe ratio equal to or greater than 1.0 except for bend 1.3 which requires a bend ratio of 1.5. Bends shall not be mitered if possible. If mitered bends are determined necessary, maximum number of miters constructably feasible are desired.

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Sensitivity Factors $\alpha_k = 1$ Minor loss factor $\alpha_f = 10$ Equivalent sand grain roughness factor

Flowrates

$Q_{d1} = 1385 \cdot cfs$	Design flow rate (low forebay) - Pipe 1	$Q_{m1} = 1506 \cdot cfs$	Max flow rate (high forebay) - Pipe 1
$Q_{d2} = 692\ cfs$	Design flow rate (low forebay) - Pipe 2	$Q_{m2} = 753 \cdot cfs$	Max flow rate (high forebay) - Pipe 2
$Q_{d3} = 692 \cdot cfs$	Design flow rate (low forebay) - Pipe 3	$Q_{m3} = 753 \cdot cfs$	Max flow rate (high forebay) - Pipe 3

Headlosses

Pipe 1

Design Flow	Max Flow	
$H_1(Q_{d1}) = 29.2\,ft$	$H_1(Q_{m1}) = 34.5\,ft$	Total losses thru Pipe 1
$h_t = 0.25\,ft$	$h_t = 0.25\,ft$	Trashrack loss
$K_e \cdot hv_1(Q_{d1}) = 0.77\,ft$	$K_e \cdot hv_1(Q_{m1}) = 0.91\,ft$	Entrance loss
$K_{bfv} \cdot hv_1(Q_{d1}) = 0.97\,ft$	$K_{bfv} \cdot hv_1(Q_{m1}) = 1.14\,ft$	Butterfly valve loss
$K_{b\_b1} \cdot hv_1(Q_{d1}) = 1.54\,ft$	$K_{b\_b1} \cdot hv_1(Q_{m1}) = 1.82\,ft$	Combinded bend loss
$K_{o1.1} \cdot hv_1(Q_{d1}) = 12.64\,ft$	$K_{o1.1} \cdot hv_1(Q_{m1}) = 14.95\,ft$	Orifice loss 1.1
$K_{o1.2} \cdot hv_1(Q_{d1}) = 11.42\,ft$	$K_{o1.2} \cdot hv_1(Q_{m1}) = 13.51\,ft$	Orifice loss 1.2
$K_{b1.3} \cdot hv_1(Q_{d1}) = 0.54\,ft$	$K_{b1.3} \cdot hv_1(Q_{m1}) = 0.64\,ft$	Bend loss 1.3
$f_1(Q_{d1}) \cdot hv_1(Q_{d1}) = 1.0797\,ft$	$f_1(Q_{m1}) \cdot hv_1(Q_{m1}) = 1.2757\,ft$	Total frictional loss
$hv_1(Q_{d1}) = 4.83\,ft$	$hv_1(Q_{m1}) = 5.72\,ft$	Velocity head within the pipe

Pipe 2

Design Flow	Max Flow	
$H_2(Q_{d2}) = 15.19\,ft$	$H_2(Q_{m2}) = 17.97\,ft$	Total head loss in Pipe 2
$K_{31}\cdot hv_2(Q_{d2}) = 0.57\,ft$	$K_{31}\cdot hv_2(Q_{m2}) = 0.68\,ft$	Y loss to Pipe 2
$K_{b\_b2.1}\cdot hv_2(Q_{d2}) = 0.2\,ft$	$K_{b\_b2.1}\cdot hv_2(Q_{m2}) = 0.23\,ft$	Combined bend loss
$K_{o2.1}\cdot hv_2(Q_{d2}) = 10.69\,ft$	$K_{o2.1}\cdot hv_2(Q_{m2}) = 12.64\,ft$	Orifice loss 2.1
$K_{b2.2}\cdot hv_2(Q_{d2}) = 3.04\,ft$	$K_{b2.2}\cdot hv_2(Q_{m2}) = 3.59\,ft$	Bend loss 2.2
$f_2(Q_{d2})\cdot hv_2(Q_{d2}) = 0.7\,ft$	$f_2(Q_{m2})\cdot hv_2(Q_{m2}) = 0.82\,ft$	Total friction loss for Pipe 2
$hv_2(Q_{d2}) = 3.82\,ft$	$hv_2(Q_{m2}) = 4.52\,ft$	Velocity head within the pipe
$Fr_2(Q_{d2}) = 1.01$	$Fr_2(Q_{m2}) = 1.1$	Froude exiting pipe 2

Pipe 3

Design Flow	Max Flow	
$H_3(Q_{d3}) = 15.19\,ft$	$H_3(Q_{m3}) = 17.97\,ft$	Total head loss in Pipe 3
$K_{31}\cdot hv_3(Q_{d3}) = 0.57\,ft$	$K_{31}\cdot hv_3(Q_{m3}) = 0.68\,ft$	Y loss to Pipe 3
$K_{b\_b3.1}\cdot hv_3(Q_{d3}) = 0.2\,ft$	$K_{b\_b3.1}\cdot hv_3(Q_{m3}) = 0.23\,ft$	Combined bend loss
$K_{o3.1}\cdot hv_3(Q_{d3}) = 10.69\,ft$	$K_{o3.1}\cdot hv_3(Q_{m3}) = 12.64\,ft$	Orifice loss 3.1
$K_{b3.2}\cdot hv_3(Q_{d3}) = 3.04\,ft$	$K_{b3.2}\cdot hv_3(Q_{m3}) = 3.59\,ft$	Bend loss 3.2
$f_3(Q)\cdot hv_3(Q_{d3}) = 0.7\,ft$	$f_3(Q)\cdot hv_3(Q_{m3}) = 0.82\,ft$	Total friction loss for Pipe 3
$hv_3(Q_{d3}) = 3.82\,ft$	$hv_3(Q_{m3}) = 4.52\,ft$	Velocity head within the pipe
$Fr_3(Q_{d3}) = 1.01$	$Fr_3(Q_{m3}) = 1.1$	Froude exiting pipe 3

Reactionary Forces

Forces in X direction as shown	Forces in flow direction as shown	Forces in Y direction as shown	
$F_{b1.1x} = 116.42 \cdot kip$		$F_{b1.1y} = -193.58 \cdot kip$	Bend 1.1
$F_{b1.2x} = 143.27 \cdot kip$		$F_{b1.2y} = 240.9 \cdot kip$	Bend 1.2
	$F_{o1.1} = 174.6 \cdot kip$		Orifice 1.1
	$F_{o1.2} = 133.73 \cdot kip$		Orifice 1.2
$F_{b1.3x} = 43.63 \cdot kip$		$F_{b1.3y} = -105.34 \cdot kip$	Bend 1.3
	$F_{wye} = -0.65 \cdot kip$		Wye - Note that force is considered in the X direction only
$F_{b2.1x} = 11.03 \cdot kip$		$F_{b2.1y} = 38.76 \cdot kip$	Bend 2.1
	$F_{o2.1} = 56.39 \cdot kip$		Orifice 2.1
$F_{b2.2x} = 41.82 \cdot kip$		$F_{b2.2y} = 41.82 \cdot kip$	Bend 2.2
$F_{b3.1x} = 11.03 \cdot kip$		$F_{b3.1y} = -38.76 \cdot kip$	Bend 3.1
	$F_{o3.1} = 56.39 \cdot kip$		Orifice 3.1
$F_{b3.2x} = 41.1 \cdot kip$		$F_{b3.2y} = 8.31 \cdot kip$	Bend 3.2

Cavitation Potential Summary

$bendcav_{1.1}$ = "Bend radius ok"

$bendcav_{1.2}$ = "Bend radius ok"

$bendcav_{1.3}$ = "Bend radius ok"

$bendcav_{2.1}$ = "Bend radius ok"

$bendcav_{2.2}$ = "Incipient cavitation initiated"

Bend 2.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$bendcav_{3.1}$ = "Bend radius ok"

$bendcav_{3.2}$ = "Incipient cavitation initiated"

Bend 3.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$check\_\sigma_{i\_1.1}$ = "check next"

Orifice 1.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.1}$ = "ok"

$check\_\sigma_{id\_1.1}$ = "ok"

$check\_\sigma_{ch\_1.1}$ = "ok"

$check\_\sigma_{i\_1.2}$ = "check next"

Orifice 1.2 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.2}$ = "ok"

$check\_\sigma_{id\_1.2}$ = "ok"

$check\_\sigma_{ch\_1.2}$ = "ok"

$check\_\sigma_{i\_2.1}$ = "check next"

Orifice 2.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_2.1}$ = "ok"

$check\_\sigma_{id\_2.1}$ = "ok"

$check\_\sigma_{ch\_2.1}$ = "ok"

$check\_\sigma_{i\_3.1}$ = "check next"

Orifice 3.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_3.1}$ = "ok"

$check\_\sigma_{id\_3.1}$ = "ok"

$check\_\sigma_{ch\_3.1}$ = "ok"

Clearances

$Ele_{bop2} = 94.75\,ft$ Elevation of the bottom of pipe 2 at fishladder crossing

$Ele_{bop3} = 94.75\,ft$ Elevation of the bottom of pipe 3 at fishladder crossing

$\Delta EFL_{ent} := 1.3ft$ Maximum differential at fish ladder entrance

$\Delta EFL_{diff} := 2.2ft$ Maximum head on diffusers from AWSC

$TW_{min} := 74.0ft$ Minimum tailwater at which the backup AWS operates

$TW_{high} := 86.0ft$ Maximum tailwater at which the backup AWS operates

$TW_{max} := 90.0ft$ Maximum tailwater at which EFL maintains criteria

$Ele_{bop2} - TW_{high} - \Delta EFL_{ent} = 7.45\,ft$ Clearance of water in fishladder to bottom of pipe 2 at emergency AWS backup high tailwater operation

$Ele_{bop2} - TW_{max} - \Delta EFL_{ent} = 3.45\,ft$ Clearance of water in fishladder to bottom of pipe 2 at max tailwater EFL operation point

Hydraulic Design Summary

Entrance Bell

Concentric eliptical bell entrance with a 5-ft primary radius and 1.5-ft secondary entrance base on guidance from EM 1110-2-1602 (Section 3-7)

Conduit

Steel, lined against corrosion with cavitation resistant material.

$k = 0.000008\,ft$ Design equivalent sand grain roughness

$D_1 = 10\,ft$	Diameter of Pipe 1	$L_1 = 190\,ft$	Length of Pipe 1
$D_2 = 7.5\,ft$	Diameter of Pipe 2	$L_2 = 110\,ft$	Length of Pipe 2
$D_3 = 7.5\,ft$	Diameter of Pipe 3	$L_3 = 110\,ft$	Length of Pipe 3

Appurtenances

Valves

One 10 ft butterfly valve (concentric) will be used at the downstream face of the dam as secondary flow closure.

Orifices

Orifices shall have openings at the invert of the pipe to allow for drainage of conduit during system shutdown.

$D_{o1.1} = 7.4\,ft$	Orifice 1.1 (Orifice 1 on Pipe 1)	$L_{o1.1} = 100\,ft$	Station of Orifice 1.1 on Pipe 1
$D_{o1.2} = 7.5\,ft$	Orifice 1.2 (Orifice 2 on Pipe 1)	$L_{o1.2} = 140\,ft$	Station of Orifice 1.2 on Pipe 1
$D_{o2.1} = 5.5\,ft$	Orifice 2.1 (Orifice 1 on Pipe 2)	$L_{o2.1} = 45\,ft$	Station of Orifce 2.1 on Pipe 2
$D_{o3.1} = 5.5\,ft$	Orifce 3.1 (Orifice 1 on Pipe 3)	$L_{o3.1} = 45\,ft$	Station of Orifice 3.1 on Pipe 3

Air Inlets

Air inlets shall be installed downstream of orifices. To be designed.

Bends

Bends shall have a radius of bending to diameter of pipe ratio equal to or greater than 1.0 except for bend 1.3 which requires a bend ratio of 1.5. Bends shall not be mitered if possible. If mitered bends are determined necessary, maximum number of miters constructably feasible are desired.

Sensitivity Factors $\alpha_k = 1$ Minor loss factor $\alpha_f = 0.1$ Equivalent sand grain roughness factor

Flowrates

$Q_{d1} = 1391 \cdot cfs$	Design flow rate (low forebay) - Pipe 1	$Q_{m1} = 1513 \cdot cfs$	Max flow rate (high forebay) - Pipe 1
$Q_{d2} = 695\,cfs$	Design flow rate (low forebay) - Pipe 2	$Q_{m2} = 756 \cdot cfs$	Max flow rate (high forebay) - Pipe 2
$Q_{d3} = 695 \cdot cfs$	Design flow rate (low forebay) - Pipe 3	$Q_{m3} = 756 \cdot cfs$	Max flow rate (high forebay) - Pipe 3

Headlosses

Pipe 1

Design Flow	Max Flow	
$H_1(Q_{d1}) = 29.1\,ft$	$H_1(Q_{m1}) = 34.38\,ft$	Total losses thru Pipe 1
$h_t = 0.25\,ft$	$h_t = 0.25\,ft$	Trashrack loss
$K_e \cdot hv_1(Q_{d1}) = 0.78\,ft$	$K_e \cdot hv_1(Q_{m1}) = 0.92\,ft$	Entrance loss
$K_{bfv} \cdot hv_1(Q_{d1}) = 0.97\,ft$	$K_{bfv} \cdot hv_1(Q_{m1}) = 1.15\,ft$	Butterfly valve loss
$K_{b\_b1} \cdot hv_1(Q_{d1}) = 1.55\,ft$	$K_{b\_b1} \cdot hv_1(Q_{m1}) = 1.83\,ft$	Combinded bend loss
$K_{o1.1} \cdot hv_1(Q_{d1}) = 12.75\,ft$	$K_{o1.1} \cdot hv_1(Q_{m1}) = 15.08\,ft$	Orifice loss 1.1
$K_{o1.2} \cdot hv_1(Q_{d1}) = 11.52\,ft$	$K_{o1.2} \cdot hv_1(Q_{m1}) = 13.62\,ft$	Orifice loss 1.2
$K_{b1.3} \cdot hv_1(Q_{d1}) = 0.54\,ft$	$K_{b1.3} \cdot hv_1(Q_{m1}) = 0.64\,ft$	Bend loss 1.3
$f_1(Q_{d1}) \cdot hv_1(Q_{d1}) = 0.7411\,ft$	$f_1(Q_{m1}) \cdot hv_1(Q_{m1}) = 0.8676\,ft$	Total frictional loss
$hv_1(Q_{d1}) = 4.87\,ft$	$hv_1(Q_{m1}) = 5.77\,ft$	Velocity head within the pipe

Pipe 2

Design Flow	Max Flow	
$H_2(Q_{d2}) = 15.1\,ft$	$H_2(Q_{m2}) = 17.86\,ft$	Total head loss in Pipe 2
$K_{31} \cdot hv_2(Q_{d2}) = 0.58\,ft$	$K_{31} \cdot hv_2(Q_{m2}) = 0.68\,ft$	Y loss to Pipe 2
$K_{b\_b2.1} \cdot hv_2(Q_{d2}) = 0.2\,ft$	$K_{b\_b2.1} \cdot hv_2(Q_{m2}) = 0.24\,ft$	Combined bend loss
$K_{o2.1} \cdot hv_2(Q_{d2}) = 10.78\,ft$	$K_{o2.1} \cdot hv_2(Q_{m2}) = 12.76\,ft$	Orifice loss 2.1
$K_{b2.2} \cdot hv_2(Q_{d2}) = 3.06\,ft$	$K_{b2.2} \cdot hv_2(Q_{m2}) = 3.62\,ft$	Bend loss 2.2
$f_2(Q_{d2}) \cdot hv_2(Q_{d2}) = 0.48\,ft$	$f_2(Q_{m2}) \cdot hv_2(Q_{m2}) = 0.56\,ft$	Total friction loss for Pipe 2
$hv_2(Q_{d2}) = 3.85\,ft$	$hv_2(Q_{m2}) = 4.56\,ft$	Velocity head within the pipe
$Fr_2(Q_{d2}) = 1.01$	$Fr_2(Q_{m2}) = 1.1$	Froude exiting pipe 2

Pipe 3

Design Flow	Max Flow	
$H_3(Q_{d3}) = 15.1\,ft$	$H_3(Q_{m3}) = 17.86\,ft$	Total head loss in Pipe 3
$K_{31} \cdot hv_3(Q_{d3}) = 0.58\,ft$	$K_{31} \cdot hv_3(Q_{m3}) = 0.68\,ft$	Y loss to Pipe 3
$K_{b\_b3.1} \cdot hv_3(Q_{d3}) = 0.2\,ft$	$K_{b\_b3.1} \cdot hv_3(Q_{m3}) = 0.24\,ft$	Combined bend loss
$K_{o3.1} \cdot hv_3(Q_{d3}) = 10.78\,ft$	$K_{o3.1} \cdot hv_3(Q_{m3}) = 12.76\,ft$	Orifice loss 3.1
$K_{b3.2} \cdot hv_3(Q_{d3}) = 3.06\,ft$	$K_{b3.2} \cdot hv_3(Q_{m3}) = 3.62\,ft$	Bend loss 3.2
$f_3(Q) \cdot hv_3(Q_{d3}) = 0.47\,ft$	$f_3(Q) \cdot hv_3(Q_{m3}) = 0.56\,ft$	Total friction loss for Pipe 3
$hv_3(Q_{d3}) = 3.85\,ft$	$hv_3(Q_{m3}) = 4.56\,ft$	Velocity head within the pipe
$Fr_3(Q_{d3}) = 1.01$	$Fr_3(Q_{m3}) = 1.1$	Froude exiting pipe 3

Reactionary Forces

Forces in X direction as shown	Forces in flow direction as shown	Forces in Y direction as shown	
$F_{b1.1x} = 116.68 \cdot kip$		$F_{b1.1y} = -194.04 \cdot kip$	Bend 1.1
$F_{b1.2x} = 143.53 \cdot kip$		$F_{b1.2y} = 241.36 \cdot kip$	Bend 1.2
	$F_{o1.1} = 175.08 \cdot kip$		Orifice 1.1
	$F_{o1.2} = 134.38 \cdot kip$		Orifice 1.2
$F_{b1.3x} = 44.32 \cdot kip$		$F_{b1.3y} = -106.99 \cdot kip$	Bend 1.3
	$F_{wye} = -1.17 \cdot kip$		Wye - Note that force is considered in the X direction only
$F_{b2.1x} = 11.19 \cdot kip$		$F_{b2.1y} = 39.39 \cdot kip$	Bend 2.1
	$F_{o2.1} = 57.06 \cdot kip$		Orifice 2.1
$F_{b2.2x} = 43.45 \cdot kip$		$F_{b2.2y} = 43.45 \cdot kip$	Bend 2.2
$F_{b3.1x} = 11.19 \cdot kip$		$F_{b3.1y} = -39.39 \cdot kip$	Bend 3.1
	$F_{o3.1} = 57.06 \cdot kip$		Orifice 3.1
$F_{b3.2x} = 42.97 \cdot kip$		$F_{b3.2y} = 6.44 \cdot kip$	Bend 3.2

Cavitation Potential Summary

$bendcav_{1.1}$ = "Bend radius ok"

$bendcav_{1.2}$ = "Bend radius ok"

$bendcav_{1.3}$ = "Bend radius ok"

$bendcav_{2.1}$ = "Bend radius ok"

$bendcav_{2.2}$ = "Incipient cavitation initiated"

Bend 2.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$bendcav_{3.1}$ = "Bend radius ok"

$bendcav_{3.2}$ = "Incipient cavitation initiated"

Bend 3.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$check\_\sigma_{i\_1.1}$ = "check next"

Orifice 1.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.1}$ = "ok"

$check\_\sigma_{id\_1.1}$ = "ok"

$check\_\sigma_{ch\_1.1}$ = "ok"

$check\_\sigma_{i\_1.2}$ = "check next"

Orifice 1.2 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.2}$ = "ok"

$check\_\sigma_{id\_1.2}$ = "ok"

$check\_\sigma_{ch\_1.2}$ = "ok"

$check\_\sigma_{i\_2.1}$ = "check next"

Orifice 2.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_2.1}$ = "ok"

$check\_\sigma_{id\_2.1}$ = "ok"

$check\_\sigma_{ch\_2.1}$ = "ok"

$check\_\sigma_{i\_3.1}$ = "check next"

Orifice 3.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_3.1}$ = "ok"

$check\_\sigma_{id\_3.1}$ = "ok"

$check\_\sigma_{ch\_3.1}$ = "ok"

Clearances

$Ele_{bop2} = 94.75\,ft$ Elevation of the bottom of pipe 2 at fishladder crossing

$Ele_{bop3} = 94.75\,ft$ Elevation of the bottom of pipe 3 at fishladder crossing

$\Delta EFL_{ent} := 1.3ft$ Maximum differential at fish ladder entrance

$\Delta EFL_{diff} := 2.2ft$ Maximum head on diffusers from AWSC

$TW_{min} := 74.0ft$ Minimum tailwater at which the backup AWS operates

$TW_{high} := 86.0ft$ Maximum tailwater at which the backup AWS operates

$TW_{max} := 90.0ft$ Maximum tailwater at which EFL maintains criteria

$Ele_{bop2} - TW_{high} - \Delta EFL_{ent} = 7.45\,ft$ Clearance of water in fishladder to bottom of pipe 2 at emergency AWS backup high tailwater operation

$Ele_{bop2} - TW_{max} - \Delta EFL_{ent} = 3.45\,ft$ Clearance of water in fishladder to bottom of pipe 2 at max tailwater EFL operation point

Hydraulic Design Summary

Entrance Bell

Concentric eliptical bell entrance with a 5-ft primary radius and 1.5-ft secondary entrance base on guidance from EM 1110-2-1602 (Section 3-7)

Conduit

Steel, lined against corrosion with cavitation resistant material.

$k = 0.00082\,ft$ Design equivalent sand grain roughness

$D_1 = 10\,ft$	Diameter of Pipe 1	$L_1 = 190\,ft$	Length of Pipe 1
$D_2 = 7.5\,ft$	Diameter of Pipe 2	$L_2 = 110\,ft$	Length of Pipe 2
$D_3 = 7.5\,ft$	Diameter of Pipe 3	$L_3 = 110\,ft$	Length of Pipe 3

Appurtenances

Valves

One 10 ft butterfly valve (concentric) will be used at the downstream face of the dam as secondary flow closure.

Orifices

Orifices shall have openings at the invert of the pipe to allow for drainage of conduit during system shutdown.

$D_{o1.1} = 7.4\,ft$	Orifice 1.1 (Orifice 1 on Pipe 1)	$L_{o1.1} = 100\,ft$	Station of Orifice 1.1 on Pipe 1
$D_{o1.2} = 7.5\,ft$	Orifice 1.2 (Orifice 2 on Pipe 1)	$L_{o1.2} = 140\,ft$	Station of Orifice 1.2 on Pipe 1
$D_{o2.1} = 5.5\,ft$	Orifice 2.1 (Orifice 1 on Pipe 2)	$L_{o2.1} = 45\,ft$	Station of Orifce 2.1 on Pipe 2
$D_{o3.1} = 5.5\,ft$	Orifce 3.1 (Orifice 1 on Pipe 3)	$L_{o3.1} = 45\,ft$	Station of Orifice 3.1 on Pipe 3

Air Inlets

Air inlets shall be installed downstream of orifices. To be designed.

Bends

Bends shall have a radius of bending to diameter of pipe ratio equal to or greater than 1.0 except for bend 1.3 which requires a bend ratio of 1.5. Bends shall not be mitered if possible. If mitered bends are determined necessary, maximum number of miters constructably feasible are desired.

Sensitivity Factors $\alpha_k = 0.9$ Minor loss factor $\alpha_f = 10$ Equivalent sand grain roughness factor

Flowrates

$Q_{d1} = 1453 \cdot cfs$	Design flow rate (low forebay) - Pipe 1	$Q_{m1} = 1579 \cdot cfs$	Max flow rate (high forebay) - Pipe 1
$Q_{d2} = 727\ cfs$	Design flow rate (low forebay) - Pipe 2	$Q_{m2} = 790 \cdot cfs$	Max flow rate (high forebay) - Pipe 2
$Q_{d3} = 727 \cdot cfs$	Design flow rate (low forebay) - Pipe 3	$Q_{m3} = 790 \cdot cfs$	Max flow rate (high forebay) - Pipe 3

Headlosses

Pipe 1

Design Flow	Max Flow	
$H_1(Q_{d1}) = 29.15\ ft$	$H_1(Q_{m1}) = 34.38\ ft$	Total losses thru Pipe 1
$h_t = 0.25\ ft$	$h_t = 0.25\ ft$	Trashrack loss
$K_e \cdot hv_1(Q_{d1}) = 0.85\ ft$	$K_e \cdot hv_1(Q_{m1}) = 1.01\ ft$	Entrance loss
$K_{bfv} \cdot hv_1(Q_{d1}) = 0.96\ ft$	$K_{bfv} \cdot hv_1(Q_{m1}) = 1.13\ ft$	Butterfly valve loss
$K_{b\_b1} \cdot hv_1(Q_{d1}) = 1.52\ ft$	$K_{b\_b1} \cdot hv_1(Q_{m1}) = 1.8\ ft$	Combinded bend loss
$K_{o1.1} \cdot hv_1(Q_{d1}) = 12.53\ ft$	$K_{o1.1} \cdot hv_1(Q_{m1}) = 14.8\ ft$	Orifice loss 1.1
$K_{o1.2} \cdot hv_1(Q_{d1}) = 11.32\ ft$	$K_{o1.2} \cdot hv_1(Q_{m1}) = 13.37\ ft$	Orifice loss 1.2
$K_{b1.3} \cdot hv_1(Q_{d1}) = 0.53\ ft$	$K_{b1.3} \cdot hv_1(Q_{m1}) = 0.63\ ft$	Bend loss 1.3
$f_1(Q_{d1}) \cdot hv_1(Q_{d1}) = 1.1884\ ft$	$f_1(Q_{m1}) \cdot hv_1(Q_{m1}) = 1.4016\ ft$	Total frictional loss
$hv_1(Q_{d1}) = 5.32\ ft$	$hv_1(Q_{m1}) = 6.28\ ft$	Velocity head within the pipe

Pipe 2

Design Flow	Max Flow	
$H_2(Q_{d2}) = 15.14\,ft$	$H_2(Q_{m2}) = 17.87\,ft$	Total head loss in Pipe 2
$K_{31} \cdot hv_2(Q_{d2}) = 0.57\,ft$	$K_{31} \cdot hv_2(Q_{m2}) = 0.67\,ft$	Y loss to Pipe 2
$K_{b\_b2.1} \cdot hv_2(Q_{d2}) = 0.2\,ft$	$K_{b\_b2.1} \cdot hv_2(Q_{m2}) = 0.23\,ft$	Combined bend loss
$K_{o2.1} \cdot hv_2(Q_{d2}) = 10.6\,ft$	$K_{o2.1} \cdot hv_2(Q_{m2}) = 12.51\,ft$	Orifice loss 2.1
$K_{b2.2} \cdot hv_2(Q_{d2}) = 3.01\,ft$	$K_{b2.2} \cdot hv_2(Q_{m2}) = 3.56\,ft$	Bend loss 2.2
$f_2(Q_{d2}) \cdot hv_2(Q_{d2}) = 0.77\,ft$	$f_2(Q_{m2}) \cdot hv_2(Q_{m2}) = 0.9\,ft$	Total friction loss for Pipe 2
$hv_2(Q_{d2}) = 4.2\,ft$	$hv_2(Q_{m2}) = 4.97\,ft$	Velocity head within the pipe
$Fr_2(Q_{d2}) = 1.06$	$Fr_2(Q_{m2}) = 1.15$	Froude exiting pipe 2

Pipe 3

Design Flow	Max Flow	
$H_3(Q_{d3}) = 15.14\,ft$	$H_3(Q_{m3}) = 17.87\,ft$	Total head loss in Pipe 3
$K_{31} \cdot hv_3(Q_{d3}) = 0.57\,ft$	$K_{31} \cdot hv_3(Q_{m3}) = 0.67\,ft$	Y loss to Pipe 3
$K_{b\_b3.1} \cdot hv_3(Q_{d3}) = 0.2\,ft$	$K_{b\_b3.1} \cdot hv_3(Q_{m3}) = 0.23\,ft$	Combined bend loss
$K_{o3.1} \cdot hv_3(Q_{d3}) = 10.6\,ft$	$K_{o3.1} \cdot hv_3(Q_{m3}) = 12.51\,ft$	Orifice loss 3.1
$K_{b3.2} \cdot hv_3(Q_{d3}) = 3.01\,ft$	$K_{b3.2} \cdot hv_3(Q_{m3}) = 3.56\,ft$	Bend loss 3.2
$f_3(Q) \cdot hv_3(Q_{d3}) = 0.77\,ft$	$f_3(Q) \cdot hv_3(Q_{m3}) = 0.91\,ft$	Total friction loss for Pipe 3
$hv_3(Q_{d3}) = 4.2\,ft$	$hv_3(Q_{m3}) = 4.97\,ft$	Velocity head within the pipe
$Fr_3(Q_{d3}) = 1.06$	$Fr_3(Q_{m3}) = 1.15$	Froude exiting pipe 3

Reactionary Forces

Forces in X direction as shown	Forces in flow direction as shown	Forces in Y direction as shown	
$F_{b1.1x} = 116.46 \cdot kip$		$F_{b1.1y} = -194.47 \cdot kip$	Bend 1.1
$F_{b1.2x} = 143.57 \cdot kip$		$F_{b1.2y} = 242.14 \cdot kip$	Bend 1.2
	$F_{o1.1} = 171.27 \cdot kip$		Orifice 1.1
	$F_{o1.2} = 133.85 \cdot kip$		Orifice 1.2
$F_{b1.3x} = 48.11 \cdot kip$		$F_{b1.3y} = -116.14 \cdot kip$	Bend 1.3
	$F_{wye} = -2.97 \cdot kip$		Wye - Note that force is considered in the X direction only
$F_{b2.1x} = 12.17 \cdot kip$		$F_{b2.1y} = 43.27 \cdot kip$	Bend 2.1
	$F_{o2.1} = 58.7 \cdot kip$		Orifice 2.1
$F_{b2.2x} = 54.29 \cdot kip$		$F_{b2.2y} = 54.29 \cdot kip$	Bend 2.2
$F_{b3.1x} = 12.17 \cdot kip$		$F_{b3.1y} = -43.27 \cdot kip$	Bend 3.1
	$F_{o3.1} = 58.7 \cdot kip$		Orifice 3.1
$F_{b3.2x} = 53.58 \cdot kip$		$F_{b3.2y} = -4.17 \cdot kip$	Bend 3.2

Cavitation Potential Summary

$bendcav_{1.1}$ = "Bend radius ok"

$bendcav_{1.2}$ = "Bend radius ok"

$bendcav_{1.3}$ = "Bend radius ok"

$bendcav_{2.1}$ = "Bend radius ok"

$bendcav_{2.2}$ = "Bend radius ok"

Bend 2.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$bendcav_{3.1}$ = "Bend radius ok"

$bendcav_{3.2}$ = "Bend radius ok"

Bend 3.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$check\_\sigma_{i\_1.1}$ = "check next"

Orifice 1.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.1}$ = "ok"

$check\_\sigma_{id\_1.1}$ = "ok"

$check\_\sigma_{ch\_1.1}$ = "ok"

$check\_\sigma_{i\_1.2}$ = "check next"

Orifice 1.2 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.2}$ = "ok"

$check\_\sigma_{id\_1.2}$ = "ok"

$check\_\sigma_{ch\_1.2}$ = "ok"

$check\_\sigma_{i\_2.1}$ = "check next"

Orifice 2.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_2.1}$ = "ok"

$check\_\sigma_{id\_2.1}$ = "ok"

$check\_\sigma_{ch\_2.1}$ = "ok"

$check\_\sigma_{i\_3.1}$ = "check next"

Orifice 3.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_3.1}$ = "ok"

$check\_\sigma_{id\_3.1}$ = "ok"

$check\_\sigma_{ch\_3.1}$ = "ok"

Clearances

$Ele_{bop2} = 94.75\,ft$ Elevation of the bottom of pipe 2 at fishladder crossing

$Ele_{bop3} = 94.75\,ft$ Elevation of the bottom of pipe 3 at fishladder crossing

$\Delta EFL_{ent} := 1.3ft$ Maximum differential at fish ladder entrance

$\Delta EFL_{diff} := 2.2ft$ Maximum head on diffusers from AWSC

$TW_{min} := 74.0ft$ Minimum tailwater at which the backup AWS operates

$TW_{high} := 86.0ft$ Maximum tailwater at which the backup AWS operates

$TW_{max} := 90.0ft$ Maximum tailwater at which EFL maintains criteria

$Ele_{bop2} - TW_{high} - \Delta EFL_{ent} = 7.45\,ft$ Clearance of water in fishladder to bottom of pipe 2 at emergency AWS backup high tailwater operation

$Ele_{bop2} - TW_{max} - \Delta EFL_{ent} = 3.45\,ft$ Clearance of water in fishladder to bottom of pipe 2 at max tailwater EFL operation point

Project Title: Dalles EFL Emergency AWS - Energy Dissipation	12/19/2013	By: Logan Negherbon Checked By: Ryan Laughery

Hydraulic Design Summary

Entrance Bell

Concentric eliptical bell entrance with a 5-ft primary radius and 1.5-ft secondary entrance base on guidance from EM 1110-2-1602 (Section 3-7)

Conduit

Steel, lined against corrosion with cavitation resistant material.

$k = 0.000082\,ft$ Design equivalent sand grain roughness

$D_1 = 10\,ft$	Diameter of Pipe 1	$L_1 = 190\,ft$	Length of Pipe 1
$D_2 = 7.5\,ft$	Diameter of Pipe 2	$L_2 = 110\,ft$	Length of Pipe 2
$D_3 = 7.5\,ft$	Diameter of Pipe 3	$L_3 = 110\,ft$	Length of Pipe 3

Appurtenances

Valves

One 10 ft butterfly valve (concentric) will be used at the downstream face of the dam as secondary flow closure.

Orifices

Orifices shall have openings at the invert of the pipe to allow for drainage of conduit during system shutdown.

$D_{o1.1} = 7.4\,ft$	Orifice 1.1 (Orifice 1 on Pipe 1)	$L_{o1.1} = 100\,ft$	Station of Orifice 1.1 on Pipe 1
$D_{o1.2} = 7.5\,ft$	Orifice 1.2 (Orifice 2 on Pipe 1)	$L_{o1.2} = 140\,ft$	Station of Orifice 1.2 on Pipe 1
$D_{o2.1} = 5.5\,ft$	Orifice 2.1 (Orifice 1 on Pipe 2)	$L_{o2.1} = 45\,ft$	Station of Orifce 2.1 on Pipe 2
$D_{o3.1} = 5.5\,ft$	Orifce 3.1 (Orifice 1 on Pipe 3)	$L_{o3.1} = 45\,ft$	Station of Orifice 3.1 on Pipe 3

Air Inlets

Air inlets shall be installed downstream of orifices. To be designed.

Bends

Bends shall have a radius of bending to diameter of pipe ratio equal to or greater than 1.0 except for bend 1.3 which requires a bend ratio of 1.5. Bends shall not be mitered if possible. If mitered bends are determined necessary, maximum number of miters constructably feasible are desired.

Sensitivity Factors $\alpha_k = 0.9$ Minor loss factor $\alpha_f = 1$ Equivalent sand grain roughness factor

Flowrates

$Q_{d1} = 1459 \cdot cfs$	Design flow rate (low forebay) - Pipe 1	$Q_{m1} = 1585 \cdot cfs$	Max flow rate (high forebay) - Pipe 1
$Q_{d2} = 729\,cfs$	Design flow rate (low forebay) - Pipe 2	$Q_{m2} = 793 \cdot cfs$	Max flow rate (high forebay) - Pipe 2
$Q_{d3} = 729 \cdot cfs$	Design flow rate (low forebay) - Pipe 3	$Q_{m3} = 793 \cdot cfs$	Max flow rate (high forebay) - Pipe 3

Headlosses

Pipe 1

Design Flow	Max Flow	
$H_1(Q_{d1}) = 29.06\,ft$	$H_1(Q_{m1}) = 34.27\,ft$	Total losses thru Pipe 1
$h_t = 0.25\,ft$	$h_t = 0.25\,ft$	Trashrack loss
$K_e \cdot hv_1(Q_{d1}) = 0.86\,ft$	$K_e \cdot hv_1(Q_{m1}) = 1.01\,ft$	Entrance loss
$K_{bfv} \cdot hv_1(Q_{d1}) = 0.97\,ft$	$K_{bfv} \cdot hv_1(Q_{m1}) = 1.14\,ft$	Butterfly valve loss
$K_{b\_b1} \cdot hv_1(Q_{d1}) = 1.54\,ft$	$K_{b\_b1} \cdot hv_1(Q_{m1}) = 1.81\,ft$	Combinded bend loss
$K_{o1.1} \cdot hv_1(Q_{d1}) = 12.63\,ft$	$K_{o1.1} \cdot hv_1(Q_{m1}) = 14.91\,ft$	Orifice loss 1.1
$K_{o1.2} \cdot hv_1(Q_{d1}) = 11.4\,ft$	$K_{o1.2} \cdot hv_1(Q_{m1}) = 13.47\,ft$	Orifice loss 1.2
$K_{b1.3} \cdot hv_1(Q_{d1}) = 0.54\,ft$	$K_{b1.3} \cdot hv_1(Q_{m1}) = 0.64\,ft$	Bend loss 1.3
$f_1(Q_{d1}) \cdot hv_1(Q_{d1}) = 0.8902\,ft$	$f_1(Q_{m1}) \cdot hv_1(Q_{m1}) = 1.0449\,ft$	Total frictional loss
$hv_1(Q_{d1}) = 5.36\,ft$	$hv_1(Q_{m1}) = 6.33\,ft$	Velocity head within the pipe

Pipe 2

Design Flow	Max Flow	
$H_2(Q_{d2}) = 15.05\,ft$	$H_2(Q_{m2}) = 17.77\,ft$	Total head loss in Pipe 2
$K_{31} \cdot hv_2(Q_{d2}) = 0.57\,ft$	$K_{31} \cdot hv_2(Q_{m2}) = 0.68\,ft$	Y loss to Pipe 2
$K_{b\_b2.1} \cdot hv_2(Q_{d2}) = 0.2\,ft$	$K_{b\_b2.1} \cdot hv_2(Q_{m2}) = 0.23\,ft$	Combined bend loss
$K_{o2.1} \cdot hv_2(Q_{d2}) = 10.68\,ft$	$K_{o2.1} \cdot hv_2(Q_{m2}) = 12.61\,ft$	Orifice loss 2.1
$K_{b2.2} \cdot hv_2(Q_{d2}) = 3.03\,ft$	$K_{b2.2} \cdot hv_2(Q_{m2}) = 3.58\,ft$	Bend loss 2.2
$f_2(Q_{d2}) \cdot hv_2(Q_{d2}) = 0.57\,ft$	$f_2(Q_{m2}) \cdot hv_2(Q_{m2}) = 0.67\,ft$	Total friction loss for Pipe 2
$hv_2(Q_{d2}) = 4.24\,ft$	$hv_2(Q_{m2}) = 5\,ft$	Velocity head within the pipe
$Fr_2(Q_{d2}) = 1.06$	$Fr_2(Q_{m2}) = 1.16$	Froude exiting pipe 2

Pipe 3

Design Flow	Max Flow	
$H_3(Q_{d3}) = 15.05\,ft$	$H_3(Q_{m3}) = 17.77\,ft$	Total head loss in Pipe 3
$K_{31} \cdot hv_3(Q_{d3}) = 0.57\,ft$	$K_{31} \cdot hv_3(Q_{m3}) = 0.68\,ft$	Y loss to Pipe 3
$K_{b\_b3.1} \cdot hv_3(Q_{d3}) = 0.2\,ft$	$K_{b\_b3.1} \cdot hv_3(Q_{m3}) = 0.23\,ft$	Combined bend loss
$K_{o3.1} \cdot hv_3(Q_{d3}) = 10.68\,ft$	$K_{o3.1} \cdot hv_3(Q_{m3}) = 12.61\,ft$	Orifice loss 3.1
$K_{b3.2} \cdot hv_3(Q_{d3}) = 3.03\,ft$	$K_{b3.2} \cdot hv_3(Q_{m3}) = 3.58\,ft$	Bend loss 3.2
$f_3(Q) \cdot hv_3(Q_{d3}) = 0.57\,ft$	$f_3(Q) \cdot hv_3(Q_{m3}) = 0.68\,ft$	Total friction loss for Pipe 3
$hv_3(Q_{d3}) = 4.24\,ft$	$hv_3(Q_{m3}) = 5\,ft$	Velocity head within the pipe
$Fr_3(Q_{d3}) = 1.06$	$Fr_3(Q_{m3}) = 1.16$	Froude exiting pipe 3

Reactionary Forces

Forces in X direction as shown	Forces in flow direction as shown	Forces in Y direction as shown	
$F_{b1.1x} = 116.67 \cdot kip$		$F_{b1.1y} = -194.83 \cdot kip$	Bend 1.1
$F_{b1.2x} = 143.78 \cdot kip$		$F_{b1.2y} = 242.51 \cdot kip$	Bend 1.2
	$F_{o1.1} = 171.65 \cdot kip$		Orifice 1.1
	$F_{o1.2} = 134.37 \cdot kip$		Orifice 1.2
$F_{b1.3x} = 48.65 \cdot kip$		$F_{b1.3y} = -117.45 \cdot kip$	Bend 1.3
	$F_{wye} = -3.38 \cdot kip$		Wye - Note that force is considered in the X direction only
$F_{b2.1x} = 12.3 \cdot kip$		$F_{b2.1y} = 43.77 \cdot kip$	Bend 2.1
	$F_{o2.1} = 59.23 \cdot kip$		Orifice 2.1
$F_{b2.2x} = 55.59 \cdot kip$		$F_{b2.2y} = 55.59 \cdot kip$	Bend 2.2
$F_{b3.1x} = 12.3 \cdot kip$		$F_{b3.1y} = -43.77 \cdot kip$	Bend 3.1
	$F_{o3.1} = 59.23 \cdot kip$		Orifice 3.1
$F_{b3.2x} = 55.06 \cdot kip$		$F_{b3.2y} = -5.65 \cdot kip$	Bend 3.2

Cavitation Potential Summary

$bendcav_{1.1}$ = "Bend radius ok"

$bendcav_{1.2}$ = "Bend radius ok"

$bendcav_{1.3}$ = "Bend radius ok"

$bendcav_{2.1}$ = "Bend radius ok"

$bendcav_{2.2}$ = "Bend radius ok"

Bend 2.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$bendcav_{3.1}$ = "Bend radius ok"

$bendcav_{3.2}$ = "Bend radius ok"

Bend 3.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$check\_\sigma_{i\_1.1}$ = "check next"

Orifice 1.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.1}$ = "ok"

$check\_\sigma_{id\_1.1}$ = "ok"

$check\_\sigma_{ch\_1.1}$ = "ok"

$check\_\sigma_{i\_1.2}$ = "check next"

Orifice 1.2 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.2}$ = "ok"

$check\_\sigma_{id\_1.2}$ = "ok"

$check\_\sigma_{ch\_1.2}$ = "ok"

$check\_\sigma_{i\_2.1}$ = "check next"

Orifice 2.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_2.1}$ = "ok"

$check\_\sigma_{id\_2.1}$ = "ok"

$check\_\sigma_{ch\_2.1}$ = "ok"

$check\_\sigma_{i\_3.1}$ = "check next"

Orifice 3.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_3.1}$ = "ok"

$check\_\sigma_{id\_3.1}$ = "ok"

$check\_\sigma_{ch\_3.1}$ = "ok"

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Clearances

$Ele_{bop2} = 94.75\,ft$ Elevation of the bottom of pipe 2 at fishladder crossing

$Ele_{bop3} = 94.75\,ft$ Elevation of the bottom of pipe 3 at fishladder crossing

$\Delta EFL_{ent} := 1.3ft$ Maximum differential at fish ladder entrance

$\Delta EFL_{diff} := 2.2ft$ Maximum head on diffusers from AWSC

$TW_{min} := 74.0ft$ Minimum tailwater at which the backup AWS operates

$TW_{high} := 86.0ft$ Maximum tailwater at which the backup AWS operates

$TW_{max} := 90.0ft$ Maximum tailwater at which EFL maintains criteria

$Ele_{bop2} - TW_{high} - \Delta EFL_{ent} = 7.45\,ft$ Clearance of water in fishladder to bottom of pipe 2 at emergency AWS backup high tailwater operation

$Ele_{bop2} - TW_{max} - \Delta EFL_{ent} = 3.45\,ft$ Clearance of water in fishladder to bottom of pipe 2 at max tailwater EFL operation point

Hydraulic Design Summary

Entrance Bell

Concentric eliptical bell entrance with a 5-ft primary radius and 1.5-ft secondary entrance base on guidance from EM 1110-2-1602 (Section 3-7)

Conduit

Steel, lined against corrosion with cavitation resistant material.

$k = 0.000008\,ft$	Design equivalent sand grain roughness		
$D_1 = 10\,ft$	Diameter of Pipe 1	$L_1 = 190\,ft$	Length of Pipe 1
$D_2 = 7.5\,ft$	Diameter of Pipe 2	$L_2 = 110\,ft$	Length of Pipe 2
$D_3 = 7.5\,ft$	Diameter of Pipe 3	$L_3 = 110\,ft$	Length of Pipe 3

Appurtenances

Valves

One 10 ft butterfly valve (concentric) will be used at the downstream face of the dam as secondary flow closure.

Orifices

Orifices shall have openings at the invert of the pipe to allow for drainage of conduit during system shutdown.

$D_{o1.1} = 7.4\,ft$	Orifice 1.1 (Orifice 1 on Pipe 1)	$L_{o1.1} = 100\,ft$	Station of Orifice 1.1 on Pipe 1
$D_{o1.2} = 7.5\,ft$	Orifice 1.2 (Orifice 2 on Pipe 1)	$L_{o1.2} = 140\,ft$	Station of Orifice 1.2 on Pipe 1
$D_{o2.1} = 5.5\,ft$	Orifice 2.1 (Orifice 1 on Pipe 2)	$L_{o2.1} = 45\,ft$	Station of Orifce 2.1 on Pipe 2
$D_{o3.1} = 5.5\,ft$	Orifce 3.1 (Orifice 1 on Pipe 3)	$L_{o3.1} = 45\,ft$	Station of Orifice 3.1 on Pipe 3

Air Inlets

Air inlets shall be installed downstream of orifices. To be designed.

Bends

Bends shall have a radius of bending to diameter of pipe ratio equal to or greater than 1.0 except for bend 1.3 which requires a bend ratio of 1.5. Bends shall not be mitered if possible. If mitered bends are determined necessary, maximum number of miters constructably feasible are desired.

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Sensitivity Factors $\alpha_k = 0.9$ Minor loss factor $\alpha_f = 0.1$ Equivalent sand grain roughness factor

Flowrates

$Q_{d1} = 1460 \cdot cfs$	Design flow rate (low forebay) - Pipe 1	$Q_{m1} = 1587 \cdot cfs$	Max flow rate (high forebay) - Pipe 1
$Q_{d2} = 730\ cfs$	Design flow rate (low forebay) - Pipe 2	$Q_{m2} = 794 \cdot cfs$	Max flow rate (high forebay) - Pipe 2
$Q_{d3} = 730 \cdot cfs$	Design flow rate (low forebay) - Pipe 3	$Q_{m3} = 794 \cdot cfs$	Max flow rate (high forebay) - Pipe 3

Headlosses

Pipe 1

Design Flow	Max Flow	
$H_1(Q_{d1}) = 29.04\ ft$	$H_1(Q_{m1}) = 34.24\ ft$	Total losses thru Pipe 1
$h_t = 0.25\ ft$	$h_t = 0.25\ ft$	Trashrack loss
$K_e \cdot hv_1(Q_{d1}) = 0.86\ ft$	$K_e \cdot hv_1(Q_{m1}) = 1.02\ ft$	Entrance loss
$K_{bfv} \cdot hv_1(Q_{d1}) = 0.97\ ft$	$K_{bfv} \cdot hv_1(Q_{m1}) = 1.14\ ft$	Butterfly valve loss
$K_{b\_b1} \cdot hv_1(Q_{d1}) = 1.54\ ft$	$K_{b\_b1} \cdot hv_1(Q_{m1}) = 1.82\ ft$	Combinded bend loss
$K_{o1.1} \cdot hv_1(Q_{d1}) = 12.65\ ft$	$K_{o1.1} \cdot hv_1(Q_{m1}) = 14.94\ ft$	Orifice loss 1.1
$K_{o1.2} \cdot hv_1(Q_{d1}) = 11.43\ ft$	$K_{o1.2} \cdot hv_1(Q_{m1}) = 13.5\ ft$	Orifice loss 1.2
$K_{b1.3} \cdot hv_1(Q_{d1}) = 0.54\ ft$	$K_{b1.3} \cdot hv_1(Q_{m1}) = 0.64\ ft$	Bend loss 1.3
$f_1(Q_{d1}) \cdot hv_1(Q_{d1}) = 0.8121\ ft$	$f_1(Q_{m1}) \cdot hv_1(Q_{m1}) = 0.9491\ ft$	Total frictional loss
$hv_1(Q_{d1}) = 5.37\ ft$	$hv_1(Q_{m1}) = 6.35\ ft$	Velocity head within the pipe

Pipe 2

Design Flow	Max Flow	
$H_2(Q_{d2}) = 15.03\,ft$	$H_2(Q_{m2}) = 17.75\,ft$	Total head loss in Pipe 2
$K_{31}\cdot hv_2(Q_{d2}) = 0.57\,ft$	$K_{31}\cdot hv_2(Q_{m2}) = 0.68\,ft$	Y loss to Pipe 2
$K_{b\_b2.1}\cdot hv_2(Q_{d2}) = 0.2\,ft$	$K_{b\_b2.1}\cdot hv_2(Q_{m2}) = 0.23\,ft$	Combined bend loss
$K_{o2.1}\cdot hv_2(Q_{d2}) = 10.7\,ft$	$K_{o2.1}\cdot hv_2(Q_{m2}) = 12.63\,ft$	Orifice loss 2.1
$K_{b2.2}\cdot hv_2(Q_{d2}) = 3.04\,ft$	$K_{b2.2}\cdot hv_2(Q_{m2}) = 3.59\,ft$	Bend loss 2.2
$f_2(Q_{d2})\cdot hv_2(Q_{d2}) = 0.52\,ft$	$f_2(Q_{m2})\cdot hv_2(Q_{m2}) = 0.61\,ft$	Total friction loss for Pipe 2
$hv_2(Q_{d2}) = 4.25\,ft$	$hv_2(Q_{m2}) = 5.01\,ft$	Velocity head within the pipe
$Fr_2(Q_{d2}) = 1.06$	$Fr_2(Q_{m2}) = 1.16$	Froude exiting pipe 2

Pipe 3

Design Flow	Max Flow	
$H_3(Q_{d3}) = 15.03\,ft$	$H_3(Q_{m3}) = 17.75\,ft$	Total head loss in Pipe 3
$K_{31}\cdot hv_3(Q_{d3}) = 0.57\,ft$	$K_{31}\cdot hv_3(Q_{m3}) = 0.68\,ft$	Y loss to Pipe 3
$K_{b\_b3.1}\cdot hv_3(Q_{d3}) = 0.2\,ft$	$K_{b\_b3.1}\cdot hv_3(Q_{m3}) = 0.23\,ft$	Combined bend loss
$K_{o3.1}\cdot hv_3(Q_{d3}) = 10.7\,ft$	$K_{o3.1}\cdot hv_3(Q_{m3}) = 12.63\,ft$	Orifice loss 3.1
$K_{b3.2}\cdot hv_3(Q_{d3}) = 3.04\,ft$	$K_{b3.2}\cdot hv_3(Q_{m3}) = 3.59\,ft$	Bend loss 3.2
$f_3(Q)\cdot hv_3(Q_{d3}) = 0.52\,ft$	$f_3(Q)\cdot hv_3(Q_{m3}) = 0.62\,ft$	Total friction loss for Pipe 3
$hv_3(Q_{d3}) = 4.25\,ft$	$hv_3(Q_{m3}) = 5.01\,ft$	Velocity head within the pipe
$Fr_3(Q_{d3}) = 1.06$	$Fr_3(Q_{m3}) = 1.16$	Froude exiting pipe 3

Reactionary Forces

Forces in X direction as shown	Forces in flow direction as shown	Forces in Y direction as shown	
$F_{b1.1x} = 116.73 \cdot kip$		$F_{b1.1y} = -194.93 \cdot kip$	Bend 1.1
$F_{b1.2x} = 143.84 \cdot kip$		$F_{b1.2y} = 242.6 \cdot kip$	Bend 1.2
	$F_{o1.1} = 171.75 \cdot kip$		Orifice 1.1
	$F_{o1.2} = 134.5 \cdot kip$		Orifice 1.2
$F_{b1.3x} = 48.79 \cdot kip$		$F_{b1.3y} = -117.79 \cdot kip$	Bend 1.3
	$F_{wye} = -3.49 \cdot kip$		Wye - Note that force is considered in the X direction only
$F_{b2.1x} = 12.34 \cdot kip$		$F_{b2.1y} = 43.9 \cdot kip$	Bend 2.1
	$F_{o2.1} = 59.36 \cdot kip$		Orifice 2.1
$F_{b2.2x} = 55.93 \cdot kip$		$F_{b2.2y} = 55.93 \cdot kip$	Bend 2.2
$F_{b3.1x} = 12.34 \cdot kip$		$F_{b3.1y} = -43.9 \cdot kip$	Bend 3.1
	$F_{o3.1} = 59.36 \cdot kip$		Orifice 3.1
$F_{b3.2x} = 55.44 \cdot kip$		$F_{b3.2y} = -6.03 \cdot kip$	Bend 3.2

Cavitation Potential Summary

$bendcav_{1.1}$ = "Bend radius ok"

$bendcav_{1.2}$ = "Bend radius ok"

$bendcav_{1.3}$ = "Bend radius ok"

$bendcav_{2.1}$ = "Bend radius ok"

$bendcav_{2.2}$ = "Bend radius ok"

Bend 2.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$bendcav_{3.1}$ = "Bend radius ok"

$bendcav_{3.2}$ = "Bend radius ok"

Bend 3.2 will have an air port located at the separation zone on the bend to alleviate the cavitation potential

$check\_\sigma_{i\_1.1}$ = "check next"

Orifice 1.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.1}$ = "ok"

$check\_\sigma_{id\_1.1}$ = "ok"

$check\_\sigma_{ch\_1.1}$ = "ok"

$check\_\sigma_{i\_1.2}$ = "check next"

Orifice 1.2 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_1.2}$ = "ok"

$check\_\sigma_{id\_1.2}$ = "ok"

$check\_\sigma_{ch\_1.2}$ = "ok"

$check\_\sigma_{i\_2.1}$ = "check next"

Orifice 2.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_2.1}$ = "ok"

$check\_\sigma_{id\_2.1}$ = "ok"

$check\_\sigma_{ch\_2.1}$ = "ok"

$check\_\sigma_{i\_3.1}$ = "check next"

Orifice 3.1 shows "Incipient cavitation" potential but does not demonstate "critical," "incipient damaging," or "choking" cavitation potential.

$check\_\sigma_{cr\_3.1}$ = "ok"

$check\_\sigma_{id\_3.1}$ = "ok"

$check\_\sigma_{ch\_3.1}$ = "ok"

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Clearances

$Ele_{bop2} = 94.75\,ft$ Elevation of the bottom of pipe 2 at fishladder crossing

$Ele_{bop3} = 94.75\,ft$ Elevation of the bottom of pipe 3 at fishladder crossing

$\Delta EFL_{ent} := 1.3ft$ Maximum differential at fish ladder entrance

$\Delta EFL_{diff} := 2.2ft$ Maximum head on diffusers from AWSC

$TW_{min} := 74.0ft$ Minimum tailwater at which the backup AWS operates

$TW_{high} := 86.0ft$ Maximum tailwater at which the backup AWS operates

$TW_{max} := 90.0ft$ Maximum tailwater at which EFL maintains criteria

$Ele_{bop2} - TW_{high} - \Delta EFL_{ent} = 7.45\,ft$ Clearance of water in fishladder to bottom of pipe 2 at emergency AWS backup high tailwater operation

$Ele_{bop2} - TW_{max} - \Delta EFL_{ent} = 3.45\,ft$ Clearance of water in fishladder to bottom of pipe 2 at max tailwater EFL operation point

Project Title: Dalles EFL Emergency AWS - Hydraulic Transient Analysis	12/19/2013	By: Logan Negherbon Checked By: Ryan Laughery

Hydraulic Transient Analysis

The scope of this document is to develop hydraulic transient analysis of the proposed emergency AWS system and define valve closure rate.

Preliminary Hydraulic Transient Analysis for Valve Closure

Reference
EM 1110-3-173 Pumping System Design
Hydroelectric Handbook by Creager and Justin
Fundamentals of Hydraulic Engineering by Prasuhn
Handbook of Hydraulics by King and Brater

Custom Units Definition

$\text{fps} := \text{ft} \cdot \text{s}^{-1}$ feet per second

$\text{cfs} := \text{ft}^2 \cdot \text{fps}$ cubic feet per second

Fluid Properties

$\rho := 1000 \frac{\text{kg}}{\text{m}^3}$

$\gamma := 62.41 \frac{\text{lbf}}{\text{ft}^3}$

Assumed temperature deg. F

$T_f := 50$

$T_c := (T_f - 32) \cdot \frac{5}{9}$

$T_c = 10$ Temp. deg. C

$$\nu := \frac{1.792 \cdot 10^{-6}}{1.0 + \left(0.0337 \cdot T_c + 0.000221 \cdot T_c^{\ 2}\right)} \cdot \frac{\text{m}^2}{\text{s}}$$

$\nu = 1.319 \times 10^{-6} \cdot \frac{\text{m}^2}{\text{s}}$ Kinematic viscosity of water from temp. relationship

Global Functions

Area function

$A(d) := \frac{\pi d^2}{4}$

Reynolds number

$Re(Q, d) := \frac{Q \cdot d}{A(d) \cdot \nu}$

Average velocity

$V(Q, d) := \frac{Q}{A(d)}$

Design Parameters

$Q := 1500\text{cfs}$ Design flow rate

	Diameter	Length
Pipe 1	$D_1 := 10\text{ft}$	$L_1 := 50\text{ft}$

EM 1110-3-173 Pumping System Design (Water Hammer Guidance)

$a_{min} := 2700fps$ Minimum wave speed for steel pipe

$a_{max} := 3900fps$ Maximum wave speed for steel pipe

$T_c := \frac{2 \cdot (L_1)}{a_{min}}$ $T_c = 0.037\ s$ Maximum time of closure

$T_c := \frac{2 \cdot (L_1)}{a_{max}}$ $T_c = 0.026\ s$ Minimum time of closure

$h_w := \frac{a_{min} \cdot V(Q, D_1)}{g}$ $h_w = 1603\ ft$ Theoretical surge in head due to instantaneous closure (using min. wave speed for steel pipe)

$h_w := \frac{a_{max} \cdot V(Q, D_1)}{g}$ $h_w = 2315\ ft$ Maximum theoretical surge in head due to instantaneous closure (using max. wave speed for steel pipe)

$t = FS \frac{L \cdot V}{g \cdot H_{av}}$ Time of closure for specified head surge

$t := 90s$ Trial time of closure

$FS := 4$ Factor of safety (typical range of FS from 1 to 4)

$H(t) := FS \frac{L_1 \cdot V(Q, D_1)}{g \cdot t}$ Reorganized to solve for head with respect to time

$H(t) = 1.319\ ft$ $H(t) \cdot \gamma = 0.572\ psi$ Head/pressure increase due to closure at specified time.

Hydroelectric Handbook (Chapter 34)

$\mu = \frac{2 \cdot L}{a}$ Critical time - Eq 1

$h = \frac{a \cdot \Delta v}{g}$ Head increase - Eq 2

$a = \frac{4675}{\sqrt{1 + \left(\frac{k \cdot d}{E \cdot e}\right)}} fps$ Pressure wave speed - Eq 3

For simple burried section of 10-ft diameter pipe

$d := 10ft$ Diameter

$e_{min} := 0.5in$ Potential minimum thickness of pipe

$e_{max} := 1.5in$ Potential maximum thickness of pipe

$k := 294000 \frac{lbf}{in^2}$ Voluminal modulus of elasticity of water in compression

$E := 29400000 \frac{lbf}{in^2}$ Modulus of elasticity of the sidewall material (steel)

$a := \frac{4675fps}{\sqrt{1 + \left(\frac{k \cdot d}{E \cdot e_{min}}\right)}}$ $a = 2535 \cdot fps$

$a := \frac{4675fps}{\sqrt{1 + \left(\frac{k \cdot d}{E \cdot e_{max}}\right)}}$ $a = 3485 \cdot fps$

For section of 10-ft diameter pipe encased in concrete/grout thru dam

$d := 10ft$ Diameter

$\frac{k \cdot d}{E \cdot e} = 0$ For a pipe in solid concrete, this fraction becomes infintesimal and the limiting value of 4675 is reached for *a*, this being the velocity of sound in water.

$a_c := 4675fps$ Max potential wave speed due to concrete encasement

Fundamentals of Hydraulic Engineering - Prasuhn

$\rho = 1.94 \cdot \frac{slug}{ft^3}$ $\rho = 62.428 \frac{lb}{ft^3}$ $\gamma = 62.41 \cdot \frac{lbf}{ft^3}$ $L := L_1 = 50\,ft$

$K := 294000 \frac{lbf}{in^2}$ Voluminal modulus of elasticity of water in compression

$E := 29400000 \frac{lbf}{in^2}$ Modulus of elasticity of the sidewall material (steel)

$D := d = 10\,ft$ Diameter

$t := 0.5in$ Thickness

$C_o := 1$ Eq 6-41c (Assuming pipe is anchored against axial movement throughout its length, but provided with expansion joints at regular intervals)

$$c := \frac{\sqrt{\frac{K}{\rho}}}{\sqrt{1 + \frac{K}{E} \cdot \frac{D}{t} \cdot C_o}}$$

Eq 6-45 Wave speed calculation $c = 2533.254 \cdot fps$

$$H = \frac{c \cdot V_o}{g} + \frac{f}{\sqrt{2}} \cdot \frac{L}{D} \cdot \frac{V_o^2}{2g} = \frac{V_o^2}{2g} \cdot \left(\frac{2 \cdot c}{V_o} + \frac{f \cdot L}{\sqrt{2 \cdot D}} \right)$$

Eq 6-47 Maximum increase in head at valve due to water hammer including friction

$$H_f = \frac{h_l}{\sqrt{2}}$$

Eq 6-46 Approximation of reduced friction loss seen at the valve at closure

$$\Delta p = \left(\rho \cdot c \cdot V_o \right) \cdot \frac{2 \cdot \frac{L}{c}}{t_c} = \frac{2 \cdot L \cdot V_o \cdot \rho}{t_c}$$

Eq 6-48 Pressure rise do to time of closure

$V_o := V(Q, d)$ $V_o = 19.099 \frac{ft}{s}$ Velocity in 10-ft pipe $T_c := \frac{2 \cdot L}{c}$ $T_c = 0.039\,s$

$\Delta p_{max} := \left(\rho \cdot c \cdot V_o \right)$ $\Delta p_{max} = 651.915\,psi$ Maximum pressure increase using wave speed derived from Prasuhn method

$\Delta p_{max} := \left(\rho \cdot a_c \cdot V_o \right)$ $\Delta p_{max} = 1203.078\,psi$ Maximum pressure increase using wave speed derived from Hydroelectric Handbook

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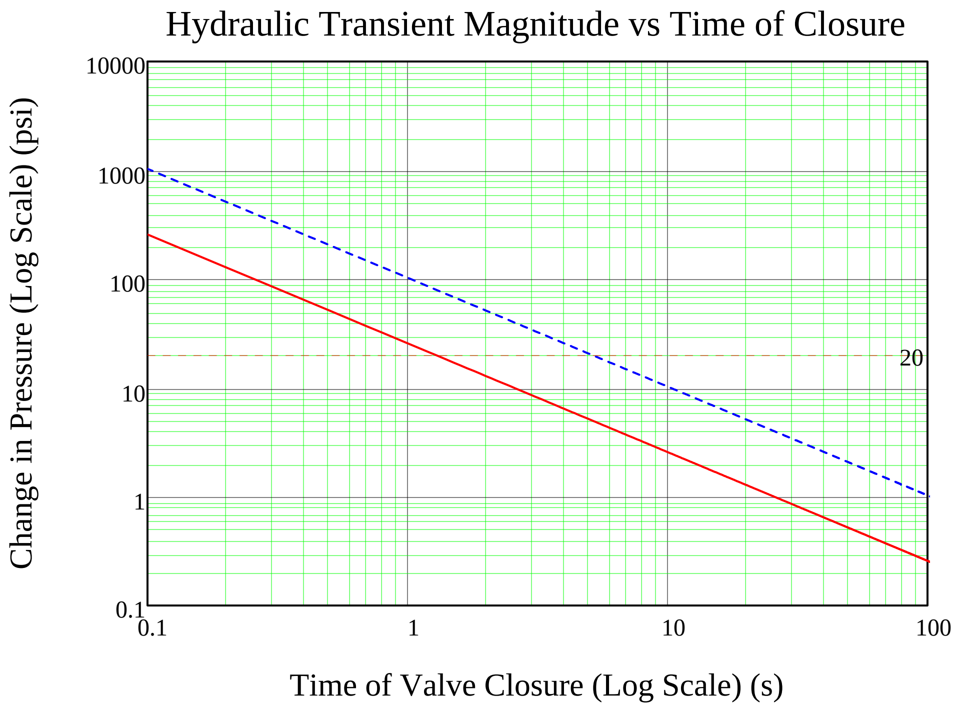
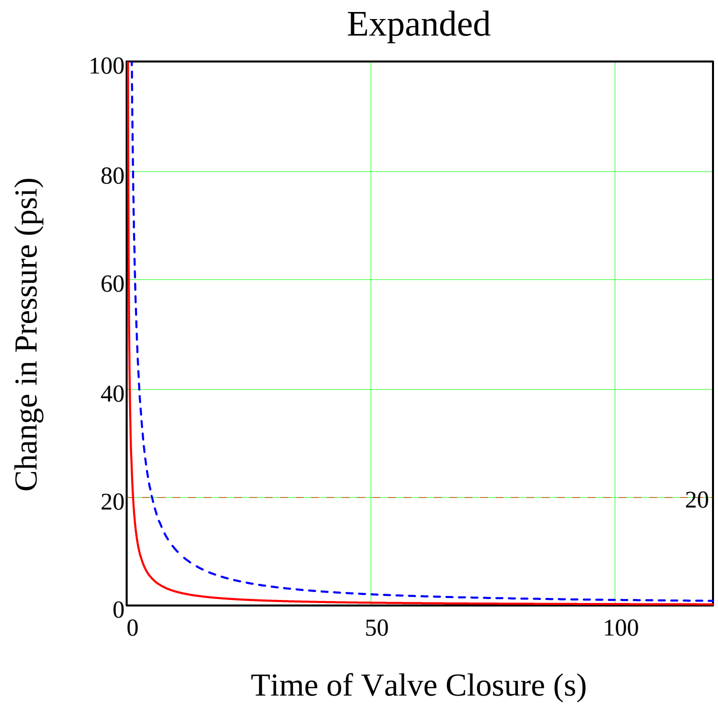
$h_l := \frac{\gamma \cdot 15ft}{\sqrt{2}} = 4.597\ psi$ Losses through the 10-ft conduit due to friction that will be not be present when velocity equals 0 for rapid closure cases.

$\Delta p(t_c) := \frac{2 \cdot L \cdot V_o \cdot \rho}{t_c}$ $t_c := 0.1s, 0.2s .. 120s$ $\Delta p(90s) = 0.286 \cdot psi$ Pressure increase due to 90s valve closure time

$FS\Delta p(t_c) := FS \frac{2 \cdot L \cdot V_o \cdot \rho}{t_c}$ Applied factor of safety noted above from EM 1110-3-173 $FS = 4$ $FS\Delta p(90s) = 1.144\ psi$ Pressure increase due to 90s valve closure time with FS





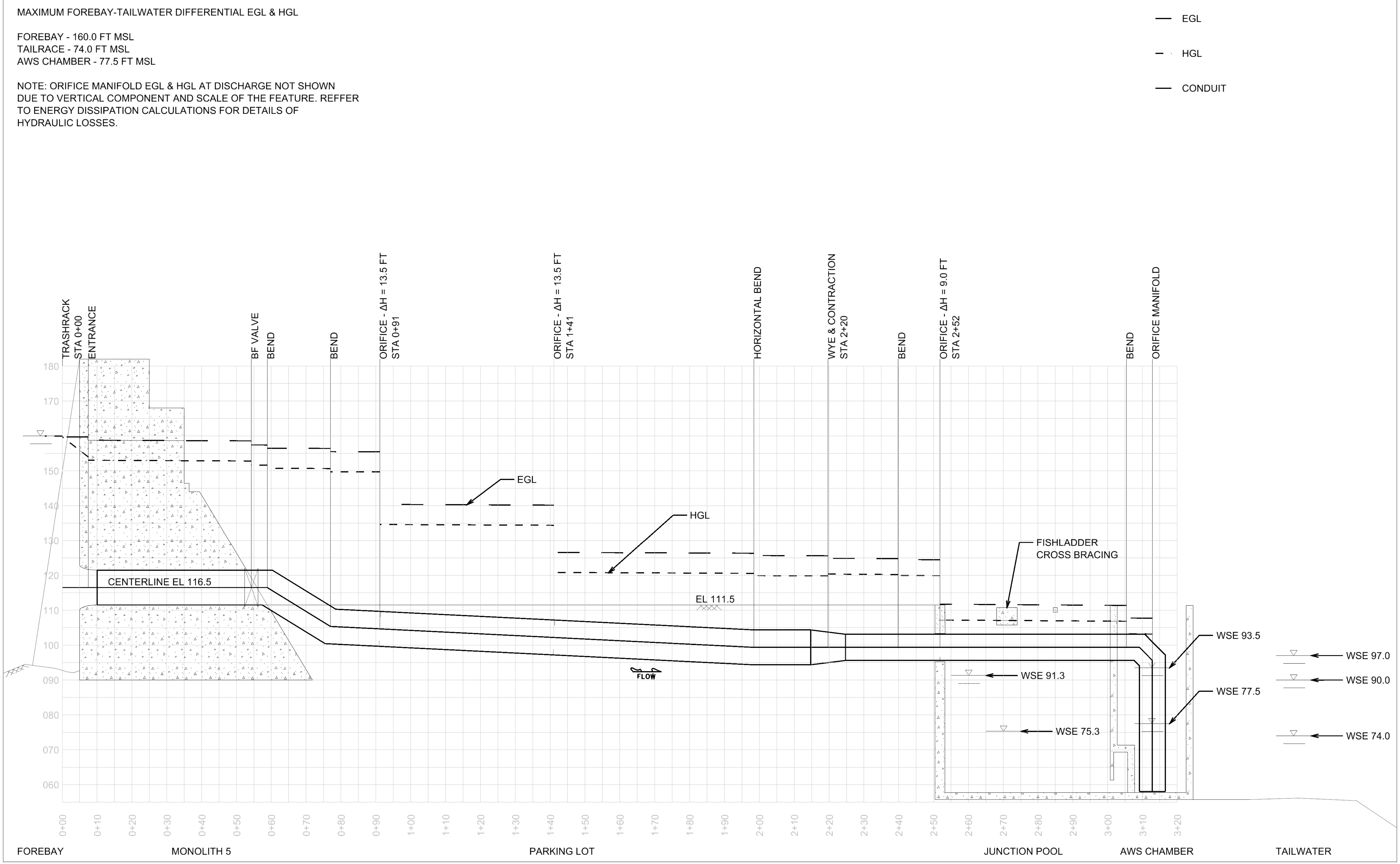
Further analysis will be completed upon defining valve actuation limitations and valve manufacture recommendations.

It is noted that the conduit will be partially encased in concrete causing the waves speed to be accelerated to the speed of sound traveling through water. However, the wave speed is not accounted for in time of closure calculations and does not affect operating limitations. EM 1110-3-175 will be used as primary design guidance; however, approximations with other methods will be used to assess the applied factor of safety.

MAXIMUM FOREBAY-TAILWATER DIFFERENTIAL EGL & HGL

FOREBAY - 160.0 FT MSL
TAILRACE - 74.0 FT MSL
AWS CHAMBER - 77.5 FT MSL

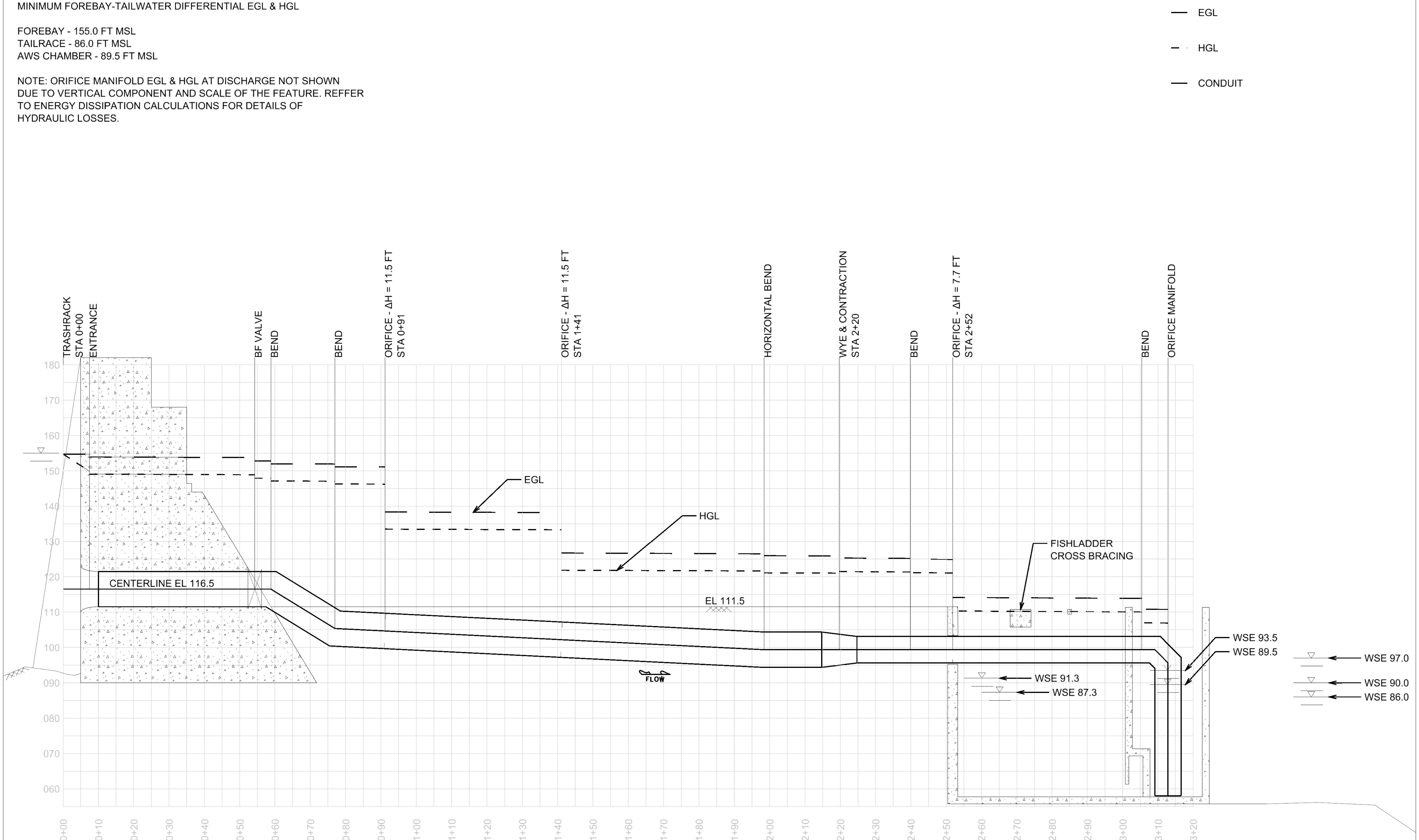
NOTE: ORIFICE MANIFOLD EGL & HGL AT DISCHARGE NOT SHOWN DUE TO VERTICAL COMPONENT AND SCALE OF THE FEATURE. REFFER TO ENERGY DISSIPATION CALCULATIONS FOR DETAILS OF HYDRAULIC LOSSES.

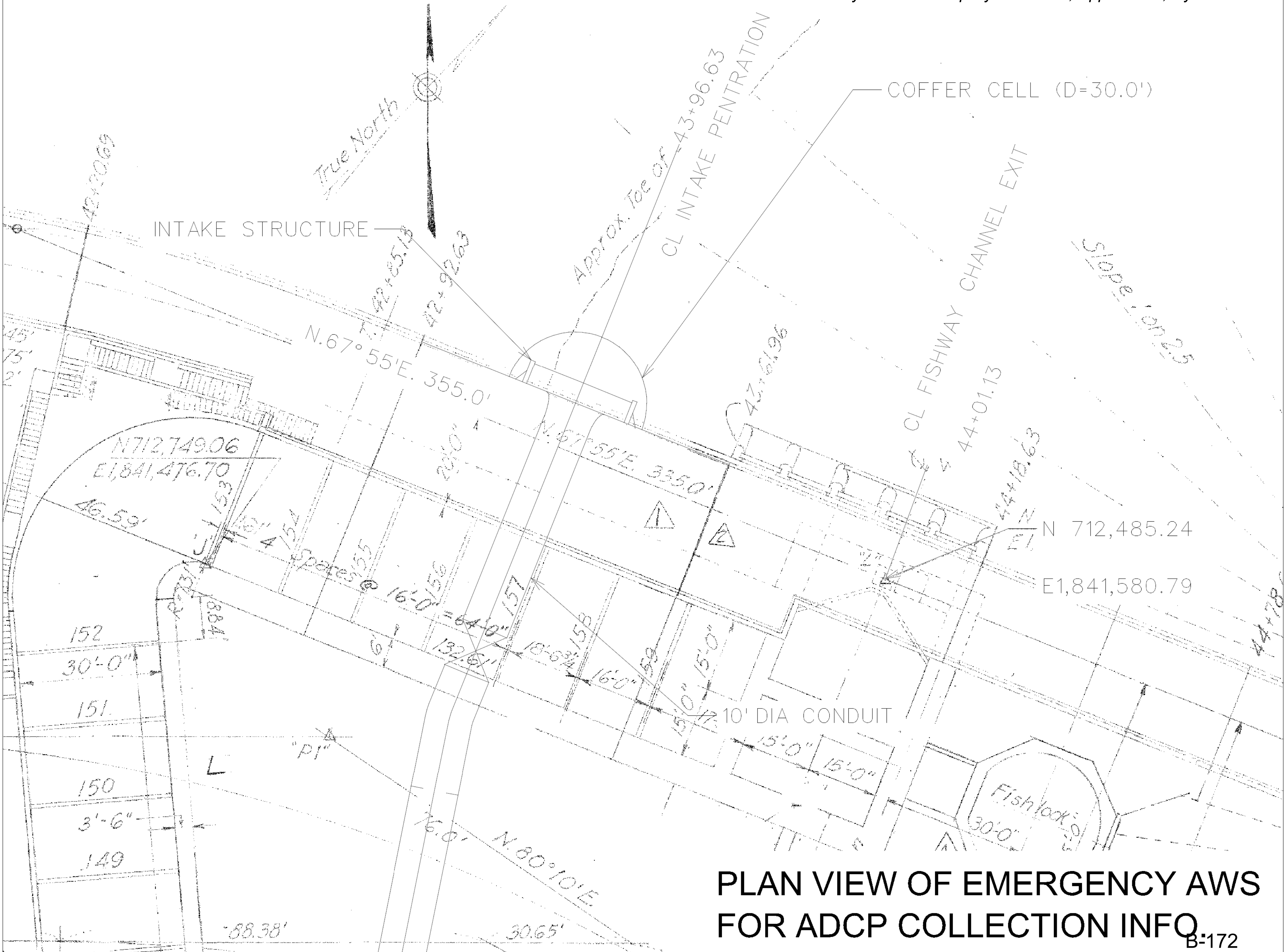


MINIMUM FOREBAY-TAILWATER DIFFERENTIAL EGL & HGL

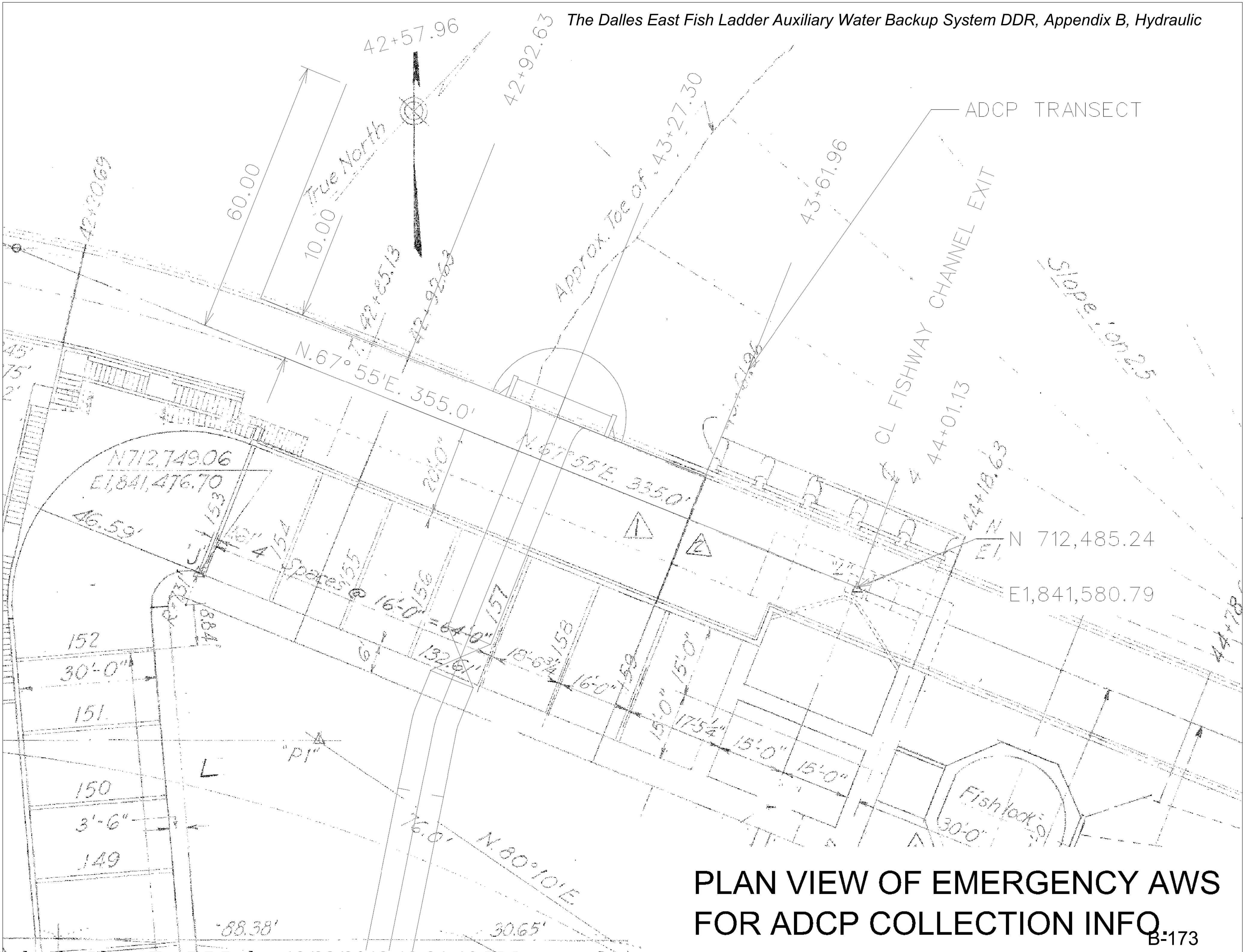
FOREBAY - 155.0 FT MSL
TAILRACE - 86.0 FT MSL
AWS CHAMBER - 89.5 FT MSL

NOTE: ORIFICE MANIFOLD EGL & HGL AT DISCHARGE NOT SHOWN DUE TO VERTICAL COMPONENT AND SCALE OF THE FEATURE. REFFER TO ENERGY DISSIPATION CALCULATIONS FOR DETAILS OF HYDRAULIC LOSSES.



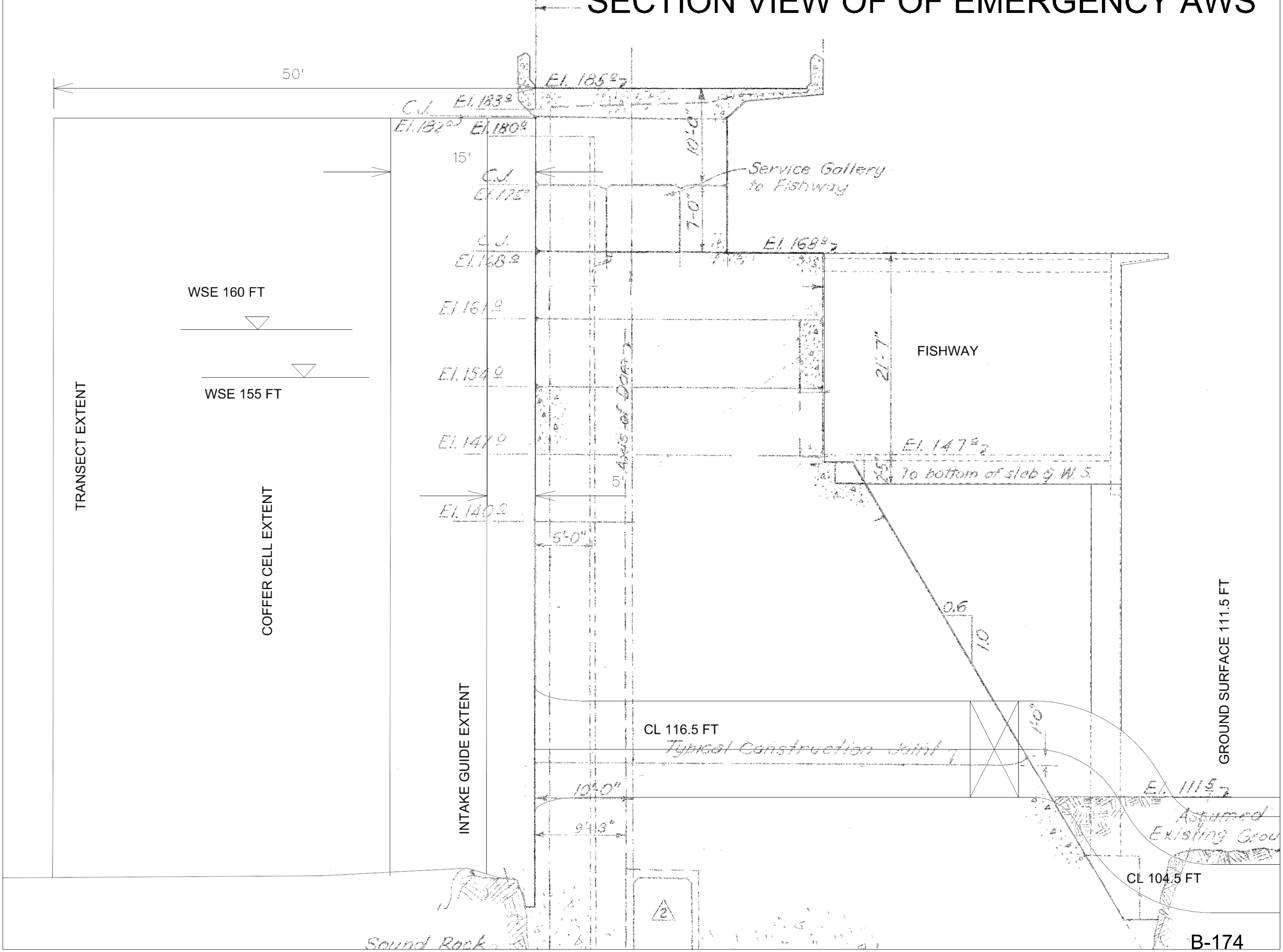


PLAN VIEW OF EMERGENCY AWS FOR ADCP COLLECTION INFO.



PLAN VIEW OF EMERGENCY AWS FOR ADCP COLLECTION INFO.

SECTION VIEW OF OF EMERGENCY AWS



The Dalles East Fish Ladder Auxiliary Water Backup System

90 Percent Design Documentation Report

APPENDIX C

Structural Quantities and Calculations

Design Criteria:

Ref 1- EM 1110-2-2105-Design hof Hydraulic Steel Structures
Ref 2- EM 1110-2-2701-Vertical Lift Gates
Ref 3-EM 1110-2-2703-Lock Gates and Operating Equipment
Ref 4-AISC 360-05 Steel Construction Manual

These calc's check flexure for a simple support beam (built up girder)- for final gate design will need to check moments at ends due to guide wheels loading and all EM load cases. Theses calc's provide enough info to preliminarily size the gate.

Note: Applied EM HSS factors at end.
Material - Steel ASTM A709 Gr. 50. Zone 2

$F_y := 50 \cdot ksi$

$F_u := 65 \cdot ksi$

$E := 29000 \cdot ksi$

$\alpha := 0.85$

$\phi_b := 0.9$ *Flexural reduction factor*

$F_{lim} := \alpha \cdot \phi_b \cdot F_y = 38.25 \cdot ksi$ *Ref 1 eqn B-5*

$H := 70 \cdot ft$ *Design Hydraulic head-max head*

$a := 32 \cdot in$ *Girder Spacing*

$b := 10 \cdot ft$ *Stiffener Spacing (Intercostal)*

$t_s := 0.75 \cdot in$ *Skinplate Thickness*

$$W := H \cdot 62.4 \cdot pcf = 4.4 \times 10^3 \cdot \frac{lbf}{ft^2}$$

$$t_{min} := \sqrt{\frac{0.5 \cdot W \cdot b^2}{F_{lim} \cdot \left[1 + 0.623 \left(\frac{b}{a}\right)^6\right]}} = 0.057 \cdot in$$ *Ref 1 eqn B-5*

$$\text{Skin\_Plate\_Thickness\_is} := \begin{vmatrix} \text{"OK"} & \text{if } t_s \ge t_{min} \\ \text{"Not OK"} & \text{otherwise} \end{vmatrix} = \text{"OK"}$$

$$\delta_s := \frac{0.0284 \cdot W \cdot b^4}{\left[1 + 1.056 \left(\frac{b}{a}\right)^5\right] \cdot E \cdot t_s^{\,3}} = 0.019 \cdot in$$ *Ref 1 eqn Section B-3(b)*

$$\delta_2 := \frac{0.0065 \cdot W \cdot 12 \cdot in \cdot a^4}{E \cdot \frac{1}{12} \cdot 12 \cdot in \cdot t_s^3} = 0.203 \cdot in$$

Based on skin plate spanning 4 members, displacement from AISC 360-05 Table 3-23 Deflection for 4 equal loaded spans assumes 1 foot distributed width with no stiffeners.

$$\Delta_{smax} := 0.4 \cdot t_s = 0.3 \cdot in$$

Max Skinplate Deflection — *Ref 2 eqn Section 3-6(b)*

$$D_{skin\_is} := \begin{cases} \text{"OK"} & \text{if } \delta_s \le \Delta_{smax} \\ \text{"Not OK"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Applied loads

$$L := 14.5 \cdot ft$$

$$M_u := \frac{W \cdot a \cdot L^2}{8} = 306.124 \cdot kip \cdot ft$$

Determine the N. A., Flange of T as base line.

Will build a WT out of Plate- Value will be close to WT prosperities in Code.

$$\frac{b}{t} = 0.38 \cdot \sqrt{\frac{E}{F_y}}$$

$$b_s := 2 \cdot t_s \cdot 0.38 \sqrt{\frac{E}{F_y}} = 13.727 \cdot in$$

effective width of skip plate while keeping compact criteria. — *Ref 4 Table B4.1 Case 2 Compact member*

$$A_{sp.eff} := b_s \cdot t_s = 10.296 \cdot in^2$$

effective skinplate area that will act as a built up member

Compression Flange

$$b_{fc} := 10 \cdot in$$

$$t_{fc} := (1) \cdot in$$

$$b_{ft} := b_s = 13.727 \cdot in$$

$$t_{ft} := t_s = 0.75 \cdot in$$

Tension Flange Skin Plate, b.ft will be governed by skinplate effective width

$$h := 16 \cdot in$$

$$t_w := \frac{1}{2} \cdot in$$

Web

$$d := h + t_{fc} + t_{ft} = 17.75 \cdot in$$

Solving for Modulus of elasticity

$$A_{fc} := b_{fc} \cdot t_{fc} = 10 \cdot in^2$$

$$d_w := d - t_{fc} - t_{ft} = 16 \cdot in$$

$$A_w := d_w \cdot t_w = 8 \cdot in^2$$

$$A_{ft} := b_{ft} \cdot t_{ft} = 10.296 \cdot in^2$$

$$A_{fc} := b_{fc} \cdot t_{fc} = 10 \cdot in^2$$

$$A_g := A_{ft} + A_{fc} + A_w = 28.296 \cdot in^2$$

$$Y_{bar} := \frac{A_{fc} \cdot \left(\frac{t_{fc}}{2}\right) + A_w \cdot \left(\frac{h}{2} + t_{fc}\right) + A_{ft} \cdot \left(\frac{t_{ft}}{2} + h + t_{fc}\right)}{A_g} = 9.043 \cdot in$$

Neutral Axis of built-up member, calculated from compression flange

$$I_w := \frac{1}{12} \cdot t_w \cdot h^3 + A_w \cdot \left(\frac{h}{2} + t_{fc} - Y_{bar}\right)^2 = 170.7 \cdot in^4$$

$$I_{fc} := \frac{1}{12} \cdot b_{fc} \cdot t_{fc}^3 + A_{fc} \cdot \left(Y_{bar} - \frac{t_{fc}}{2}\right)^2 = 730.7 \cdot in^4$$

$$I_{ft} := \frac{1}{12} \cdot b_{ft} \cdot t_{ft}^3 + A_{ft} \cdot \left(d - Y_{bar} - \frac{t_{ft}}{2}\right)^2 = 715.2 \cdot in^4$$

$$I_x := I_w + I_{fc} + I_{ft} = 1616.6 \cdot in^4$$

Built-up member modulus of elasticity

$$S_{xt} := \frac{I_x}{d - Y_{bar}} = 185.7 \cdot in^3$$

$$S_{xc} := \frac{I_x}{Y_{bar}} = 178.8 \cdot in^3$$

Plastic Section Modulus of elasticity for composite shape

$$Z = A_{wt} \cdot d_1 + A_{wc} \cdot d_2 + A_{ft} \cdot d_3 + A_{fc} \cdot d_4$$

Find PNA Where Area Compression = Area Tension This is the center of the built up shape based on Area

Given

$$x := 2 \cdot in$$

$$\frac{A_g}{2} = 14.148 \cdot in^2$$

$$\frac{A_g}{2} - A_{fc} - t_w \cdot x = 0$$

$$x := Find(x) = 8.296 \cdot in$$

$$x = 8.296 \cdot in$$

$$Y_{bar.pna} := x + t_{fc} = 9.296 \cdot in$$

Distance from edge of compression flange to PNA

$$d_1 := \frac{d_w - x}{2} = 3.852 \cdot in$$

$$d_2 := \frac{x}{2} = 4.148 \cdot in$$

$$d_3 := 2 \cdot d_1 + \frac{t_{ft}}{2} = 8.079 \cdot in$$

$$d_4 := 2 \cdot d_2 + \frac{t_{fc}}{2} = 8.796 \cdot in$$

$$A_{wt} := 2d_1 \cdot t_w = 3.852 \cdot in^2$$

$$A_{wc} := 2 \cdot d_2 \cdot t_w = 4.148 \cdot in^2$$

$$Z_{xpna} := A_{wt} \cdot d_1 + A_{wc} \cdot d_2 + A_{ft} \cdot d_3 + A_{fc} \cdot d_4 = 203.18 \cdot in^3$$

$$Z_x := Z_{xpna}$$

Check limiting Width- Thickness Ratios for compression members Table B4.1

$$K_c := \frac{4}{\sqrt{\frac{h}{t_w}}} \qquad K_c = 0.707 \qquad k_c := \begin{cases} 0.35 & \text{if } K_c < 0.35 \\ 0.76 & \text{if } K_c > 0.76 \\ K_c & \text{otherwise} \end{cases} \qquad k_c = 0.707$$

$$\frac{S_{xt}}{S_{xc}} = 1.039$$

$$F_L := 0.7 \cdot F_y \qquad F_L = 35 \cdot ksi$$

Reference foot note on AISC Table B4.1, Major axis bending of slender-web built up I shaped members

Flange limiting thickness ratio, unstiffened element

Table B4.1   Case 2

$$\lambda_{fc} := \frac{b_{fc}}{2t_{fc}} \qquad \lambda_{fc} = 5$$

$$\lambda_{ft} := \frac{b_{ft}}{2t_{ft}} \qquad \lambda_{ft} = 9.152$$

$$\lambda_{pf} := 0.38 \cdot \sqrt{\frac{E}{F_y}} \qquad \lambda_{pf} = 9.152$$ *compact*

$$\lambda_{rf} := 0.95 \cdot \sqrt{\frac{E \cdot k_c}{F_L}} \qquad \lambda_{rf} = 22.995$$ *noncompact*

Web limiting thickness ratio, stiffened element

Table B4.1   Case 11

$$h_c := 2 \cdot (Y_{bar} - t_{fc}) \qquad h_c = 16.087 \cdot in$$

Twice the distance from the centroid to the inside face of the compression flange   Ref. B4.2(b)

$$h_p := 2(Y_{bar.pna} - t_{fc}) = 16.591 \cdot in$$

Twice the distance from the PNA to the inside face of the compression flange   Ref. B4.2(b)

$$M_p := \begin{cases} Z_x \cdot F_y & \text{if } Z_x \cdot F_y \le 1.6 \cdot S_{xc} \cdot F_y \\ 1.6 \cdot S_{xc} \cdot F_y & \text{otherwise} \end{cases} \qquad M_p = 846.6 \cdot kip \cdot ft$$

$$M_{yc} := F_y \cdot S_{xc} \qquad M_{yc} = 744.8 \cdot kip \cdot ft$$

$$\lambda_w := \frac{h_c}{t_w} \qquad \lambda_w = 32.173 \qquad \lambda_{rw} := 5.70 \cdot \sqrt{\frac{E}{F_y}} \qquad \lambda_{rw} = 137.3$$ *noncompact*

$$\lambda pw := \frac{\frac{h_c}{h_p}\cdot\sqrt{\frac{E}{F_y}}}{\left(0.54\frac{M_p}{M_{yc}} - 0.09\right)^2} \qquad \lambda pw = 85.1$$

compact

$$\lambda_{pw} := \min(\lambda pw, \lambda_{rw}) \qquad \lambda_{pw} = 85.115$$

Check Compression Flange

$$\text{Compression\_Flange\_is\_} := \begin{cases} \text{"Compact"} & \text{if } \lambda_{fc} < \lambda_{pf} \\ \text{"Noncompact"} & \text{if } \lambda_{pf} < \lambda_{fc} \le \lambda_{rf} \\ \text{"Slender Elements"} & \text{otherwise} \end{cases} = \text{"Compact"}$$

$\text{Compression\_Flange\_is\_} = \text{"Compact"}$

Check Web

$$\text{Web\_is\_} := \begin{cases} \text{"Compact"} & \text{if } \lambda_w < \lambda_{pw} \\ \text{"Noncompact"} & \text{if } \lambda_{pw} < \lambda_w \le \lambda_{rw} \\ \text{"Slender Elements"} & \text{otherwise} \end{cases} = \text{"Compact"}$$

$\text{Web\_is\_} = \text{"Compact"}$

$\text{Web\_is\_} = \text{"Compact"}$

From Table F1.1 - AISE Section F4
Check:
1. (Y) Yielding (compression flange yielding) Section F4.1
2. (LTB) Lateral torsional buckling Section F4.2
3. (FLB) Flange Local Buckling Section F4.3
4. (TFY) tension flange yielding Section F4.4

Calculate the plastification factor corresponding to compression:

$$Z_x\cdot F_y = 846.6\cdot kip\cdot ft \qquad 1.6\cdot S_{xc}\cdot F_y = 1191.7\cdot kip\cdot ft$$

$$M_p := \begin{cases} Z_x\cdot F_y & \text{if } Z_x\cdot F_y \le 1.6\cdot S_{xc}\cdot F_y \\ 1.6\cdot S_{xc}\cdot F_y & \text{otherwise} \end{cases} \qquad M_p = 846.6\cdot kip\cdot ft$$

$$M_{yc} := F_y\cdot S_{xc} \qquad M_{yc} = 744.8\cdot kip\cdot ft$$

Eqn (F4-4)

$$Rpc := \left[\frac{M_p}{M_{yc}} - \left(\frac{M_p}{M_{yc}} - 1\right)\left(\frac{\lambda_w - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}}\right)\right] \qquad Rpc = 1.275$$

Eqn (F4-9b)

$$R_{pc} := \begin{cases} Rpc & \text{if } Rpc \le \frac{M_p}{M_{yc}} \\ \frac{M_p}{M_{yc}} & \text{otherwise} \end{cases} \qquad R_{pc} = 1.137$$

1. (Y) Yielding (compression flange yielding) Section F4.1

$M_{n.y} := R_{pc} \cdot F_y \cdot S_{xc}$ $\quad M_{n.y} = 846.6 \cdot kip \cdot ft$ *Eqn (F4-1)*

2. (LTB) Lateral torsional buckling Section F4.1

$$a_w := \frac{h_c \cdot t_w}{b_{fc} \cdot t_{fc}} = 0.804$$ *Eqn (F4-11)*

$$h_o := d - \frac{t_{fc}}{2} - \frac{t_{ft}}{2} = 16.875 \cdot in$$ *Distance between flange centroids*

$$r_t := \frac{b_{fc}}{\sqrt{12\left(\frac{h_o}{d} + \frac{1}{6} \cdot a_w \cdot \frac{h^2}{h_o \cdot d}\right)}} = 0.233\ ft$$ *Eqn (F4-10)*

$$L_p := 1.1 \cdot r_t \cdot \sqrt{\frac{E}{F_y}} = 6.175\ ft$$

$$r_{st} := \frac{b_{fc}}{\sqrt{12 \cdot \left(1 + \frac{1}{6} \cdot \frac{h\, t_w}{b_{fc} \cdot t_{fc}}\right)}} = 2.712 \cdot in$$

$$L_r := \pi \cdot r_{st} \cdot \sqrt{\frac{E}{0.7 \cdot F_y}} = 20.435 \cdot ft$$ *Section F4.2(b)*

$C_b := 1.0 \quad L_b := L$

$$LTB := \begin{cases} \text{"Eqn F4-2"} & \text{if } L_p < L_b < L_r \\ \text{"Change"} & \text{otherwise} \end{cases} = \text{"Eqn F4-2"}$$

$$M_{n.LTB.F4.2} := C_b \cdot \left[R_{pc} \cdot M_{yc} - \left(R_{pc} \cdot M_{yc} - F_L \cdot S_{xc}\right) \cdot \left(\frac{L_b - L_p}{L_r - L_p}\right)\right] = 656.7 \cdot kip \cdot ft$$ *Eqn (F4-2)*

$$M_{n.LTB} := \min\left(M_{n.LTB.F4.2}, R_{pc} \cdot M_{yc}\right) = 656.7 \cdot kip \cdot ft$$

3. (FLB) Flange Local Buckling (compression flange local buckling) Section F4.1

$$F_L := \begin{cases} 0.7 \cdot F_y & \text{if } \frac{S_{xt}}{S_{xc}} \geq 0.7 \\ F_y \cdot \frac{S_{xt}}{S_{xc}} & \text{if } \frac{S_{xt}}{S_{xc}} < 0.7 \end{cases} \qquad F_L = 35 \cdot ksi$$ *Eqn (F4-6a)* *Eqn (F4-6b)*

$$M_{n.FLB.F4.12} := \left[R_{pc} \cdot M_{yc} - \left(R_{pc} \cdot M_{yc} - F_L \cdot S_{xc}\right) \left(\frac{\lambda_{fc} - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}\right)\right]$$ *Eqn (F4-12)*

$$M_{n.FLB.F4.13} := \frac{0.9 \cdot E \cdot k_c \cdot S_{xc}}{\lambda_{fc}^{\;2}}$$

$M_{n.FLB.F4.12} = 944.1 \cdot kip \cdot ft$

$M_{n.FLB.F4.13} = 10996.9 \cdot kip \cdot ft$ *Eqn (F4-12)*

Compression_Flange_is_ = "Compact"

$M_{n.FLB} :=$ | "Does not apply" if Compression_Flange_is_ = "Compact"
| $M_{n.FLB.F4.12}$ if Compression_Flange_is_ = "Noncompact"
| $M_{n.FLB.F4.13}$ if Compression_Flange_is_ = "Slender Elements"

$M_{n.FLB}$ = "Does not apply" $\cdot kip \cdot ft$

$M_{n.FLB}$ = "Does not apply" $\cdot kip \cdot ft$

4. (TFY) tension flange yielding Section F4.4

Calculate the plastification factor corresponding to tension:

$M_{yt} := S_{xt} \cdot F_y$ $\qquad M_{yt} = 773.6 \cdot kip \cdot ft$

$$Rpt := \left[\frac{M_p}{M_{yt}} - \left(\frac{M_p}{M_{yt}} - 1\right)\left(\frac{\lambda_w - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}}\right)\right]$$

$Rpt = 1.19$ *Eqn (F4-15b)*

$R_{pt} :=$ | Rpc if $Rpc \le \frac{M_p}{M_{yt}}$
| $\frac{M_p}{M_{yt}}$ otherwise

$R_{pt} = 1.094$

$M_{n.TFY} :=$ | "Does Not Apply" if $S_{xt} \ge S_{xc}$
| $R_{pt} \cdot M_{yt}$ if $S_{xt} < S_{xc}$

$M_{n.TFY}$ = "Does Not Apply" $\cdot kip \cdot ft$

Determine Mn, Lowest value for (Y, LTB,FLB,TFY)

$M_n := \min(M_{n.y}, M_{n.LTB}) = 656.72 \cdot kip \cdot ft$

$M_n = 656.7 \cdot kip \cdot ft$

LFRD design capacity | *ASD Design Capacity*

$\phi_c := 0.9$ $\qquad \Omega_c := 1.67$ $\qquad M_u = 306.1 \cdot kip \cdot ft$

$\alpha \cdot \phi_c \cdot \frac{M_n}{1.4} = 358.9 \cdot kip \cdot ft$ LRFD

$0.87 \left(\frac{M_n}{\Omega_c}\right) = 342.1 \cdot kip \cdot ft$ ASD

Dalles AWS

Trash Rack Design to 30% These cacls are for checking grating loaded that is loaded on the opposite side than bar grating catalog. The compression side is not braced with cross braces every 4"

Will used SS. (1-1/4"-3/16) with bar spacing at 15/16" o.c. This provides a 3/4" clear opening between bars. Use S.S. for reduced maintenance.

Bar Grating will be loaded opposite than design catalogs to allow for a trash rake to push debris off. This mean the unbraced length will be between supports. These calculations are more conservative than when using NAAMM Manual MBG 354-94 Metal bar grating engineering design manual. The MBG-354-94 calcs follow these calcs.

Based on AISC 360-05 manual

Section F11 Rectangular Bars bent about the major axis

These values come from ANSI/NAAMM MBG 531-00 Metal Bar Grating Manual 6th ed. For SS. If use SS 304/316 F=30ksi, if use SS 304L/316L F=25ksi- for design assume 304L. 304L is easier to weld. If works for 304L it will work for 304.

$E := 28000\text{ksi}$ — *Modulus of elasticity of steel*

$F_y := 16.5 \cdot \text{ksi}$ — *Yield strength of S.S.*

$d := 1.25 \cdot \text{in}$ — *depth of bar*

$t := \frac{3}{16} \cdot \text{in}$ — *thickness of bar*

$s := \frac{15}{16} \cdot \text{in}$ — *bar spacing*

$L_b := 3 \cdot \text{ft}$ — *True unbraced length would be between inflection points*

$C_b := 1.0$ — *lateral torsional buckling modification factor- assumed 1, conservative.*

$\Omega := 1.67$ — *AISC 360-05 ASD reduction factor*

Section

$$S_x := \frac{t \cdot d^2}{6} = 0.0488 \cdot \text{in}^3$$

$$Z_x := \frac{t \cdot d^2}{4} = 0.0732 \cdot \text{in}^3$$

$$F_{cr} := \frac{1.9 \cdot E \cdot C_b}{\left(\frac{L_b \cdot d}{t^2}\right)} = 41.6 \cdot \text{ksi}$$ *eqn F11-4*

$M_y := S_x \cdot F_y = 0.1 \cdot \text{kip} \cdot \text{ft}$ — *Yield moment about the axis of bending, Salmon on Johnson 4ed page 373.*

$$\text{Limit\_1} := \frac{L_b \cdot d}{t^2} = 1280$$

$$\text{Limit\_2} := \frac{0.08 \cdot E}{F_y} = 135.8$$

$$\text{Limit\_3} := \frac{1.9 \cdot E}{F_y} = 3224.2$$

$M_{n.F11.1} := \min\left(F_y \cdot Z_x, 1.6 \cdot M_y\right) = 0.101 \cdot kip \cdot ft$ *eqn F11-1*

$M_{n.F11.2} := \min\left[C_b \cdot \left[1.52 - 0.274\left(\frac{L_b \cdot d}{t^2}\right) \cdot \frac{F_y}{E}\right] \cdot M_y, M_{n.F11.1}\right] = 0.088 \cdot kip \cdot ft$ *eqn F11-2*

$M_{n.F11.3} := \min\left(F_{cr} \cdot S_x, M_{n.F11.1}\right) = 0.101 \cdot kip \cdot ft$ *eqn F11-3*

$$M_n := \begin{cases} M_{n.F11.1} & \text{if Limit\_1} \le \text{Limit\_2} \\ M_{n.F11.2} & \text{if Limit\_2} < \text{Limit\_1} \le \text{Limit\_3} \\ M_{n.F11.3} & \text{if Limit\_1} > \text{Limit\_3} \end{cases} = 0.088 \cdot kip \cdot ft$$

$K := \frac{12 \cdot in}{s} = 12.8$ *Number of bars per foot*

$M_{nK} := M_n \cdot K = 1.1 \cdot kip \cdot ft$ *flexural capacity per foot.*

$\frac{M_n \cdot K}{\Omega} = 0.68 \cdot kip \cdot ft$ *allowable flexural capacity per foot.*

Iteration 1. Loads from H&H Load from H&H

$P_d := 42.1 \cdot psf$ *pressure on bar grating with 75% open space (this assume 71% open for steel)*

Load per foot of bar grating

$w := P_d \cdot L_b = 0.13 \cdot \frac{kip}{ft}$

$M := \frac{w \cdot L_b^{\,2}}{8} = 0.142 \cdot kip \cdot ft$ *This is assuming simply supported ends, if continuous beams then moment will be less.*

$$\text{Flexure\_is\_} := \begin{cases} \text{"OK"} & \text{if } M \le M_n \cdot \frac{K}{\Omega} \\ \text{"NOT OK"} & \text{otherwise} \end{cases} = \text{"OK"}$$

$P_d := 62.4 \cdot pcf \cdot 5 \cdot ft = 312 \cdot psf$ *EM 1110-2-3104 Unusual loading for trash racks is 5 feet of pressure.*

$w := P_d \cdot L_b = 0.94 \cdot \frac{kip}{ft}$

$M := \frac{w \cdot L_b^{\,2}}{12} = 0.702 \cdot kip \cdot ft$ *Moment for continuous beam*

$\frac{M_n \cdot K}{\Omega} = 0.68 \cdot kip \cdot ft$ *allowable flexural capacity per foot.*

For this loading case, trash rack bars are slightly under rated, but this is an unusual load case, thus the FOS could be reduces slightly- See bar grating capacity calcs below. Thoughs calcs indicate that the capacity is adequate for the unusual loading condition.

NBG 531-00 ANSI/NAAMM Metal Bar Grating Manual 6th ed.

304&316 S.S. bar grating loading @4' values are with bar spacing of 1-3/16":
U=411psf
Du=0.274 in
C=822 lb per ft of grading
Dc=0.219 in
Shear is OK based on NBG 531-00 Catalog

Note: these values are for grating with cross bars on compression side of members.

These calcs are based on NAAMM MBG 534-94 Metal Bar Grating Engineering Design Manual

*Applied load is 5*ft of water pressure, 5ft*62.4pcf=312psf load, based on EM 1110-2-3104*

$d := 1.25 \cdot in$

$b := t = 0.1875 \cdot in$ *Thickness of individual bars*

$A_w := s = 0.9375 \cdot in$ *Bearing Bar spacing*

$K := \frac{12 \cdot in}{A_w} = 12.8$ *Number of bearing bars per foot of width*

$S_g := \frac{K \cdot b \cdot d^2}{6} = 0.625 \cdot in^3$ *Section modulus per foot of width*

$F_a := 16.5ksi$ *Design allowable based on material properties from guidance*

$M_g := F_a \cdot S_g = 10312.5 \cdot lbf \cdot in$ *Max bending moment for grating per foot width.*

$M_{g\_unit} := \frac{M_g}{lbf \cdot in} = 10312.5$ *remove units for empirical equation- units in lb-in*

$L := \frac{L_b}{in} = 36$ *units in inches*

$C := \frac{4 \cdot M_{g\_unit}}{L} = 1145.8$ Lbf /foot width *concentrated load per foot width*

$U := 96 \cdot \frac{M_{g\_unit}}{L^2} = 763.9$ psf *uniform load per foot width.*

$P_d = 312 \cdot psf$ *applied load on grating with 5 ft of head*

U is greater than P.d, grating is OK for loads based on the metal bar grating Engineering deign Manual, MBG-534-94

Rectangular HSS in Flexure

AISC 360-05 Design Guidance

This is the calc for the frame that supports the SS grating for the Trash rack.
The trash rack will span approx 23.' and be in section of 12' tall. The frame will be built out of HSS ss tubes.

10x4x3/8 s.s.- called Ryerson Tull, they produce this size of SS tubes.

$F_y := 30 \cdot ksi$ ASTM A 304

$E := 28000ksi$

$Z_x := 27 \cdot in^3$ axis resisting water load

$Z_y := 14 \cdot in^3$ axis resisting dead load and grating weight

$C := 24.4 \cdot in^3$

$d := 10 \cdot in$ $d_y := 4 \cdot in$ y is weak axis

$t_w := 0.349 \cdot in$ $I_x := 24.3 \cdot in^4$

$W_b := 32.51 \cdot plf$ Beam weight

Applied

$w := 126 \cdot \frac{lbf}{ft}$

This assume 42.1psf applied load with 3ft span of grating applied from debris

$w_g := 7psf$

$W_g := w_g \cdot 6 \cdot ft = 42 \cdot plf$ Weight of grating on beam

$L := 23 \cdot ft$ Unbraced length of beam- conservative for hydraulic loading-grating will brace compression face.

$M_a := \frac{w \cdot L^2}{12} = 5.55 \cdot kip \cdot ft$ $M_{ay} := \frac{(W_g + W_b) \cdot L^2}{12} = 3.3 \cdot kip \cdot ft$

$M_r := M_a = 5.554 \cdot kip \cdot ft$ $M_{ry} := M_{ay}$

Applied Shear

$V_a := \frac{w \cdot L}{2} = 1.449 \cdot kip$ $V_{ay} := \frac{(W_g + W_b) \cdot L}{2} = 0.9 \cdot kip$

$V_r := V_a$ $V_{ry} := V_{ay}$

Applied Torsion

$e := \frac{d}{2} + \frac{1.25}{2} \cdot in = 5.625 \cdot in$ Center of beam to center of grating

$T_a := \frac{W_g \cdot L \cdot e}{2} = 0.226 \cdot kip \cdot ft$

$T_r := T_a$

Check Slenderness Ratio Table B4.1 Case 12 and 13

$\lambda_f := 8.46$

Check Flange Table B4.1 Case

$\lambda_{pf} := 1.12 \sqrt{\frac{E}{F_y}} = 34.2$ *compact*

$\lambda_{rf} := 1.4 \sqrt{\frac{E}{F_y}} = 42.8$ *noncompact*

$\lambda_w := 25.7$

Check Web Table B4.1 Case 13

$\lambda_{pw} := 2.42 \sqrt{\frac{E}{F_y}} = 73.9$ *compact*

$\lambda_{rw} := 5.70 \sqrt{\frac{E}{F_y}} = 174.1$ *noncompact*

$$\text{Flange\_is\_} := \begin{cases} \text{"Compact"} & \text{if } \lambda_f < \lambda_{pf} \\ \text{"Non Compact"} & \text{if } \lambda_{pf} < \lambda_f \le \lambda_{rf} \\ \text{"Slender"} & \text{otherwise} \end{cases}$$

$$\text{Web\_is\_} := \begin{cases} \text{"Compact"} & \text{if } \lambda_w < \lambda_{rw} \\ \text{"Non Compact"} & \text{if } \lambda_{pf} < \lambda_f \le \lambda_{rf} \\ \text{"Slender"} & \text{otherwise} \end{cases}$$

$\text{Flange\_is\_} = \text{"Compact"}$

$\text{Web\_is\_} = \text{"Compact"}$

For bending about the dead load axis (y-weak) the member will still be compact, λf and λw would be switched

Check Flexure Chapter F

From Table F1.1 use AISE Section F7- Square and Rectangular HSS and Box Shaped Members
Check:
1. (Y) Yielding Section F7-1
2. (FLB) Flange Local Buckling Section F7-2
3. (WLB) Web Local Buckling Section F7-3

Section F7-1
Yielding

$\Omega_b := 1.67$

$M_n := F_y \cdot Z_x = 67.5 \cdot kip \cdot ft$

$M_c := \frac{M_n}{\Omega_b} = 40.42 \cdot kip \cdot ft$

Dead load value

$M_{ny} := F_y \cdot Z_y = 35 \cdot kip \cdot ft$ *eqn F7-1*

$M_{cy} := \frac{M_{ny}}{\Omega_b} = 21 \cdot kip \cdot ft$

Section F7-2 Flange Local Buckling
Does not apply for compact sections

Section F7-3 Web Local Buckling
Does not apply for compact sections

$$\text{Flexure\_is} := \begin{cases} \text{"OK"} & \text{if } M_r \le M_c \\ \text{"Not OK"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Shear Chapter G

$\Omega_v := 1.67$

$h := d - 2(3 \cdot t_w) = 7.906 \cdot in$ *Height of web in shear minus radius*

$A_w := 2 \cdot h \cdot t_w = 5.518 \cdot in^2$ *Area of web minus radius*

$k_v := 5$

$$C_v := \begin{cases} 1 & \text{if } \lambda_w \le 1.10 \cdot \sqrt{k_v \cdot \frac{E}{F_y}} \\ \dfrac{1.10 \cdot \sqrt{k_v \cdot \frac{E}{F_y}}}{\lambda_w} & \text{if } 1.10 \cdot \sqrt{k_v \cdot \frac{E}{F_y}} < \lambda_w \le 1.37 \cdot \sqrt{k_v \cdot \frac{E}{F_y}} \\ \dfrac{1.51 \cdot E \cdot k_v}{(\lambda_w)^2 \cdot F_y} & \text{if } \lambda_w > 1.37 \cdot \sqrt{k_v \cdot \frac{E}{F_y}} \end{cases} = 1$$

eqn G2-3

eqn G2-4

eqn G2-5

$V_n := 0.6 \cdot F_y \cdot A_w \cdot C_v = 99.3 \cdot kip$ *eqn G2-1*

$$V_c := \frac{V_n}{\Omega_v} = 59.5 \cdot kip$$

$$\text{Shear\_is} := \begin{cases} \text{"OK"} & \text{if } V_r \le V_c \\ \text{"Not OK"} & \text{otherwise} \end{cases} = \text{"OK"}$$

$h_y := d_y - 2 \cdot 3 \cdot t_w = 1.906 \cdot in$ *Dead load value*

$A_{wy} := 2 \cdot h_y \cdot t_w = 1.33 \cdot in^2$

$V_{ny} := 0.6 \cdot F_y \cdot A_{wy} \cdot C_v = 23.947 \cdot kip$

$$V_{cy} := \frac{V_{ny}}{\Omega_v} = 14.34 \cdot kip$$

Design for member in Torsion and Flexure H3-6b

$$\frac{h}{t} = \lambda_w \qquad \Omega_t := 1.67$$

$$(0.6 \cdot F_y) = 18 \cdot ksi$$

$$F_{cr} := \begin{cases} (0.6 \cdot F_y) & \text{if } \lambda_w \le 2.45 \cdot \sqrt{\frac{E}{F_y}} \\ 0.6 \cdot F_y \cdot \frac{\left(2.45 \sqrt{\frac{E}{F_y}}\right)}{\lambda_w} & \text{if } 2.45 \cdot \sqrt{\frac{E}{F_y}} < \lambda_w \le 3.07 \cdot \sqrt{\frac{E}{F_y}} \\ 0.458 \cdot \pi^2 \cdot \frac{E}{\lambda_w^{\ 2}} & \text{if } 3.07 \cdot \sqrt{\frac{E}{F_y}} < \lambda_w \le 260 \end{cases} = 18 \cdot ksi$$

eqn H3-3

eqn H3-4

eqn H3-5

$$T_n := F_{cr} \cdot C = 36.6\, ft \cdot kip$$

eqn H3-1

$$T_c := \frac{T_n}{\Omega_t} = 21.916\, ft \cdot kip$$

$$\text{Torsion\_is} := \begin{cases} \text{"OK"} & \text{if } T_r \le T_c \\ \text{"Not OK"} & \text{otherwise} \end{cases} = \text{"OK"}$$

$$\left(\frac{M_r}{M_c} + \frac{M_{ry}}{M_{cy}}\right) + \left(\frac{V_r}{V_c} + \frac{V_{ry}}{V_{cy}} + \frac{T_r}{T_c}\right)^2 = 0.3$$

If Less than or equal to 1-is OK, Gravity loads will be less under water.

eqn H3-6

$$\Delta := \frac{W_g \cdot L^4}{384 \cdot E \cdot I_x} = 0.078 \cdot in$$

Based on EM 1110-2-3104, unusal loading conditons- Trash rachs shall be designed to 5 feet of water pressure.

$w := 5 \cdot ft \cdot 62.4 \cdot pcf \cdot 3 \cdot ft = 936\, ft \cdot psf$ *distrubuted width 3 foot spacing*

$w := \frac{w}{1.33}$ *reduced for infrequacy of event*

$w_g := 7psf$

$W_g := w_g \cdot 6 \cdot ft = 42 \cdot plf$ *Weight of grating on beam*

$L := 23 \cdot ft$ *Unbraced length of beam- conservative for hydraulic loading-grating will brace compression face.*

$M_a := \frac{w \cdot L^2}{12} = 31.02 \cdot kip \cdot ft$

$M_r := M_a = 31.024 \cdot kip \cdot ft$

$M_{ay} := \frac{(W_g + W_b) \cdot L^2}{12} = 3.3 \cdot kip \cdot ft$

$M_{ry} := M_{ay}$

Applied Shear

$V_a := \frac{w \cdot L}{2} = 8.093 \cdot kip$

$V_r := V_a$

$V_{ay} := \frac{(W_g + W_b) \cdot L}{2} = 0.9 \cdot kip$

$V_{ry} := V_{ay}$

Applied Torsion

$e := \frac{d}{2} + \frac{1.25}{2} \cdot in = 5.625 \cdot in$ *Center of beam to center of grating*

$T_a := \frac{W_g \cdot L \cdot e}{2} = 0.226 \cdot kip \cdot ft$

$T_r := T_a$

Check Flexure Chapter F

From Table F1.1 use AISE Section F7- Square and Rectangular HSS and Box Shaped Members
Check:
1. (Y) Yielding Section F7-1
2. (FLB) Flange Local Buckling Section F7-2
3. (WLB) Web Local Buckling Section F7-3

Section F7-1
Yielding

Dead load value

$\Omega_b := 1.67$

$M_n := F_y \cdot Z_x = 67.5 \cdot kip \cdot ft$

$M_c := \frac{M_n}{\Omega_b} = 40.42 \cdot kip \cdot ft$

$M_{ny} := F_y \cdot Z_y = 35 \cdot kip \cdot ft$ *eqn F7-1*

$M_{cy} := \frac{M_{ny}}{\Omega_b} = 21 \cdot kip \cdot ft$

Section F7-2 Flange Local Buckling

Does not apply for compact sections

Section F7-3 Web Local Buckling

Does not apply for compact sections

$$\text{Flexure\_is} := \begin{cases} \text{"OK"} & \text{if } M_r \le M_c \\ \text{"Not OK"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Shear Chapter G

$\Omega_v := 1.67$

$h := d - 2(3 \cdot t_w) = 7.906 \cdot in$ *Height of web in shear minus radius*

$A_w := 2 \cdot h \cdot t_w = 5.518 \cdot in^2$ *Area of web minus radius*

$k_v := 5$

$$C_v := \begin{cases} 1 & \text{if } \lambda_w \le 1.10 \cdot \sqrt{k_v \cdot \frac{E}{F_y}} \\ \frac{1.10 \cdot \sqrt{k_v \cdot \frac{E}{F_y}}}{\lambda_w} & \text{if } 1.10 \cdot \sqrt{k_v \cdot \frac{E}{F_y}} < \lambda_w \le 1.37 \cdot \sqrt{k_v \cdot \frac{E}{F_y}} \\ \frac{1.51 \cdot E \cdot k_v}{(\lambda_w)^2 \cdot F_y} & \text{if } \lambda_w > 1.37 \cdot \sqrt{k_v \cdot \frac{E}{F_y}} \end{cases} = 1$$

eqn G2-3

eqn G2-4

eqn G2-5

$V_n := 0.6 \cdot F_y \cdot A_w \cdot C_v = 99.3 \cdot kip$ *eqn G2-1*

$$V_c := \frac{V_n}{\Omega_v} = 59.5 \cdot kip$$

$$\text{Shear\_is} := \begin{cases} \text{"OK"} & \text{if } V_r \le V_c \\ \text{"Not OK"} & \text{otherwise} \end{cases} = \text{"OK"}$$

$h_y := d_y - 2 \cdot 3 \cdot t_w = 1.906 \cdot in$ *Dead load value*

$A_{wy} := 2 \cdot h_y \cdot t_w = 1.33 \cdot in^2$

$V_{ny} := 0.6 \cdot F_y \cdot A_{wy} \cdot C_v = 23.947 \cdot kip$

$$V_{cy} := \frac{V_{ny}}{\Omega_v} = 14.34 \cdot kip$$

Design for member in Torsion and Flexure H3-6b

$\frac{h}{t} = \lambda_w$ $\Omega_t := 1.67$ $(0.6 \cdot F_y) = 18 \cdot ksi$

$$F_{cr} := \begin{cases} (0.6 \cdot F_y) & \text{if } \lambda_w \le 2.45 \cdot \sqrt{\frac{E}{F_y}} \\ 0.6 \cdot F_y \cdot \frac{\left(2.45 \sqrt{\frac{E}{F_y}}\right)}{\lambda_w} & \text{if } 2.45 \cdot \sqrt{\frac{E}{F_y}} < \lambda_w \le 3.07 \cdot \sqrt{\frac{E}{F_y}} \\ 0.458 \cdot \pi^2 \cdot \frac{E}{\lambda_w^2} & \text{if } 3.07 \cdot \sqrt{\frac{E}{F_y}} < \lambda_w \le 260 \end{cases} = 18 \cdot ksi$$

eqn H3-3

eqn H3-4

eqn H3-5

$T_n := F_{cr} \cdot C = 36.6 \, ft \cdot kip$ *eqn H3-1*

$T_c := \frac{T_n}{\Omega_t} = 21.916 \, ft \cdot kip$

$$Torsion\_is := \begin{cases} \text{"OK"} & \text{if } T_r \le T_c \\ \text{"Not OK"} & \text{otherwise} \end{cases} = \text{"OK"}$$

$$\left(\frac{M_r}{M_c} + \frac{M_{ry}}{M_{cy}}\right) + \left(\frac{V_r}{V_c} + \frac{V_{ry}}{V_{cy}} + \frac{T_r}{T_c}\right)^2 = 0.97$$

If Less than or equal to 1-is OK, Gravity loads will be less under water.

eqn H3-6

$$\Delta := \frac{W_g \cdot L^4}{384 \cdot E \cdot I_x} = 0.078 \cdot in$$

Dalles AWS
Size steel pipe in non-overflow Monolith

Reference:
1. Steel Penstocks 2nd ed, Bambei Jr. John H., ASCE, 2012
2. AWWA M11, Steel Pipe- A guide for Design and Installation

Note Pipes in concrete are typically governed by buckling lobe based on Amstutz Formulations. Other factors will need to be checked such as internal pressure and water hammer pressure. For 30% DDR will just check Amztutz Formulations. Calcs can be refined in final design.

This is a quick check for internal pressures to validate the assumption that lobe buckling will govern the design. Based on AWWA M11 Table 4-2, for allowable stress of the steel pipe to reach 15000psi (FOS of approx 2.4) a120" 1/2 wall pipe can handle 125 psi. Internal water pressure at the inlet has 67 feet of head with 29psi internal pressure. the steel pipe is adequate for the loads. Note, thicker pipe will increase in pressure loading capacity. Water hammer should be checked in final design.

Pipe properties through Dam.

$t := \frac{5}{8} \cdot in$ — *Pipe thickness*

$D := 10 \cdot ft = 120 \cdot in$ — *DIA of Pipe*

$E := 29000ksi$ — *Modulus of Elasticity of steel*

$\nu := 0.3$ — *Poisson's Ratio*

$\sigma_y := 35 \cdot ksi$ — *yield stress*

Applied load at pipe elevation

$\gamma_w := 62.4 \cdot \frac{lbf}{ft^3}$

$H_w := 178.4ft - 111.5 \cdot ft = 66.9\,ft$ — *PMF water elevation to base of Pipe*

$P := \gamma_w \cdot H_w = 29\,psi$ — *Required external pressure to resist by pipe, based on Steel Penstocks 2nd ed*

Determine Pipe Wall Thickness

$t_{min} := \frac{(D + 20in)}{400}$ — *Minimum Wall Thickness, based on handling* — *AWWA M11 section 4.6 , eqn 4-6*

$t_{min} = 0.4 \cdot in$

$FS := 1.5$

Factor of safety is based on Section 3.5.5. Buckling FS for empty tunnel liner is 1.5 The buckling FOS for an exposed penstock in 2.4 (based on a theoretical FOS of 3 and a knockdown factor of 0.8)

$t_{min2} := \frac{P \cdot \frac{D}{2}}{\frac{\sigma_y}{FS}} = 0.07 \cdot in$ — *eqn (4-1)*

Steel Penstock Chapter 6- Steel Tunnel Liners

Design For external Pressures

"The critical external buckling pressure for an unstiffened steel liner is determined by considering a gap between the steel liner an the concrete backfill surround caused by concrete shrinkage and temperature differences. The gap can realistically vary from 0 to 0.001 times the radius." (Steel Penstocks, Section 6.2)

Amstutz Formulation

$E^* := \frac{E}{(1 - \nu^2)} = 31868.1 \cdot ksi$ *reduced modulus when axial stress exceeds 80% of yield stress*

$\mu := 1.5 - 0.5\left[\frac{1}{\left(1 - 0.002 \cdot \frac{E}{\sigma_y}\right)}\right]^2$ *Supporting effects coefficient (which can be set equal to 1 to allow for shape irregularities)*

$\mu = 0.3$

$\mu := 1.0$ *Set to 1.0*

$\sigma^*_y := \frac{\mu \cdot \sigma_y}{(1 - \nu + \nu^2)^{\frac{1}{2}}}$ $\sigma^*_y = 39378.1\ psi$

$i := \frac{t}{\sqrt{12}} = 0.2 \cdot in$

$e := \frac{t}{2} = 0.3 \cdot in$

$r := \frac{D}{2} = 60 \cdot in$ *Tunnel liner radius*

$F := t$ *Total cross sectional area of ring between stiffeners*

$\sigma_v = -\left(\frac{\Delta}{r}\right) \cdot E^*$

$\frac{\Delta}{r} = \gamma$ *Gap ratio, for gaps ratios between steel and concrete see Fig 6.3 and 6.4- Penstock Design*

$\frac{D}{t} = 192$ *Used for Amstutz curves (Figures to check math)*

$\Delta := 0.0003 \cdot r = 0.018 \cdot in$ *Assume a 46 deg temp difference*

$\frac{\Delta}{r} = 0.0003$ *Used for Amstutz curves (Figures to check math)*

$\sigma_v := -\left(\frac{\Delta}{r}\right) \cdot E^* = -9560.4\ psi$

$\sigma_N := 0.8 \cdot \sigma_y = 28000\ psi$

Given

$$\frac{\sigma_N - \sigma_v}{\sigma^*_y - \sigma_N} \cdot \left[\left(\frac{r}{i}\right) \cdot \sqrt{\frac{\sigma_N}{E^*}}\right]^3 = 1.73 \cdot \left(\frac{r}{e}\right)\left[1 - 0.225\left(\frac{r}{e}\right) \cdot \frac{\sigma^*_y - \sigma_N}{E^*}\right]$$ *eqn (6-1)*

$\sigma_N := Find(\sigma_N)$

$\sigma_N = 14106.7\ psi$ *circumferential axial stress in plate liner ring*

$$\left| \begin{array}{l} \text{"Use E* "} \quad \text{if } \sigma_N \ge 0.8 \cdot \sigma_y \\ \text{"Unity in equations"} \quad \text{if } \sigma_N < 0.8 \cdot \sigma_y \end{array} \right. = \text{"Unity in equations"} \qquad \sigma_y = 35 \cdot ksi$$

$$P_{cr} := \left(\frac{F}{r}\right) \cdot \sigma_N \cdot \left[1 - 0.175 \left(\frac{r}{e}\right) \frac{\sigma^*_y - \sigma_N}{E^*}\right] = 143\ psi$$

Penstock - Eqn 6-2 Critical external Buckling Pressure

$P_{cr} = 143\ psi$

$$P_{all.m} := \frac{P_{cr}}{FS} = 95.4\ psi$$

Allowable buckling pressure (with modified E)

Now Calculate with E not modified, Based on the text, E modified is required if 80% of the axial stress were to exceed about 80% of yield stress. The current sizing has less than 80% if yield stress.

$$E^* := \left| \begin{array}{l} E^* \quad \text{if } \sigma_N \ge 0.8 \cdot \sigma_y \\ E \quad \text{if } \sigma_N < 0.8 \cdot \sigma_y \end{array} \right. = 29000 \cdot ksi$$

Given

$$\frac{\sigma_N - \sigma_v}{\sigma^*_y - \sigma_N} \cdot \left[\left(\frac{r}{i}\right) \cdot \sqrt{\frac{\sigma_N}{E^*}}\right]^3 = 1.73 \cdot \left(\frac{r}{e}\right) \left[1 - 0.225 \left(\frac{r}{e}\right) \cdot \frac{\sigma^*_y - \sigma_N}{E^*}\right]$$

$$\sigma_N := \text{Find}(\sigma_N)$$

$\sigma_N = 13342.5\ psi$

circumferential axial stress in plate liner ring

$$\left| \begin{array}{l} \text{"Use E* "} \quad \text{if } \sigma_N \ge 0.8 \cdot \sigma_y \\ \text{"Unity in equations"} \quad \text{if } \sigma_N < 0.8 \cdot \sigma_y \end{array} \right. = \text{"Unity in equations"} \qquad \sigma_y = 35 \cdot ksi$$

$$P_{cr} := \left(\frac{F}{r}\right) \cdot \sigma_N \cdot \left[1 - 0.175 \left(\frac{r}{e}\right) \frac{\sigma^*_y - \sigma_N}{E^*}\right] = 134.8\ psi$$

$P_{cr} = 134.8\ psi$

$$P_{all.nm} := \frac{P_{cr}}{FS} = 89.9\ psi$$

Allowable buckling pressure (without modified E)

$P_{all} := \min(P_{all.nm}, P_{all.m}) = 89.9\ psi$

Used the minimum allowable bucking pressure

$$\text{Pressure\_is\_} := \left| \begin{array}{l} \text{"OK"} \quad \text{if } P_{all} \ge P \\ \text{"Not OK"} \quad \text{otherwise} \end{array} \right. = \text{"OK"}$$

Compare allowable pressures to applied pressures.

Dalles AWS
Size steel pipe buried under soil

Reference:
1. Steel Penstocks 2nd ed, Bambei Jr. John H., ASCE, 2012
2. AWWA M11, Steel Pipe- A guide for Design and Installation

This calc is checking an HS-20 load over the pipe with 2feet of fill material. This is to check for displacements on the buried steel pipe. This is one set of calc's based on AWWA M11 and steel penstock design. For final design all calculations should be performed.

Pipe properties

$t := \frac{1}{2} \cdot in$ — *Pipe thickness*

$D := 10 \cdot ft = 120 \cdot in$ — *DIA of Pipe*

$E := 29000ksi$ — *Modulus of Elasticity of steel*

$r := \frac{D + t}{2} = 60.3\,in$ — *Pipe mean radius*

$I := \frac{t^3}{12} = 0.0104\,\frac{in^4}{in}$ — *Moment of inertia of pipe wall*

$B_c := D + 2 \cdot t = 121\,in$ — *Pipe outside DIA*

$D_l := 1.5$ — *Deflection lag factor AWWA M11 Note at base of page, Varies from 1.0-1.5. 1.0 for pressure pipes. Accounts for long term settlement in soil.*

$K := 0.1$ — *Bedding Constant, AWWA M11*

$E' := 1000psi$ — *soil modulus: Course soil with little or no fines, 90% relative compaction- assumed see AWWA M11 2004 table 6-1 values*

$H := 2 \cdot ft$ — *soil cover*

$w := 120 \cdot \frac{lbf}{ft^3}$ — *unit weight of soil*

$W_L := 800psf \cdot (B_c) = 672.2\,\frac{lbf}{in}$ — *Surface live load, assume highway HS-20 live load: see Table 6-3 from AWWA M11 2004*

$W_c := w \cdot H \cdot B_c = 201.7\,\frac{lbf}{in}$ — *Soil Dead Load*

$W := W_c + W_L = 873.9\,\frac{lbf}{in}$ — *Surface live load+soil dead load*

$E := 29000ksi$ — *Modulus of elasticity of steel*

Buried pipes with HS-20 Load

$x := D_l \cdot \left(\frac{K \cdot W \cdot r^3}{E \cdot I + 0.061 \cdot E' \cdot r^3} \right) = 2.1\,in$ *Modified Iowa formula for horizontal deflection, per AWWA M11 2004, eqn 6-5*

$\Delta := \frac{x}{D} = 0.0175$

$\Delta = 1.8\,\%$ — *Modified Iowa formula for horizontal deflection in %*

AWWA M11 (2004) Allowable pipe deflection for various coatings

Mortar lined coated= 2% Pipe DIA
Mortar lined and flexible coated= 3% Pipe DIA
Flexible lined and coated= 5% Pipe DIA

These calc's do not represent soil displacements, they are only for the structural integrity of the steel pipe. Note that soil displacement and settlements calc's need to be determined in final design.

$\delta_{all5\%} := D \cdot 5\% = 6\,\text{in}$

$\delta_{all3\%} := D \cdot 3\% = 3.6\,\text{in}$

This pipe should be flexible lined and coated-epoxy paint- 5% Pipe DIA will be used for displacement

$$\text{Pipe\_displacement\_is} := \begin{cases} \text{"OK"} & \text{if } x \le \delta_{all5\%} \\ \text{"Not OK"} & \text{otherwise} \end{cases} = \text{"OK"}$$

AWWA -M11

45' span

The flexure stress S_f should be calculated in the usual manner. In single spans, this stress is maximum at the center between supports and may be quite small over the support if flexible joints are used at the pipe ends. In multiple-span cases, the flexure stress in rigidly joined pipe will be that indicated by the theory of continuous beams.

For pipe with diameters of 6 in. to 144 in., Table 7-1 gives practical safe spans that may be on the conservative side for pipes supporting their weight plus that of the contained water. Other live loads such as earthquake, wind, or the like should also be calculated. Data for calculating spans for large pipe on saddles have been published.[2]

Table 7-1 Practical Safe Spans for Simply Supported Pipe in 120° Contact Saddles*

Nominal Size *in.*	Wall Thickness *in.*: 3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1
	Span *L* *ft*									
6	36	40	44							
8	38	42	45							
10	39	43	46							
12	40	44	47							
14	40	44	47							
16	41	45	48							
18	41	46	49	52						
20	42	46	50	53						
22	42	46	51	54						
24	42	48	52	55	58	60				
26	43	48	52	56	59	61				
28	43	48	53	56	59	62				
30	43	49	53	57	60	63				
32	44	49	54	57	61	64				
34	44	49	54	58	61	64				
36	44	50	54	58	62	65	70			
38	44	50	55	59	62	65	70			
40	44	50	55	59	63	66	71			
42	44	50	55	59	63	66	72			
45		51	55	60	63	67	72			
48		51	56	60	64	67	73	78		
51		51	56	60	64	68	74	79		
54		51	56	61	65	68	74	79		
57		51	57	61	65	69	75	80		
60		51	57	61	65	69	75	80		
63		52	57	62	66	69	76	81		
66		52	57	62	66	70	76	81	86	90
72		52	58	62	66	70	77	82	87	92
78			58	62	67	71	77	83	88	93
84			58	63	67	71	78	84	89	94
90			58	63	67	71	78	84	90	94
96			58	63	68	72	79	85	90	95
102			58	63	68	72	79	85	91	96
108				64	68	72	80	86	91	96
114				64	68	73	80	86	92	97
120					69	73	80	87	92	98
126					69	73	81	87	93	98
132					69	73	81	87	93	98
138					69	73	81	88	94	99
144					69	74	81	88	94	99

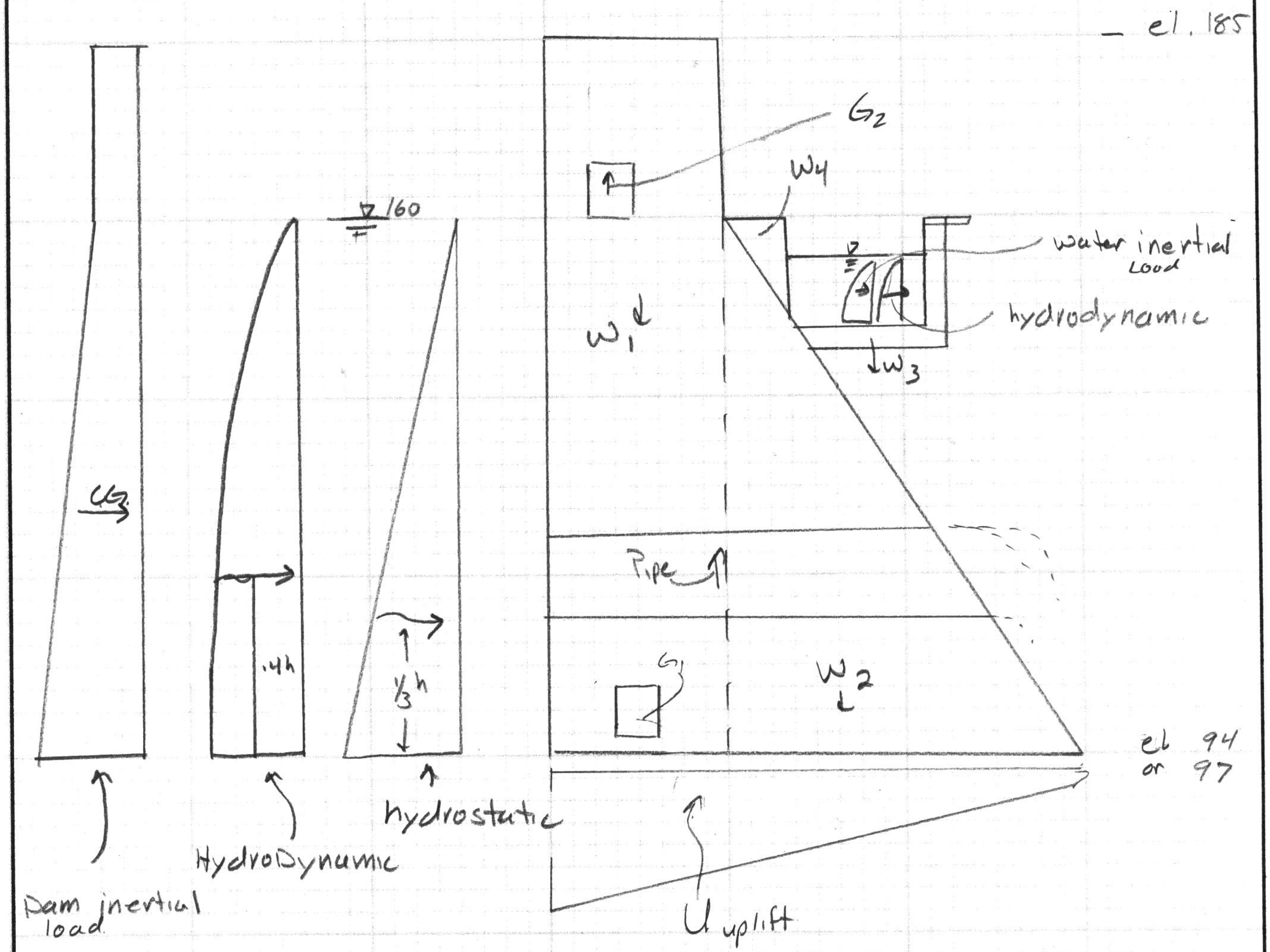
*After Cates[3]: *d* and *t* are pipe diameter and thickness (in inches) respectively, and *L* is in feet; fiber stress = 8000 psi, loaded by dead weight of pipe plus container water.

U.S. ARMY CORPS OF ENGINEERS OFFICE SYMBOL:

PROJECT: Dalles Dam AWS DDR	COMPUTED BY:	DATE:
SUBJECT: stability (sliding)	CHECKED BY:	SHT. OF PART:

Non overflow monolith 5, South side.

Gravity method.



These calcs check normal pool elevation for base condition

Monolith 5 Stability Check
Reference Hand Sketch for sections
Calcs are per monolith width of 69'-4"
Ignored water pressure in fish ladder- MathCAD seismic calcs showed this had little effect.
Moment arm about toe of dam
Base elevation of Dam 94 - assumed, based on drawings DDF-1-4-5/P2 and DDf-1-4-5/P3 to find gallery base
Top of Dam 185
Ignore soil at toe of dam

Specific Gravity Water	62.5	lb/ft^3	
Wt Concrete	150	lb/ft^3	
Normal high Pool	160	ft	
Max Pool	181.8	ft	
Tail water is below Toe- 100yr event			
EL of base of monolith	94	ft	
Length of Monolith	64.4	ft	Based on depth of 94ft
Depth of Monolith	69.33	ft	

Assume a 60 ft tall coffer cell

	L	H	Area	Volume	Weight/ Force	M arm	Moment	
	ft	ft	ft^2	ft^3	kip	ft	kip-ft	
W1	20	91	1820	126181	18927	54.4	**1029634**	See hand sketch
W2			1642.8	113895	17084	29.6	**505695**	See hand sketch
W3	21.4	2.417	51.7238	3586	538	18.9	**10166**	See hand sketch
W4			83.35	5779	867	37.7	**32678**	See hand sketch
Pipe area				0	0	0.0	**0**	Pipe Area
G1	7.68	7	53.76	3727	-559	53.2	**-29762**	Gallery 1
G2	6	8	48	3328	-499	51.4	**-25658**	Gallery 2
Uplift	2062.5				-9209	42.9	**-395363**	
Water	2062.5				-9438	22.0	**-207626**	
Coffer Cell load					0	0.0	**0**	
Sum Vertical Force	kip				**27149**			
Sum Moments	kip-ft						**919765**	

M/V=	ft	**33.88**	
Middle 2/3 Range			
1/3 Range	ft	21.47	OK if M/V is in this Range
2/3 Range	ft	42.93	

Sliding These calcs check normal pool elevation for base condition

Case 4 Phi=0 C=0psi

Phi	45	deg	Angle of internal friction of the foundation material under the structural wedge
c	0	kip/ft^2	Cohesive strength of the foundation material under structural wedge
W	36358	kip	Sum of Gravity loads- minus uplift
U	9209	kip	Uplift
P	9438	kip	Hydraulic Pressure
T	9438	kip	Shear force acting parallel to the base of the wedge
N	27149	kip	Force acting normal to the sliding failure plane under the structural wedge
FS	**2.88**		

Case 3 Phi=45 C=250psi

Phi	45	deg
c	36	kip/ft^2
W	36358	kip
U	9209	kip
P	9438	kip
T	9438	kip
N	27149	kip
FS	**19.91**	

Case 2 Phi=40deg C=200psi

Phi	40	deg
c	28.8	kip/ft^2
W	36358	kip
U	9209	kip
P	9438	kip
T	9438	kip
N	27149	kip
FS	**16.04**	

Case1 Phi=30deg C=36psi

Phi	30	deg
c	5.18	kip/ft^2
W	36358	kip
U	9209	kip
P	9438	kip
T	9438	kip
N	27149	kip
FS	**4.11**	

These calcs check normal pool elevation with a 10' DIA pipe removed from monolith

Monolith 5 Stability Check
Reference Hand Sketch for sections
Ignored water pressure in fish ladder- MathCAD seismic calcs showed this had little effect.
Calcs are per monolith width of 69'-4"
Moment arm about toe of dam
Base elevation of Dam 94 - assumed, based on drawings DDF-1-4-5/P2 and DDf-1-4-5/P3 to find gallery base
Top of Dam 185
Ignore soil at toe of dam

Specific Gravity Water	62.5	lb/ft^3	
Wt Concrete	150	lb/ft^3	
Normal high Pool	160	ft	
Max Pool	181.8	ft	
Tail water is below Toe- 100yr event			
EL of base of monolith	94	ft	
Length of Monolith	64.4	ft	Based on depth of 94ft
Depth of Monolith	69.33	ft	

Assume a 60 ft tall coffer cell

	L	H	Area	Volume	Weight/ Force	M arm	Moment	
	ft	ft	ft^2	ft^3	kip	ft	kip-ft	
W1	20	91	1820	126181	18927	54.4	**1029634**	See hand sketch
W2			1642.8	113895	17084	29.6	**505695**	See hand sketch
W3	21.4	2.417	51.7238	3586	538	18.9	**10166**	See hand sketch
W4			83.35	5779	867	37.7	**32678**	See hand sketch
Pipe area				3925	-589	25.0	**-14719**	Pipe Area
G1	7.68	7	53.76	3727	-559	53.2	**-29762**	Gallery 1
G2	6	8	48	3328	-499	51.4	**-25658**	Gallery 2
Uplift	2062.5				-9209	42.9	**-395363**	
Water	2062.5				-9438	22.0	**-207626**	
Coffer Cell load					0	0.0	**0**	
Sum Vertical Force	kip				**26560**			
Sum Moments	kip-ft						**905046**	
M/V=	ft	**34.08**						
Middle 2/3 Range								
1/3 Range	ft	21.47	OK if M/V is in this Range					
2/3 Range	ft	42.93						

Sliding — These calcs check normal pool elevation with a 10' DIA pipe removed from monolith

Case 4 Phi=0 C=0psi

Phi	45	deg	Angle of internal friction of the foundation material under the structural wedge
c	0	kip/ft^2	Cohesive strength of the foundation material under structural wedge
W	35769	kip	Sum of Gravity loads- minus uplift
U	9209	kip	Uplift
P	9438	kip	Hydraulic Pressure
T	9438	kip	Shear force acting parallel to the base of the wedge
N	26560	kip	Force acting normal to the sliding failure plane under the structural wedge
FS	**2.81**		

Case 3 Phi=45 C=250psi

Phi	45	deg
c	36	kip/ft^2
W	35769	kip
U	9209	kip
P	9438	kip
T	9438	kip
N	26560	kip
FS	**19.85**	

Case 2 Phi=40deg C=200psi

Phi	40	deg
c	28.8	kip/ft^2
W	35769	kip
U	9209	kip
P	9438	kip
T	9438	kip
N	26560	kip
FS	**15.99**	

Case1 Phi=30deg C=36psi

Phi	30	deg
c	5.18	kip/ft^2
W	35769	kip
U	9209	kip
P	9438	kip
T	9438	kip
N	26560	kip
FS	**4.08**	

These calcs check normal pool elevation with a 10' DIA pipe removed and a 35' DIA half coffer cell on face of dam.

Monolith 5 Stability Check
Reference Hand Sketch for sections
Calcs are per monolith width of 69'-4"
Ignored water pressure in fish ladder- MathCAD seismic calcs showed this had little effect.
Moment arm about toe of dam
Base elevation of Dam 94 - assumed, based on drawings DDF-1-4-5/P2 and DDf-1-4-5/P3 to find gallery base
Top of Dam 185
Ignore soil at toe of dam

Specific Gravity Water	62.5	lb/ft^3	
Wt Concrete	150	lb/ft^3	
Normal high Pool	160	ft	
Max Pool	181.8	ft	
Tail water is below Toe- 100yr event			
EL of base of monolith	94	ft	
Depth of Monolith	69.33	ft	
Length of Monolith	64.4	ft	Based on depth of 94ft

Assume a 60 ft tall coffer cell

	L	H	Area	Volume	Weight/ Force	M arm	Moment	
	ft	ft	ft^2	ft^3	kip	ft	kip-ft	
W1	20	91	1820	126180.6	18927	54.4	**1029634**	See hand sketch
W2			1642.8	113895.3	17084	29.6	**505695**	See hand sketch
W3	21.4	2.417	51.7238	3586.011	538	18.9	**10166**	See hand sketch
W4			83.35	5778.656	867	37.7	**32678**	See hand sketch
Pipe Volume				3925	-589	25.0	**-14719**	Pipe Area
G1	7.68	7	53.76	3727.181	-559	53.2	**-29762**	Gallery 1
G2	6	8	48	3327.84	-499	51.4	**-25658**	Gallery 2
Uplift	2062.5				-9209	42.9	**-395363**	
Water	2062.5				-9438	22.0	**-207626**	
Coffer Cell load				28848.75	-1803	71.6	**-129089**	
Sum Vertical Force	kip				**24757**			
Sum Moments	kip-ft						**775957**	
M/V=	ft		**31.34**					
Middle 2/3 Range								
1/3 Range	ft		23.11	OK if M/V is in this Range				
2/3 Range	ft		46.22					

Sliding — These calcs check normal pool elevation with a 10' DIA pipe removed and a 35' DIA half coffer cell on face of dam.

Case 4 Phi=0 C=0psi

Phi	45	deg	Angle of internal friction of the foundation material under the structural wedge
c	0	ksf	Cohesive strength of the foundation material under structural wedge
W	33966	Kip	Sum of Gravity loads- minus uplift
U	9209	Kip	Uplift
P	9438	kip	Hydraulic Pressure
T	9438	kip	Shear force acting parallel to the base of the wedge
N	24757	kip	Force acting normal to the sliding failure plane under the structural wedge
FS	**2.62**		

Case 3 Phi=45 C=250psi

Phi	45	deg
c	36	ksf
W	33966	
U	9209	
P	9438	kip
T	9438	kip
N	24757	kip
FS	**19.65**	

Case 2 Phi=40deg C=200psi

Phi	40	deg
c	28.8	ksf
W	33966	
U	9209	
P	9438	kip
T	9438	kip
N	24757	kip
FS	**15.83**	

Case1 Phi=30deg C=36psi

Phi	30	deg
c	5.18	ksf
W	33966	
U	9209	
P	9438	kip
T	9438	kip
N	24757	kip
FS	**3.97**	

Dalles AWS monolith 5 sliding calcs with seismic

These calculations are to check sliding stability for Monolith 5 with a 10foot DIA hole installed for the AWS pipe. The calculations will include Hydrodynamic load for seismic conditions. The intent is to verify the SSR and original calcs that flood load governs design.

References
The Dalles Lock and Dam Seismic Safety Review (SSR) Dated 27 September 2013 (95% PCCR Draft)
EM 1110-2-2100
EM 1110-2-2200
DDF-1-4-5/P2- monolith 5 drawing
Original Hand Calcs

Ignored from calculation (this is conservative)
- *Fill/rock at toes of dam*
- *Potential shear key around grout gallery.*

$\gamma_c := 150\text{pcf}$ — *specific weight of concrete*

$\gamma_w := 62.5\text{pcf}$ — *specific weight of water*

$W_{el\_1} := 160\text{ft}$ — *Hi normal pool elevation*

$W_{el\_2} := 94\text{ft}$ — *Approx base of monolith*

$h := W_{el\_1} - W_{el\_2} = 66\,\text{ft}$ — *Depth of water acting on Monolith*

$L_{m5} := 69.33\text{ft}$ — *Monolith length*

Tail water is below base of monolith

$\text{Deck\_el} := 185\cdot\text{ft}$ — *deck elevation*

$\text{Base\_el} := W_{el\_2} = 94\,\text{ft}$ — *Base elevation*

$M_{5\_base} := 20\cdot\text{ft} + .6\cdot(168.\text{ft} - \text{Base\_el}) = 64.4\,\text{ft}$ — *Monolith thickness*

Develop weights- Reference hand sketch

$W_1 := 20\text{ft}\cdot(\text{Deck\_el} - \text{Base\_el})\cdot\gamma_c\cdot L_{m5} = 18927\cdot\text{kip}$ $\quad \text{Deck\_el} - \text{Base\_el} = 91\,\text{ft}$

$W_2 := \frac{1}{2}\cdot(168\cdot\text{ft} - \text{Base\_el})\cdot[.6\cdot(168\text{ft} - \text{Base\_el})]\cdot\gamma_c\cdot L_{m5} = 17084\cdot\text{kip}$

$W_3 := 21.4\text{ft}\cdot 2\cdot\text{ft}\cdot\gamma_c\cdot L_{m5} = 445\cdot\text{kip}$

$W_4 := \frac{1}{2}\cdot 10\text{ft}\cdot 16.67\cdot\text{ft}\cdot\gamma_c\cdot L_{m5} = 867\cdot\text{kip}$ — *Approx Fish ladder weight*

Galleries

$U_1 := 6\cdot\text{ft}\cdot 8\cdot\text{ft}\cdot\gamma_c\cdot L_{m5} = 499\cdot\text{kip}$

$U_2 := 7.68\cdot\text{ft}\cdot 7\cdot\text{ft}\cdot\gamma_c\cdot L_{m5} = 559\cdot\text{kip}$

Pipe

$P_{pipe} := \frac{\pi}{4}\cdot(10\text{ft})^2\cdot 50\cdot\text{ft}\cdot\gamma_c = 589\cdot\text{kip}$ — *Weight of concrete removed from pipe*

Weight of Dam

$$W_d := W_1 + W_2 + W_3 + W_4 - U_1 - U_1 - P_{pipe} = 35736 \cdot kip$$

Water Pressure

$$P_{water} := \frac{1}{2} \cdot (h)^2 \cdot \gamma_w \cdot L_{m5} = 9438 \cdot kip$$

Water pressure- high normal

$$P_{uplift} := \frac{1}{2} \cdot (h) \cdot \gamma_w \cdot L_{m5} \cdot M_{5\_base} = 9209 \cdot kip$$

Seismic Loading

$k := 0.126$ — *Seismic coefficient (stability)=2/3 EPGA=0.126 from SSR 2013.*

$P_E := \frac{7}{12} \cdot k \cdot h \cdot \gamma_w \cdot h^2 = 1321 \cdot kip$ — *Effect of water Hydrodynamic forces/Westergaard* — *eqn 4-2, EM 1110-2-2100*

$F_h := k \cdot W_d = 4503 \cdot kip$ — *Inertia force due to structure mass* — *eqn 4-1, EM 1110-2-2100*

Water loads due to Fish ladder

$h_{fl} := 11 \cdot ft$ — *Approx height of water in fish ladder*

$w_{fl} := 30 \cdot ft$ — *width of fish ladder*

$W_{water\_fl} := h_{fl} \cdot w_{fl} \cdot \gamma_w \cdot L_{m5} = 1430 \cdot kip$ — *Fish ladder water weight*

$P_{E\_fl} := \frac{7}{12} \cdot k \cdot h_{fl} \cdot \gamma_w \cdot h_{fl}^2 = 6 \cdot kip$ — *Westergaard load on fish ladder water*

$F_{h\_fl} := k \cdot W_{water\_fl} = 180 \cdot kip$ — *inertia force due to structure mass of water in fish ladder*

Moment arms- sum moments about the toe

$$L_{W1} := M_{5\_base} - 10 \cdot ft = 54.4\,ft$$

$$M_{5\_base} - 20 \cdot ft = 44.4\,ft$$

$$L_{W2} := \frac{2}{3}\left(M_{5\_base} - 20 \cdot ft\right) = 29.6\,ft$$

$$L_{W3} := M_{5\_base} - 30 \cdot ft - \frac{31}{2} \cdot ft = 18.9\,ft$$

$$L_{W4} := M_{5\_base} - 20 \cdot ft - \frac{2}{3} \cdot 10 \cdot ft = 37.7\,ft$$

$$L_{U1} := M_{5\_base} - 10 \cdot ft - 3 \cdot ft = 51.4\,ft$$

$$L_{U2} := M_{5\_base} - 7.33 \cdot ft - \frac{7.68 \cdot ft}{2} = 53.2\,ft$$

$$L_{pipe} := \frac{50 \cdot ft}{2} = 25\,ft$$

$$L_{water} := \frac{1}{3} \cdot h = 22\,ft$$

$L_{uplift} := \frac{2}{3} \cdot M_{5\_base} = 42.9\,ft$

$L_{P.E} := 0.4 \cdot h = 26.4\,ft$

$L_{PE\_fl} := 0.4 \cdot h_{fl} + (Deck\_el - Base\_el) - 38 \cdot ft = 57.4\,ft$ — *Fish ladder Westergaard distance*

$L_{water\_fl} := M_{5\_base} - 30 \cdot ft - \frac{30ft}{2} = 19.4\,ft$ — *fish ladder water distance*

$L_{h\_fl} := (Deck\_el - Base\_el) - 38 \cdot ft + \frac{1}{2} h_{fl} = 58.5\,ft$ — *Fish ladder inertia distance*

Determine Approx location for CG of monolith

$d_1 := \frac{Deck\_el - Base\_el}{2} = 45.5\,ft$

$d_2 := [(Deck\_el - Base\_el) - 17 \cdot ft] \cdot \frac{1}{3} = 24.7\,ft$

$d_3 := (Deck\_el - Base\_el) - 39.25 \cdot ft = 51.75\,ft$

$d_4 := (Deck\_el - Base\_el) - 17 \cdot ft - \frac{1}{3} 16.67 \cdot ft = 68.4\,ft$

$d_5 := 4 \cdot ft$

$d_6 := (Deck\_el - Base\_el) - 13.5 \cdot ft = 77.5\,ft$

$$Y_{bar} := \frac{d_1 \cdot W_1 + d_2 \cdot W_2 + d_3 \cdot W_3 + d_4 \cdot W_4 + d_5 \cdot (-U_1) + d_6 \cdot (-U_2)}{W_1 + W_2 + W_3 + W_4 - U_1 - U_2} = 36.389\,ft$$

Moments

$M_{W1} := W_1 \cdot L_{W1} = 1029634 \cdot kip \cdot ft$

$M_{W2} := W_2 \cdot L_{W2} = 505695 \cdot kip \cdot ft$

$M_{W3} := W_3 \cdot L_{W3} = 8412 \cdot kip \cdot ft$

$M_{W4} := W_4 \cdot L_{W4} = 32707 \cdot kip \cdot ft$

$M_{U1} := U_1 \cdot L_{U1} = 25658 \cdot kip \cdot ft$

$M_{U2} := U_2 \cdot L_{U2} = 29760 \cdot kip \cdot ft$

$M_{pipe} := L_{pipe} \cdot P_{pipe} = 14726 \cdot kip \cdot ft$

$M_{water} := P_{water} \cdot L_{water} = 207626 \cdot kip \cdot ft$

$M_{uplift} := P_{uplift} \cdot L_{uplift} = 395363\,ft \cdot kip$

$M_{PE} := P_E \cdot L_{P.E} = 34866 \cdot kip \cdot ft$

$M_{F.h} := F_h \cdot Y_{bar} = 163847 \cdot kip \cdot ft$

$M_{w\_fl} := W_{water\_fl} \cdot L_{water\_fl} = 27741 \cdot kip \cdot ft$

$M_{E\_fl} := P_{E\_fl} \cdot L_{PE\_fl} = 351 \cdot kip \cdot ft$

$M_{h\_fl} := F_{h\_fl} \cdot L_{h\_fl} = 10540 \cdot kip \cdot ft$

Sum Moments

$M_{toe1} := M_{W1} + M_{W2} + M_{W3} + M_{W4} + M_{w\_fl} = 1604189 \cdot kip \cdot ft$

$M_{toe2} := -M_{U1} - M_{U2} - M_{pipe} - M_{water} - M_{uplift} - M_{PE} - M_{F.h} - M_{E\_fl} - M_{h\_fl} = -882737 \cdot kip \cdot ft$

$M_d := M_{toe1} + M_{toe2} = 721453 \cdot kip \cdot ft$

Positive and negative moments were separated due to space on sheet. Moments are added to gather in Md

Sum Vertical Forces

$V_d := W_d - P_{uplift} + W_{water\_fl} = 27957 \cdot kip$

$\frac{1}{3} \cdot M_{5\_base} = 21.5\,ft \qquad \frac{2}{3} \cdot M_{5\_base} = 42.9\,ft$

$\frac{M_d}{V_d} = 25.8\,ft$ *Resultant*

Factor of Safety EM 1110-2-2100 eqn 5-3

$FS_s = \frac{N \cdot \tan\phi + c \cdot L}{T}$

$T := P_{water} + P_E + F_h + F_{h\_fl} + P_{E\_fl} = 15447 \cdot kip$ *Shear force acting parallel to the base of the wedge*

$N := W_d - P_{uplift} = 26527 \cdot kip$ *Force acting normal to the sliding failure plane under the structural wedge*

$L := M_{5\_base} \cdot L_{m5} = 4465\,ft^2$

Case 4

$\phi_{case4} := 45 \cdot deg$ *Angle of internal friction of the foundation material under the structural wedge*

$c_{case4} := 0 \cdot \frac{kip}{ft^2}$ *Cohesive strength of the foundation material under structural wedge*

$FS_{s4} := \frac{N \cdot \tan(\phi_{case4}) + c_{case4} \cdot L}{T} = 1.72$

Case 3

$\phi_{case3} := 45 \cdot deg$

$c_{case3} := 36 \cdot \frac{kip}{ft^2}$

$FS_{s3} := \frac{N \cdot \tan(\phi_{case3}) + c_{case3} \cdot L}{T} = 12.12$

Case 2

$\phi_{case2} := 40 \cdot deg$

$c_{case2} := 28.8 \cdot \frac{kip}{ft^2}$

$FS_{s2} := \frac{N \cdot \tan(\phi_{case2}) + c_{case2} \cdot L}{T} = 9.77$

Case 1

$\phi_{case1} := 30 \cdot deg$

$c_{case1} := 5.18 \cdot \frac{kip}{ft^2}$

$FS_{s1} := \frac{N \cdot \tan(\phi_{case1}) + c_{case1} \cdot L}{T} = 2.49$

$$FS_s := \begin{pmatrix} FS_{s1} \\ FS_{s2} \\ FS_{s3} \\ FS_{s4} \end{pmatrix} = \begin{pmatrix} 2.49 \\ 9.77 \\ 12.12 \\ 1.72 \end{pmatrix}$$

Check max applies stress, stress=M/S+P/A

$S := \frac{1}{6} \cdot L_{m5} \cdot M_{5\_base}{}^2 = 47923 \cdot ft^3$

$\sigma_{axial} := \frac{W_d}{L_{m5} \cdot M_{5\_base}} = 55.6\ psi$

$\sigma_{flexual} := \frac{M_d}{S} = 104.5\ psi$

$\sigma_{seismic} := \sigma_{axial} + \sigma_{flexual} = 160.1\ psi$

$\sigma_{seismic} = 23058.3 \cdot psf$

Dalles AWS monolith 5 sliding calcs with seismic

These calculations are to check sliding stability for Monolith 5 with a 10foot DIA hole installed for the AWS pipe. The calculations will include Hydrodynamic load for seismic conditions. The intent is to verify the SSR and original calcs that flood load governs design.

References
The Dalles Lock and Dam Seismic Safety Review (SSR) Dated 27 September 2013 (95% PCCR Draft)
EM 1110-2-2100
EM 1110-2-2200
DDF-1-4-5/P2- monolith 5 drawing
Original Hand Calcs

Ignored from calculation (this is conservative)
 Fill/rock at toes of dam
 Potential shear key around grout gallery.

$\gamma_c := 150\text{pcf}$ — *specific weight of concrete*

$\gamma_w := 62.5\text{pcf}$ — *specific weight of water*

$W_{el\_1} := 160\text{ft}$ — *Hi normal pool elevation*

$W_{el\_2} := 97\text{ft}$ — *Approx base of monolith*

$h := W_{el\_1} - W_{el\_2} = 63\,\text{ft}$ — *Depth of water acting on Monolith*

$L_{m5} := 69.33\text{ft}$ — *Monolith length*

Tail water is below base of monolith

$\text{Deck\_el} := 185\cdot\text{ft}$ — *deck elevation*

$\text{Base\_el} := W_{el\_2} = 97\,\text{ft}$ — *Base elevation*

$M_{5\_base} := 20\cdot\text{ft} + .6\cdot(168.\text{ft} - \text{Base\_el}) = 62.6\,\text{ft}$ — *Monolith thickness*

Develop weights- Reference hand sketch

$W_1 := 20\text{ft}\cdot(\text{Deck\_el} - \text{Base\_el})\cdot\gamma_c\cdot L_{m5} = 18303\cdot\text{kip}$ $\quad \text{Deck\_el} - \text{Base\_el} = 88\,\text{ft}$

$W_2 := \frac{1}{2}\cdot(168\cdot\text{ft} - \text{Base\_el})\cdot[.6\cdot(168\text{ft} - \text{Base\_el})]\cdot\gamma_c\cdot L_{m5} = 15727\cdot\text{kip}$

$W_3 := 21.4\text{ft}\cdot 2\cdot\text{ft}\cdot\gamma_c\cdot L_{m5} = 445\cdot\text{kip}$

$W_4 := \frac{1}{2}\cdot 10\text{ft}\cdot 16.67\cdot\text{ft}\cdot\gamma_c\cdot L_{m5} = 867\cdot\text{kip}$ — *Approx Fish ladder weight*

Galleries

$U_1 := 6\cdot\text{ft}\cdot 8\cdot\text{ft}\cdot\gamma_c\cdot L_{m5} = 499\cdot\text{kip}$

$U_2 := 7.68\cdot\text{ft}\cdot 7\cdot\text{ft}\cdot\gamma_c\cdot L_{m5} = 559\cdot\text{kip}$

Pipe

$P_{pipe} := \frac{\pi}{4}\cdot(10\text{ft})^2\cdot 50\cdot\text{ft}\cdot\gamma_c = 589\cdot\text{kip}$ — *Weight of concrete removed from pipe*

Dalles AWS
Stability
ST. Calc.

By: EW
Checked By :

Weight of Dam

$$W_d := W_1 + W_2 + W_3 + W_4 - U_1 - U_1 - P_{pipe} = 33755 \cdot kip$$

Water Pressure

$$P_{water} := \frac{1}{2} \cdot (h)^2 \cdot \gamma_w \cdot L_{m5} = 8599 \cdot kip$$

Water pressure- high normal

$$P_{uplift} := \frac{1}{2} \cdot (h) \cdot \gamma_w \cdot L_{m5} \cdot M_{5\_base} = 8544 \cdot kip$$

Seismic Loading

$k := 0.126$ — *Seismic coefficient (stability)=2/3 EPGA=0.126 from SSR 2013.*

$$P_E := \frac{7}{12} \cdot k \cdot h \cdot \gamma_w \cdot h^2 = 1149 \cdot kip$$

Effect of water Hydrodynamic forces/Westergaard — *eqn 4-2, EM 1110-2-2100*

$$F_h := k \cdot W_d = 4253 \cdot kip$$

Inertia force due to structure mass — *eqn 4-1, EM 1110-2-2100*

Water loads due to Fish ladder

$h_{fl} := 11 \cdot ft$ — *Approx height of water in fish ladder*

$w_{fl} := 30 \cdot ft$ — *width of fish ladder*

$W_{water\_fl} := h_{fl} \cdot w_{fl} \cdot \gamma_w \cdot L_{m5} = 1430 \cdot kip$ — *Fish ladder water weight*

$P_{E\_fl} := \frac{7}{12} \cdot k \cdot h_{fl} \cdot \gamma_w \cdot h_{fl}^2 = 6 \cdot kip$ — *Westergaard load on fish ladder water*

$F_{h\_fl} := k \cdot W_{water\_fl} = 180 \cdot kip$ — *inertia force due to structure mass of water in fish ladder*

Moment arms- sum moments about the toe

$$L_{W1} := M_{5\_base} - 10 \cdot ft = 52.6\,ft$$

$$M_{5\_base} - 20 \cdot ft = 42.6\,ft$$

$$L_{W2} := \frac{2}{3}\left(M_{5\_base} - 20 \cdot ft\right) = 28.4\,ft$$

$$L_{W3} := M_{5\_base} - 30 \cdot ft - \frac{31}{2} \cdot ft = 17.1\,ft$$

$$L_{W4} := M_{5\_base} - 20 \cdot ft - \frac{2}{3} \cdot 10 \cdot ft = 35.9\,ft$$

$$L_{U1} := M_{5\_base} - 10 \cdot ft - 3 \cdot ft = 49.6\,ft$$

$$L_{U2} := M_{5\_base} - 7.33 \cdot ft - \frac{7.68 \cdot ft}{2} = 51.4\,ft$$

$$L_{pipe} := \frac{50 \cdot ft}{2} = 25\,ft$$

$$L_{water} := \frac{1}{3} \cdot h = 21\,ft$$

$L_{uplift} := \frac{2}{3} \cdot M_{5\_base} = 41.7\,ft$

$L_{P.E} := 0.4 \cdot h = 25.2\,ft$

$L_{PE\_fl} := 0.4 \cdot h_{fl} + (Deck\_el - Base\_el) - 38 \cdot ft = 54.4\,ft$ — *Fish ladder Westergaard distance*

$L_{water\_fl} := M_{5\_base} - 30 \cdot ft - \frac{30ft}{2} = 17.6\,ft$ — *fish ladder water distance*

$L_{h\_fl} := (Deck\_el - Base\_el) - 38 \cdot ft + \frac{1}{2} h_{fl} = 55.5\,ft$ — *Fish ladder inirtia distance*

Determine Approx location for CG of monolith

$d_1 := \frac{Deck\_el - Base\_el}{2} = 44\,ft$

$d_2 := [(Deck\_el - Base\_el) - 17 \cdot ft] \cdot \frac{1}{3} = 23.7\,ft$

$d_3 := (Deck\_el - Base\_el) - 39.25 \cdot ft = 48.75\,ft$

$d_4 := (Deck\_el - Base\_el) - 17 \cdot ft - \frac{1}{3} 16.67 \cdot ft = 65.4\,ft$

$d_5 := 4 \cdot ft$

$d_6 := (Deck\_el - Base\_el) - 13.5 \cdot ft = 74.5\,ft$

$$Y_{bar} := \frac{d_1 \cdot W_1 + d_2 \cdot W_2 + d_3 \cdot W_3 + d_4 \cdot W_4 + d_5 \cdot (-U_1) + d_6 \cdot (-U_2)}{W_1 + W_2 + W_3 + W_4 - U_1 - U_2} = 35.361\,ft$$

Moments

$M_{W1} := W_1 \cdot L_{W1} = 962744 \cdot kip \cdot ft$

$M_{W2} := W_2 \cdot L_{W2} = 446651 \cdot kip \cdot ft$

$M_{W3} := W_3 \cdot L_{W3} = 7611 \cdot kip \cdot ft$

$M_{W4} := W_4 \cdot L_{W4} = 31147 \cdot kip \cdot ft$

$M_{U1} := U_1 \cdot L_{U1} = 24759 \cdot kip \cdot ft$

$M_{U2} := U_2 \cdot L_{U2} = 28753 \cdot kip \cdot ft$

$M_{pipe} := L_{pipe} \cdot P_{pipe} = 14726 \cdot kip \cdot ft$

$M_{water} := P_{water} \cdot L_{water} = 180581 \cdot kip \cdot ft$

$M_{uplift} := P_{uplift} \cdot L_{uplift} = 356590\,ft \cdot kip$

$M_{PE} := P_E \cdot L_{P.E} = 28946 \cdot kip \cdot ft$

$M_{F.h} := F_h \cdot Y_{bar} = 150395 \cdot kip \cdot ft$

$M_{w\_fl} := W_{water\_fl} \cdot L_{water\_fl} = 25167 \cdot kip \cdot ft$

$M_{E\_fl} := P_{E\_fl} \cdot L_{PE\_fl} = 332.6 \cdot kip \cdot ft$

$M_{h\_fl} := F_{h\_fl} \cdot L_{h\_fl} = 10000 \cdot kip \cdot ft$

Sum Moments

$M_{toe1} := M_{W1} + M_{W2} + M_{W3} + M_{W4} + M_{w\_fl} = 1473320 \cdot kip \cdot ft$

$M_{toe2} := -M_{U1} - M_{U2} - M_{pipe} - M_{water} - M_{uplift} - M_{PE} - M_{F.h} - M_{E\_fl} - M_{h\_fl} = -795083 \cdot kip \cdot ft$

$M_d := M_{toe1} + M_{toe2} = 678238 \cdot kip \cdot ft$

Positive and negative moments were separated due to space on sheet. Moments are added to gather in Md

Sum Vertical Forces

$V_d := W_d - P_{uplift} + W_{water\_fl} = 26640 \cdot kip$

$\frac{1}{3} \cdot M_{5\_base} = 20.9\,ft \qquad \frac{2}{3} \cdot M_{5\_base} = 41.7\,ft$

$\frac{M_d}{V_d} = 25.5\,ft$ *Resultant*

Factor of Safety EM 1110-2-2100 eqn 5-3

$FS_s = \frac{N \cdot \tan\phi + c \cdot L}{T}$

$T := P_{water} + P_E + F_h + F_{h\_fl} + P_{E\_fl} = 14187 \cdot kip$ *Shear force acting parallel to the base of the wedge*

$N := W_d - P_{uplift} = 25210 \cdot kip$ *Force acting normal to the sliding failure plane under the structural wedge*

$L := M_{5\_base} \cdot L_{m5} = 4340\,ft^2$

Case 4

$\phi_{case4} := 45 \cdot deg$ *Angle of internal friction of the foundation material under the structural wedge*

$c_{case4} := 0 \cdot \frac{kip}{ft^2}$ *Cohesive strength of the foundation material under structural wedge*

$FS_{s4} := \frac{N \cdot \tan(\phi_{case4}) + c_{case4} \cdot L}{T} = 1.78$

Case 3

$\phi_{case3} := 45 \cdot deg$

$c_{case3} := 36 \cdot \frac{kip}{ft^2}$

$FS_{s3} := \frac{N \cdot \tan(\phi_{case3}) + c_{case3} \cdot L}{T} = 12.79$

Case 2

$\phi_{case2} := 40 \cdot deg$

$c_{case2} := 28.8 \cdot \frac{kip}{ft^2}$

$FS_{s2} := \frac{N \cdot tan(\phi_{case2}) + c_{case2} \cdot L}{T} = 10.3$

Case 1

$\phi_{case1} := 30 \cdot deg$

$c_{case1} := 5.18 \cdot \frac{kip}{ft^2}$

$FS_{s1} := \frac{N \cdot tan(\phi_{case1}) + c_{case1} \cdot L}{T} = 2.61$

$$FS_s := \begin{pmatrix} FS_{s1} \\ FS_{s2} \\ FS_{s3} \\ FS_{s4} \end{pmatrix} = \begin{pmatrix} 2.611 \\ 10.301 \\ 12.79 \\ 1.777 \end{pmatrix}$$

Check max applies stress, stress=M/S+P/A

$S := \frac{1}{6} \cdot L_{m5} \cdot M_{5\_base}{}^2 = 45281 \cdot ft^3$

$\sigma_{axial} := \frac{W_d}{L_{m5} \cdot M_{5\_base}} = 54\,psi$

$\sigma_{flexual} := \frac{M_d}{S} = 104\,psi$

$\sigma_{seismic} := \sigma_{axial} + \sigma_{flexual} = 158\,psi$

$\sigma_{seismic} = 22755.8 \cdot psf$

Walton, Eric D NWW

om:	Vincent, David E NWP
it:	Friday, July 19, 2013 2:48 PM
:	Walton, Eric D NWW
Cc:	Scofield, David H NWP
Subject:	RE: Dalles AWS Monolith 5 Stability (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: NONE

Eric

I don't have the specific Monolith 5 values.

Apparently original designers may have used phi = 30 degrees and c = 36 psi. The values likely depend on specific features analyzed.

I have assumed the following general preliminary values phi = 40 and c = 200 psi.

DM29, 1994 presents the following rock values:

phi = 45 and c = 250 psi (Table 9-6)

DM29, 1994 presents the following rock fill values:

hi = 45 and c = 0 psi

anks

David Vincent

-----Original Message-----
From: Walton, Eric D NWW
Sent: Friday, July 19, 2013 1:10 PM
To: Vincent, David E NWP
Cc: Chase, Matthew T NWP; Lee, Randall T NWP; Laughery, Ryan O NWW
Subject: RE: Dalles AWS Monolith 5 Stability (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: NONE

David,

Do you have an angle of internal friction and a cohesive values for Monolith 5 (non overflow) for the Dalles Dam?

I have run some stability calcs using Phi=45deg and C=0, but should probably use actual values if they are known.

Thanks

ic Walton
NWW-EC-D-ST
509 527-7548

N. W. HANER & ASSOCIATES — MOFFATT, NICHOL & TAYLOR P1

ASSOCIATED ENGINEERS

PROJECT: THE DALLES DAM – EAST FISHLADDER PAGE 10 OF 32

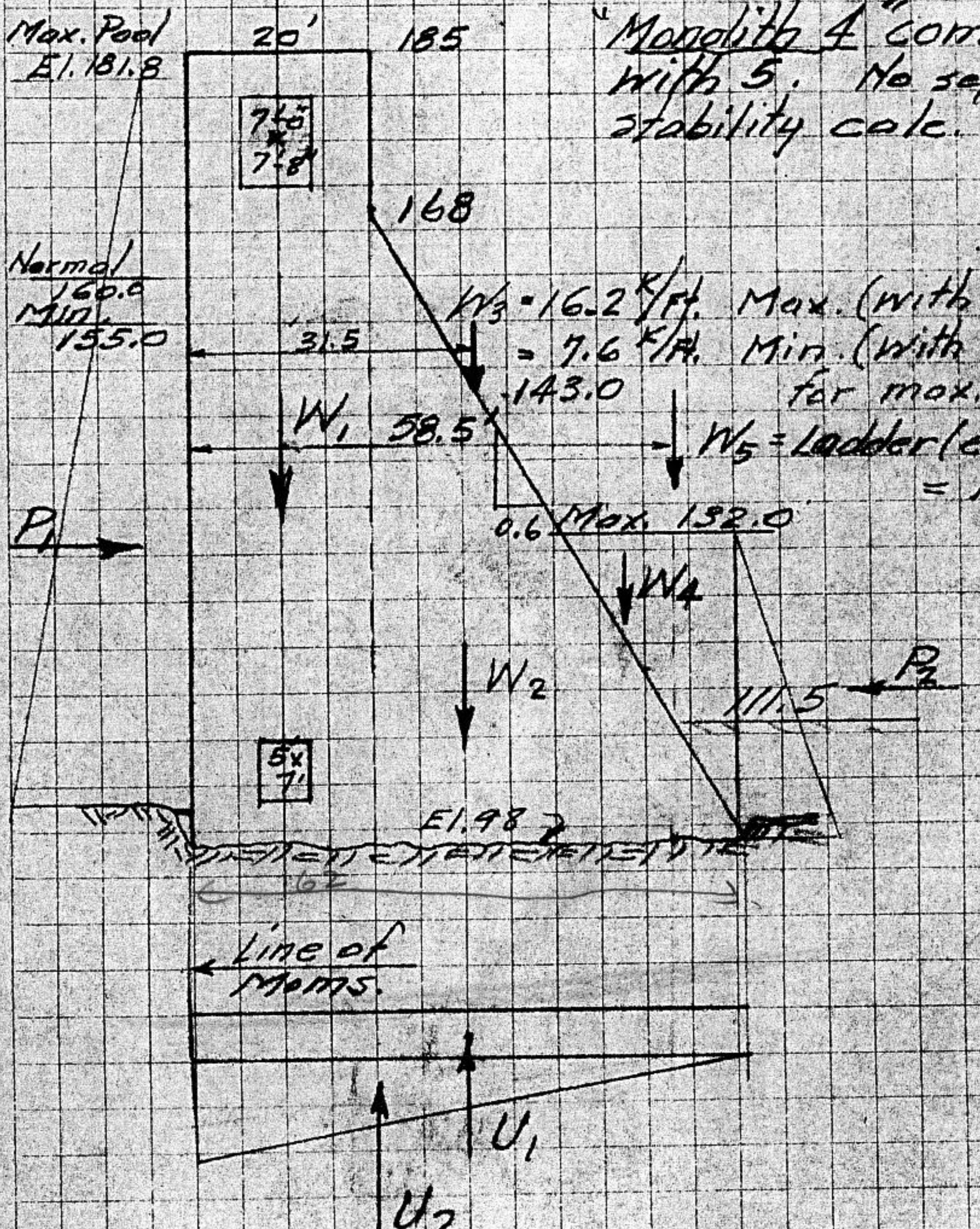
ITEM EAST NON-OVERFLOW DAM BY NWH RPC. DATE 1/6/53

Manolith 5 – Stability.

"Monolith 4" comparable with 5. No separate stability calc. made.

W_3 = 16.2 k/ft. Max. (with normal pool)
= 7.6 k/ft. Min. (with ladder empty) for max. pool.

W_5 = Ladder (empty wt.) = 10.9 k



11

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ASSOCIATED ENGINEERS

PROJECT: THE DALLES DAM — EAST FISHLADDER
ITEM EAST NON-OVERFLOW DAM
BY NWH / H.P.C. DATE 1/6/53

(+ ↷)

Plane at El. 155

	Force (Kips)	Arm (Ft.)	Moment (K-Ft.)
$W_1 = [(20)(30)-54]0.15$	+81.9	10.0	+819.0
$W_2 = (13)(7.8)(\frac{1}{2})(0.15)$	7.6	22.6	+171.0
$U_2 = (26.8)(0.0625)(\frac{1}{2})(27.8)(\frac{1}{2})$	-11.6	9.27	-105.6
$P_1 = (26.8)(0.0625)(26.8)\frac{1}{2}$	(22.4)	8.93	+200.5
Totals	78.9		+1085.9

$f = \frac{22.4}{77.9} = 0.29 \qquad a = \frac{1085.9}{77.9} = 13.9'$

$\frac{2}{3}(27.8) = 18.5'$ inside mid $\frac{1}{3}$ by 4.6'

Plane at El. 125

	Force	Arm	Moment
$W_1 = [(20)(60)-54]0.15$	+171.9	10.0	+1719.0
$W_2 = (43)(25.8)(\frac{1}{2})(0.15)$	+83.2	28.6	+2372.0
$W_3 = 7.6^K$	+7.6	31.5	+240.0
$U_1 = (7)(0.0625)(\frac{1}{2})(45.8)$	-10.0	22.9	-229.0
$U_2 = (49.8)(0.0625)(\frac{1}{2})(45.8)(\frac{1}{2})$ (ΔH)	-36.6	15.3	-545.0
$P_1 = (56.8)(0.0625)(56.8)\frac{1}{2}$	(+101.0)	18.9	+1910.0
$P_2 = (7)(0.0625)(7)(\frac{1}{2})$	(-1.5)	2.3	-3.0
Totals	216.1		+5464.0

$f = \frac{99.5}{216.1} = 0.46 \qquad a = \frac{5464.0}{216.1} = 25.3'$

$\frac{2}{3}(45.8) = 30.6'$ Inside mid $\frac{1}{3}$ by 5.3'

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ASSOCIATED ENGINEERS

PROJECT: THE DALLES DAM — EAST FISHLADDER PAGE 12 OF 32

ITEM EAST NON-OVERFLOW DAM BY NWH H.P.C. DATE 1/7/52

Base at El. 98.0	Force	Arm	Moment
$W_1 = [(20)(87) - 89]\,0.15$ (gallery)	+247.6	10.0	+2,476.0
$W_2 = (70)(42)(\frac{1}{2})(0.15)$	+221.0	34.0	+7,510.0
$W_5 =$ (Ladder load)	+10.9	58.5	+638.0
$W_3 =$ " "	+7.6	31.5	+240.0
(water load) $W_4 = (34)(20.4)(0.0625)\frac{1}{2}$	+21.7	55.2	+1197.0
$U_1 = (34)(0.0625)(62.0)$ (TW)	−131.8	31.0	−4090.0
$U_2 = (49.8)(0.0625)(\frac{2}{3})(62.0)\frac{1}{2}$ (ΔH, Fw, 2/3 EM)	−64.3	20.67	−1,330.0
$P_1 = (83.8)(0.0625)(83.8)(\frac{1}{2})$	(+219.0)	27.9	+6,110.0
$P_2 = (34.0)(0.0625)(34.0)(\frac{1}{2})$	(−36.2)	11.3	−409.0
Totals	312.7		+12,342.0

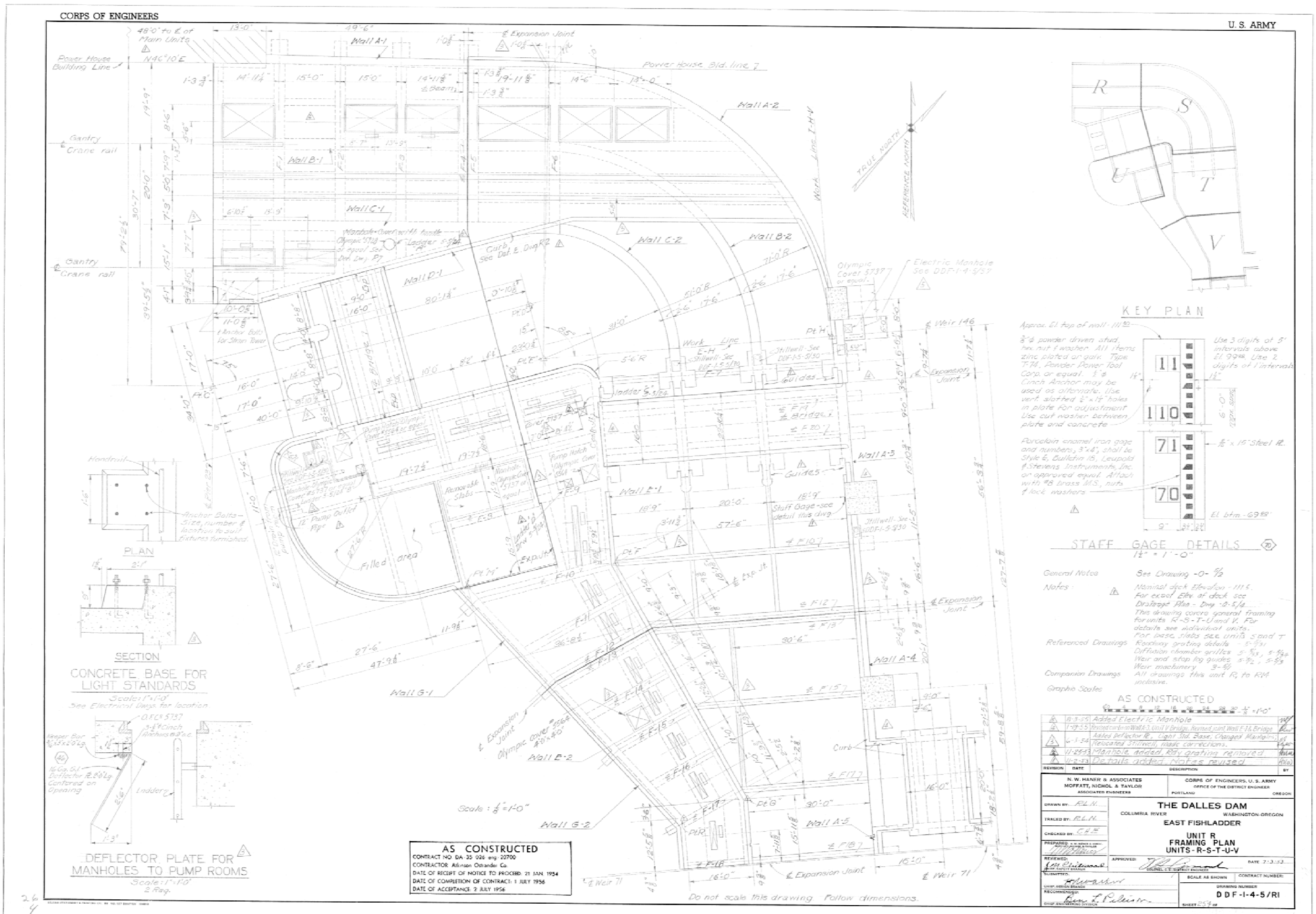
$$f = \frac{182.8}{312.7} = 0.585 \qquad a = \frac{12,342.0}{312.7} = 39.5$$

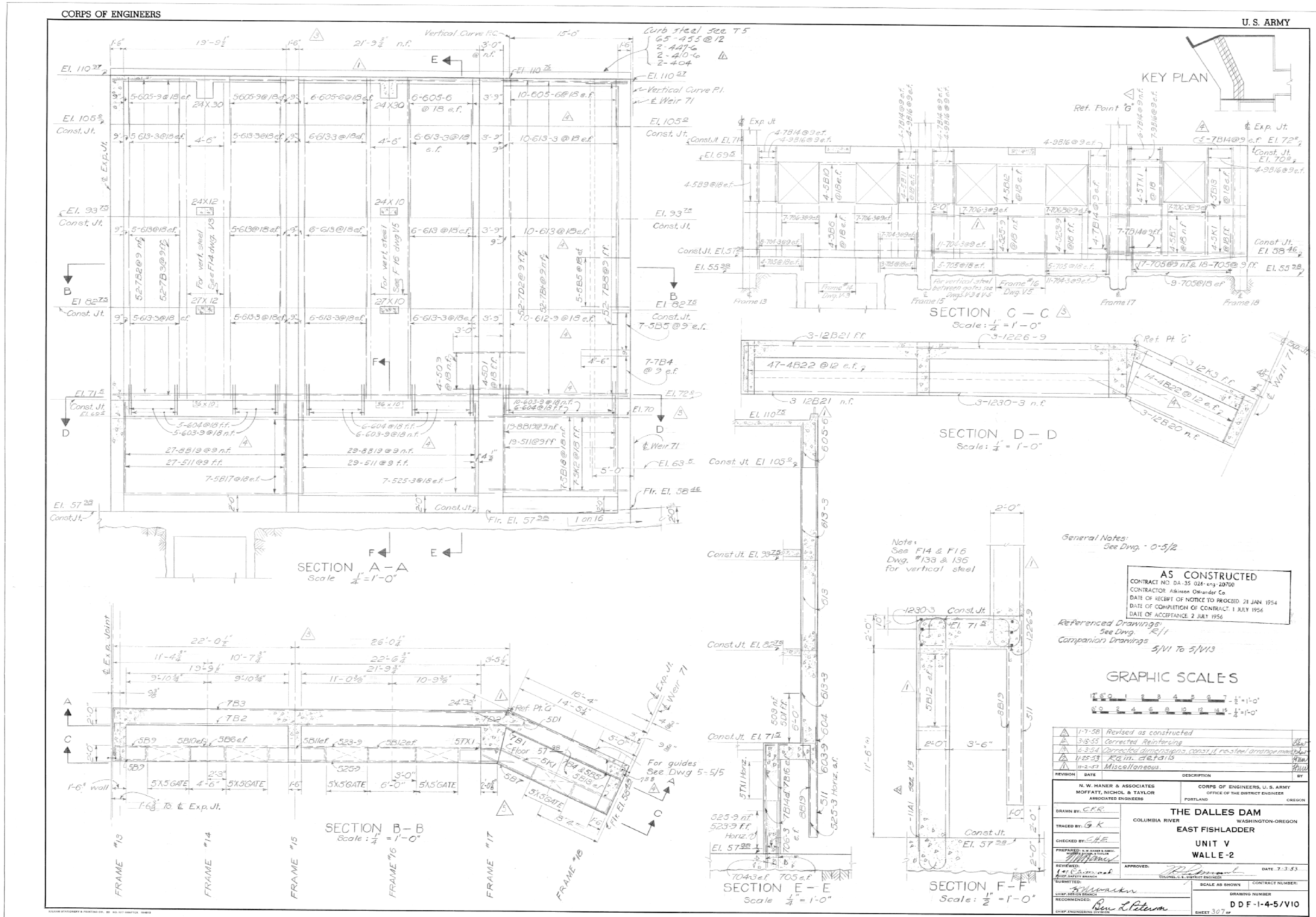
$$\frac{2}{3}(62.0) = 41.2' \quad \text{Inside mid } \tfrac{1}{3} \text{ by } 1.7'$$

Base Loading:

$$\text{Ave.} = \frac{312.7}{62} = 5.05^{k}/_{\square'}$$

$$\text{Max} = 5.05\left(1 + \frac{39.5}{41.2}\right) = 9.90^{k}/_{\square'}$$


CORPS OF ENGINEERS
U. S. ARMY
KEY PLAN
STAFF GAGE DETAILS
CONCRETE BASE FOR LIGHT STANDARDS
DEFLECTOR PLATE FOR MANHOLES TO PUMP ROOMS
AS CONSTRUCTED
CONTRACT NO. DA-35-026-eng-20700
CONTRACTOR: Atkinson Ostrander Co.
DATE OF RECEIPT OF NOTICE TO PROCEED: 21 JAN. 1954
DATE OF COMPLETION OF CONTRACT: 1 JULY 1956
DATE OF ACCEPTANCE: 2 JULY 1956
Do not scale this drawing. Follow dimensions.
N. W. HANER & ASSOCIATES
MOFFATT, NICHOL & TAYLOR
ASSOCIATED ENGINEERS
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
PORTLAND OREGON
THE DALLES DAM
COLUMBIA RIVER WASHINGTON-OREGON
EAST FISHLADDER
UNIT R
FRAMING PLAN
UNITS - R-S-T-U-V
DDF-1-4-5/R1


CORPS OF ENGINEERS
U. S. ARMY
KEY PLAN
SECTION A – A
Scale 1/4" = 1'-0"
SECTION B – B
Scale : 1/4" = 1'-0"
SECTION C – C
Scale : 1/4" = 1'-0"
SECTION D – D
Scale : 1/4" = 1'-0"
SECTION E – E
Scale 1/4" = 1'-0"
SECTION F – F
Scale : 1/2" = 1'-0"
General Notes:
See Dwg. - 0-5/2
AS CONSTRUCTED
CONTRACT NO. DA-35 026-eng-20700
CONTRACTOR Atkinson Ottlander Co.
DATE OF RECEIPT OF NOTICE TO PROCEED 21 JAN 1954
DATE OF COMPLETION OF CONTRACT 1 JULY 1956
DATE OF ACCEPTANCE 2 JULY 1956
Referenced Drawings:
See Dwg. R/1
Companion Drawings 5/V1 To 5/V13
GRAPHIC SCALES
1-7-58 Revised as constructed
3-18-55 Corrected Reinforcing
6-3-54 Corrected dimensions, const. jt., re-steel arrangement
1-25-53 Rdm. details
11-2-53 Miscellaneous
N. W. HANER & ASSOCIATES
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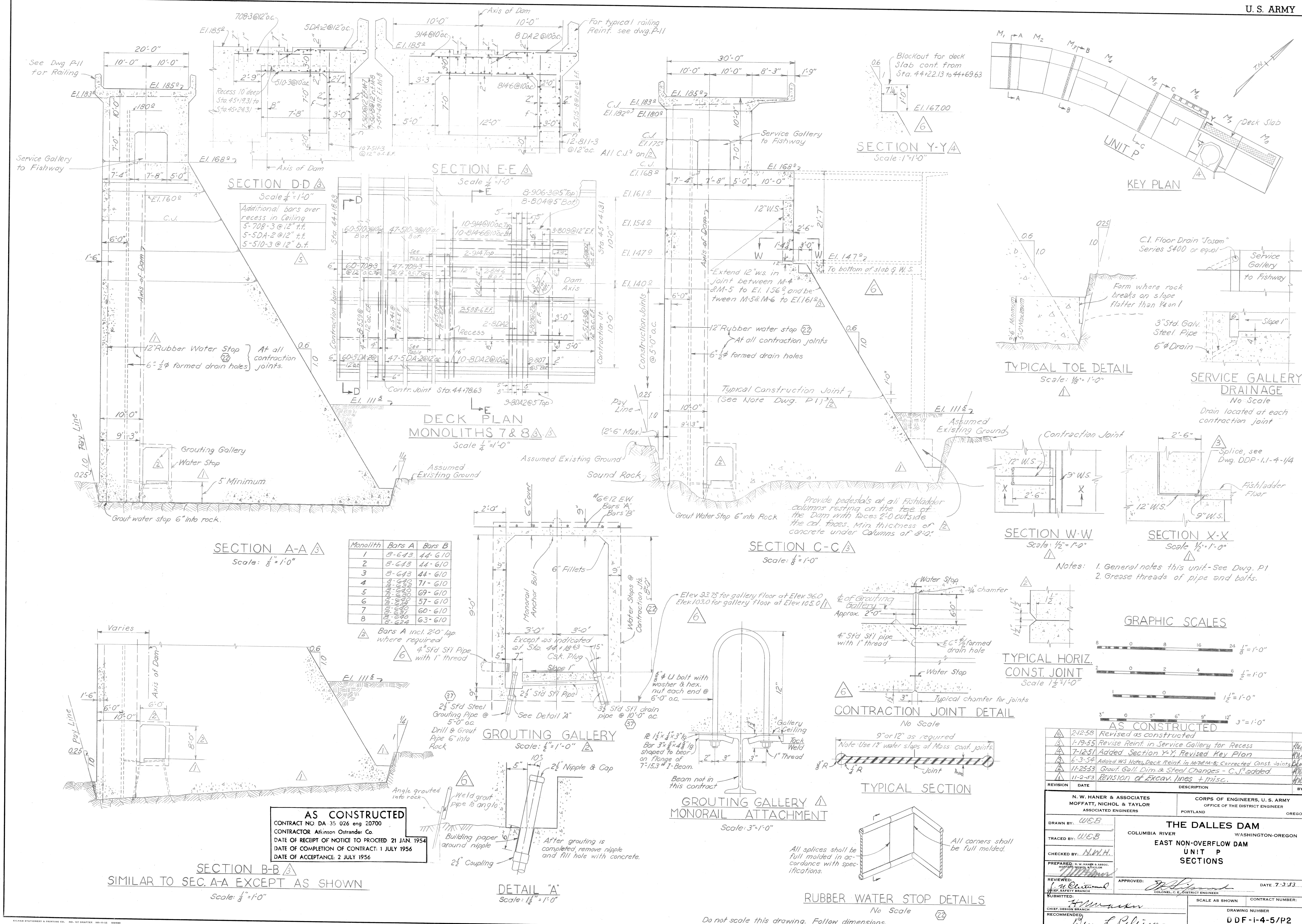
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
PORTLAND OREGON
THE DALLES DAM
COLUMBIA RIVER WASHINGTON-OREGON
EAST FISHLADDER
UNIT V
WALL E-2
SCALE AS SHOWN
DRAWING NUMBER
DDF-1-4-5/V10

CORPS OF ENGINEERS

U. S. ARMY



Monolith	Bars A	Bars B
1	8-643	44-610
2	8-643	44-610
3	8-643	44-610
4	8-643	71-610
5	8-643	69-610
6	8-643	57-610
7	8-643	60-610
8	8-624	63-610

Bars A incl. 2'-0" lap where required

AS CONSTRUCTED

CONTRACT NO DA 35 026 eng 20700
CONTRACTOR Atkinson Ostrander Co.
DATE OF RECEIPT OF NOTICE TO PROCEED 21 JAN. 1954
DATE OF COMPLETION OF CONTRACT: 1 JULY 1956
DATE OF ACCEPTANCE: 2 JULY 1956

AS CONSTRUCTED

REVISION	DATE	DESCRIPTION	BY
6	2-12-58	Revised as constructed	
5	1-19-55	Revise Reinf. in Service Gallery for Recess	HNW
4	7-12-51	Added Section Y-Y, Revised Key Plan	HNW
3	6-3-54	Added WS Notes, Deck Reinf. in M-7 & M-8; Corrected Const. Joints	BLW
2	11-25-53	Grout. Gall. Dim & Steel Changes - C.J.'s added	HNW
1	11-2-53	Revision of Excav. lines + misc.	HNW

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CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
PORTLAND, OREGON

DRAWN BY: WEB
TRACED BY: WEB
CHECKED BY: N.W.H.

THE DALLES DAM
COLUMBIA RIVER — WASHINGTON-OREGON
EAST NON-OVERFLOW DAM
UNIT P
SECTIONS

APPROVED: COLONEL, C.E., DISTRICT ENGINEER — DATE 7-3-53
REVIEWED: CHIEF, SAFETY BRANCH
SUBMITTED: CHIEF, DESIGN BRANCH
RECOMMENDED: CHIEF, ENGINEERING DIVISION
SCALE AS SHOWN
CONTRACT NUMBER:
DRAWING NUMBER DDF-1-4-5/P2
SHEET 244 OF

24

X	Y	Width
0.0	1.0	3.00
1.0	0.94	3.11
1.5	0.87	3.27
2.0	0.75	3.51
2.25	0.66	3.68
2.5	0.55	3.89
2.6	0.50	4.00
2.7	0.44	4.13
2.8	0.36	4.28
2.9	0.26	4.49
2.95	0.18	4.64
3.0	0.0	5.00

Coordinates for the 3'-0" Bellmouth

X	Y	Width
0	1.16	3.50
0.5	1.15	3.52
1.0	1.11	3.60
1.5	1.05	3.72
2.0	0.95	3.92
2.25	0.89	4.04
2.5	0.81	4.20
2.6	0.78	4.27
2.8	0.70	4.43
3.0	0.60	4.63
3.2	0.47	4.89
3.3	0.39	5.05
3.4	0.28	5.28
3.5	0.0	5.83

Coordinates for the 3'-6" Bellmouth

Notes:
1. For structure above El. 147, See Dwg. P6.
2. Wood float finish on Valve Pit floor.
3. Transitions, 90° miter bends, and pipe to be fabricated from ⅜" structural quality steel plate.
4. The details of the structure and the excavation for Monolith 6 may be revised pending final design of Fishlock and Fishlock Approach Ladder.

REVISION	DATE	DESCRIPTION	BY
7	3-20-58	Revised as constructed	
6	10-20-54	Corrected Handrails in Ent. to Valve Pit; and Rub Water Stops	
5	8-6-54	Changed sump location. Added 4" C.I. pipe, Note 3.	
4	7-12-54	Changed Contr. Joint @ Mono. 7, removed steel liner	
3	6-3-54	Added Steel liner and U-Bolts; Revised Reinf., added hatch supp.	
2	11-19-53	Steel Pipes Added & General Revisions	
1	11-2-53	General Revisions	

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CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
PORTLAND, OREGON

THE DALLES DAM
COLUMBIA RIVER — WASHINGTON-OREGON
EAST NON-OVERFLOW DAM
UNIT P
MONOLITH-6
DETAILS

DRAWN BY: WEB
TRACED BY: WEB
CHECKED BY: N.W.H.
DATE 7-3-53
SCALE AS SHOWN
DRAWING NUMBER DDF-1-4-5/P3
SHEET 245

AS CONSTRUCTED
CONTRACT NO DA 35 026 eng 20700
CONTRACTOR Atkinson Ostrande Co.
DATE OF RECEIPT OF NOTICE TO PROCEED 21 JAN. 1954
DATE OF COMPLETION OF CONTRACT: 1 JULY 1956
DATE OF ACCEPTANCE: 2 JULY 1956

DDDC0001.CIT

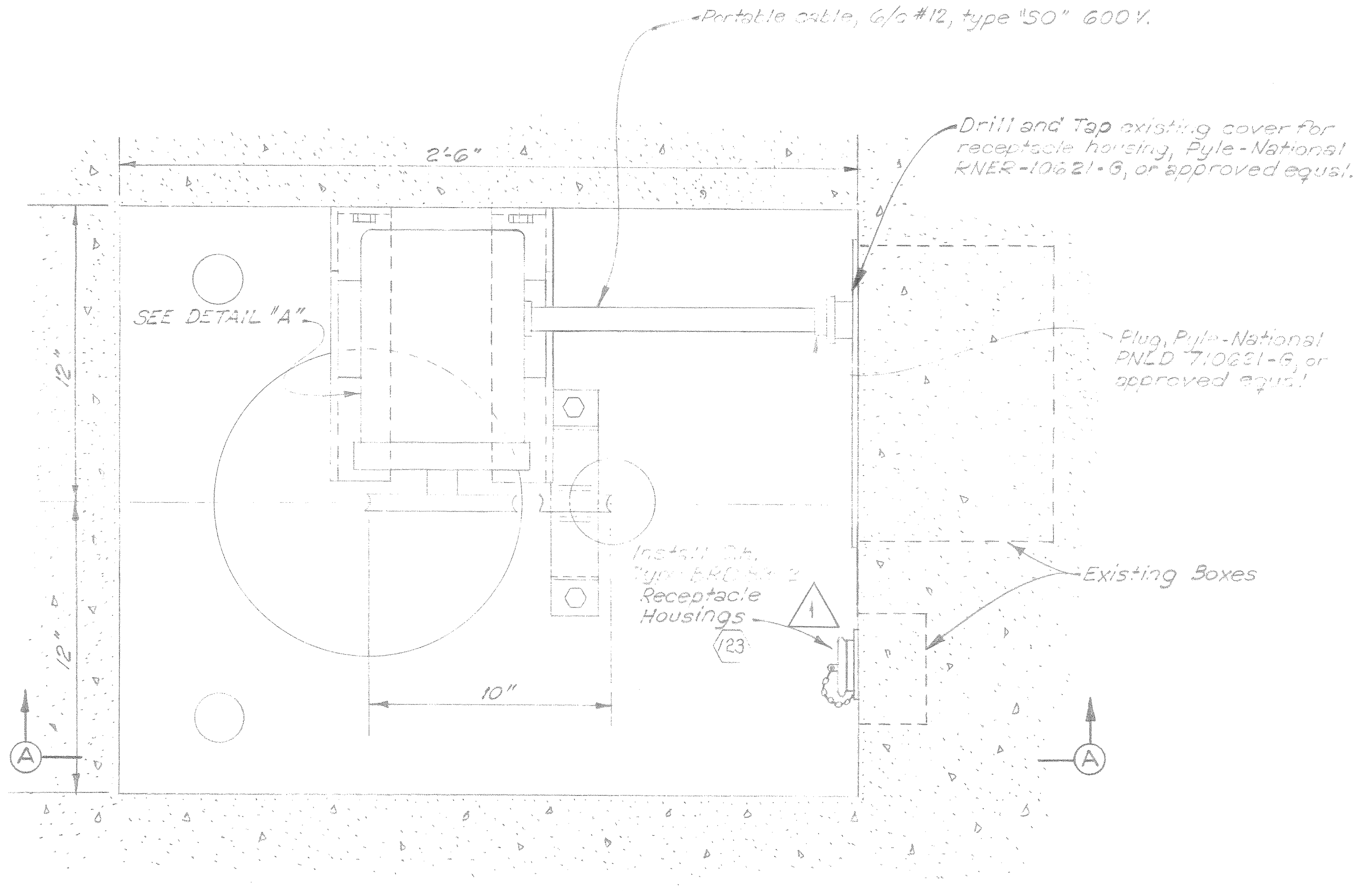
The Dalles East Fish Ladder Auxiliary Water Backup System

90 Percent Design Documentation Report

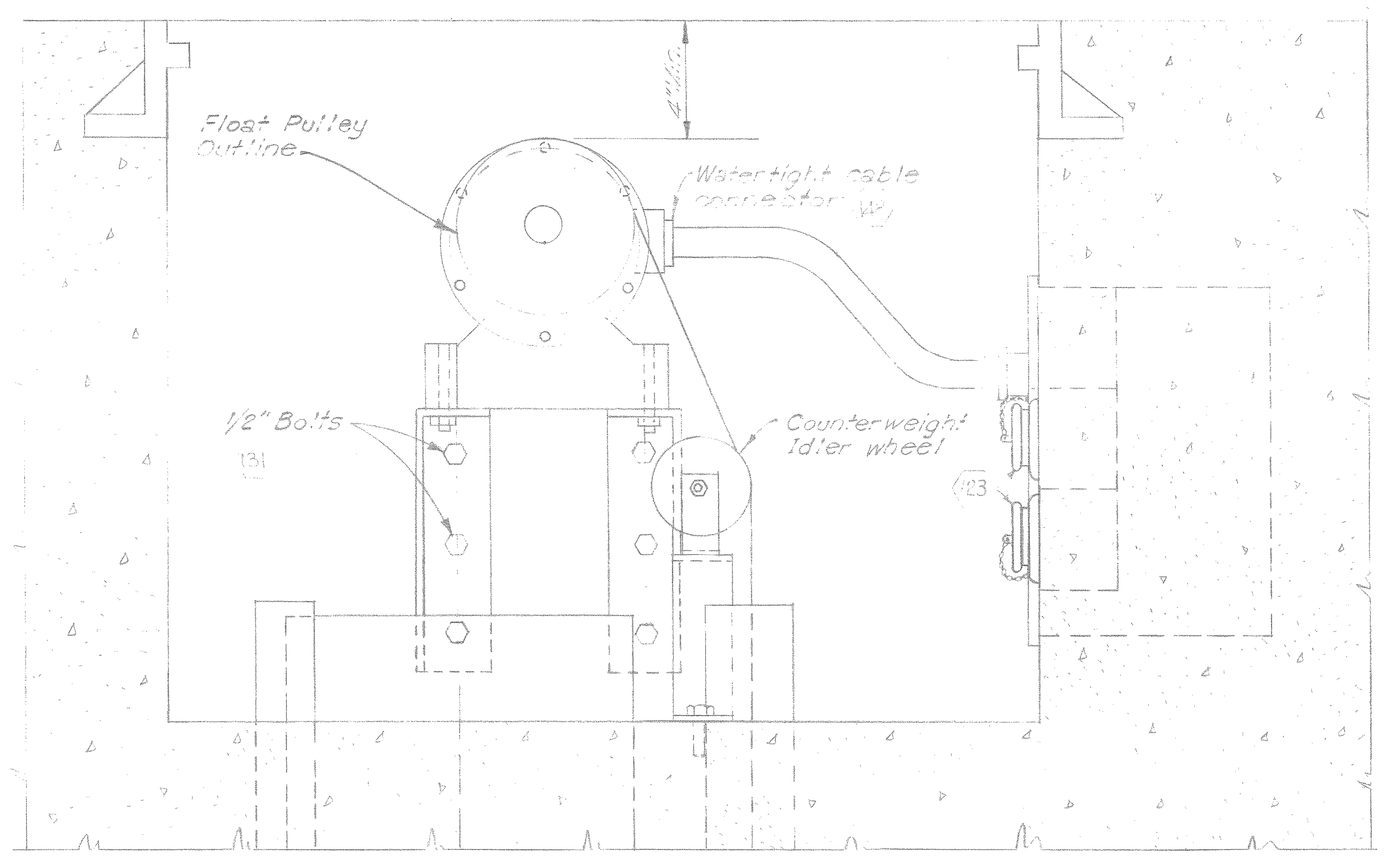
APPENDIX D

Electrical

CORPS OF ENGINEERS — U. S. ARMY



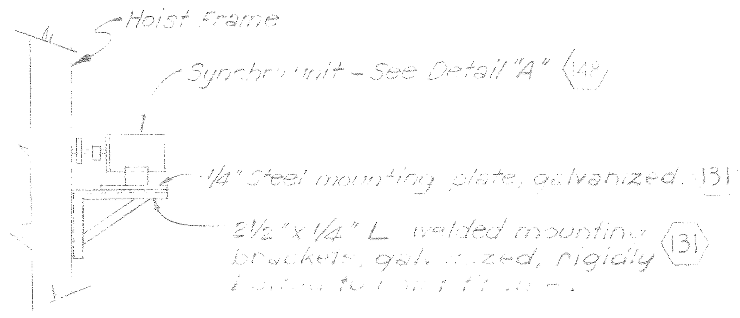
PLAN - TYPICAL FLOATWELL EQUIPMENT
Scale: 3"=1'-0"



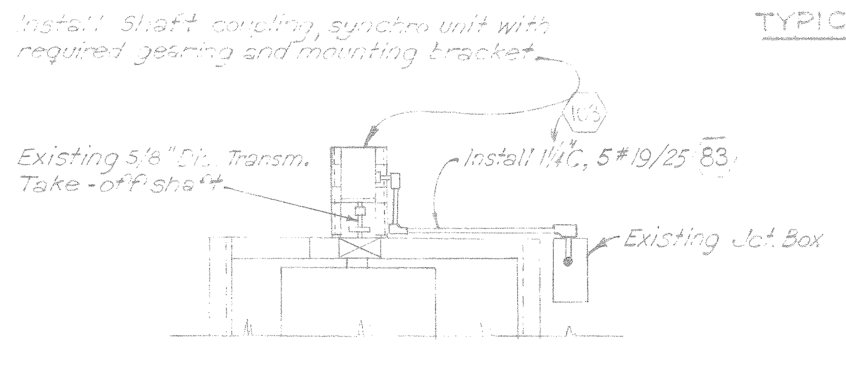
SECTION A-A
Scale: 3"=1'-0"

REFERENCE DRAWINGS:

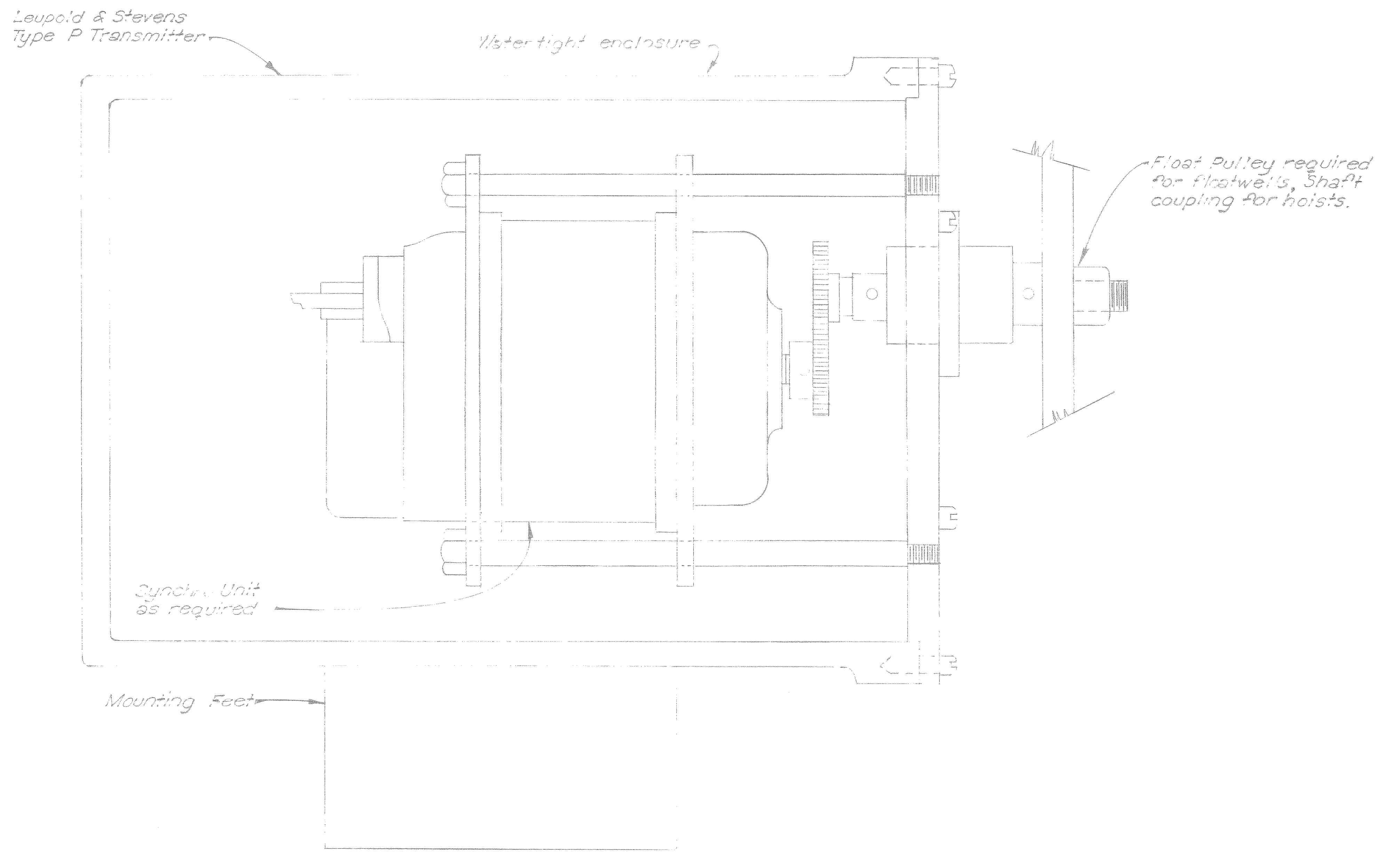
1. Plan - East Fishladder, Fishlock and Fishlock Channel — DDF-1-6-4.2/1.
2. Fishlock Control Bench, Arrangement & Details — DDF-1-6-4.2/4.
3. Fishlock Control Bench, One Line & Elem. Wiring Diagrams — DDF-1-6-4.2/5.



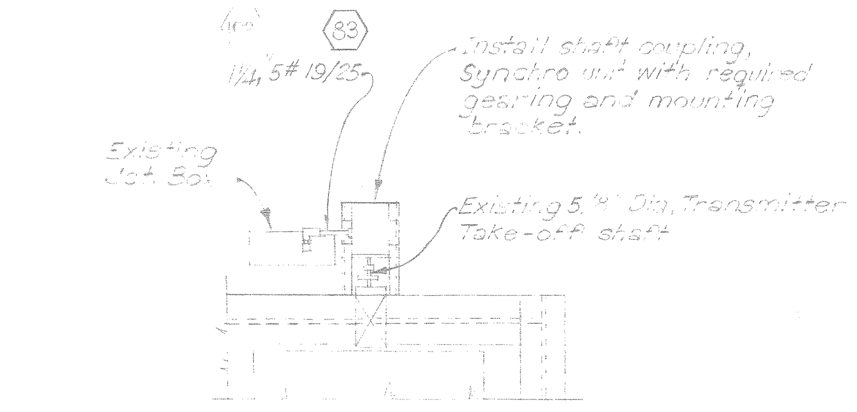
TYPICAL HOIST TRANSMITTER MOUNTING DETAIL
Scale: 1/2"=1'-0"



PLAN - FISHLOCK BRAIL HOIST TRANSMITTER
Scale: 1/2"=1'-0"



DETAIL "A"
No Scale



PLAN - ENTRANCE GATE HOIST TRANSMITTER
Scale: 3/4"=1'-0"

NOTE:

1. The floatwell equipment shall be complete with water level transmitter, pulleys, tape or chain, float, counterweight and connecting portable cable with plug and receptacle. Pulleys, tape or chain and float shall be of non-corrosive metal.
2. The Fishlock, Holding Pool, Forebay and Tailwater floatwell shall be equipped with 10" float operated transmitters, similar or equal to Leupold & Stevens Type "P" Transmitters.
3. The Brail and Entrance Gate Hoists shall be equipped with Leupold & Stevens Type "P" Transmitters, [illegible] to take-off shafts furnished by the Hoist Manufacturers.
4. The Fishlock and Holding Pool Transmitters must have the same ratio of unit angular displacement of the rotors to unit linear movement of the floats.
5. The Transmitter and counterweight idler wheel mounting brackets shall be fastened to the concrete with cinch anchors and shall be hot dip galvanized steel.
6. See Specifications for descriptions of transmitter functions and accuracy requirements.
7. The Synchro Transmitters shall have gearing to provide one rotation for each ten feet variation in elevation.
8. One complete rotation of the take-off shaft for the Brail Hoist is equivalent to a difference of elevation of 7.195 feet and for the entrance gate take-off shaft, 7.85 feet. These figures are approximate and shall be verified by the [illegible] for the exact gearing requirements.

AS CONSTRUCTED
CONTRACT NO. DA-35-026-civeng-56-155
CONTRACTOR E.V. Lane Corp., Gunther & Shirley Co.
DATE OF RECEIPT OF NOTICE TO PROCEED 21 Dec. 55
DATE OF COMPLETION OF CONTRACT 30 Nov. 60
DATE OF ACCEPTANCE 30 Nov. 60

REVISION	DATE	DESCRIPTION	BY
1			

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

DESIGNED: J.V.S.
DRAWN: R.A.B.
CHECKED: R.H.D.
REVIEWED: D.V. MacCollum, CHIEF, SAFETY BRANCH

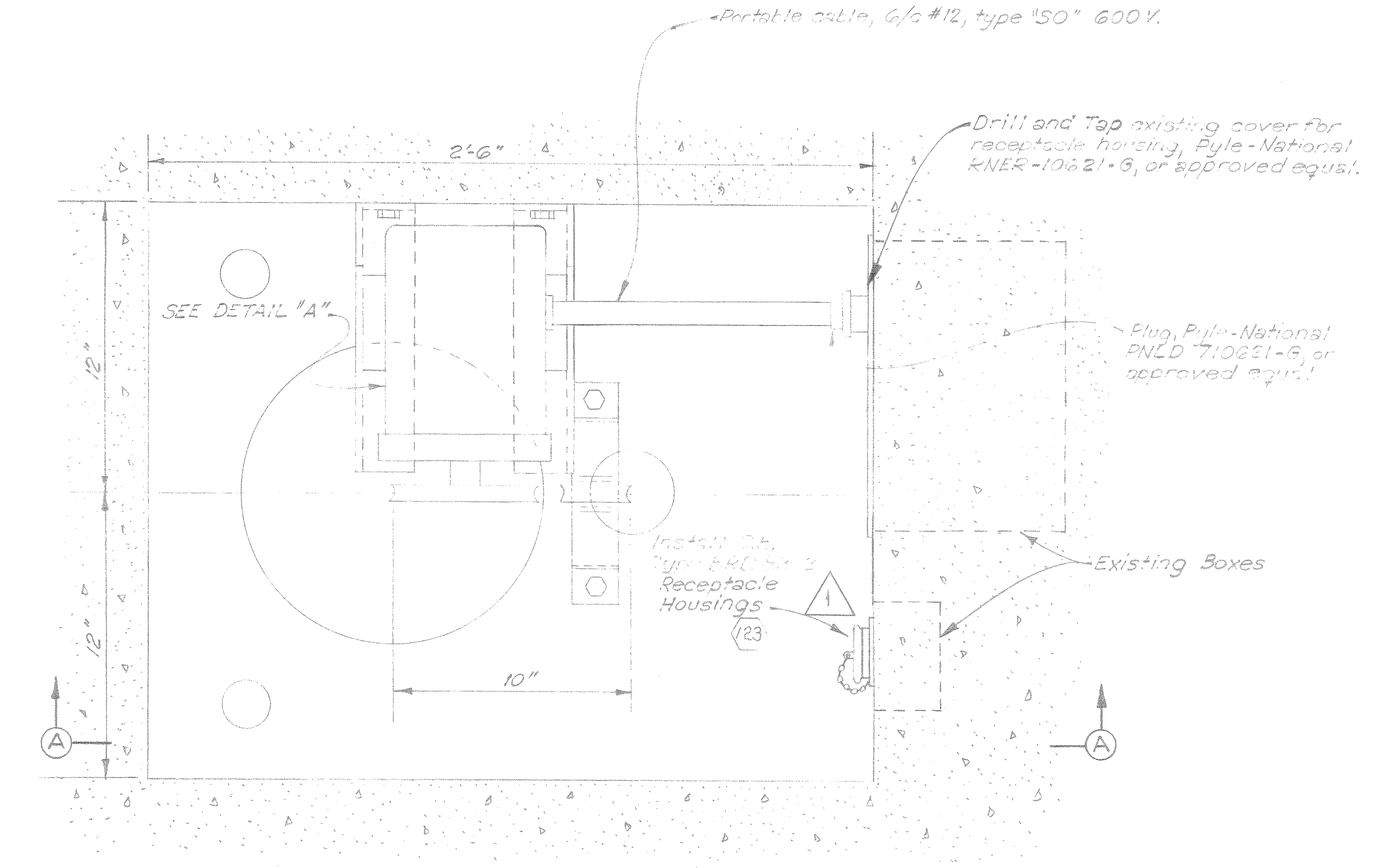
THE DALLES DAM
COLUMBIA RIVER — WASHINGTON - OREGON
EAST FISHLADDER & FISHLOCK
ELECTRICAL
FLOATWELLS & FISHLOCK HOISTS REMOTE INDICATING SYSTEM MOUNTING DETAILS

SUPERVISED: C. E. Wall, CHIEF, ELECTRICAL SECTION
SUBMITTED: [signature], CHIEF, DESIGN BRANCH
RECOMMENDED: Ben L. Peterson, CHIEF, ENGINEERING DIVISION
APPROVED: [signature], Acting, COLONEL C. E. DISTRICT ENGINEER — DATE July 29, 1955
SCALE AS SHOWN
SHEET 358 OF — DDF-1-6-4.2/3

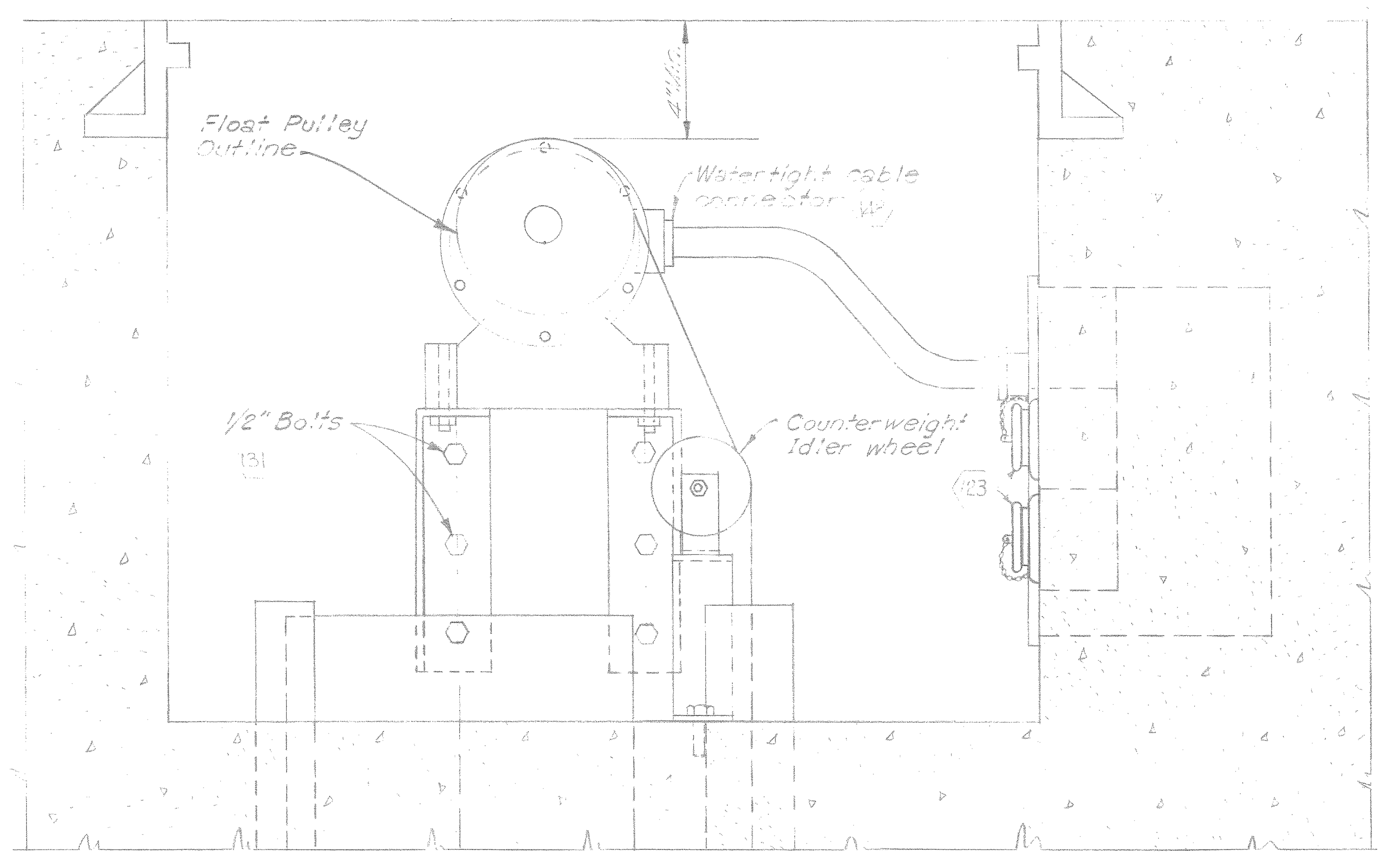
DDFE0014.CIT

342

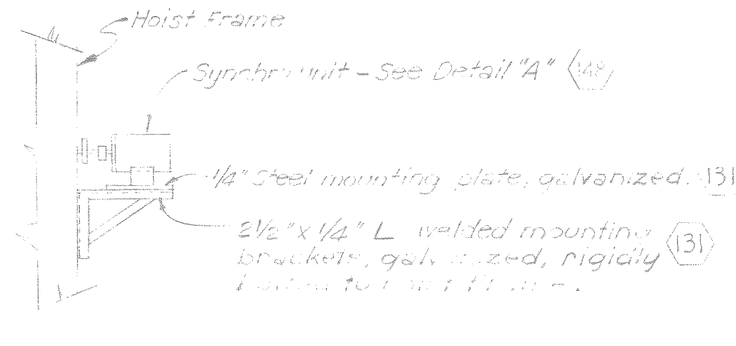
CORPS OF ENGINEERS   U. S. ARMY



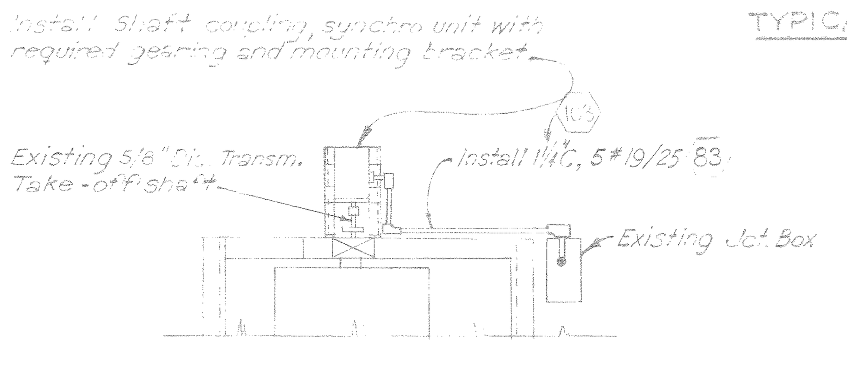
PLAN - TYPICAL FLOATWELL EQUIPMENT
Scale: 3"=1'-0"



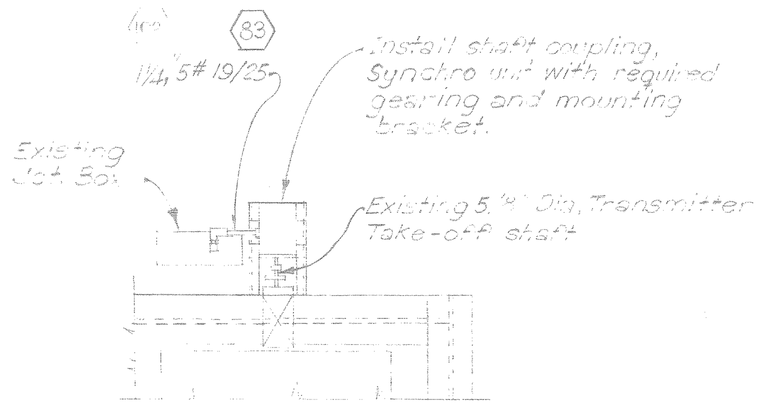
SECTION A-A
Scale: 3"=1'-0"



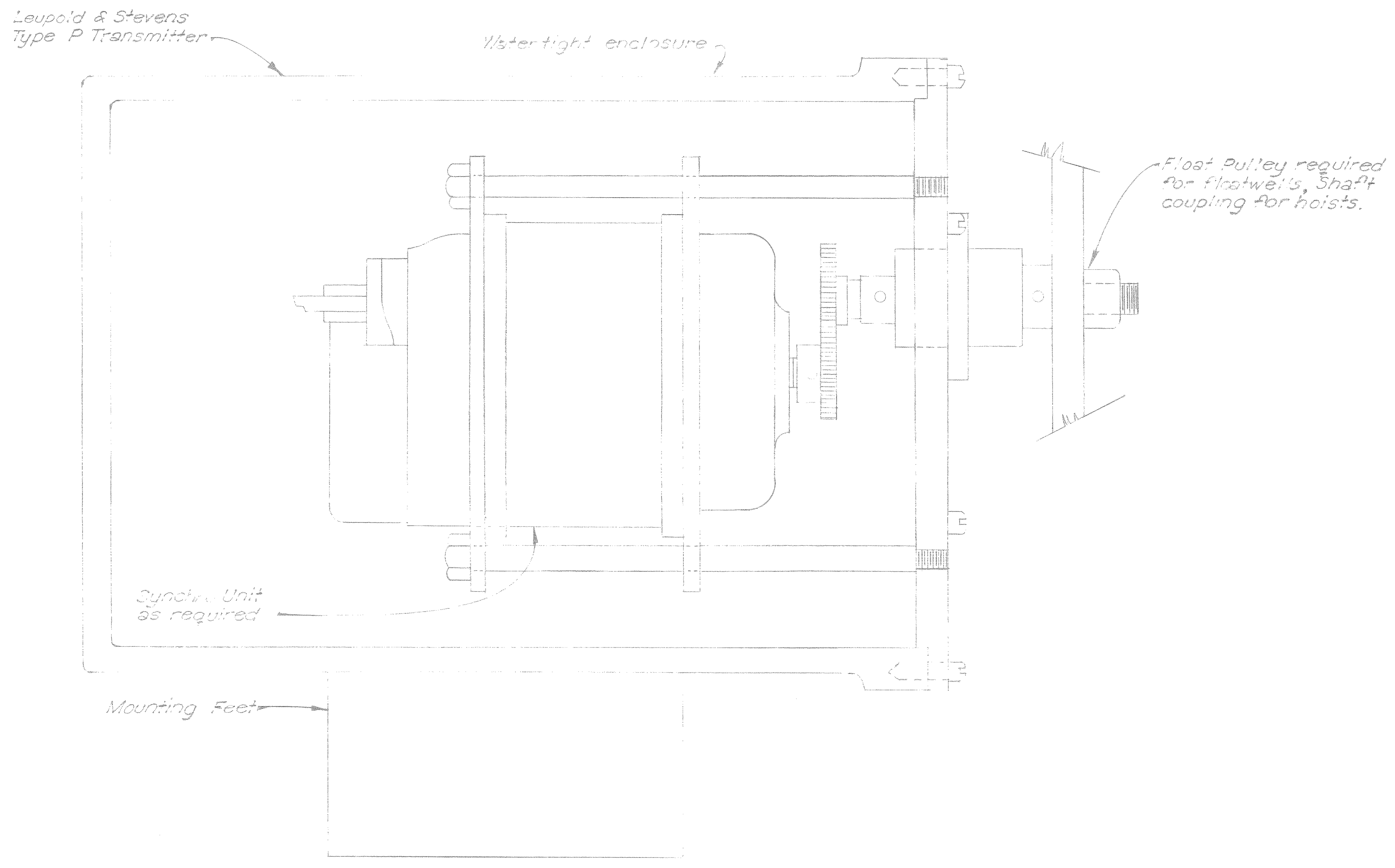
TYPICAL HOIST TRANSMITTER MOUNTING DETAIL
Scale: 1/2"=1'-0"



PLAN - FISHLOCK BRAIL HOIST TRANSMITTER
Scale: 1/2"=1'-0"



PLAN - ENTRANCE GATE HOIST TRANSMITTER
Scale: 3/4"=1'-0"



DETAIL "A"
No Scale

REFERENCE DRAWINGS:

1. Plan - East Fishladder, Fishlock and Fishlock Channel — DDF-1-6-4.2/1.
2. Fishlock Control Bench, Arrangement & Details — DDF-1-6-4.2/4.
3. Fishlock Control Bench, One Line & Elem. Wiring Diagrams — DDF-1-6-4.2/5.

NOTE:

1. The floatwell equipment shall be complete with water level transmitter, pulleys, tape or chain, float, counterweight and connecting portable cable with plug and receptacle. Pulleys, tape or chain and float shall be of non-corrosive metal.
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5. The Transmitter and counterweight idler wheel mounting brackets shall be fastened to the concrete with cinch anchors and shall be hot dip galvanized steel.
6. See Specifications for descriptions of transmitter functions and accuracy requirements.
7. The Synchro Transmitters shall have gearing to provide one rotation for each ten feet variation in elevation.
8. One complete rotation of the take-off shaft for the Brail Hoist is equivalent to a difference of elevation of 7.195 feet and for the entrance gate take-off shaft, 7.85 feet. These figures are approximate and shall be verified by the [illegible] for the exact gearing requirements.

AS CONSTRUCTED
CONTRACT NO. DA-35-026-civeng-56-155
CONTRACTOR E.V. Lane Corp., Gunther & Shirley Co.
DATE OF RECEIPT OF NOTICE TO PROCEED 21 Dec. 55
DATE OF COMPLETION OF CONTRACT 30 Nov. 60
DATE OF ACCEPTANCE 30 Nov. 60

REVISION	DATE	DESCRIPTION	BY
1			

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

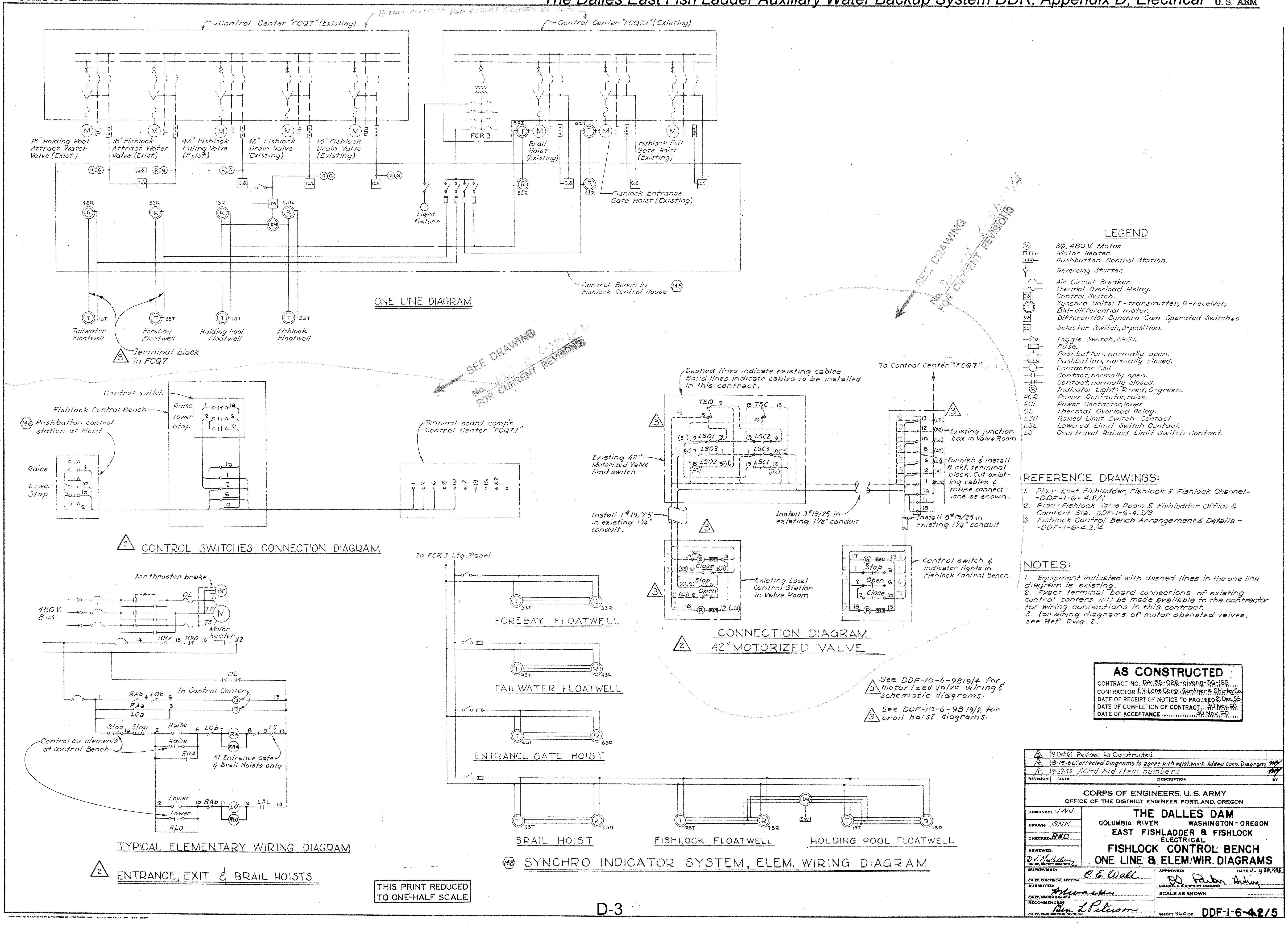
DESIGNED: J.V.S.
DRAWN: R.A.B.
CHECKED: R.H.D.
REVIEWED: D.V. MacCollum — CHIEF, SAFETY BRANCH

THE DALLES DAM
COLUMBIA RIVER — WASHINGTON - OREGON
EAST FISHLADDER & FISHLOCK
ELECTRICAL
FLOATWELLS & FISHLOCK HOISTS
REMOTE INDICATING SYSTEM
MOUNTING DETAILS

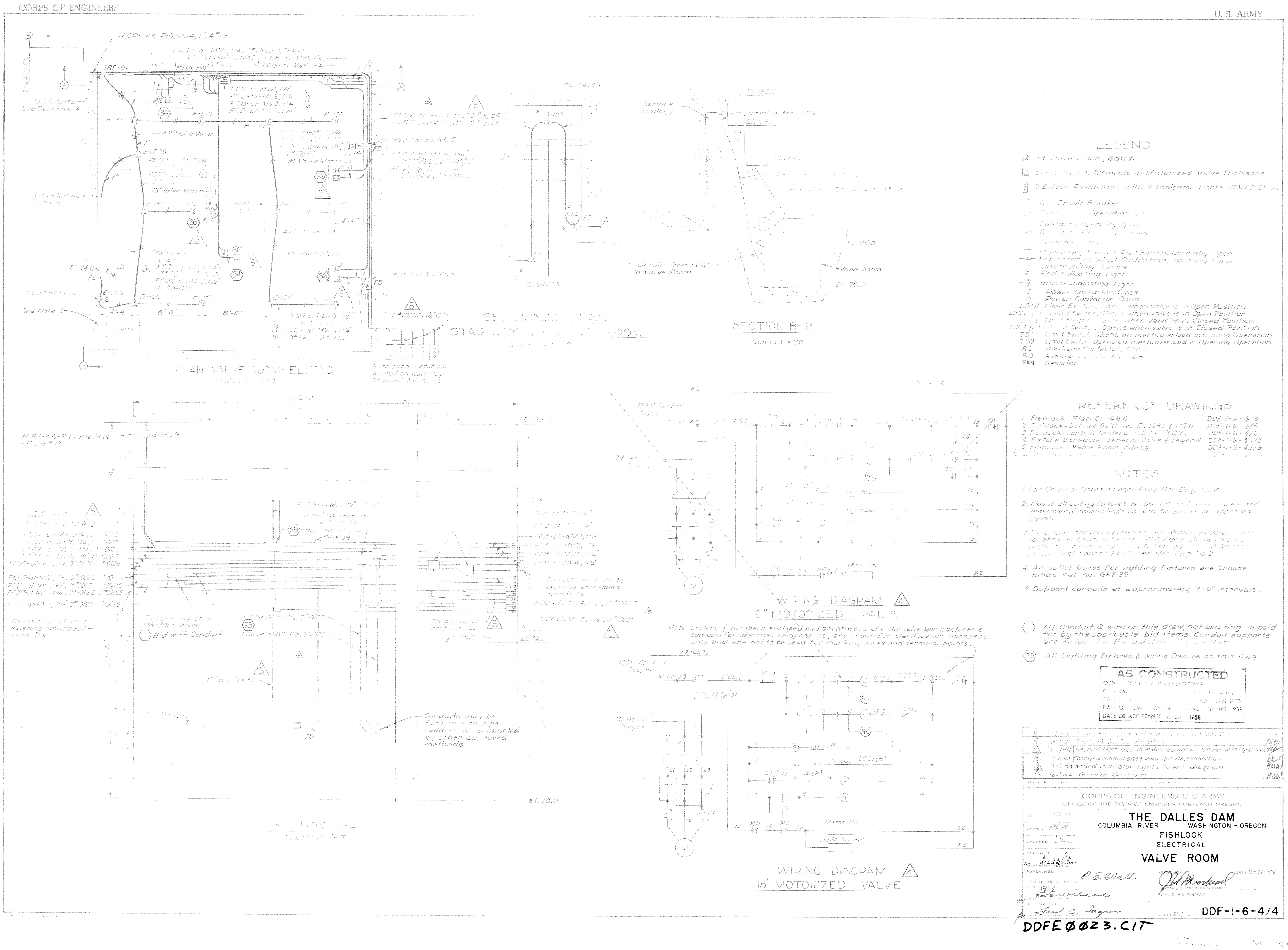
SUPERVISED: C. E. Wall — CHIEF, ELECTRICAL SECTION
SUBMITTED: [signature] — CHIEF, DESIGN BRANCH
RECOMMENDED: Ben L. Peterson — CHIEF, ENGINEERING DIVISION
APPROVED: [signature], Acting — COLONEL C. E. DISTRICT ENGINEER — DATE July 29, 1955
SCALE AS SHOWN
SHEET 358 OF — DDF-1-6-4.2/3

342

DDFE0014.CIT

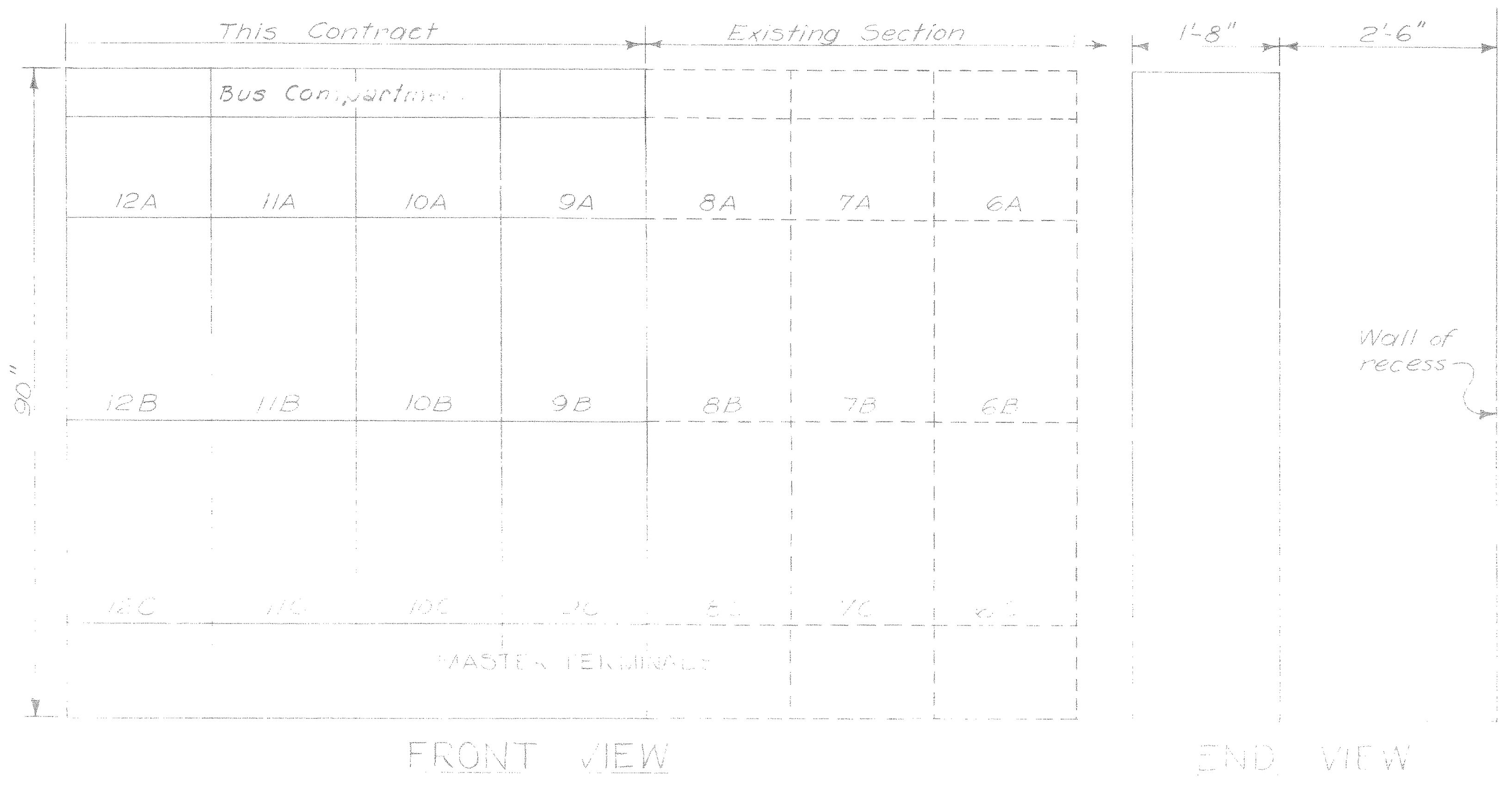

Control Center "FCQ7" (Existing)
Control Center "FCQ7.1" (Existing)
18" Holding Pool Attract. Water Valve (Exist.)
18" Fishlock Attract. Water Valve (Exist.)
42" Fishlock Filling Valve (Exist.)
42" Fishlock Drain Valve (Existing)
18" Fishlock Drain Valve (Existing)
FCR 3
Brail Hoist (Existing)
Fishlock Exit Gate Hoist (Existing)
Fishlock Entrance Gate Hoist (Existing)
Light fixture
Control Bench in Fishlock Control House
ONE LINE DIAGRAM
Tailwater Floatwell
Forebay Floatwell
Holding Pool Floatwell
Fishlock Floatwell
Terminal block in FCQ7
SEE DRAWING No. FOR CURRENT REVISIONS
Control switch
Fishlock Control Bench
Pushbutton control station at Hoist
Raise
Lower
Stop
Terminal board compt. Control Center "FCQ7.1"
CONTROL SWITCHES CONNECTION DIAGRAM
For thrustor brake
480 V. Bus
Motor heater
In Control Center
Control sw. elements at control Bench
At Entrance Gate & Brail Hoists only
TYPICAL ELEMENTARY WIRING DIAGRAM
ENTRANCE, EXIT & BRAIL HOISTS
To FCR 3 Ltg. Panel
FOREBAY FLOATWELL
TAILWATER FLOATWELL
ENTRANCE GATE HOIST
BRAIL HOIST
FISHLOCK FLOATWELL
HOLDING POOL FLOATWELL
SYNCHRO INDICATOR SYSTEM, ELEM. WIRING DIAGRAM
Dashed lines indicate existing cables. Solid lines indicate cables to be installed in this contract.
To Control Center "FCQ7"
Existing 42" Motorized Valve limit switch
Existing junction box in Valve Room
Furnish & install 8 ckt. terminal block. Cut existing cables & make connections as shown.
Install 1#19/25 in existing 1¼" conduit.
Install 3#19/25 in existing 1½" conduit
Install 8#19/25 in existing 1¼" conduit
Existing Local Control Station in Valve Room
Control switch & indicator lights in Fishlock Control Bench.
CONNECTION DIAGRAM 42" MOTORIZED VALVE
See DDF-10-6-9B19/4 for motorized valve wiring & schematic diagrams.
See DDF-10-6-9B19/2 for brail hoist diagrams.
LEGEND
3Ø, 480 V. Motor.
Motor Heater.
Pushbutton Control Station.
Reversing Starter.
Air Circuit Breaker.
Thermal Overload Relay.
Control Switch.
Synchro Units: T-transmitter, R-receiver, DM-differential motor.
Differential Synchro Cam Operated Switches
Selector Switch, 3-position.
Toggle Switch, SPST.
Fuse.
Pushbutton, normally open.
Pushbutton, normally closed.
Contactor Coil.
Contact, normally open.
Contact, normally closed.
Indicator Light: R-red, G-green.
PCR Power Contactor, raise.
PCL Power Contactor, lower.
OL Thermal Overload Relay.
LSR Raised Limit Switch Contact.
LSL Lowered Limit Switch Contact.
LS Overtravel Raised Limit Switch Contact.
REFERENCE DRAWINGS:
1. Plan - East Fishladder, Fishlock & Fishlock Channel - DDF-1-6-4.2/1
2. Plan - Fishlock Valve Room & Fishladder Office & Comfort Sta. - DDF-1-6-4.2/2
3. Fishlock Control Bench Arrangement & Details - DDF-1-6-4.2/4
NOTES:
1. Equipment indicated with dashed lines in the one line diagram is existing.
2. Exact terminal board connections of existing control centers will be made available to the contractor for wiring connections in this contract.
3. For wiring diagrams of motor operated valves, see Ref. Dwg. 2.
AS CONSTRUCTED
CONTRACT NO. DA-35-026-civeng-56-155
CONTRACTOR F.V. Lane Corp., Gunther & Shirley Co.
DATE OF RECEIPT OF NOTICE TO PROCEED 21 Dec. 55
DATE OF COMPLETION OF CONTRACT 30 Nov. 60
DATE OF ACCEPTANCE 30 Nov. 60
19 Oct 61 Revised As Constructed
8-15-56 Corrected Diagrams to agree with exist. work. Added Conn. Diagram
9-23-55 Added bid item numbers
REVISION DATE DESCRIPTION BY
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON
THE DALLES DAM
COLUMBIA RIVER WASHINGTON-OREGON
EAST FISHLADDER & FISHLOCK
ELECTRICAL
FISHLOCK CONTROL BENCH
ONE LINE & ELEM. WIR. DIAGRAMS
SCALE AS SHOWN
SHEET 360 OF DDF-1-6-4.2/5
THIS PRINT REDUCED TO ONE-HALF SCALE

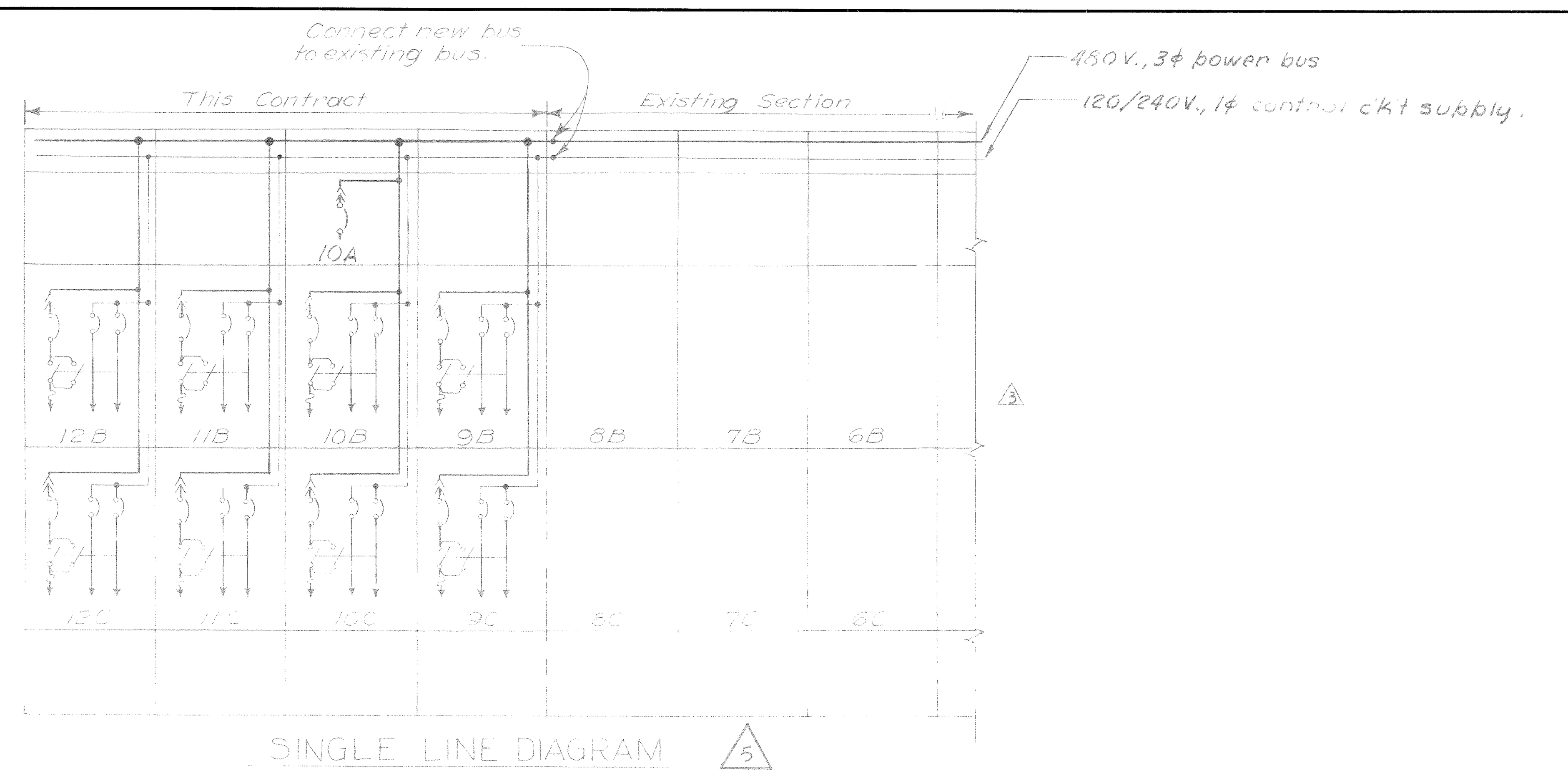

CORPS OF ENGINEERS
U. S. ARMY
(109) Furnish & install straight adapter with 1 1/4" conduit hub for Crouse Hinds No. 10485 receptacle box. Remove angle adapter and return to Resident Engineer. Make taps to exist. receptacle circuit.
Unwatering Pump Motor (139)
3#2, 1 1/4"C. (75) (103)
3/4", 2#19/25 (Heater) (101) (83)
1", 3#19/22 (Motor) (102) (89)
Exist. G.I. at El. 94.5
Connect #6 ground cable between the existing G.I. and motor base with approved cable connectors (109)
Motor Controller, See Note No. 4 & 5 (139)
Existing 480 Volt 3φ receptacle
PLAN - STORAGE ROOM - EL. 90.0
WEST FISH ENTRANCE - P.H.
Scale: 3/16" = 1'-0"
Existing 6"x8"x6" cast iron jct. box in curb at El. 111.5, make taps to existing 3#2
FCQ6-g5.11, 1 1/2" (104)
3-1/c #2 (75)
Drill & tap the inside of the Jct. box & the Sump Pump Motor terminal box. Connect #8 bare to boxes with solderless connectors & non-corrosive bolts. (109)
Unwatering Pump Motor (139)
Motor Controller, provide interior ground term. See Note No. 4 & 5 (139)
1", 3#19/22 (Motor) (102) (89)
3/4", 2#19/25 (Heater) (101) (83)
(EAST POWERHOUSE FISH ENTR.)
PLAN - SUMP PUMP ROOM - EL. 93.0
EAST FISHLADDER
Scale: 1/4" = 1'-0"
West P.H. Fish Entr. Sump
East P.H. Fish Entr. Sump
Junction Pool Sump
KEY MAP
Connect No. 6 ground cable (109) between existing cable tray grounding cable & motor base with approved cable connectors
Make taps to existing (75) 3-1/c #2 in Cable Tray
Existing 3-1/c #2 in Cable tray
Terminate conduit with elbow & O.Z. sealing bushing at cable tray (103)
Existing Cable Tray El. 108.75
Unwatering Pump Motor Ladder (139)
(103) FCQ6-g5.12, 1 1/4" 3-1/c #2
Motor Controller, See Note No. 4 & 5 (139)
(101) (83) 3/4", 2#19/25 (Heater)
(102) (89) 1", 3#19/22 (Motor)
PLAN - SUMP PUMP ROOM - EL. 93.0 - JCT. POOL
Scale: 1/4" = 1'-0"
PERMANENT UNWATERING PUMPS
3φ, 480V Supply
PC
OL
0.3KVA 480-120V Control Transf.
Disc. Sw.
Motor Htr.
Cab. Htr. 75W.
Stop
Start
WIRING DIAGRAM
WIRING DIAGRAM
PORTABLE UNWATERING PUMPS
REFERENCE DRAWINGS:
1. Plan - East Fishladder, Fishlock & Fishlock Channel - DDF-1-6-4.2/1
2. Plan - Fislock Valve Room & Fishladder Office & Comfort Sta. - DDF-1-6-4.2/2
NOTES:
1. Legends on Ref. Dwg. #1 & #2 applicable to this Dwg.
2. Fasten exposed ground cable at approx. two-foot intervals.
3. Portable cables & ground cables on this Dwg. shall be furnished by the contractor. All other cables are furnished by the Government.
4. Motor controllers shall be ACB combination motor starters, 480V, 3P, NEMA size 2, type IV enclosure, with built-in push buttons, control transformer, control & heater fuses, heater disconnect switch & cabinet heater.
5. Mount bottom of motor controllers 3'-6" above floor.
6. Unless otherwise indicated, Crouse-Hinds catalogue numbers have been used to indicate device and box types. Approved equivalents of other manufacturers may be substituted.
℄ Pier 2, 6, 9, & 13
Install 3-1/c #2 and (75) make terminal connections
Existing AREA 10485 El. 113.5 portable pump receptacle.
10'-0"
GENERATOR ROOM DOWNSTREAM WALL
PLAN EL. 111.5 (2)
Scale: 1/4" = 1'-0"
Provide Lifting hooks or eyes
Cable storage hangers
NEMA IV cabinet
Water tight, CGB (139) cable connector, rubber bushing
Plug: APJ 10485 (139)
Start and Stop-Reset pushbuttons
ARE 3483 (139) Receptacle
40' Portable cable 3/c #8, type G (139)
(139) APJ 3485 plug
(139) 10' portable cable 3/c #8, type G. Connect to motor leads & to motor terminal box with CGB watertight cable connector
3'-0"
PORTABLE MOTOR CONTROLLER (139)
PORTABLE UNWATERING PUMPS
AS CONSTRUCTED
CONTRACT NO. DA-35-026-civeng-56-155
CONTRACTOR E.V. Lane Corp., Gunther & Shirley Co.
DATE OF RECEIPT OF NOTICE TO PROCEED 21 Dec. 55
DATE OF COMPLETION OF CONTRACT 30 Nov. 60
DATE OF ACCEPTANCE 30 Nov. 60
Pier ℄
86'-0"
See Plan Elev. 111.5
Existing 1 1/2"C in Gallery ceiling, install 3-1/c #2 (75)
FCQ1, 2, 3, or 4 - g3
Fishway Gallery
Install 3-1/c #2 in Cable Tray (75)
Existing Cable Tray
Existing Motor Control Center FCQ1, 2, 3, or 4
Existing F3Q1, 2, 3, or 4
Make terminal connections to 100 Amp. breaker in Compartment 2A-1 - Nameplate designation "Portable Pump Receptacle"
TYPICAL PLAN UNITS 2, 6, 9, & 13
TYPICAL PLAN UNITS 3, 7, 10 & 14
FISHWAY GALLERY PLAN EL. 94.0 (2)
Scale: 1/4" = 1'-0"
REVISION | DATE | DESCRIPTION | BY
2 | 3-22-56 | Added Fishway Gallery Plan & Plan Elev. 111.5
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON
DESIGNED: J.N.D.
DRAWN: R.A.B.
CHECKED: R.H.D.
THE DALLES DAM
COLUMBIA RIVER WASHINGTON - OREGON
FISHWAYS, EAST FISHLADDER & FISHLOCK
ELECTRICAL
FISHWAY UNWATERING PUMPS
CONDUIT INSTALLATIONS
REVIEWED:
CHIEF, SAFETY BRANCH
SUPERVISED: George J. Zeh
CHIEF, ELECTRICAL SECTION
SUBMITTED:
CHIEF, DESIGN BRANCH
RECOMMENDED: Ben L. Peterson
CHIEF, ENGINEERING DIVISION
APPROVED:
COLONEL, C. E. DISTRICT ENGINEER
SCALE AS SHOWN
SHEET 36 OF
DDF-1-6-4.2/6
345
DDFE0016.CIT

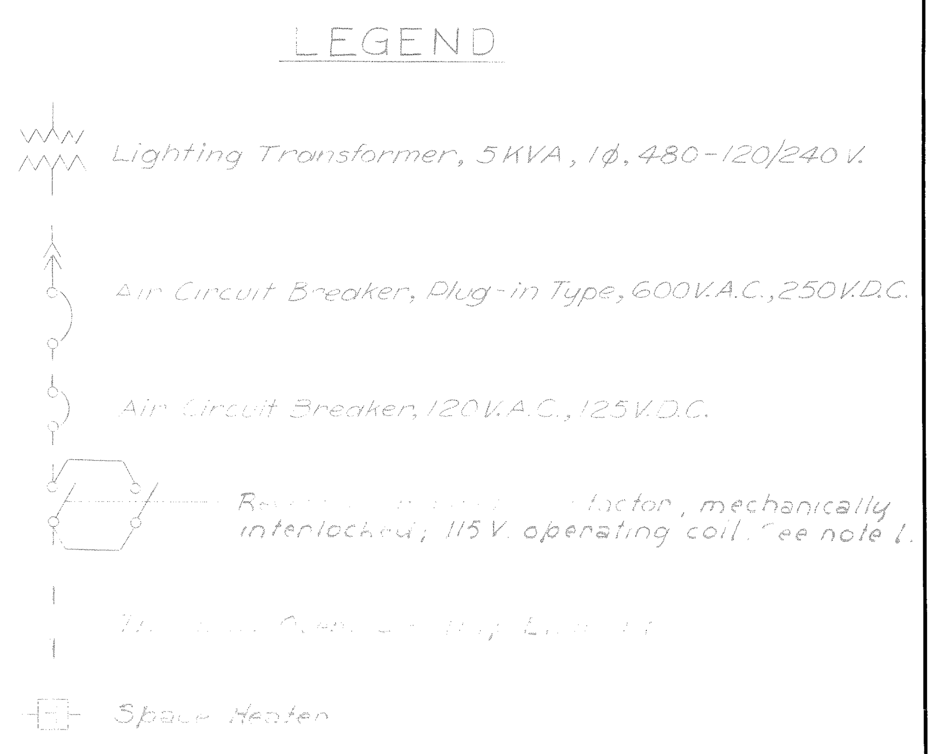

CORPS OF ENGINEERS
U. S. ARMY
PLAN-VALVE ROOM-EL. 70.0
SECTIONAL PLAN
SECTION B-B
Scale: 1" = 20'
SECTION A-A
WIRING DIAGRAM
42" MOTORIZED VALVE
WIRING DIAGRAM
18" MOTORIZED VALVE
Note: Letters & numbers enclosed by parentheses are the Valve Manufacturer's symbols for identical components, are shown for clarification purposes only and are not to be used for marking wires and terminal points.
LEGEND
3 Button Pushbutton with 2 Indicator Lights.
Air Circuit Breaker
Operating Coil
Momentary Contact Pushbutton, Normally Open
Momentary Contact Pushbutton, Normally Close
Disconnecting Device
Red Indicating Light
Green Indicating Light
C Power Contactor, Close
O Power Contactor, Open
LSO1 Limit Switch, Closes when valve is in Open Position
LSC1 & 3 Limit Switch, Opens when valve is in Closed Position
TSC Limit Switch, Opens on mech. overload in Closing Operation
TSO Limit Switch, Opens on mech. overload in Opening Operation
RES Resistor
REFERENCE DRAWINGS
1. Fishlock - Plan El. 168.0 DDF-1-6-4/3
2. Fishlock - Service Galleries El. 168.0 & 175.0 DDF-1-6-4/5
3. Fishlock - Control Centers FCQ7 & FCQ7.1 DDF-1-6-4/6
4. Fixture Schedule, General Notes & Legend DDF-1-6-3.1/2
5. Fishlock - Valve Room Piping DDF-1-3-4.1/9
NOTES
1. For General Notes & Legend see Ref. Dwg. No. 4.
2. Mount all ceiling fixtures B-150 hub cover, Crouse Hinds Co. Cat. No. GRF12 or approved equal.
4. All outlet boxes for lighting fixtures are Crouse-Hinds cat. no. GRF 39.
5. Support conduits at approximately 7'-0" intervals.
All Conduit & wire on this draw, not existing, is paid for by the applicable bid items. Conduit supports
73 All Lighting Fixtures & Wiring Devices on this Dwg.
AS CONSTRUCTED
DATE OF COMPLETION OF CONTRACT 18 SEPT. 1958
DATE OF ACCEPTANCE 18 SEPT. 1958
4 6-7-56 Revised Motorized Valve Wiring Diagram to agree with Equip. Furn.
3 5-16-55 Changed conduit size & indicator lts. connection.
2 11-17-54 Added indicator lights to wir. diagram
1 10-11-54 General Revisions
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON
THE DALLES DAM
COLUMBIA RIVER WASHINGTON - OREGON
FISHLOCK
ELECTRICAL
VALVE ROOM
DRAWN: REW
DATE 8-31-54
SCALE AS SHOWN
DDF-1-6-4/4
DDFE ØØ23.CIT


CORPS OF ENGINEERS
U. S. ARMY
PLAN - SERVICE GALLERIES, ELEV. 168.0 & 175.0
Control Center "FCQ7"
Service Gallery, Elev. 168.0
Control Center "FCQ7.1"
Service Gallery
Elev. 175.0
Lighting Panel, FCR1 (existing)
Existing sound powered outlet, elev. 173.0 approx. connect 4#16 to exist. ckt.
Existing conduits at Elev. 167.5 For continuation, see dwg. DDF-1-6-4/3.
12 conduits, see Section A-A on dwg. DDF-1-6-4/3
For continuation, see dwg. DDF-1-6-4/4
All embedded conduits are existing. Wire & cable listed with the ckt no's are in this contract.
Valve Pit, Elev. 70.0
Elev. 110.5 For continuation, see dwg. DDF-1-6-4/1.
Elev. 111.0 For continuation, see dwg. DDF-1-6-4/1.
℄ of Fishlock
Elev. 111.5
Sectional Plan to El. 111.5
NOTES:
1. For General Notes and Legend, see dwg. DDD-1-6-3.1/2.
2. All embedded conduits shown on this drawing are existing.
4. Conduits with wire and cable terminating in Control Centers shall be terminated with ground bushings & be grounded to the main grounding system. Existing conduits under Control Centers shall be extended with 3" long nipples before terminating with gr. bushings.
FRONT
FCQ7 CONTROL CENTER CONDUIT LAYOUT - BOTTOM
No Scale
FCQ7 CONTROL CENTER CONDUIT LAYOUT - TOP
No Scale
BOTTOM
TOP
FCQ7.1 CONTROL CENTER - CONDUIT LAYOUT
No Scale
AS CONSTRUCTED
DATE OF COMPLETION OF CONTRACT 18 SEPT. 1955
DATE OF ACCEPTANCE 18 SEPT. 1958
11-28-55 Deleted wire
11-17-54 Revised circuit wires & notes.
10-1-54 General revisions
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON
THE DALLES DAM
COLUMBIA RIVER WASHINGTON - OREGON
FISHLOCK
ELECTRICAL
SERVICE GALLERIES
ELEVATIONS 168.0 AND 175.0
SCALE AS SHOWN
DDF-1-6-4/5
DDFE0024.CIT

CORPS OF ENGINEERS U. S. ARMY



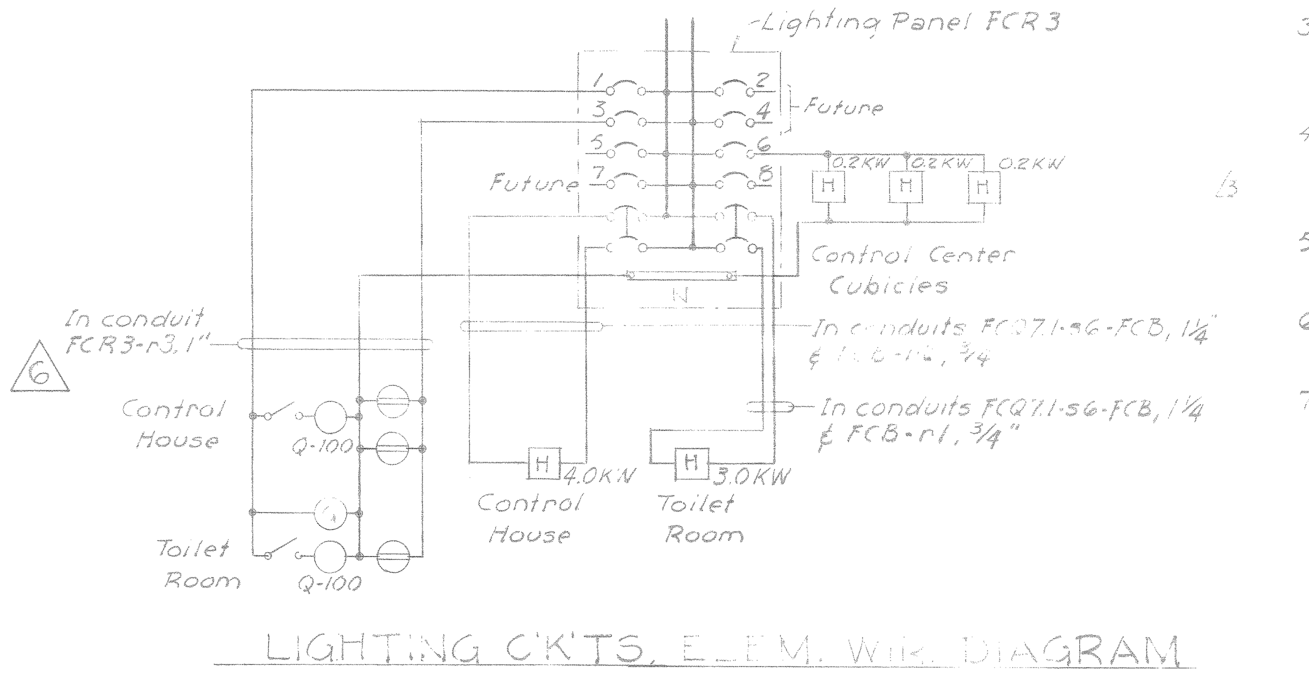




Comp't	Namplate Data	Circuit Rating	Circuit Breaker, 600V. Frame	Circuit Breaker, 600V. Trip	Circuit Breaker, 600V. No. of Poles	Starter Size	Control Breaker, 1 Pole, 125V. Control Ckt. Frame	Control Ckt. Trip	Motor Htr. Ckt. Frame	Motor Htr. Ckt. Trip	Remarks
6B	Entrance Weir A "AEW1"										Furnish and install nameplate
6C	Entrance Weir B "AEW2"										Furnish and install nameplate
9B	Telescoping Weir 78 "AW1"		100	15	3	2	50	15	50	15	
9C	Telescoping Weir 79 "AW2"		100	15	3	2	50	15	50	15	
10B	Telescoping Weir 80 "AW3"		100	15	3	2	50	15	50	15	
10C	Motorized Valve No. 1		100	15	3	1	50	15	50	15	
11B	Motorized Valve No. 2		100	15	3	1	50	15	50	15	
11C	Motorized Valve No. 3		100	15	3	[illegible]	50	15	50	15	
12B	Motorized Valve No. 4		100	15	3	1	50	15	50	15	
12C	Motorized Valve No. 5		100	15	3	1	50	15	50	15	
10A	Valve Room Sump Pump Supply		100	15	3						

CONTROL CENTER - FCQ7 (115)

No Scale

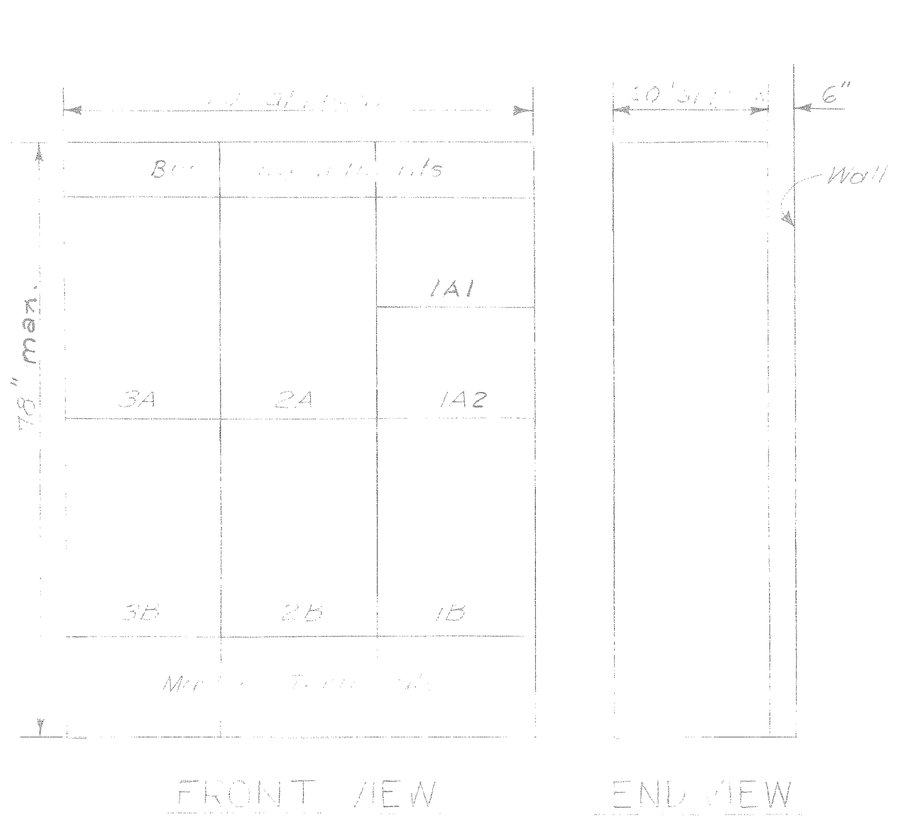


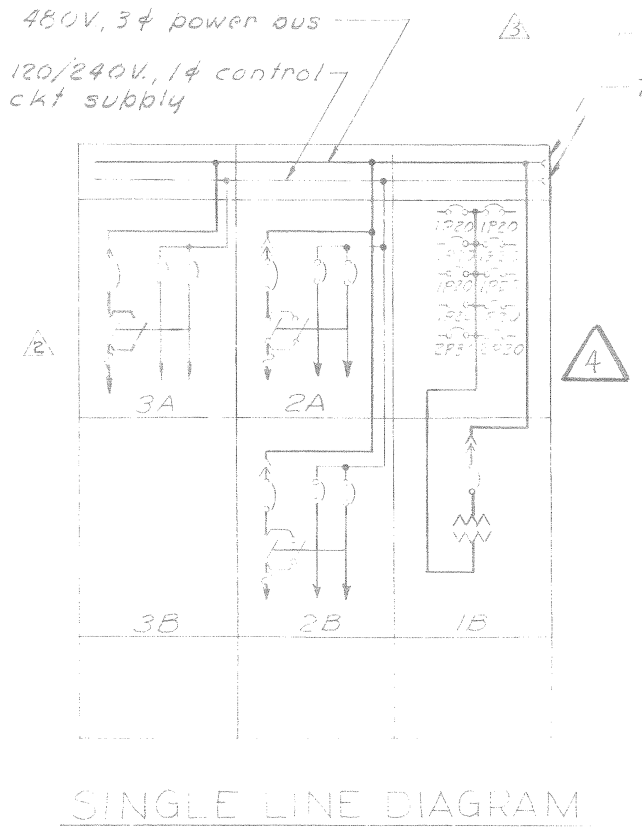
NOTES:

1. Each controller in motor control compartments shall be furnished with green & red indicator lights as shown on the wiring diagrams.
2. FCQ7.1 shall be assembled in units suitable for lowering thru a 3'-0" diameter hatch.
3. The additional cubicles of Control Center FCQ7 shall be structurally connected to the existing unit to form an integral rigid structure and busing shall be made continuous between the existing unit and the new unit.
4. 10 extra terminal points shall be provided at the master terminal board of each cubicle furnished under this contract.
5. For complete wiring diagrams of equipment with starters in the Control Centers on this dwg., see ref. dwgs. 1 & 2.
6. Each motor heater circuit is to be routed thru a normally closed auxiliary contact of each motors' respective starter.
7. An enclosure grounding terminal and a 200W. space heater is to be installed in each unit structure.

REFERENCE DRAWINGS:

1. Fishlock Channel Weirs - Wiring Diagram & Details — DDF-1-6-4/2.
2. Valve Room — DDF-1-6-4/4
3. Service Galleries, Elev. 168.0 & 175.0 — DDF-1-6-4/5





Comp't	Namplate Data	Circuit Rating	Circuit Breaker, 600V. Frame	Circuit Breaker, 600V. Trip	Circuit Breaker, 600V. No. of Poles	Starter Size	Control Breaker, 1 Pole, 125V. Control Ckt. Frame	Control Ckt. Trip	Motor Htr. Ckt. Frame	Motor Htr. Ckt. Trip	Remarks
1A	Fishlock L'tg Panel FCR3										3W, 1φ, 125/240V., 8-1P, 20A, 1-2P, 20A & 1-2P, 20A.
1B	L'tg Transformer 480-120/240V.	10KVA, 1φ	100	30	2						Dry type
2A	Fishlock Entrance Gate		100	50	3	2	50	15	50	15	
2B	Fishlock Exit Gate		100	50	3	2	50	15	50	15	
3A	Fishlock Brail Hoist		100	70	3	[illegible]	50	15	50	15	
3B	Blank space										

Sw. No.	LIGHTING PANELBOARD FCR3 DIRECTORY DATA
1	Fishlock Control House - Lighting
2	[illegible] Heater
3	Spare
4	Fishlock Floodlights
5	Fishlock Control House - Receptacles
6	Control Center FCQ7.1 - Space Heaters
7	[illegible] - 120V.A.C. Supply
8	Spare
9	Fishlock Control Room - space Heater
10	Toilet Room - Space Heater

CONTROL CENTER FCQ7.1 (116)

No Scale

AS CONSTRUCTED
CONTRACT [illegible]
CONTRACTOR [illegible] - Austin
DATE [illegible] JAN. 1955
DATE OF COMPLETION OF CONTRACT 18 SEPT. 1958
DATE OF ACCEPTANCE 18 SEPT. 1958

REVISION	DATE	DESCRIPTION	BY
6	11-17-61	Revised As Constructed	CEW
5	3-30-56	Added ACB in Comp't 10A	WWE
4	11-28-55	[illegible]	WWE
3	11-17-54	Deleted comp't 6B & 6C equipment. Revised starter sizes & notes.	HWW
2	10-11-54	[illegible] comp't 3A & notes.	HWW
1	9-27-54	Redrawing supersedes dwg. DDF-1-6-4/6 titled "Control Center FCQ7"	HWW

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

DESIGNED: REW
DRAWN: REW
CHECKED: JWd
REVIEWED: J. W. Clitwood — CHIEF, SAFETY BRANCH

THE DALLES DAM
COLUMBIA RIVER — WASHINGTON - OREGON
FISHLOCK
ELECTRICAL
CONTROL CENTERS FCQ7 AND FCQ7.1

SUPERVISED: C. E. Wall — CHIEF, ELECTRICAL SECTION
SUBMITTED: [signature] — CHIEF, DESIGN BRANCH
RECOMMENDED: Ben L. Peterson — CHIEF, ENGINEERING DIVISION
APPROVED: J. H. Moorhead — COLONEL C. E. DISTRICT ENGINEER
DATE 8-31-54
SCALE AS SHOWN
SHEET 289 OF — DDF-1-6-4/6

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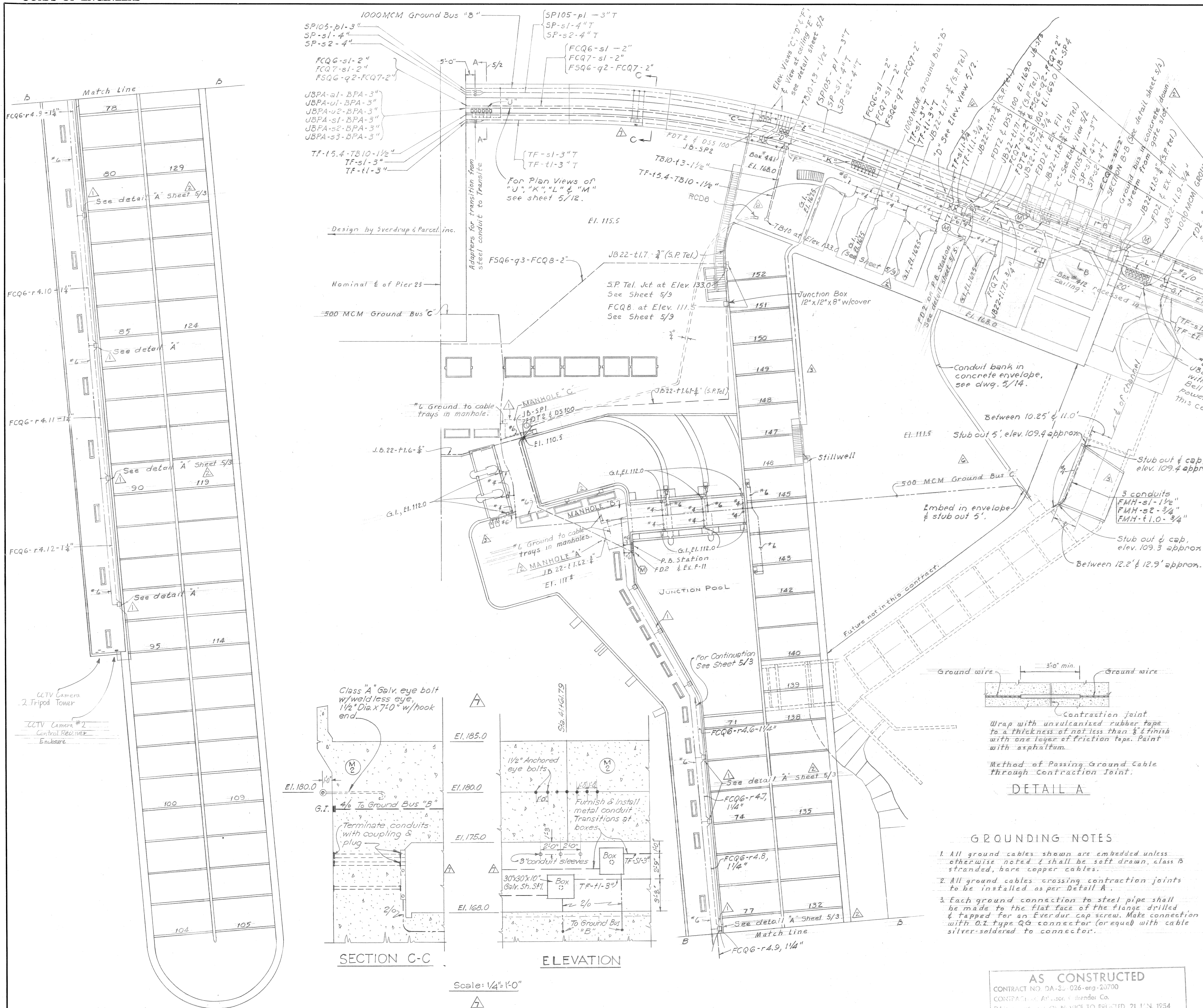
CORPS OF ENGINEERS — U. S. ARMY



NOTES

1. All equipment & exposed metal is to be grounded in accordance with National Electric Code.
2. All steel conduits passing thru contraction joints to be provided with expansion couplings O Z type AX with AJ bonding jumper or equal.
3. All cement asbestos conduits passing thru contraction joints to be provided with expansion coupling having tapered bore on one end, cylindrical bore on the other end equipped with rubber sealing ring.
4. Exact location of conduit termination at motors, switchboard & other electrical equipment to be determined or verified after exact dimension of equip. are available.
5. Special conduit boxes are detailed on sheet 5/5.
6. For detail of grounding at Floatwells see sheet 5/3.
7. All junction boxes in Service Gallery El. 168.0 grounded with no. 6 from ground bus "B".
8. Transite conduit runs shall have transite to steel transition & steel conduit 5 feet before entering junction boxes.

LEGEND — SHEETS 5/1 TO 5/5 INCL.

- Conduit embedded
- Conduit exposed and above hung ceiling
- Conduit turning toward observer.
- Conduit turning away from observer.
- Ground cable & ground insert - embedded. O Z type QG connector or equal with cable silver soldered to connector.
- Embedded ground cable tap.

COMPANION DRAWINGS

5/2, 5/3, 5/5, 5/12

GRAPHIC SCALE

1" = 20'-0"

GROUNDING NOTES

1. All ground cables shown are embedded unless otherwise noted & shall be soft drawn, class B stranded, bare copper cables.
2. All ground cables crossing contraction joints to be installed as per Detail A.
3. Each ground connection to steel pipe shall be made to the flat face of the flange drilled & tapped for an Everdur cap screw. Make connection with O.Z. type QG connector (or equal) with cable silver-soldered to connector.

REVISION	DATE	DESCRIPTION	BY
	2-21-91	Added 2 CCTV Cameras	
	7-28-75	Added RCD6 & 3/4" pipe	
	10-11-57	As Constructed	G.Z.
	4-29-55	Added boxes, conduits, eye bolts & Section "C-C"	
	2-15-55	Added conduits & revised ground cables at railroad bridge	
	19 Jan 55	Added conduit sleeve bank & deleted boxes & conduit, Serv. Gall. El. 175	
	19 Nov. 54	Added conduits & boxes. Re-designated circuits.	
	9-16-54	Made structural corrections. Relocated FCQ7 & stillwells. Added gr. inserts & stubouts & extended S.P. tel. conduit	
	11-25-53	Added notes & manholes.	
	11-2-53	General revisions at Elev. 111.5 and 175.0	

AS CONSTRUCTED
CONTRACT NO. DA-35-026-eng-20700
DATE OF COMPLETION OF CONTRACT: 1 JULY 1956
DATE OF ACCEPTANCE: 2 JULY 1956

N. W. HANER & ASSOCIATES
MOFFATT, NICHOL & TAYLOR
ASSOCIATED ENGINEERS

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
PORTLAND, OREGON

THE DALLES DAM

COLUMBIA RIVER — WASHINGTON-OREGON

EAST FISHLADDER
POWER CONTROL & GROUNDING
SERVICE GALLERY
EL. 168.0, EL. 111.5, & LADDER

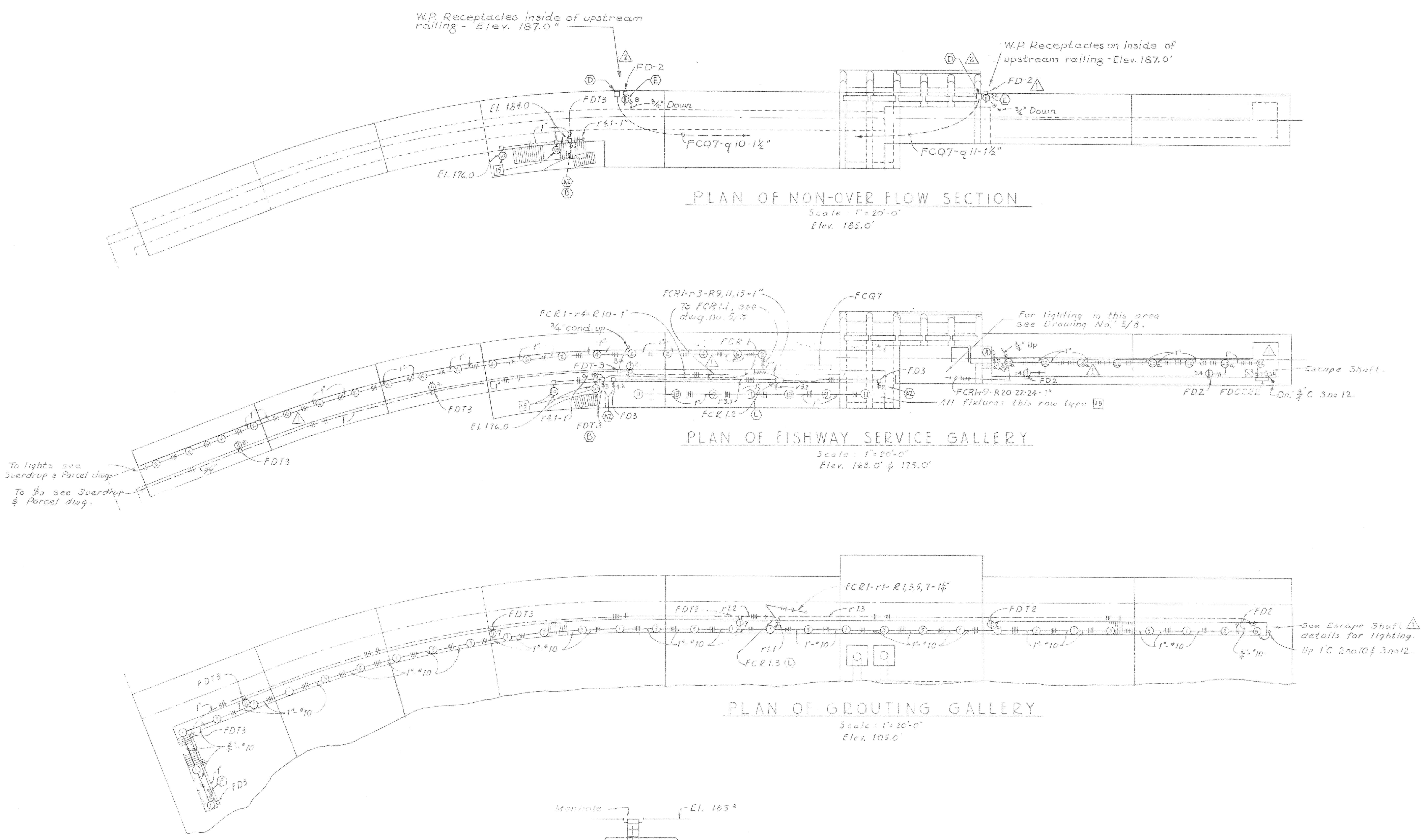
DRAWN BY: M. P.
TRACED BY: M. P.
CHECKED BY: W.e.G.
DATE 7-3-53
SCALE AS SHOWN
DRAWING NUMBER DDF-1-6-5/1
SHEET 353

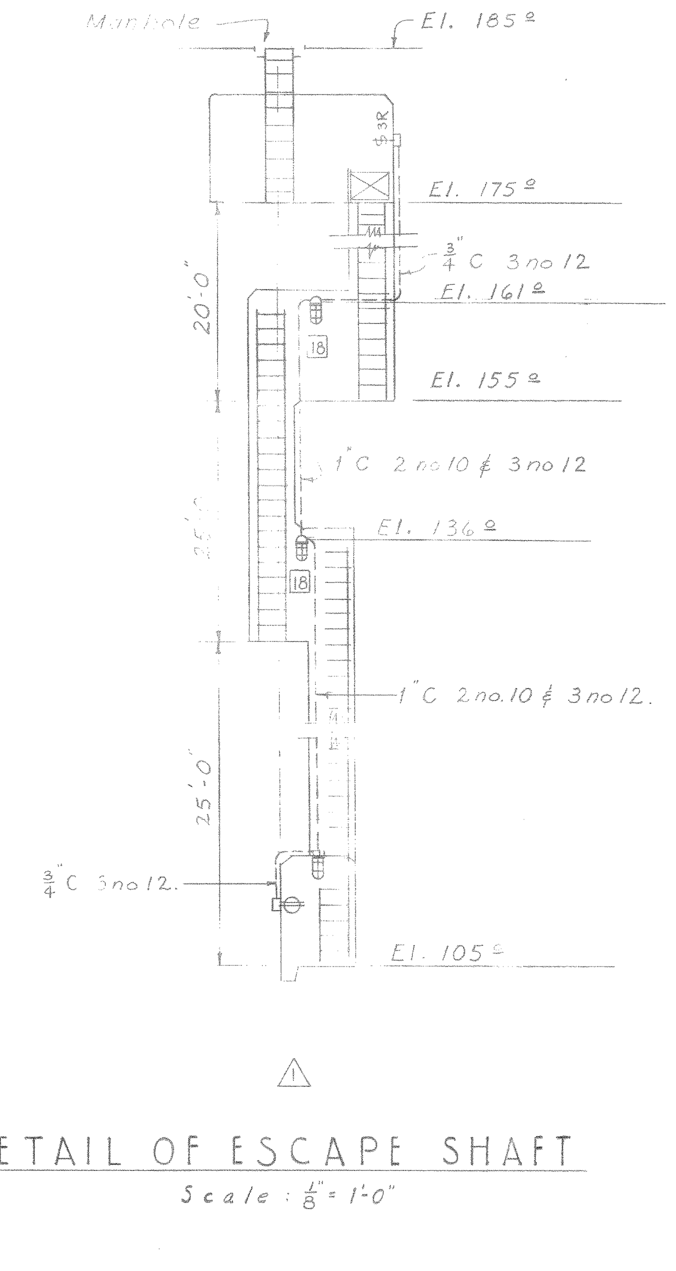
DDFE ØØ13.CIT

MICROFILMED

CORPS OF ENGINEERS

U. S. ARMY





ELECTRICAL SYMBOLS

- Embedded conduit in ceiling
- Embedded conduit in floor or walls
- Exposed conduit above suspended ceilings
- Conduit turning up or toward observer
- Conduit turning down or away from observer
- Ceiling fixture (incandescent)
- Ceiling fixture (fluorescent)
- Wall fixture
- Receptacle, 1ϕ 120 V.
- Wall heater, flush, 208V. 1ϕ
- $ Tumbler switch, SPST, 115 V.
- $3 Tumbler switch, 3-way, 115 V.
- $R Remote control switch
- Hash marks indicate number of conductors in conduit
- [3] Indicates item number of lighting fixtures as shown on sheet 5/11
- (A) Indicates item number of wiring device or accessory as shown on sheet 5/11
- FCR1-r2-R2,4,6,8-1¼" Indicates lighting circuits R2, 4, 6 & 8 in 1¼" conduit, r2, from lighting panelboard FCR1. Circuit numbers shall correspond with panelboard breaker numbers.
- (1) Indicates item no. of portable elec. heaters as shown on sht.

GENERAL NOTES

1. All conduits shall be 3/4" I.P.S., galvanized rigid steel, unless otherwise noted, and the conduit system shall be installed in accordance with the specifications.
2. All embedded conduits crossing contraction joints shall have expansion and deflection couplings, O.Z. type EX or equal, with EJ bonding jumper.
3. All Lighting wire shall be solid, single conductor, #12 AWG, unless otherwise noted.
4. All switches near doors shall be located within 1'-0" of door opening.
5. Mount wall switches and receptacles 4'-6" and 1'-0", respectively, above finished floor unless otherwise noted.
6. Color coding shall be as follows:
   Black - B - Phase A (ckts 1, 2, 7, 8, 13, 14)
   Red - R - Phase B (ckts 3, 4, 9, 10)
   Green - G - Phase C (ckts 5, 6, 11, 12)
   White - W - Neutral
   Orange / Blue } For use with 3- and 4-way switches. Orange to be used for switch legs.
   White with black tracer - W/b - battery common.
   Red with black tracer - R/b - battery negative and positive.
7. All lighting fixtures in Service Gallery to be type [54] unless otherwise noted. Elev. 168.0' & 175.0'
8. All lighting fixtures in Grouting Gallery to be type [16] unless otherwise noted. Elev. 105.0'
9. All switches to be item (B), convenience outlets item (C) with galvanized steel cover plates unless otherwise noted.

AS CONSTRUCTED
CONTRACT NO. DA-35-026-eng-20700
CONTRACTOR: A[illegible] [illegible] Co.
DATE OF RECEIPT OF NOTICE TO PROCEED: 14 JAN. 1954
DATE OF COMPLETION OF CONTRACT: 1 JULY 1956
DATE OF ACCEPTANCE: 2 JULY 1956

GRAPHIC SCALES

1" = 20'-0"

1/8" = 1'-0"

REFERENCE DRAWINGS
5/10, 5/11

COMPANION DRAWINGS
5/7, 5/8

REVISION	DATE	DESCRIPTION	BY
4	10-11-57	As Constructed	G.Z.
3	9-16-54	Minor revisions. Relocated type [54] fixture to dwg. 5/8	HW
2	11-25-53	Receptacles added at Elev. 187°	HW
1	11-2-53	General plan revisions	HW

N. W. HANER & ASSOCIATES
MOFFATT, NICHOL & TAYLOR
ASSOCIATED ENGINEERS

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
PORTLAND OREGON

DRAWN BY: J. N.
TRACED BY: S. J. Z.
CHECKED BY: W.E.C.
PREPARED: N. W. HANER & ASSOC. MOFFATT, NICHOL & TAYLOR

THE DALLES DAM

COLUMBIA RIVER — WASHINGTON-OREGON

EAST FISHLADDER

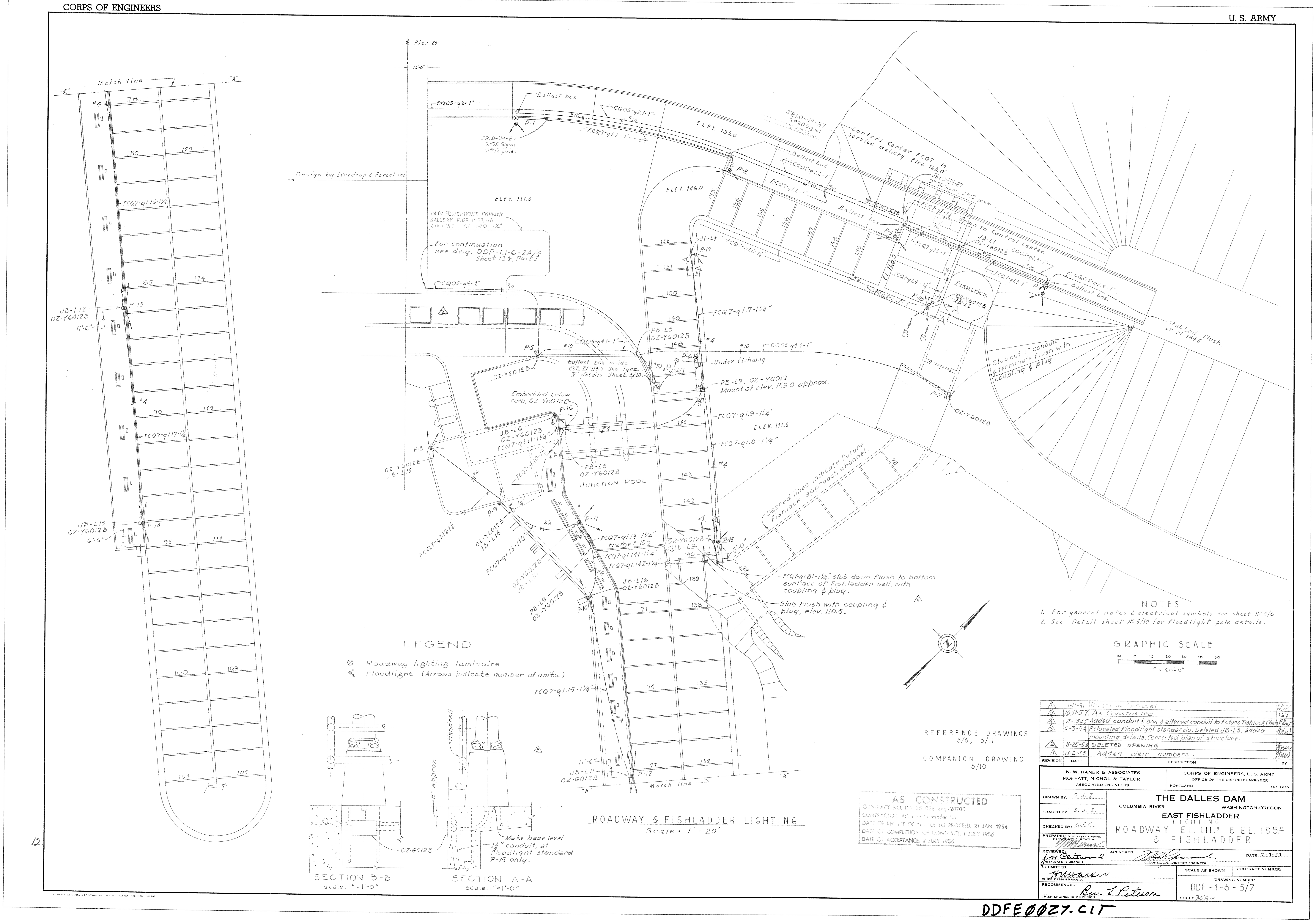
LIGHTING
SERVICE & GROUTING GALLERYS

REVIEWED: CHIEF, SAFETY BRANCH
APPROVED: COLONEL, C. E., DISTRICT ENGINEER — DATE 7-3-53
SUBMITTED: CHIEF, DESIGN BRANCH
RECOMMENDED: Ben L. Peterson, CHIEF, ENGINEERING DIVISION

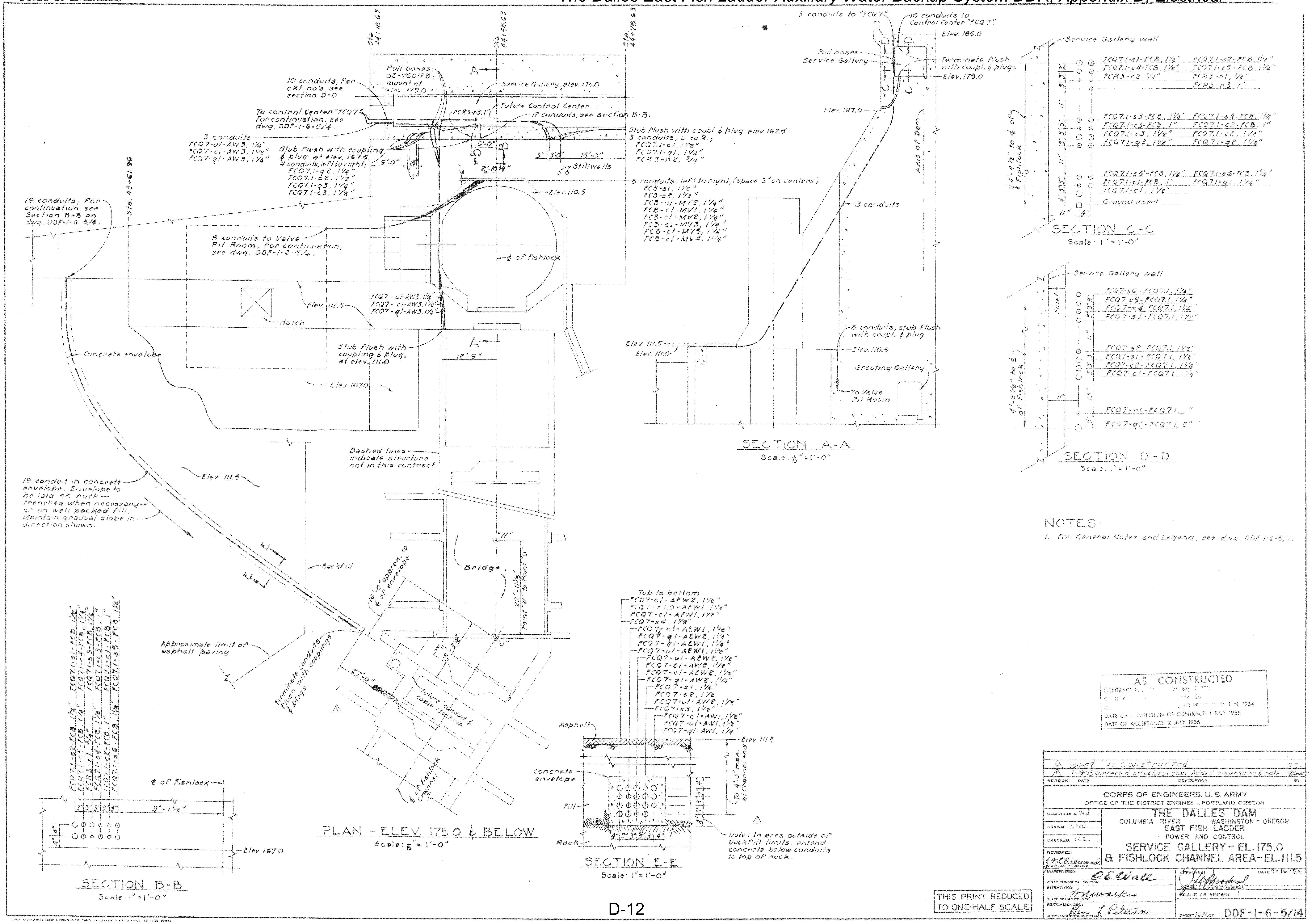
SCALE AS SHOWN
CONTRACT NUMBER:
DRAWING NUMBER DDF-1-6-5/6
SHEET 35-8 OF

DDFE∅∅26.CIT

Sep 69


CORPS OF ENGINEERS
U. S. ARMY
Design by Sverdrup & Parcel inc.
ELEV. 185.0
ELEV. 146.0
ELEV. 111.5
JUNCTION POOL
FISHLOCK
Dashed lines indicate future Fishlock approach channel
Control Center FCQ7 in Service Gallery Elev. 168.0
For continuation, see dwg. DDP-1.1-6-2A/4 Sheet 134, Part 1
Stub flush with coupling & plug, elev. 110.5.
LEGEND
Roadway lighting luminaire
Floodlight (Arrows indicate number of units)
SECTION B-B
scale: 1"=1'-0"
SECTION A-A
scale: 1"=1'-0"
ROADWAY & FISHLADDER LIGHTING
Scale: 1" = 20'
NOTES
1. For general notes & electrical symbols see sheet Nº 5/6
2. See Detail sheet Nº 5/10 for floodlight pole details.
GRAPHIC SCALE
1" = 20'-0"
REFERENCE DRAWINGS 5/6, 5/11
COMPANION DRAWING 5/10
AS CONSTRUCTED
DATE OF NOTICE TO PROCEED: 21 JAN 1954
DATE OF COMPLETION OF CONTRACT: 1 JULY 1956
DATE OF ACCEPTANCE: 2 JULY 1956
6 | 3-11-91 | Revised As Constructed
5 | 10-11-57 | As Constructed | GZ
4 | 2-15-55 | Added conduit & box & altered conduit to future Fishlock Chan.
3 | 6-3-54 | Relocated floodlight standards. Deleted JB-L3. Added mounting details. Corrected plan of structure.
2 | 11-25-53 | DELETED OPENING
1 | 11-2-53 | Added weir numbers.
REVISION | DATE | DESCRIPTION | BY
N. W. HANER & ASSOCIATES
MOFFATT, NICHOL & TAYLOR
ASSOCIATED ENGINEERS
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
PORTLAND OREGON
DRAWN BY: S. J. Z.
TRACED BY: S. J. Z.
CHECKED BY: W.E.C.
PREPARED: N. W. HANER & ASSOC. MOFFATT, NICHOL & TAYLOR
THE DALLES DAM
COLUMBIA RIVER WASHINGTON-OREGON
EAST FISHLADDER
LIGHTING
ROADWAY EL. 111.5 & EL. 185.0 & FISHLADDER
REVIEWED: CHIEF, SAFETY BRANCH
APPROVED: COLONEL, C.E., DISTRICT ENGINEER
DATE 7-3-53
SUBMITTED: CHIEF, DESIGN BRANCH
RECOMMENDED: CHIEF, ENGINEERING DIVISION
SCALE AS SHOWN
CONTRACT NUMBER:
DRAWING NUMBER
DDF-1-6-5/7
SHEET 359
DDFE0027.CIT


CORPS OF ENGINEERS
U. S. ARMY
VIEW "T-T" MANHOLE-"A"
Scale: 1/2" = 1'-0"
VIEW "S-S" MANHOLE-"A"
Scale: 1/2" = 1'-0"
ELEVATION VIEW "N-N"
Scale: 1/4" = 1'-0"
ELEVATION VIEW "G"
Not to scale.
ELEVATION VIEW "H"
Not to scale.
Note: Leave 18" Ground Bus coiled in box for future extension.
BOX 403, 408, 411 412.
BOX 428
BOX 423,424
BOX 422
BOX 466 THRU 468
BOX 446 THRU 460
BOX 443, 444.
BOX 440
VIEW "X-X" MANHOLE-"C"
Scale: 1/2" = 1'-0"
VIEW "U-U" MANHOLE "B"
Scale: 1/2" = 1'-0"
VIEW "V-V" MANHOLE "B"
Scale: 1/2" = 1'-0"
SECTION F-F-SHEET 5/3
Scale: 1/2" = 1'-0"
NOTES:
For details of cable trays & supports, see sheet 5/13.
REFERENCE DRAWINGS
COMPANION DRAWINGS 5/1, 5/3, 5/5, 5/13
GRAPHIC SCALE
VIEW "Y-Y" MANHOLE "C"
Scale: 1/2" = 1'-0"
SECTIONAL PLAN OF SERVICE GALLERIES AT CEILING ELEVATION.
Scale: 1/4" = 1'-0"
10-11-57 As Constructed
8-3-55 Revised Views U-U, V-V, X-X, & Y-Y; added Section F-F.
13 July 55 Added 3/4" & 2" conduits. Revised View S-S.
19 Jan 55 Added elev. view "N-N". Deleted boxes. Revised plan & elev. details.
19 Nov. 54 Added boxes & plan detail. Revised ckt. no's.
9-16-54 Terminated spare conduit in Manhole "C". Added dimension.
REVISION DATE DESCRIPTION BY
N. W. HANER & ASSOCIATES
MOFFATT, NICHOL & TAYLOR
ASSOCIATED ENGINEERS
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
PORTLAND OREGON
THE DALLES DAM
COLUMBIA RIVER WASHINGTON-OREGON
EAST FISHLADDER
POWER & CONTROL
MANHOLE DETAILS
EL. 111.5 & BOX DETAILS
DATE 11-30-53
SCALE AS SHOWN
DRAWING NUMBER
DDF-1-6-5/12
DDFE 0032.CIT



NOTES:

1. For General Notes and Legend, see dwg. DDF-1-6-5/1.

REVISION	DATE	DESCRIPTION	BY
2	10-4-57	As Constructed	G.Z.
1	1-1955	Corrected structural plan. Added dimensions & note.	

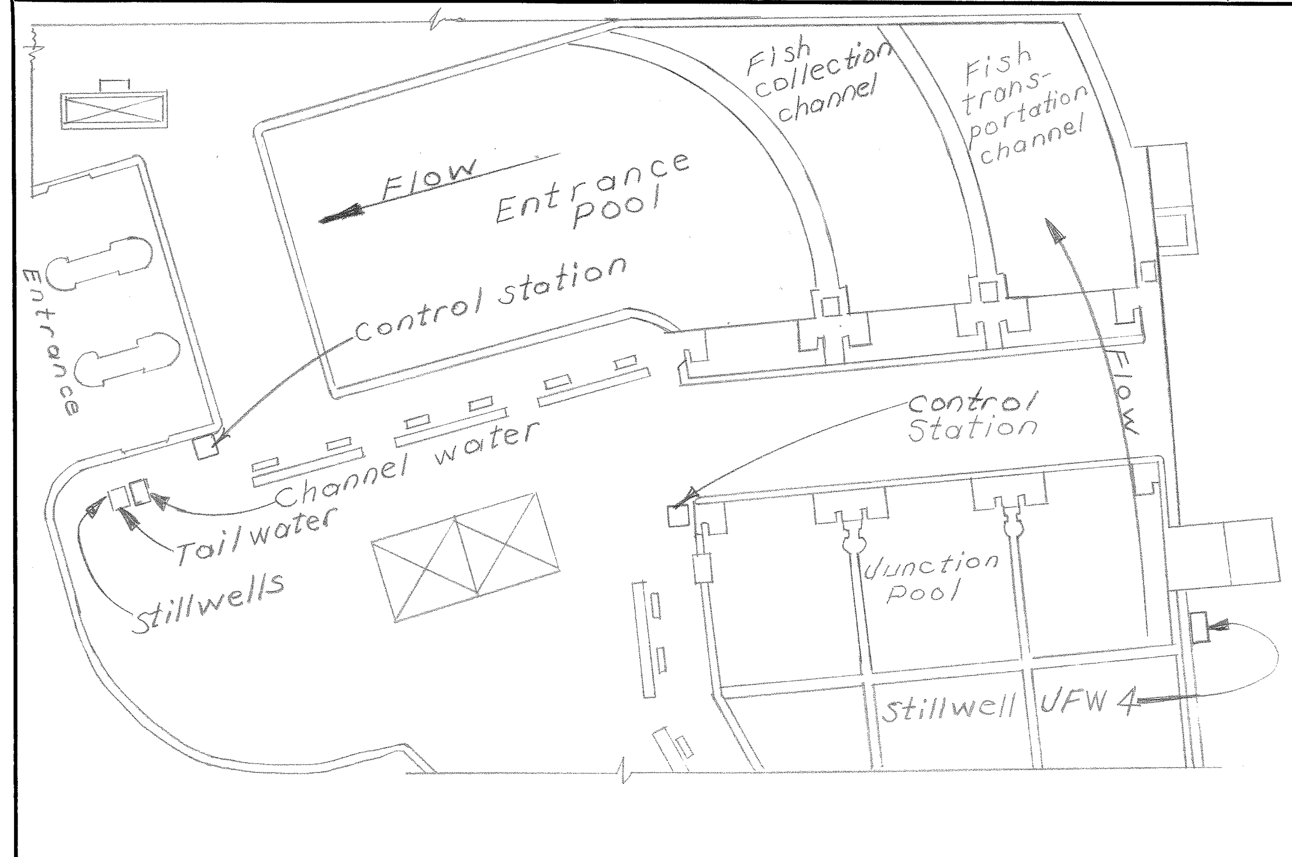
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

THE DALLES DAM
COLUMBIA RIVER WASHINGTON - OREGON
EAST FISH LADDER
POWER AND CONTROL
SERVICE GALLERY - EL. 175.0
& FISHLOCK CHANNEL AREA - EL. 111.5

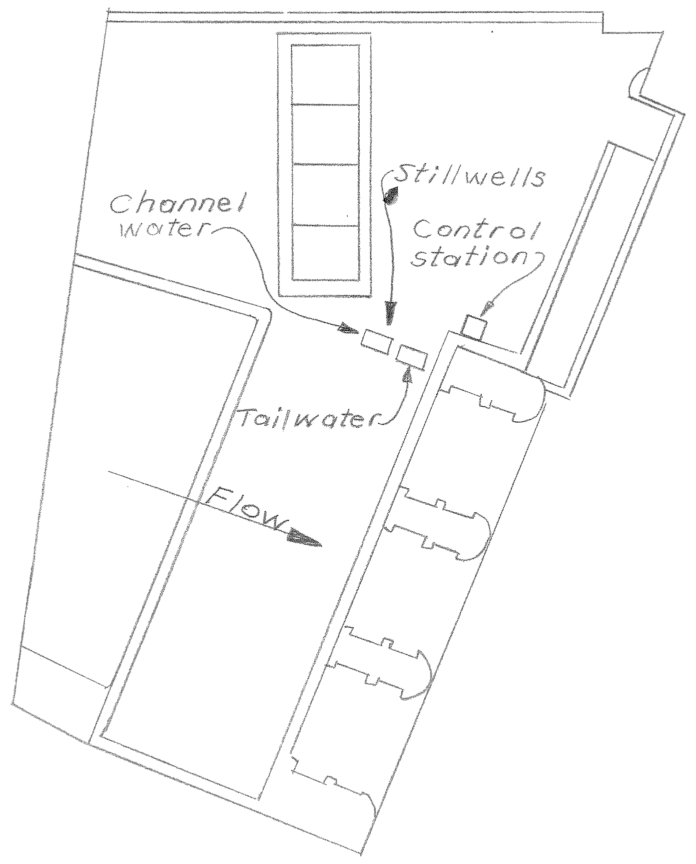
DESIGNED: JWJ
DRAWN: JWJ
CHECKED: G.Z.
SCALE AS SHOWN
DATE 9-16-54
SHEET 363 OF DDF-1-6-5/14

THIS PRINT REDUCED TO ONE-HALF SCALE

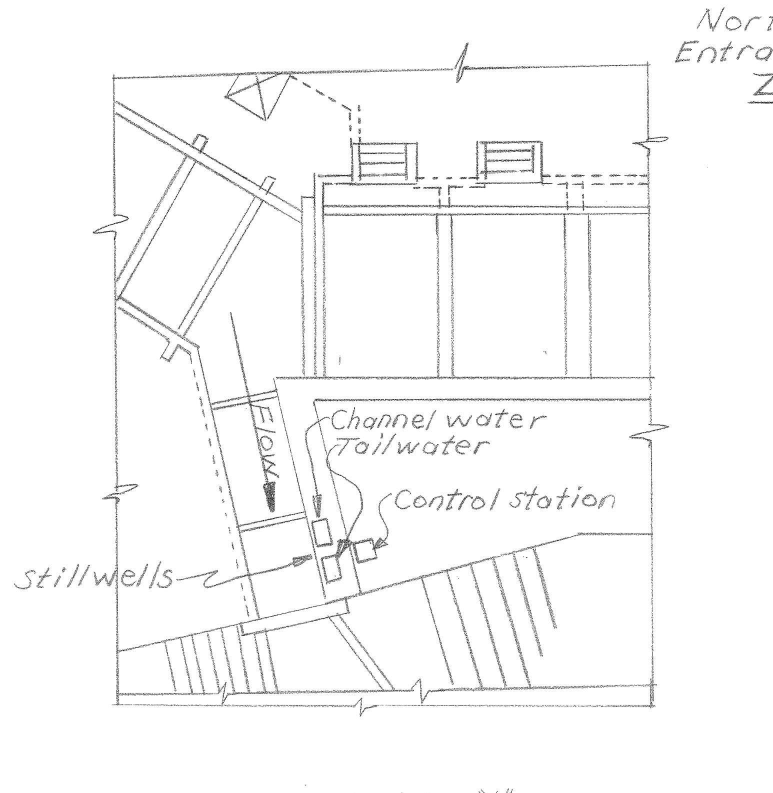
CORPS OF ENGINEERS 4 3 2 1 U. S. ARMY



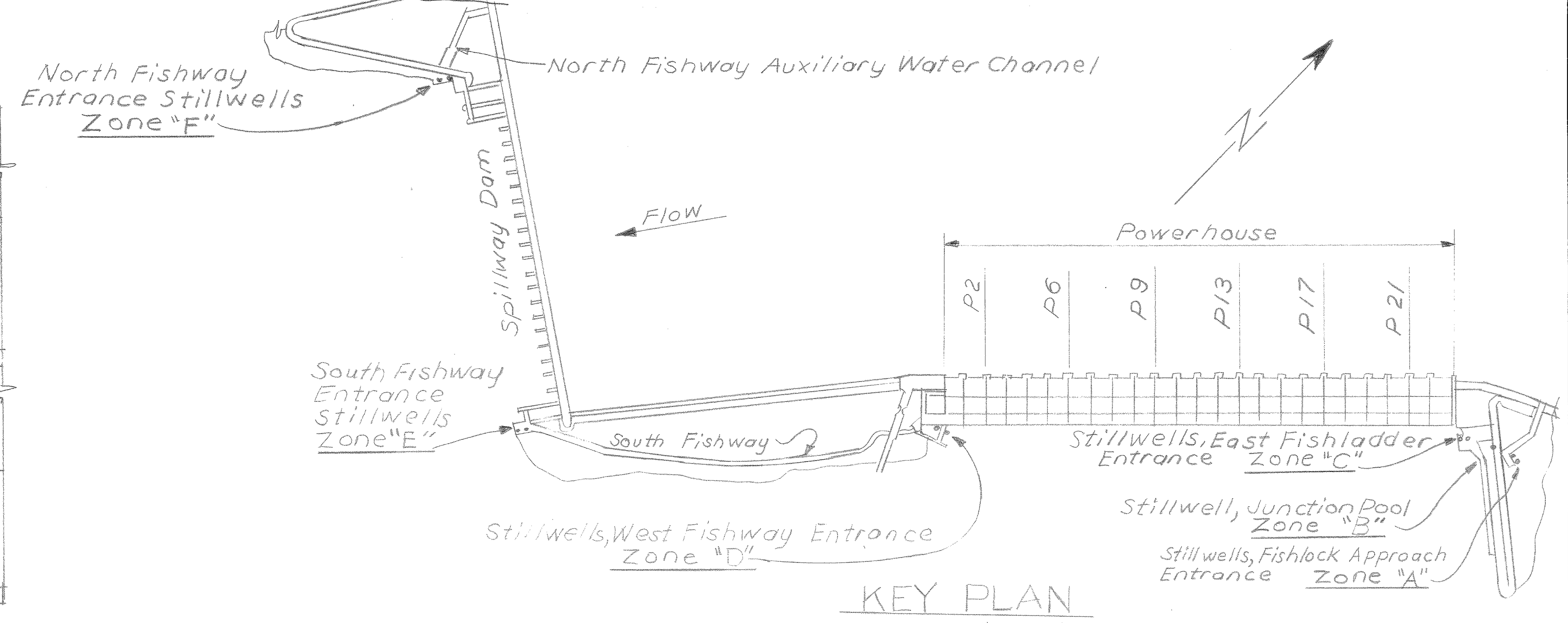
ZONE "C" ZONE "B"
EAST P.H. FISHLADDER ENTRANCE AND JUNCTION POOL
SCALE: 1/16" = 1'-0"



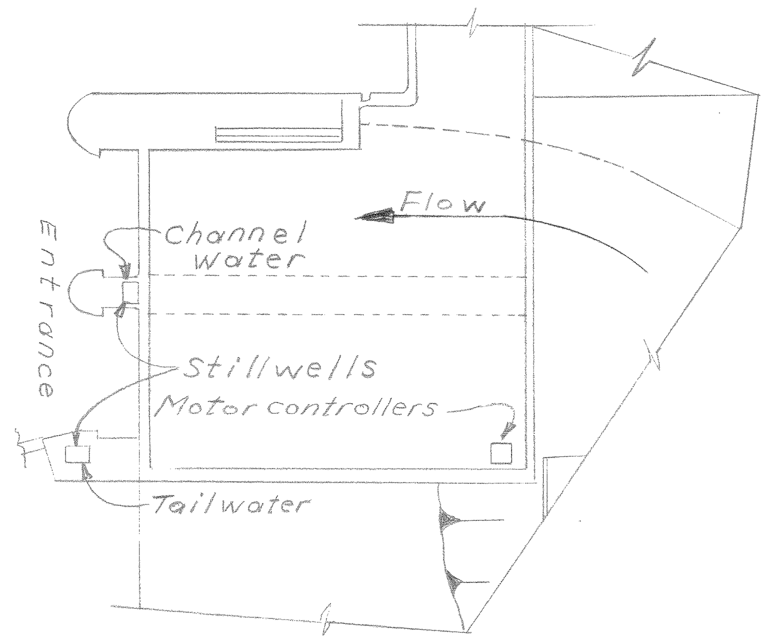
ZONE "D"
WEST FISHWAY ENTRANCE
SCALE: 3/32" = 1'-0"



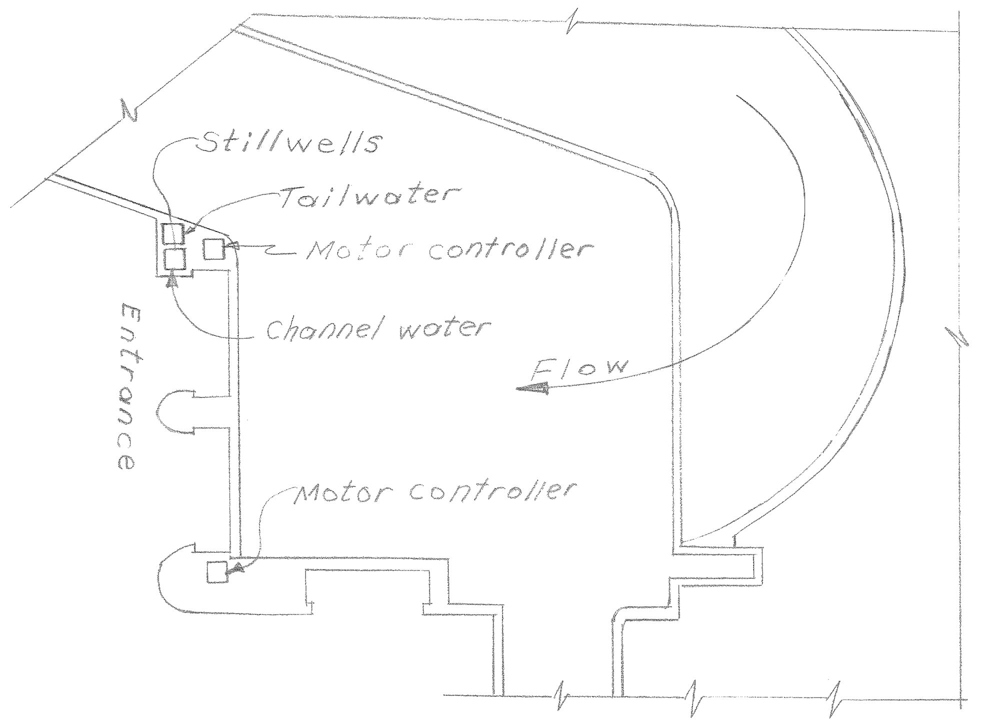
ZONE "A"
FISHLOCK APPROACH ENTRANCE
SCALE: 1/16" = 1'-0"



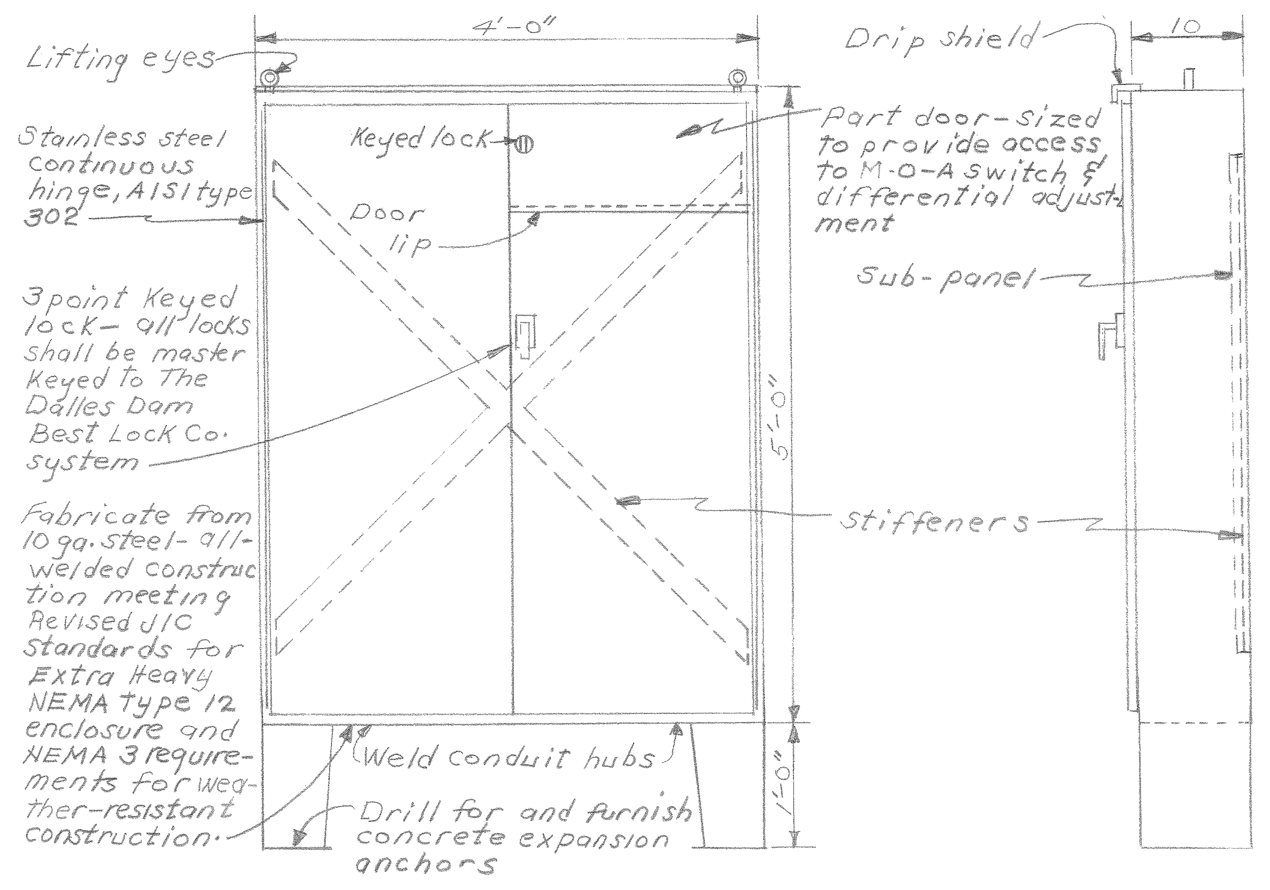
KEY PLAN
Scale: 1" = 400'



ZONE "E"
SOUTH FISHWAY ENTRANCE
SCALE: 1/16" = 1'-0"



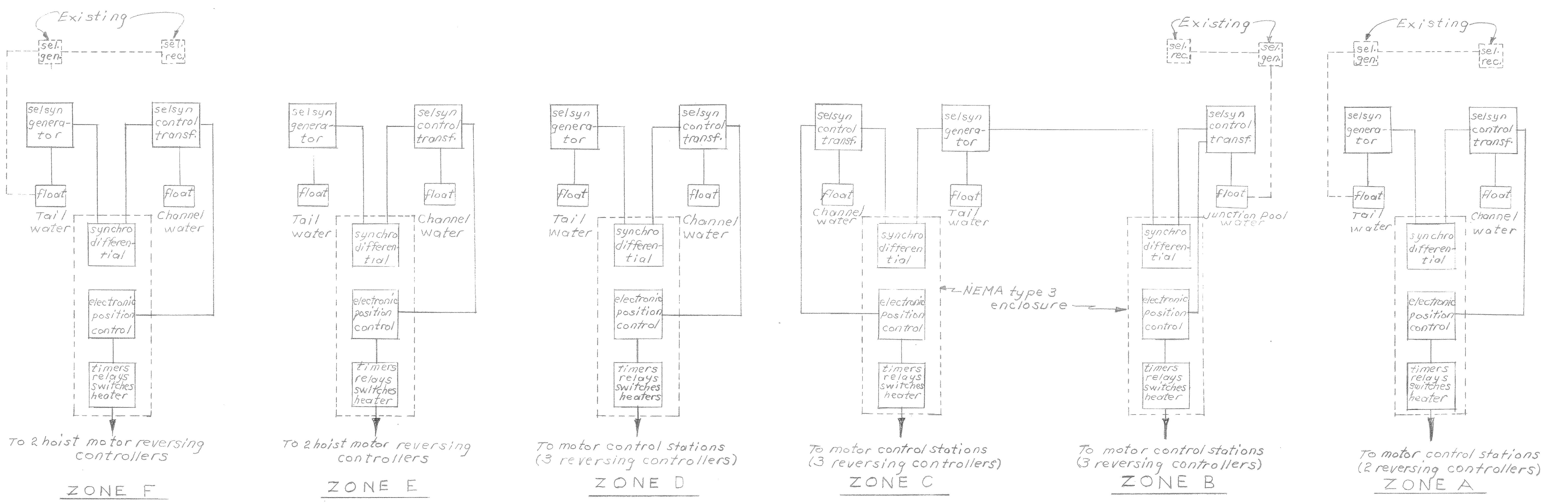
ZONE "F"
NORTH FISHWAY ENTRANCE
SCALE: 1/16" = 1'-0"



FRONT SIDE
TYPICAL ENCLOSURE
SCALE: 1" = 1'-0"

NOTES:

1. THE CONTROL SCHEME SHALL PROVIDE FOR A 1.5' DIFFERENTIAL BETWEEN TAILWATER AND JUNCTION POOL WATER LEVEL AND FOR A 1.0' DIFFERENTIAL BETWEEN TAILWATER AND CHANNEL WATER FOR ALL OTHER ZONES. DIFFERENTIAL LEVEL SHALL BE MAINTAINED AT ±0.1'.
2. ALL STILLWELLS ARE EXISTING AND EACH IS EQUIPPED WITH FLOAT, COUNTERWEIGHT AND PULLEY. THREE STILLWELLS HAVE SELSYN EQUIPMENT ASSOCIATED WITH THEM.
3. THE CONTRACTOR SHALL SUPPLY THE MECHANICAL CONNECTION BETWEEN DRIVE PULLEY AND SELSYN AND A MOUNTING OR SUPPORT FOR EACH SELSYN ITEM SUPPLIED. IN THOSE STILLWELLS WITH EXISTING SELSYN EQUIPMENT, THE CONTRACTOR SHALL SUPPLY AN EXTENSION TO THE EXISTING SUPPORT, IF REQUIRED. THE MOUNTING OR SUPPORT SHALL BE OF STEEL, HOT-DIP ZINC-COATED, AFTER FABRICATION. EACH SUPPORT SHALL BE CLEARLY IDENTIFIED AS TO ITS FUTURE LOCATION. COUNTERWEIGHTS SHALL BE MODIFIED AS REQUIRED.
4. EACH ZONE OR AREA SHALL HAVE ITS OWN COMPONENT CONTROL ITEMS AND SHALL OPERATE INDEPENDENT OF OTHER ZONES EXCEPT FOR ZONES B AND C WHERE ONE SELSYN GENERATOR MAY BE USED TO DRIVE TWO DIFFERENTIAL SELSYNS.
5. THE THREE EXISTING SELSYN GENERATORS, AT THE CONTRACTOR'S OPTION, MAY BE INCORPORATED IN THE CONTROL SCHEME, PROVIDED CHARACTERISTICS CAN BE MATCHED. ALL SELSYN EQUIPMENT IN ANY ONE ZONE SHALL BE THE PRODUCT OF ONE MANUFACTURER.
6. AUXILIARY RELAYS OR RELAY CONTACTS SHALL BE SUFFICIENT IN NUMBER TO PROVIDE FOR SIMULTANEOUS OPERATION OF THE NUMBER OF REVERSING CONTROLLERS INDICATED FOR EACH ZONE. THE RELAY CONTACTS SHALL HAVE THE CAPACITY FOR OPERATING NEMA SIZE 2 CONTROLLERS. ONE SET EACH OF NORMALLY OPEN AND NORMALLY CLOSED SPARE CONTACTS SHALL BE PROVIDED ON THE EQUIPMENT IN EACH ZONE.
7. ALL GATE HOISTS AT ANY ONE LOCATION SHALL BE OPERATED SIMULTANEOUSLY BY THE RESPECTIVE CONTROL STATION.
8. THE OPERATING RANGE OF THE DIFFERENTIAL CONTROL SHALL BE FROM ZERO TO 4'-0", WITH INTERVALS OF 0.2 FOOT PROVIDED ON THE ADJUSTING DIAL.
9. A MANUAL-OFF-AUTOMATIC CONTROL SWITCH SHALL BE PROVIDED WITHIN EACH ENCLOSURE.
10. ENCLOSURES SHALL BE DESIGNED AS FREE STANDING STRUCTURES FOR INSTALLATION ON CONCRETE DECKS, ADJACENT TO STILL WELLS IN EACH ZONE.



BLOCK DIAGRAMS

REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, PORTLAND
CORPS OF ENGINEERS
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

DESIGNED: RHD
DRAWN: RHD
CHECKED: RHD
REVIEWED:
CHIEF, SAFETY BRANCH
SUPERVISED: CHIEF, ELECTRICAL SECTION
SUBMITTED: CHIEF, DESIGN BRANCH
RECOMMENDED: CHIEF, ENGINEERING DIVISION

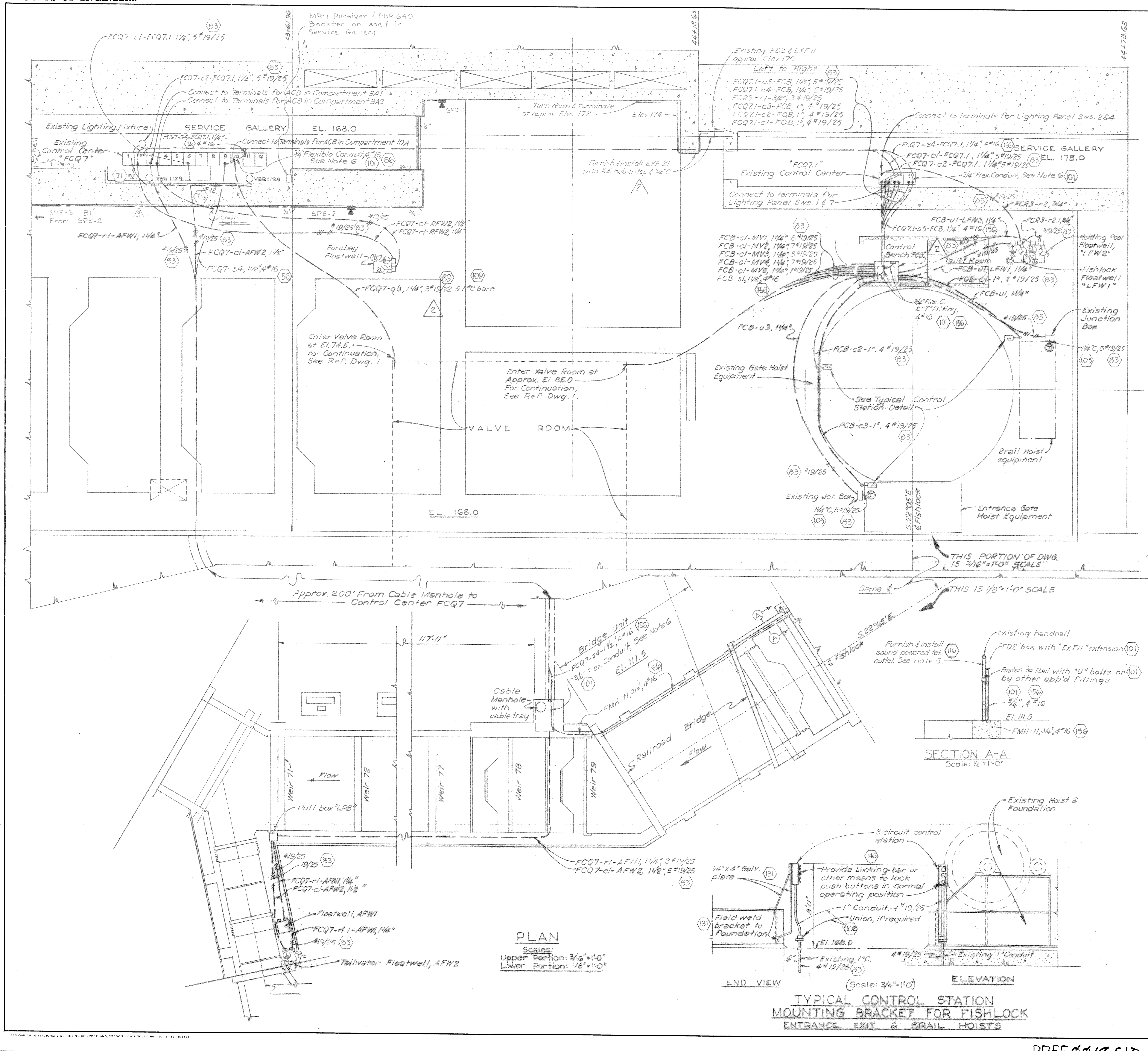
THE DALLES DAM
COLUMBIA RIVER WASHINGTON-OREGON
FISH FACILITIES ELECTRICAL
AUTOMATIC WATER LEVEL CONTROL AT ENTRANCES

APPROVED: COLONEL, C. E., DISTRICT ENGINEER DATE
SCALE AS SHOWN SPEC. NO.
SHEET 1 OF 1 DDF-1-6-6

DDFE0051.CIT

4 3 2 1

CORPS OF ENGINEERS U. S. ARMY

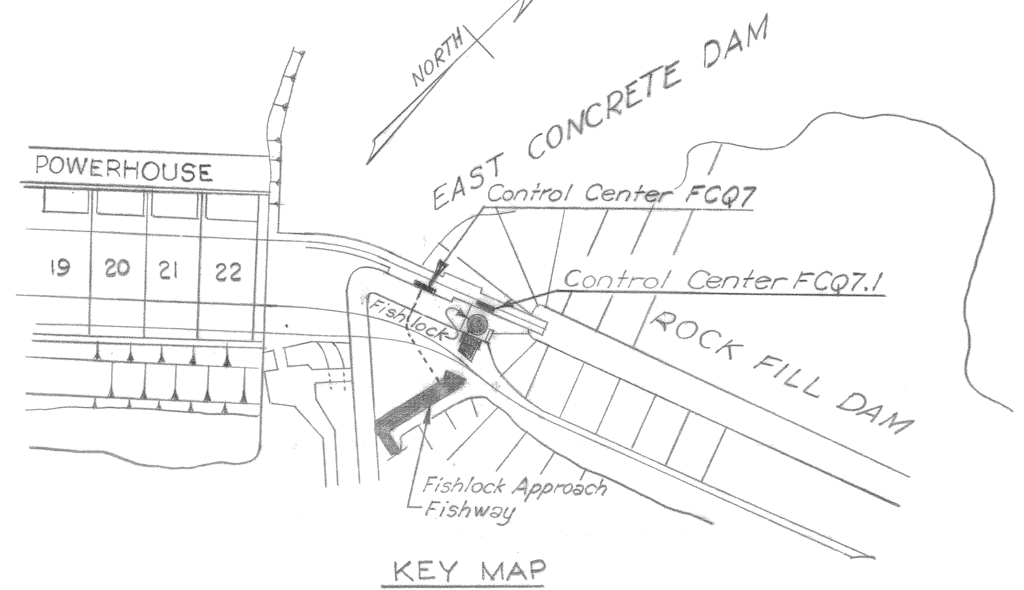


PLAN
Scales:
Upper Portion: 3/16" = 1'-0"
Lower Portion: 1/8" = 1'-0"

SECTION A-A
Scale: 1/2" = 1'-0"

END VIEW — ELEVATION
(Scale: 3/4" = 1'-0")

TYPICAL CONTROL STATION
MOUNTING BRACKET FOR FISHLOCK
ENTRANCE, EXIT & BRAIL HOISTS



KEY MAP

LEGEND

- (123) VGR 1129 — Light fixture, wallmounted, Crouse-Hinds type VGR 1129 or equal
- Cast Box
- (148) Synchro Transmitter
- 5W., 6P. Receptacle, Pyle-National RNER-10621-G or app'd equal
- (123) 2P. Receptacle, Crouse Hinds BRD 8302, or approved equal. Numeral indicates No. of receptacles.
- (146) 3 button pushbutton with locking bar & padlock, NEMA IV enclosure
- (116) Sound powered Tel. Outlet, See Note 5
- Exposed Conduit, hash marks indicate no. of wires.
- Embedded Conduit, existing.
- (148) Flexible cable, 6/c #12, type "SO", & plug, Pyle-National PLND-710621-G or approved equal.
- Conduit turning toward observer
- Conduit turning away from observer
- Bid Item
- Public Address Speakers

REFERENCE DRAWINGS:

1. East Fishladder & Fishlock-Plan-Fishlock Valve Room & Fishladder Office & Comfort Sta.- DDF-1-6-4.2/2
2. Floatwells & Fishlock Hoists-Remote Indicating System Mounting Details:- DDF-1-6-4.2/3
3. Sound Power Telephone System Details- DDP-1.3-6-3A8/3

NOTES:

1: All embedded conduits are existing. Exposed conduits, unless marked existing, are in this contract.

2: Existing embedded conduits with cables entering at the top of Control Centers FCQ7 & FCQ7.1 are to be extended into the Control Centers by an approved method with exposed conduit & terminated with locknuts & ground bushing. For circuits entering at the bottom, the conduits shall be extended with 3" nipples & terminated with ground bushings. Connect ground bushings to enclosure grounding terminal or bus with #6 AWG bare copper.

3: Circuits Terminated in or routed through Control Centers and thru cable manhole and pull box LPB are to be grouped and laced to maintain their circuit identity. Spare terminal boards are existing in the Control Centers for circuits in this contract.

4: See Reference Drawing No. 2 for equipment mounting details in float wells

5: For sound powered telephone outlet detail, See Detail "A", Ref. Dwg. No. 3.

6: Sound powered telephone circuits carrying 4#16 wire shall be made continuous through Control Centers, Control Bench & Manhole, with 3/4" galvanized flexible conduit, coupled to the rigid conduit terminations with the necessary reducers & Fittings. An extra large "C" or "T" conduit fitting shall be placed in each flexible conduit run, positioned for accessibility, and the flexible conduit shall be supported in the Control Centers and Bench cubicles by an approved method.

AS CONSTRUCTED
CONTRACT NO. DA-35-026-civeng-56-155
CONTRACTOR E.V. Lane Corp., Gunther & Shirley Co.
DATE OF RECEIPT OF NOTICE TO PROCEED 21 Dec. 55
DATE OF COMPLETION OF CONTRACT 30 Nov. 60
DATE OF ACCEPTANCE 30 Nov. 60

REVISION	DATE	DESCRIPTION	BY
4	5-18-78	Added PA Speakers	DRL
3	6-26-73	Added code bell.	
2	8-15-56	Deleted ckt. FCQ7-s1-VP. Added Toilet Room to plan, added 3/4"C.	[illegible]
1	9-23-55	Added sound powered tel. ckts. & made minor revisions	[illegible]

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

DESIGNED: J.W.J.
DRAWN: R.A.B.
CHECKED: RHD
REVIEWED: D. V. MacCollum, CHIEF, SAFETY BRANCH, for

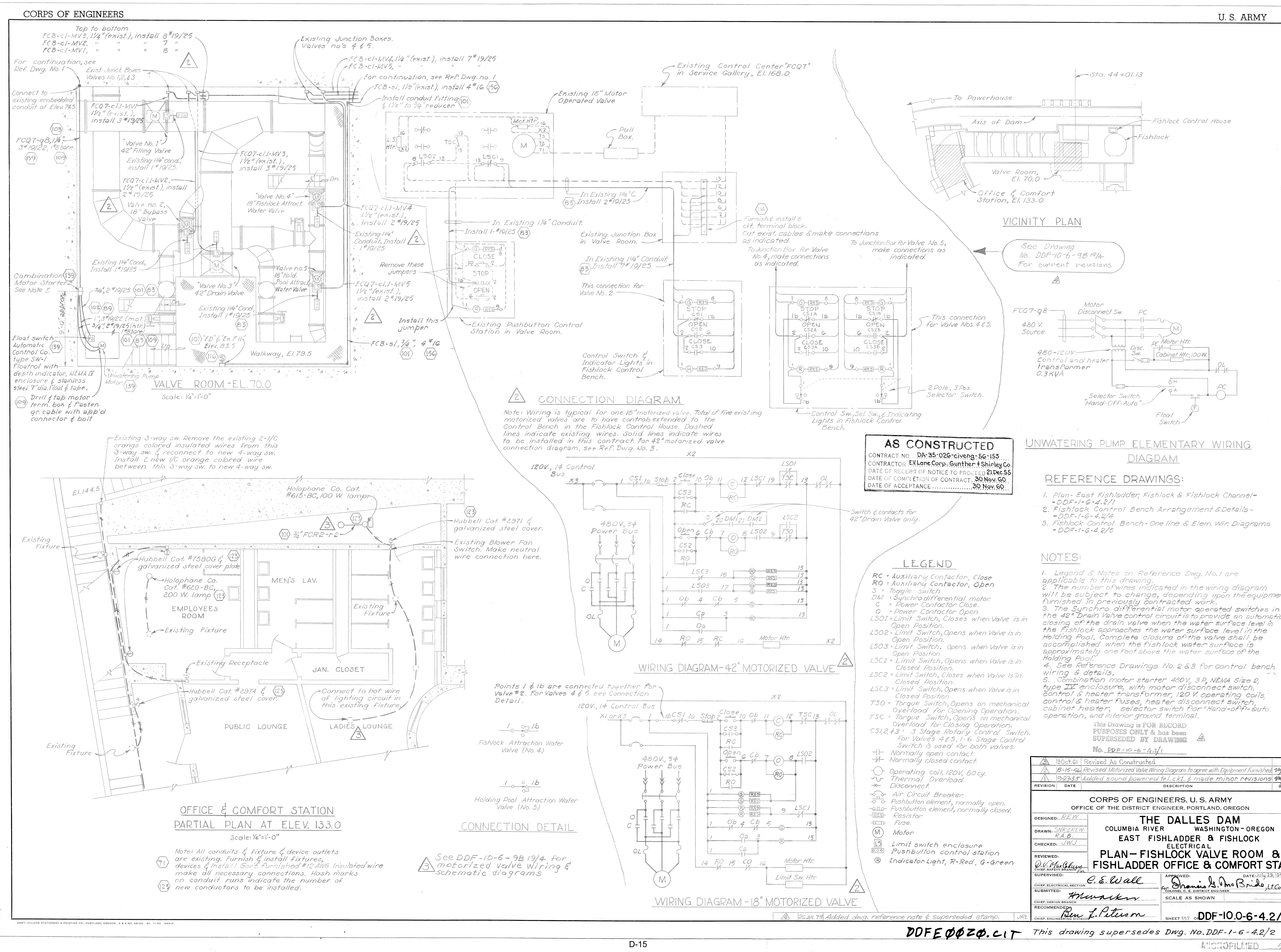
THE DALLES DAM
COLUMBIA RIVER WASHINGTON – OREGON
ELECTRICAL
PLAN – EAST FISHLADDER FISHLOCK & FISHLOCK CHANNEL

SUPERVISED: C. E. Wall, CHIEF, ELECTRICAL SECTION
SUBMITTED: [signature], CHIEF, DESIGN BRANCH
RECOMMENDED: Ben L. Peterson, CHIEF, ENGINEERING DIVISION
APPROVED: [signature] Acting, COLONEL C. E. DISTRICT ENGINEER — DATE July 29, 1955
SCALE AS SHOWN
SHEET 356 OF DDF-100-6-4.2/1

DDFE0018.CIT — This drawing supersedes Dwg. No. DDF-1-6-4.2/1

3

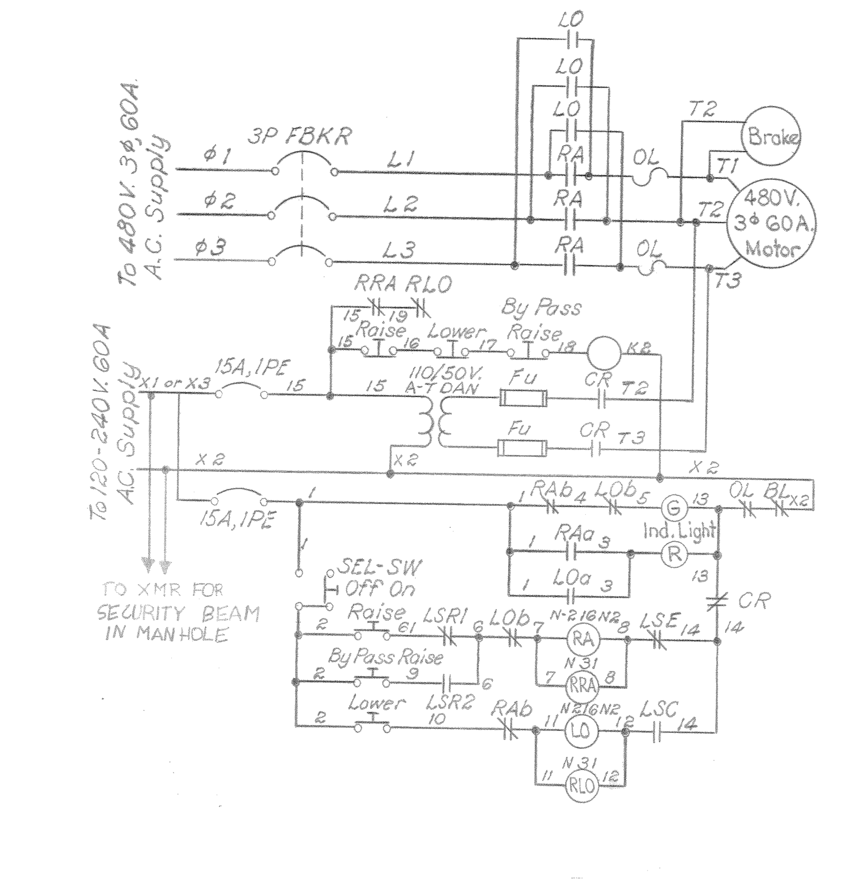
MICROFILMED Sep 1969


CORPS OF ENGINEERS
U. S. ARMY
VALVE ROOM - EL. 70.0
Scale: 1/4"=1'-0"
Existing Junction Boxes, Valves no's 4 & 5.
Existing Control Center "FCQ7" in Service Gallery, El. 168.0.
Existing 18" Motor Operated Valve
Pull Box.
In Existing 1 1/4" Conduit.
Existing Junction Box in Valve Room.
Existing Pushbutton Control Station in Valve Room.
Remove these jumpers
Install this jumper
CONNECTION DIAGRAM
Note: Wiring is typical for one 18" motorized valve. Total of five existing motorized valves are to have controls extended to the Control Bench in the Fishlock Control House. Dashed lines indicate existing wires. Solid lines indicate wires to be installed in this contract. For 42" motorized valve connection diagram, see Ref. Dwg. No. 3.
Control Switch & Indicator Lights in Fishlock Control Bench.
This connection for Valve Nos. 4 & 5.
2 Pole, 3 Pos. Selector Switch.
Control Sw., Sel. Sw., & Indicating Lights in Fishlock Control Bench.
VICINITY PLAN
Sta. 44+01.13
To Powerhouse
Axis of Dam
Fishlock Control House
Fishlock
Valve Room, El. 70.0
Office & Comfort Station, El. 133.0
See Drawing No. DDF-10-6-9B 19/4 For current revisions
UNWATERING PUMP ELEMENTARY WIRING DIAGRAM
AS CONSTRUCTED
CONTRACT NO. DA-35-026-civeng-56-155
CONTRACTOR E.V. Lane Corp., Gunther & Shirley Co.
DATE OF RECEIPT OF NOTICE TO PROCEED 21 Dec. 55
DATE OF COMPLETION OF CONTRACT 30 Nov. 60
DATE OF ACCEPTANCE 30 Nov. 60
WIRING DIAGRAM - 42" MOTORIZED VALVE
Switch & contacts for 42" Drain Valve only.
480V, 3φ Power Bus
120V, 1φ Control Bus
OFFICE & COMFORT STATION PARTIAL PLAN AT ELEV. 133.0
Scale: 1/4"=1'-0"
Note: All conduits & fixture & device outlets are existing. Furnish & install fixtures, devices & install Gov't. Furnished #12 AWG insulated wire make all necessary connections. Hash marks on conduit runs indicate the number of new conductors to be installed.
MEN'S LAV.
EMPLOYEES ROOM
JAN. CLOSET
PUBLIC LOUNGE
LADIES LOUNGE
Points 1 & 1b are connected together for Valve #2. For Valves 4 & 5 see Connection Detail.
Fishlock Attraction Water Valve (No. 4)
Holding Pool Attraction Water Valve (No. 5)
CONNECTION DETAIL
See DDF-10-6-9B 19/4 for motorized valve wiring & schematic diagrams
WIRING DIAGRAM - 18" MOTORIZED VALVE
REFERENCE DRAWINGS:
1. Plan - East Fishladder, Fishlock & Fishlock Channel - DDF-1-6-4.2/1
2. Fishlock Control Bench Arrangement & Details - DDF-1-6-4.2/4
3. Fishlock Control Bench - One line & Elem. Wir. Diagrams - DDF-1-6-4.2/5
NOTES:
1. Legend & Notes on Reference Dwg. No. 1 are applicable to this drawing.
2. The number of wires indicated in the wiring diagram will be subject to change, depending upon the equipment furnished in previously contracted work.
3. The Synchro differential motor operated switches in the 42" Drain Valve control circuit is to provide an automatic closing of the drain valve when the water surface level in the Fishlock approaches the water surface level in the Holding Pool. Complete closure of the valve shall be accomplished when the fishlock water surface is approximately one foot above the water surface of the Holding Pool.
4. See Reference Drawings No. 2 & 3 for control bench wiring & details.
5. Combination motor starter 480V, 3P, NEMA Size 2, type IV enclosure, with motor disconnect switch, control & heater transformer, 120 V. operating coils, control & heater fuses, heater disconnect switch, cabinet heater, selector switch for "Hand-off-Auto" operation, and interior ground terminal.
This Drawing is FOR RECORD PURPOSES ONLY & has been SUPERSEDED BY DRAWING No. DDF-10-6-4.2/1
LEGEND
RC - Auxiliary Contactor, Close
RO - Auxiliary Contactor, Open
S - Toggle Switch
DM - Synchro differential motor
C - Power Contactor Close
O - Power Contactor Open
LSO1 - Limit Switch, Closes when Valve is in Open Position.
LSO2 - Limit Switch, Opens when Valve is in Open Position.
LSO3 - Limit Switch, Opens when Valve is in Open Position.
LSC1 - Limit Switch, Opens when Valve is in Closed Position.
LSC2 - Limit Switch, Closes when Valve is in Closed Position.
LSC3 - Limit Switch, Opens when Valve is in Closed Position.
TSO - Torque Switch, Opens on mechanical Overload for Opening Operation.
TSC - Torque Switch, Opens on mechanical Overload for Closing Operation.
CS1, 2 & 3 - 3 Stage Rotary Control Switch. For Valves 4 & 5, 1-6 Stage Control Switch is used for both valves.
Normally open contact.
Normally closed contact.
Operating coil, 120V, 60cy.
Thermal Overload.
Disconnect.
Air Circuit Breaker.
Pushbutton element, normally open.
Pushbutton element, normally closed.
Resistor
Fuse.
Motor
Limit switch enclosure
Pushbutton control station
Indicator Light, R-Red, G-Green
18 Oct. 61 Revised As Constructed
8-15-56 Revised Motorized Valve Wiring Diagram to agree with Equipment Furnished
9-23-55 Added sound powered tel. ckt. & made minor revisions
REVISION DATE DESCRIPTION BY
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON
THE DALLES DAM
COLUMBIA RIVER WASHINGTON - OREGON
EAST FISHLADDER & FISHLOCK
ELECTRICAL
PLAN - FISHLOCK VALVE ROOM & FISHLADDER OFFICE & COMFORT STA.
SCALE AS SHOWN
DDF-10.0-6-4.2/2
26 JUL 73 Added dwg. reference note & superseded stamp.
DDFE0020.CIT
This drawing supersedes Dwg. No. DDF-1-6-4.2/2
MICROFILMED

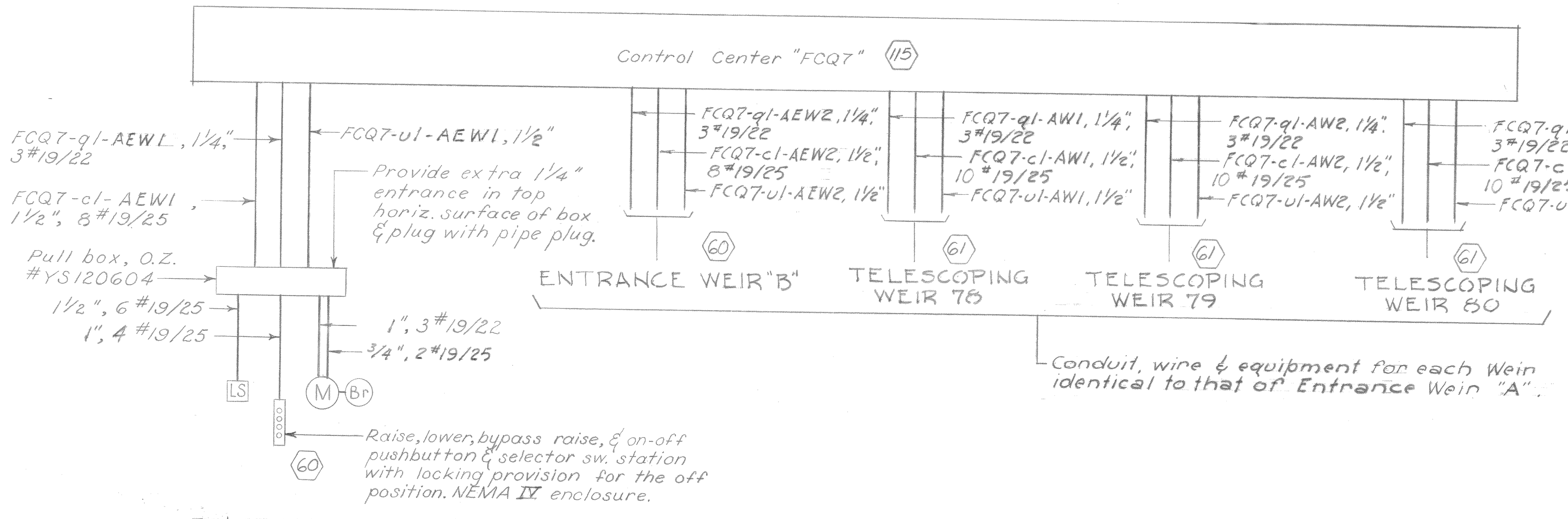

CORPS OF ENGINEERS
U. S. ARMY
SECTION E-E
Scale: 1½" = 1'-0"
Crouse-Hinds FAR 338
"FD" Box
1" nipple, 3" long
4" approx.
4"x4"x4" cast box
El. 111.0
SECTION C-C
No Scale
¼" galv. plate
Crouse-Hinds #AREA 10485
1½" Conduit
½" anchor bolts
1½" x 1½" ∟
VIEW D-D
No Scale
GENERAL PLAN-EL. 111.5
Scale: ⅛" = 1'-0"
Existing Structure
For Continuation See Detail B
FLOW
For continuation see Ref. Dwg. No. 5
Existing conduit bank & gr. cable in concrete envelope.
Extend conduit bank, gr. cable & concrete envelope to Manhole.
500MCM
Manhole; see notes 4 & 6 & Sectional Plan.
Install 3-2" & 2-1½" sleeves with flush couplings & plugs at elev. 110.5, spaced 4" center to center
2 Floodlight units & standard
2 Floodlight Units & Standard
Telesc. Weir Hoist Mach. 78
Telesc. Weir Hoist Mach. 79
Telesc. Weir Hoist Mach. 80
Exist. Bridge
Connect to exist. gr. cable & conduits, elev. 109.5 approx.
Conduits & gr. cable in bridge are exist.
4/0 to B.P.A. tower
Pull Box LPB-12"X12"X12" Hope #H5809 or equal.
Stub flush with coupl. & plug.
Entrance Weir Hoist Machinery "B"
Entrance Weir Hoist Machinery "A"
4/0 Grnd. cable to tower thru fill and sleeve in fish ladder
For Section B-B see Section B-B on Ref. Dwg. No. 4.
Install PY Controller
12 Circuits
FCQ7-cl-AFW1, 1½"
FCQ7-r1.0-AFW1, 1¼"
FCQ7-cl-AFW2, 1½"
FCQ7-ql-AEW1, 1¼", 3#19/22
FCQ7-cl-AEW1, 1½", 8#19/25
FCQ7-ul-AEW1, 1¼"
FCQ7-ql-AEW2, 1¼", 3#19/22
FCQ7-cl-AEW2, 1½", 8#19/25
FCQ7-ul-AEW2, 1¼"
FMH-s1-LPB, 1½"
FMH-s2-LPB, ¾"
FMH-s3-LPB, ¾"
FCQ7-ql-AW1, 1¼", 3#19/22
FCQ7-cl-AW1, 1½", 8#19/25
FCQ7-ul-AW1, 1¼"
FCQ7-ql-AW2, 1¼", 3#19/22
FCQ7-cl-AW2, 1½", 8#19/25
FCQ7-ul-AW2, 1¼"
FCQ7.1-ql-AW3, 1¼", 3#19/22
FCQ7.1-cl-AW3, 1½", 8#19/25
FCQ7.1-ul-AW3, 1¼"
SECTIONAL PLAN-MANHOLE
Scale: ½" = 1'-0"
SECTION F-F
Scale: ½" = 1'-0"
Cable tray
Kindorf F-711-3, or equal. Space from wall
½" expans. shield & bolt
Elev. 104.0
Conduit sleeves, elev. 110.5
NOTES:
1. For details of 2 Floodlight Units and Standard see Floodlight Fixture & Pole Detail on Ref. Dwg. No. 2.
2. For wiring and electrical equipment at Hoist Machineries see Ref. Dwg. No. 3.
3. Exact location of conduits at Hoist Machineries shall be determined from the shop drawings of the Hoist manufacturer.
4. Wire & cable through Manhole are to be tied with twine or taped together and grouped to maintain their circuit identity.
5.
6. Conduits in Manhole are to be terminated with grounding bushings and connected to the ground system.
REFERENCE DRAWINGS:
1. Fixture Schedule, Legend, & General Notes DDD-1-6-3.1/2
2. South Fishway Entrance - Plan & Grounding DDF-1-6-3/2
3. Fishlock Approach Fishway - Fishlock Channel Weirs - Wiring Diagrams & Details DDF-1-6-4/2
4. Fishlock - El. 168.0 DDF-1-6-4/3
5. Fishlock - Service Galleries - El. 168.0 & 175.0 DDF-1-6-4/5
6. Wiring Diagram Selsyn Control System-Fishlock Approach entrance - DDF-67-c-0054-8
7. Schematic Diagram Selsyn Control System Fishlock Approach entrance DDF-67-c-0054-2
8. Automatic Water Level Control at Entrances DDF-1-6-6
DETAIL - A
Scale: 1" = 40'
Control Center FCQ7 in Service Gallery El. 168.0
Fishlock
Conduit Bank approx. 200' from FCQ7 to Manhole.
Conduits are existing. Wire and cable, only, are in this contract within these limits.
Manhole
DETAIL B
Scale: 1/16" = 1'-0"
(Plan of Existing Structure at East Fishladder Junction Pool, El. 111.5)
Make connections to circuit in existing Junction Box.
Existing 500 MCM Ground Cable.
New 250 MCM Ground Cable 700' long.
Conduit shown is existing. Wire listed, is in this contract.
Bury in Fill.
Existing pull boxes
Existing conduit stubbed flush with coupling El. 110.5
Coil Ground Cable at base of column & provide protective covering.
Beam E-8
SECTION A-A
Scale: 1" = 1'-0"
Top to bottom
Asphalt
Concrete envelope
Fill
El. 107.17
Rock
Gr cable
Modified for Fish Entrance Automation
Revised As Constructed
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON
THE DALLES DAM
COLUMBIA RIVER WASHINGTON - OREGON
FISHLOCK APPROACH FISHWAY
ELECTRICAL
FISHLOCK CHANNEL
DATE: 25 NOV 1968
SCALE AS SHOWN
DDF-10.0-6-4/1
This drawing supersedes Dwg. No. DDF-1-6-4/1
DDFE0019.CIT

CORPS OF ENGINEERS

U. S. ARMY



TYPICAL SCHEMATIC WIR. DIAGRAM FOR TELESCOPING WEIRS



RISER DIAGRAM

Contact designation	Gate Position		
	Closed	Raised	Extreme raised
LSC			
LSR1			
LSR2			
LSE			

L. S. OPER. CHART

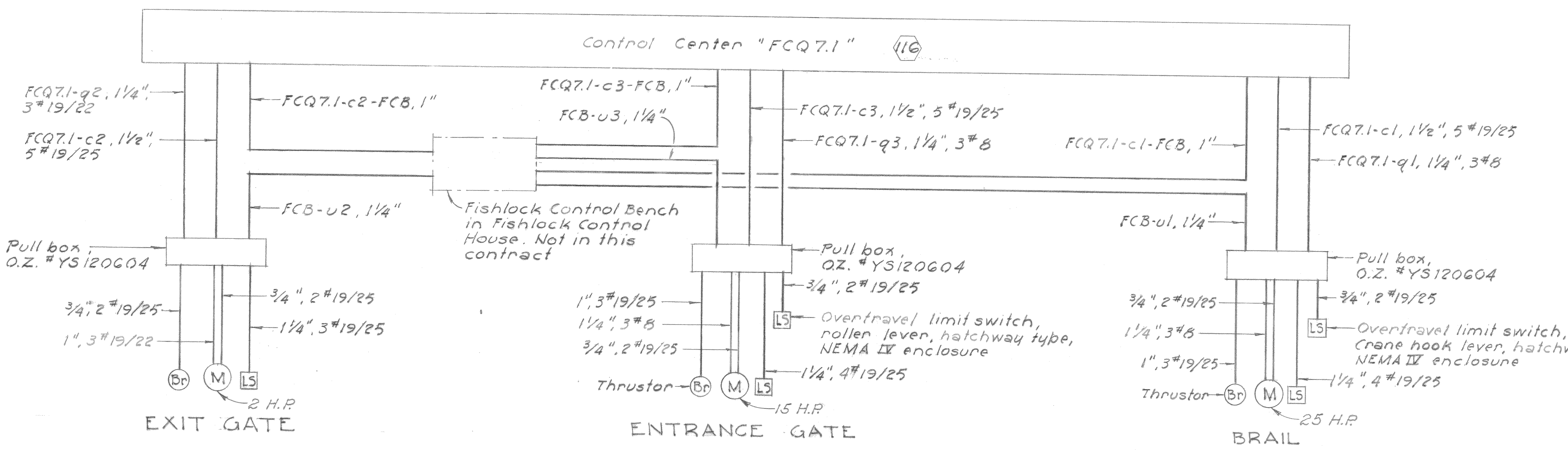
ENTRANCE WEIRS "A" & "B" & TELESCOPING WEIRS 78, 79 & 80.

LEGEND

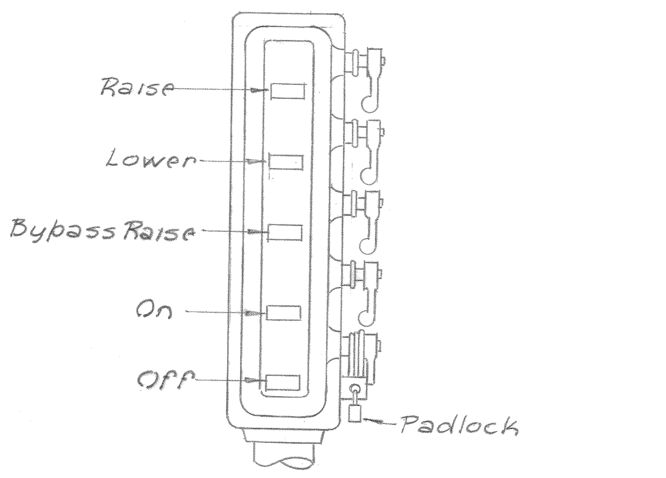
- (M) Hoist Motor
- (Br) Brake, solenoid operated, unless otherwise noted
- LS Limit Switch, NEMA IV enclosure. Rotating cam, traveling nut or rotating gear type, unless otherwise noted.
- Air Circuit Breaker
- Contactor Operating Coil
- Contact, Normally Open
- Contact, Normally Closed
- Overload Relay
- Maintained Contact Selector Switch
- Pushbutton, Normally Open
- Disconnecting Device
- Mechanical Interlock
- (G) Green Indicator Light
- (R) Red Indicator Light

REFERENCE DRAWINGS:

1. Fishlock Channel — DDF-1-6-4/1
2. Plan, El. 168.0 — DDF-1-6-4/3
3. Control Centers FCQ7 & FCQ7.1 — DDF-1-6-4/6
4. Entrance Weir Hoists Assembly — DDF-1-3-4.1/2
5. Telescoping Weir Hoists 78, 79, 80 Assembly — DDF-1-3-4.1/3
6. Automatic Water Level Control at Entrances DDF-1-6-6
7. Schematic Diagram Selsyn Control System DDF-67-C-0054-2
8. Wiring " " " " " -8



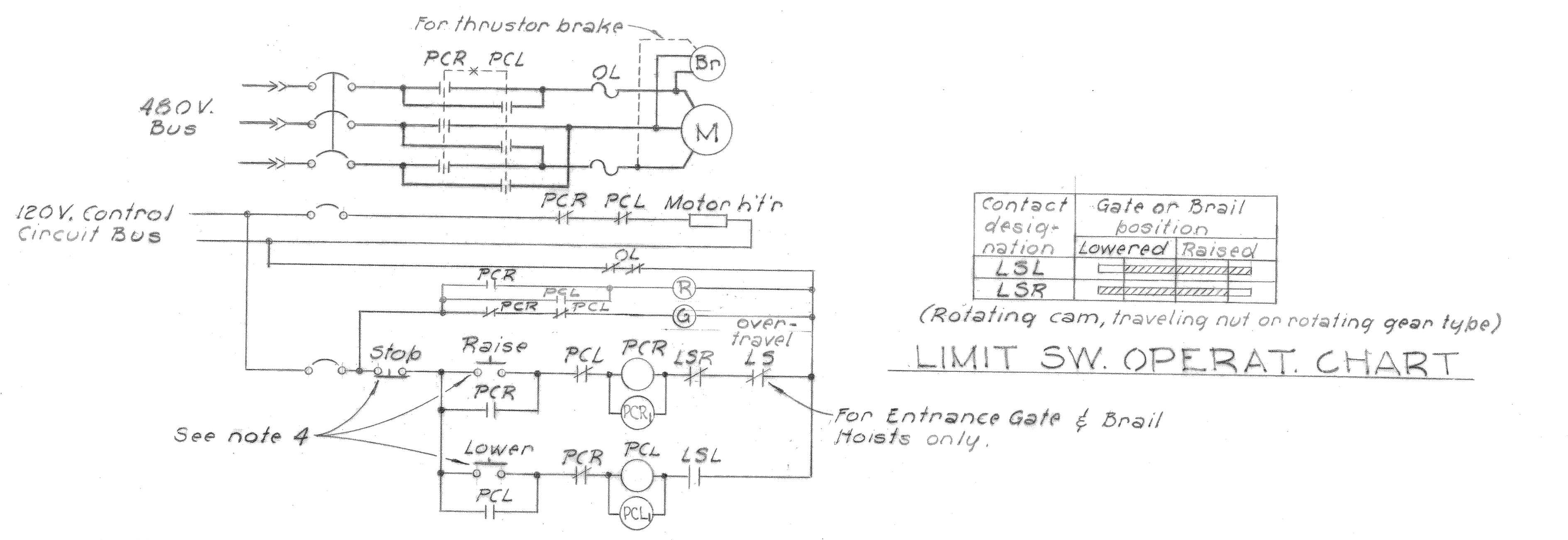
RISER DIAGRAM



CONTROL STATION
No Scale
(Weirs "A", "B", 78, 79 & 80.)

NOTES:

1. For equipment in Control Centers FCQ7 & FCQ7.1, see ref. dwg. no. 3.
2. Limit Switch contacts have been shown with the equipment in the lowered position.
3. The raised position of the hoist is to be the upper limit during normal operating conditions. Extreme raised position will be that point whereby the Weirs can be dogged into a rest position prior to removal or servicing.
4. Raise, lower & stop switches for the Entrance Gate, Exit Gate & Brail Hoists will be furnished and installed under another contract. For testing purposes, the contractor shall provide a temporary push-button station for each hoist.

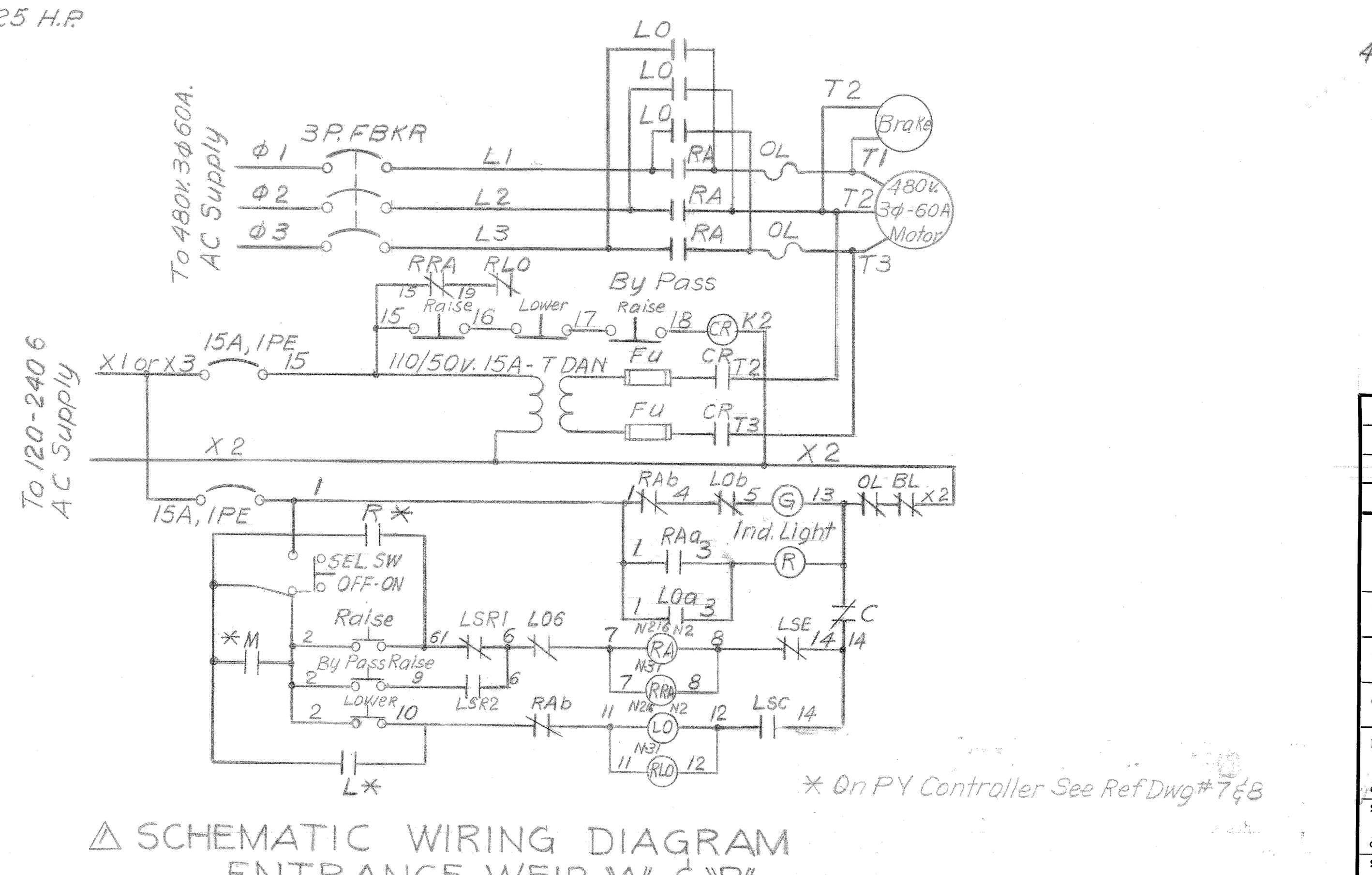


Contact designation	Gate or Brail position	
	Lowered	Raised
LSL		
LSR		

(Rotating cam, traveling nut or rotating gear type)

LIMIT SW. OPERAT. CHART

SCHEM. WIR. DIAGRAM FOR ONE HOIST - EXIT GATE & BRAIL HOISTS



△ SCHEMATIC WIRING DIAGRAM ENTRANCE WEIR "A" & "B"

This dwg. supersedes Dwg. DDF-1-6-4/2

REVISION	DATE	DESCRIPTION	BY
△	12-4-91	Revised As Constructed	
△	7.2.1968	Add new Schem Diagram for Fish Entrance Automation	MKV

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

THE DALLES DAM
COLUMBIA RIVER — WASHINGTON - OREGON
FISHLOCK APPROACH FISHWAY
ELECTRICAL
FISHLOCK CHANNEL WEIRS
WIRING DIAGRAM AND DETAILS

DESIGNED:
DRAWN: M.K.V.
CHECKED:
REVIEWED:
CHIEF, SAFETY BRANCH
SUPERVISED: C. C. Cooper
CHIEF, ELECTRICAL SECTION
SUBMITTED:
CHIEF, DESIGN BRANCH
RECOMMENDED:
CHIEF, ENGINEERING DIVISION
APPROVED: DATE 7.2.1968
LTC, CE COLONEL, C.E. DISTRICT ENGINEER
SCALE AS SHOWN
SHEET 285 OF — DDF-10.0-6-4/2

DDFE0021.CIT

MICROFILMED

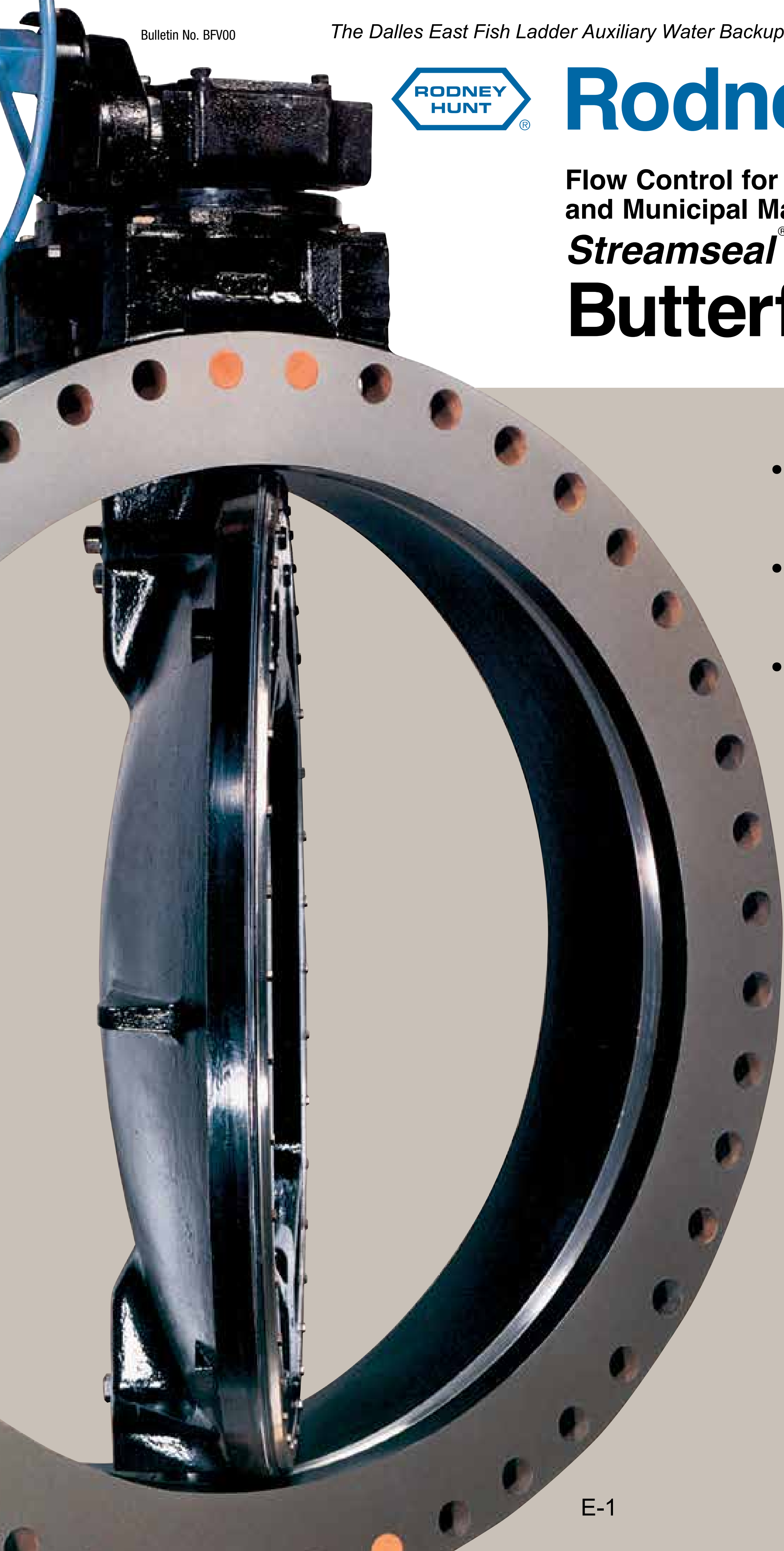

Control Center "FCQ7"
Control Center "FCQ7.1"
VALVE #5 18" Holding Pool Attract. Water Valve
VALVE #4 18" Fishlock Attract
VALVE #1 42" Fishlock Filling Valve
VALVE #3 42" Fishlock Drain Valve
VALVE #2 18" Fishlock Drain Valve
FCR 3
Brail Hoist
Fishlock Exit Gate Hoist
Fishlock Entrance Gate Hoist
Light Fixture
Control Bench in Fishlock Control House
ONE LINE DIAGRAM
Tailwater Floatwell
Forebay Floatwell
Holding Pool Floatwell
Fishlock Floatwell
TERMINAL BLOCK IN FCQ7.1
NOTE: THE SYNCHRO DIFFERENTIAL MOTOR OPERATED SWITCHES IN THE 42" DRAIN VALVE (VALVE NO. 2) CONTROL CIRCUIT PROVIDES AN AUTOMATIC CLOSING OF THIS VALVE WHEN THE WATER SURFACE LEVEL IN THE FISHLOCK APPROACHES THE WATER SURFACE LEVEL IN THE HOLDING POOL. COMPLETE CLOSURE OF THE VALVE IS ACCOMPLISHED WHEN THE FISHLOCK WATER SURFACE IS APPROX. ONE FOOT ABOVE THE WATER SURFACE OF THE HOLDING POOL.
FCQ7-98 3#19/22 480V Source
Motor Disconnect Sw
480-120V Control and heater transformer 0.3 KVA
Selector Switch
FLOAT SWITCH
VALVE PIT UNWATERING PUMP ELEMENTARY WIRING DIAGRAM
To Powerhouse
Sta. 44+01.13
Axis of Dam
FISHLOCK CONTROL HOUSE
FISHLOCK
Valve Room, El. 70.0
Office & Comfort Station, El. 133.0
VICINITY PLAN
Top to bottom
FCB-cl-MV3, 1¼" 8 #19/25
FCB-cl-MV2 " 7 "
FCB-cl-MV1 " 8 "
Junction Boxes Valves No 1, 2 & 3
Junction Boxes Valves no's 4 & 5
FCB-cl-MV4, 1¼" 7 #19/25
FCB-cl-MV5, " " "
FOR CONTINUATION SEE DWG. # DDF-1-6-4.2/1
FCB-51, 1½", 4 #16
1½" TO ¾" REDUCER
FCQ7 98, 1¼" 3#19/22, 1#8 BARE
"Valve No. 1" 42" Filling Valve
FCQ7-cl.1-MV3, 1½"
FCQ7-cl.1-MV2
Valve no 2 18" Bypass Valve
"Valve No. 4" 18" Fishlock Attract Water Valve
FCQ7-cl.1-MV4 1½"
Combination Motor Starter 480V-3φ, NEMA Size 2, Type IV enclosure, with motor disconnect switch, control & htr. transf. 120V operating coils, control & heater fuses, heater disconnect switch, cab. htr., Selector Sw for "Hand-off-auto" operation & interior ground terminal.
Valve No 5 18" hold Pool Attract Water Valve
"Valve No 3" 42" Drain Valve
FCQ7-cl/1-MV5, 2 #19/25
Float switch Automatic Control Co. type SW-1 Floatrol with depth indicator NEMA IV Enclosure & 5½" dia float & tape
Unwatering Pump Motor
"FD" & "Ex Fill" Elev. 83.5
Walkway, El. 79.5
FCB-51, ¾", 4#16
VALVE ROOM - EL. 70.0
3 Way Switch
El. 144.5
BLOWER FAN SWITCH
HUBBELL CAT #2971 & GALVANIZED STEEL COVER
HOLOPHANE CO. CAT. #615-BC, 100W LAMP
FCR2-r2-¾"
HUBBELL CAT #7580G & GALVANIZED STL. COVER
HOLOPHANE CO CAT. #620-BC, 200W LAMP
MEN'S LAV.
EMPLOYEES ROOM
EMBEDDED CONDUIT
JAN. CLOSET
HUBBEL CAT. #2974 & GALVANIZED STL. COVER
PUBLIC LOUNGE
LADIES LOUNGE
OFFICE & COMFORT STATION PARTIAL PLAN AT ELEV 133.0
TO FCR3 LIGHTING PANEL
FOREBAY FLOATWELL
TAILWATER FLOATWELL
ENTRANCE GATE HOIST
BRAIL HOIST
FISHLOCK FLOATWELL
HOLDING POOL FLOATWELL
SYNCHRO INDICATOR SYSTEM, ELEM WIRING DIAGRAM
LEGEND
EMBEDDED CONDUIT
LIMIT SWITCH
LIGHT FIXTURE
RECEPTACLE
SWITCH
AIR CIRCUIT BREAKER
MOTOR HEATER
PUSHBUTTON CONTROL STATION
REVERSING STARTER
THERMAL OVERLOAD RELAY
3φ - 480V MOTOR
SYNCHRO UNIT - DIFFERENTIAL MOTOR
" " - RECEIVER
" " - TRANSMITTER
CONTROL SWITCH
FLOAT SWITCH
DIFFERENTIAL SYNCHRO CAM OPERATED SWITCHES
SELECTOR SWITCH - 3 POSITION
POWER CONTACTOR COIL
CONTACT - NORMALLY OPEN
CONTACT - NORMALLY CLOSED
INDICATING LIGHT - GREEN
" " - RED
NOTE: THIS DRAWING WAS MADE FROM DDF-1-6-4.2/2 & 5 AND IT INCLUDES ALL POST CONSTRUCTION REVISIONS.
REFERENCE DRAWINGS
1. PLAN-EAST FISHLADDER, FISHLOCK, & FISHLOCK CHANNEL - DDF-1-6-4.2/1
2. FISHLOCK CONTROL BENCH - ARRANGEMENT & DETAILS - DDF-1-6-4.2/4
3. ENTRANCE GATE, EXIT GATE, & BRAIL HOISTS - WIRING & SCHEM. DIAG. - DDF-10-6-98/19/2
4. MOTORIZED VALVES NO. 1 THRU 5 - WIRING & SCHEMATIC DIAGRAMS - DDF10-6-98/19/4
REVISION DATE DESCRIPTION BY
U. S. ARMY ENGINEER DISTRICT, PORTLAND
CORPS OF ENGINEERS
THE DALLES DAM
COLUMBIA RIVER WASHINGTON-OREGON
EAST FISHLADDER & FISHLOCK-ELECTRICAL
PLAN FISHLOCK VALVE RM - FISHLADDER OFFICE & COMFORT STATION - CONTROL BENCH ONE LINE DIAGRAM
FIELD CHECKED G. Gardner
SCALE AS SHOWN
DATE 19 JUNE, 1963
DRAWING NUMBER DDF-10-6-4.2/1
PLATE NUMBER 5.10a/2
DDFE0017.C17
CORPS OF ENGINEERS
U. S. ARMY

The Dalles East Fish Ladder Auxiliary Water Backup System

90 Percent Design Documentation Report

APPENDIX E

Mechanical



Rodney Hunt

Flow Control for the Power and Municipal Marketplace

Streamseal®

Butterfly Valves

- **Cast**
- **Fabricated**
- **Rubber-covered**

SIZES 24"–192" and Larger

AWWA Standard C504

RODNEY HUNT ®

Rodney Hunt and the STREAMSEAL® Tradition

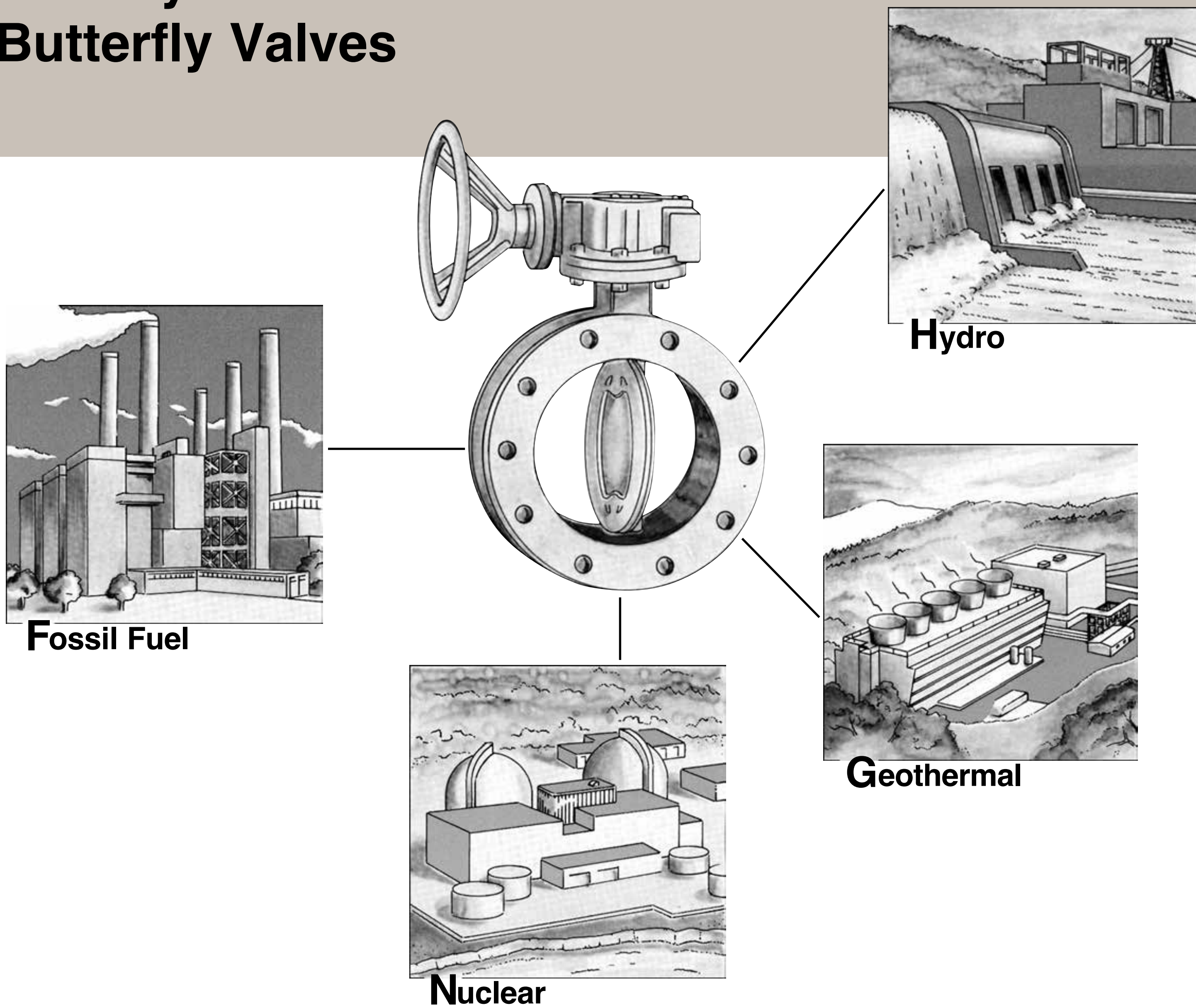
Rodney Hunt Company, located in Orange, Massachusetts, is one of the most respected names in cast and fabricated gates, valves, and actuation equipment for flow control applications.

Inside...

The cast, rubber-covered and fabricated Streamseal Butterfly Valves manufactured today by Rodney Hunt Company are the latest in a series of butterfly valve designs previously offered by AC Valve, Inc., and first introduced by Allis Chalmers Corporation over 50 years ago. While the basic Streamseal design manufactured today remains consistent with Streamseal Butterfly Valves of the past, advances in metallurgy, actuation equipment technology, and manufacturing techniques make the Rodney Hunt Streamseal Butterfly Valve better than ever before for all heavy duty flow control applications.

Rodney Hunt Company is an international leader in the design and manufacture of cast and fabricated gates, valves and actuation equipment for water control applications. Located in Orange, Massachusetts, Rodney Hunt facilities include a modern foundry, advanced fabrication and machining areas, continually updated CAD capabilities, and hydrostatic testing facilities. Interdisciplinary design engineering expertise, and a commitment to ongoing technological development help Rodney Hunt achieve outstanding levels of customer service, quality, and value on every project.

Rodney Hunt Streamseal® Butterfly Valves



Rodney Hunt designs and manufactures a broad range of Streamseal cast, fabricated, and rubber-covered butterfly valves 24” and larger to meet your flow control needs. For over 50 years, coal, petroleum, natural gas, nuclear, hydro and geothermal facilities and municipalities have been using Streamseal Butterfly Valves manufactured by Allis-Chalmers, AC Valve, and now Rodney Hunt.

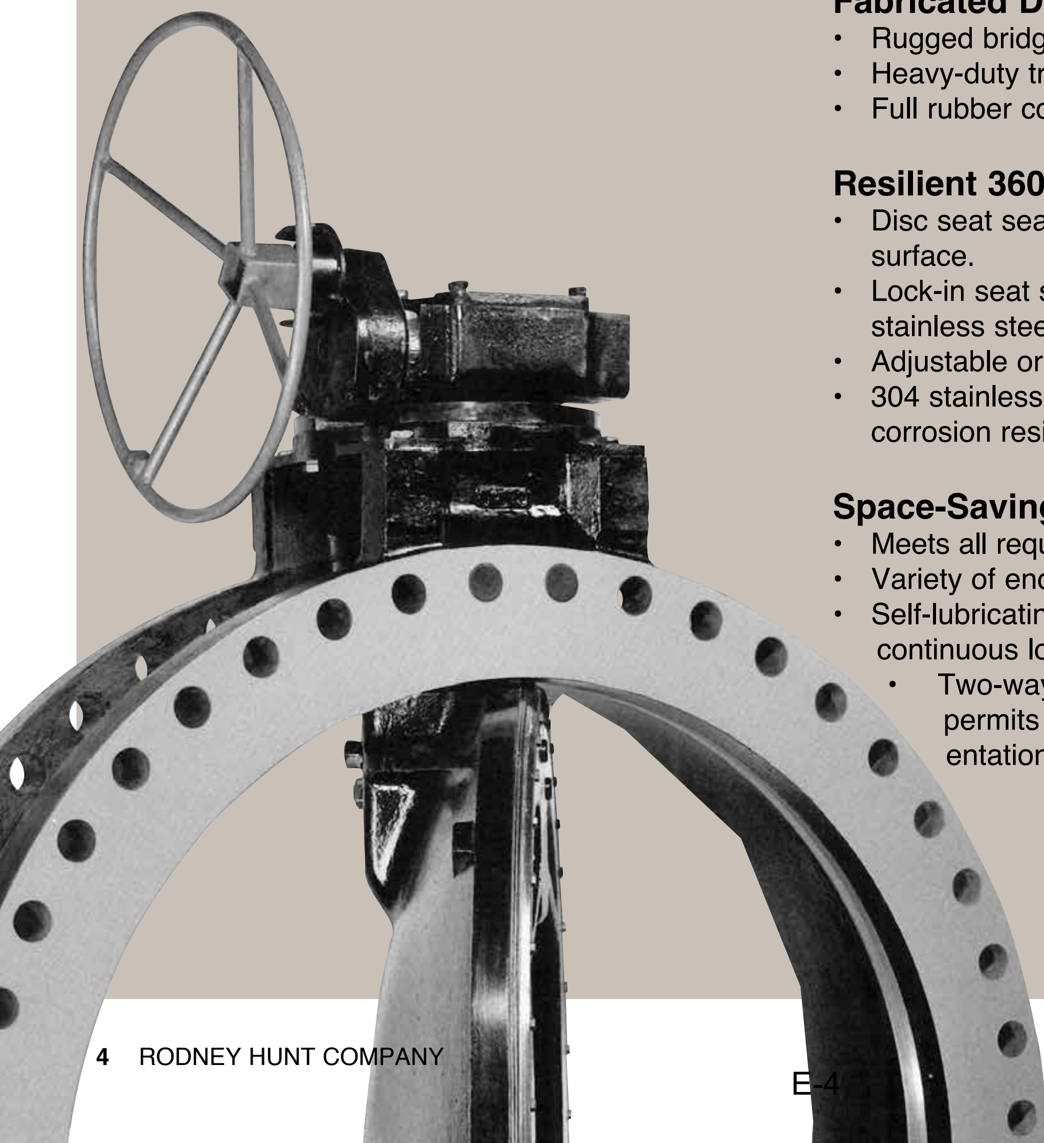
Butterfly valves play a critical role in the efficient performance of a power or treatment facility. Streamseal Butterfly Valves from Rodney Hunt are known for their ruggedness, serviceability, and lower life-cycle cost. Rodney Hunt also works with designers, contractors and operators to ensure that the appropriate valve is selected for each application.

Cast, fabricated or rubber-covered

The Streamseal® Butterfly Valve is designed to be the easiest valve to install and operate... with minimum maintenance required.

Design Versatility

- Pre-engineered to meet various applications.
- Cast or fabricated body and disc options.
- Hard rubber coating available for corrosive service.
- Design, cast, fabricate, machine, actuate and test...at one location.
- Rodney Hunt manual, pneumatic, hydraulic, and electric actuation options.
- Hydrostatic testing facilities.



Domed Disk Design

- Ductile iron for maximum strength.
- No foundry coring for consistent quality.
- Exceptional hydraulic stability.
- Less dynamic torque for reduced actuator sizing and energy requirements.
- Less head loss, reduced pumping costs.
- Full rubber coating (optional).

Flow-Through and Low-Profile Fabricated Disc Designs

- Rugged bridge truss (flow-through).
- Heavy-duty trunnions.
- Full rubber coating (optional).

Resilient 360° Lock-in Seating

- Disc seat seals against stainless steel mating surface.
- Lock-in seat secured by easily replaced stainless steel retainer ring.
- Adjustable or replaceable without special tools.
- 304 stainless steel body seat provides corrosion resistant mating surface.

Space-Saving Body Design

- Meets all requirements of AWWA Standard C-504.
- Variety of end connections available.
- Self-lubricating bushings for continuous low-friction operation.
- Two-way, field-adjustable thrust bearing permits flexibility in valve and actuator orientation.

Design Features

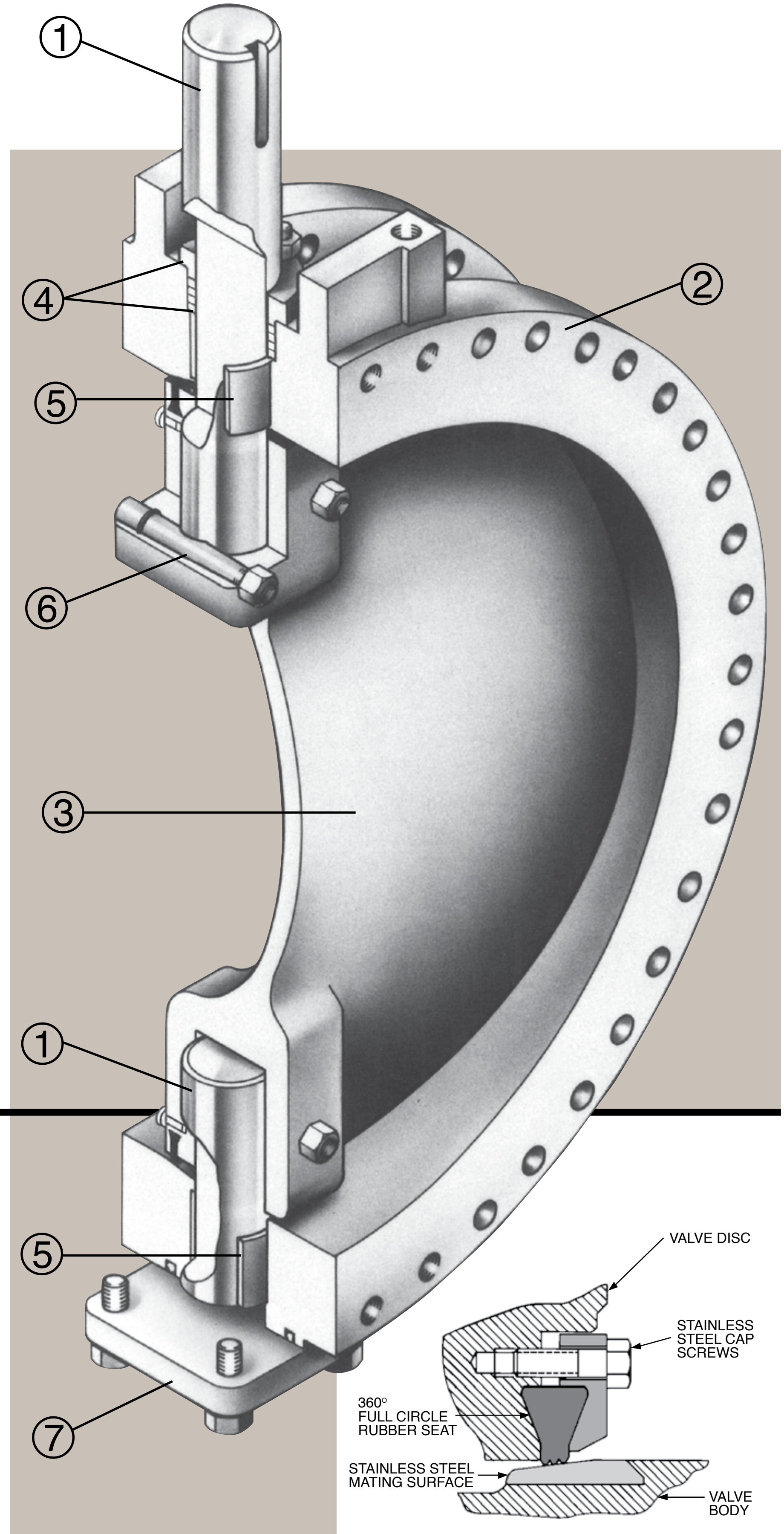
Meets established requirements of AWWA Standard C504.

1. **Shafts**–stainless steel ASTM A276 Type 304 standard. Monel and 316 stainless steel shafts available.
2. **Valve body**–ASTM A126 Class B or C cast-iron or ASTM A516 Grade 70 fabricated steel, depending on size and pressure class.
3. **Valve disc**–ASTM A536 Grade 65-45-12 ductile iron or ASTM A516, Grade 70 fabricated steel, depending on size and pressure class.
4. **Shaft seals**–bronze packing gland with square TFE impregnated Teflon packing.
5. **Shaft bearings**–Corrosion resistant, self-fabricated sleeve type.
6. **Taper pins**–Tangential pins of stainless steel ASTM A582 Type 416HT securely fasten disc to stub shafts. Tangential pinning reduces pin shear stresses. Pins held in place by stainless steel jam nuts and washers.
7. **End cover**–Same material as body. Buna-N O-ring seal.

Lock-in Rubber Seat Design

Offers positive retention, total rubber control, and maximum user flexibility.

- Rubber seat fully locked-in by dovetail configuration. Does not require adhesives for retention.
- Cap screws do not penetrate rubber-eliminating any tendency to "waffle" or "scallop" the seating edge.
- Two-way adjustable. By changing the torque on the cap screws, the amount of rubber projection can be controlled to provide drip-tight closure under all line conditions.
- Independent of line pressure for positive shut-off.



Lock-in Rubber Seat Design

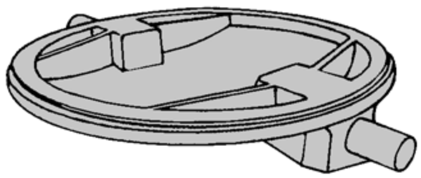
RODNEY HUNT®

AWWA Cast Streamseal® Butterfly Valve

24" and Larger

- Exclusive domed disc design.
  –Solid cast disc without internal coring.
  –Concave/convex curvilinear shape provides excellent hydraulic stability, even in turbulent flows.
  –Maximum reliability in on/off or throttling service.
  –Reduced head loss, lower pumping costs.
  –Reduced dynamic torques and torque reversals.
  Less actuator energy requirements.
  –Ductile iron (ASTM A536 Grade 65-45-12) to withstand shock loads.
- Resilient lock-in seat is secured to the domed disc edge by a corrosion resistant retainer ring.
- Variety of disc seat materials available.
- Body Mating Surface: Type 304 stainless steel.
- Shafts: Type 304 stainless steel.
- Taper pins: Tangentially positioned to prevent shear failure, O-ring sealed.
- End connections: Flanged, mechanical joint, grooved, plain, or combinations as required.

Cast domed disc being machined.



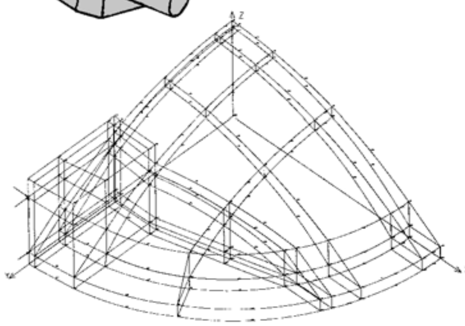
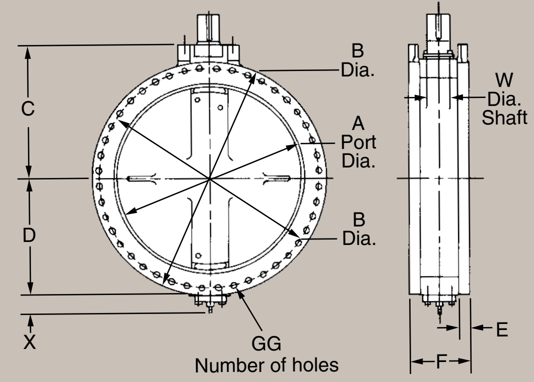


Figure 1: Domed Disc Finite Element Model (quarter section)

The Streamseal Domed Disc Design

The ductile iron domed disc for cast Streamseal Butterfly Valves was developed to enhance disc strength and improve flow characteristics. Elimination of foundry coring was an important factor in the development process, and the resulting design permits the easy inspection, testing and measurement of all disc surfaces. Finite element analysis was used to optimize strength and disc thickness. Head loss and flow coefficients for Streamseal Butterfly Valves are shown in Fig. 2.

Standard Dimensions



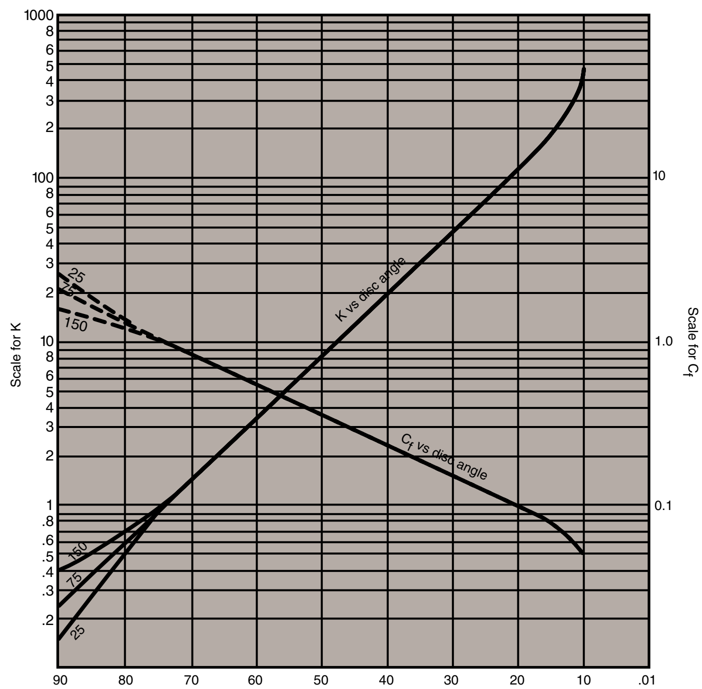
Size	A	B	C	D	E	F	G	GG	W*	X
24	22.88	32.00	21.75	16.25	1.88	8.00	29.50	20	3.00	6.88
30	29.00	38.75	24.75	19.62	2.12	12.00	36.00	28	3.62	6.88
36	34.94	46.00	27.88	23.25	2.38	12.00	42.75	32	4.50	6.88
42	40.88	53.00	30.88	26.75	2.62	12.00	49.50	36	5.00	6.88
48	46.88	59.50	34.25	29.88	2.75	15.00	56.00	44	5.75	6.88
54	52.88	66.25	37.75	33.38	3.00	15.00	62.75	44	6.75	7.31
60	58.88	73.00	40.88	36.75	3.12	15.00	69.25	52	7.50	7.56
66	64.88	80.00	44.50	40.50	3.38	18.00	76.00	52	7.75	7.56
72	70.88	86.50	47.62	43.62	3.50	18.00	82.50	60	8.50	6.02
78	76.88	93.25	50.25	47.00	3.75	21.00	89.00	66	9.25	6.02
84	82.88	99.75	60.00	55.00	3.88	21.00	95.50	66	10.00	6.02
90	88.88	106.50	55.88	53.50	4.06	22.50	102.00	68	10.75	6.02
96	94.00	113.25	60.00	57.25	4.25	24.00	108.50	68	11.50	6.02

Valve may be installed with shaft in either the horizontal or vertical position.

*Shaft dimensions for 150B rating.

Dimensions in inches.

Streamseal Butterfly Valve with Domed Disc–Head Loss and Flow Coefficients



K and C_f versus disc position

$$H_L = \frac{KV^2}{2g} = \frac{V^2}{2gC_f^2}$$

H_L=head loss across valve in feet of water

K-head loss coefficient

C_f=flow coefficient

V=fluid velocity in pipe in feet per second

g=gravitational constant (32.2) feet per sec.^{2}

NOTE: Actual performance of the valve will be affected by the parameters of the complete system.

Figure 2

Materials

Body Material ....ASTM A126, Class B Cast Iron
Disc Material..................ASTM A536, Grade 65-45-12 Ductile Iron
Shaft .... ASTM A276, Type 304 Stainless Steel
Seat Material ....Buna-N
Shaft Seals ....Conventional packing with bronze gland
Mating Seat Surface................ ASTM A276, Type 304 Stainless Steel
Shaft Bearings....... Corrosion resistant, self-lubricated sleeve type
Coating ....High solids, high build epoxy

Other materials available upon request to meet system requirements.

End Configurations

Flanged (ANSI-B16.1 Class 125), mechanical joint (AWWA C110), grooved, plain, metric flanges, higher pressure rated flanges.

Sizes

24”, 30”, 36”, 42”, 48”, 54”, 60”, 66”, 72”, 78”, 84”, 90”, 96”, 108”, 120” (metric sizes also available).

Pressure Classes

25, 75, 150, 250 psi

Testing

AWWA C504 (latest edition)

RODNEY HUNT®

Rubber-covered Streamseal® Butterfly Valve

24" and Larger

Rodney Hunt rubber-covered Streamseal Butterfly Valves are designed for the most corrosive service applications. Two distinct layers of rubber (Fig. 3) protect all ferrous metal parts exposed to corrosive liquid. This layered rubber covering is applied to all wetted surfaces of body, disc, and end cover. A tie-gum or soft rubber underlayment provides a strong bond between the grit blasted base metal and the rubber outer layer.

The soft rubber underlayment allows for some flexibility (65 Shore A Durometer). The hard rubber (43 to 70 Shore D Durometer) outer layer provides a non-hygroscopic, machinable, and rugged covering, extending into all areas of body and disc, including close tolerance locations (shaft bores, thrust bearing recess, and stuffing box). The entire cover is bonded in place, then vulcanized for absolute adhesion of rubber to metal.

All rubber-covered surfaces are given a dielectric spark test (before and after vulcanization) to ensure complete coverage.

Applications

Rubber-covered Streamseal Butterfly Valves are used in a variety of process applications to control the flow of corrosive fluids. Figure 4 shows potential process locations in a typical circulating water service, where prolonged reuse of water progressively increases mineral content, or where the original water source is saline or brackish.

Figure 5 illustrates a condenser partition valve installation, where the actuator is located externally from the condenser.

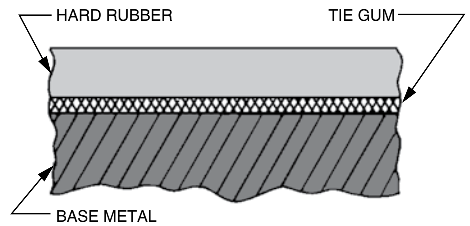


Figure 3: Cross Section

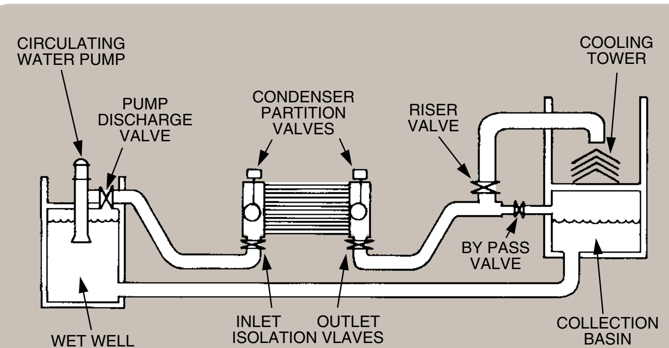


Figure 4: Typical Circulatory Water System

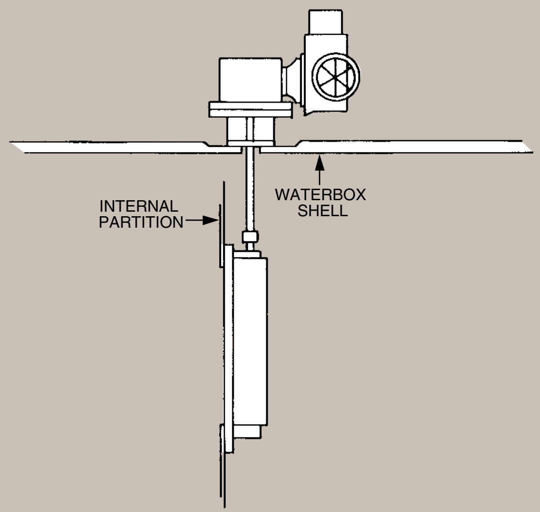
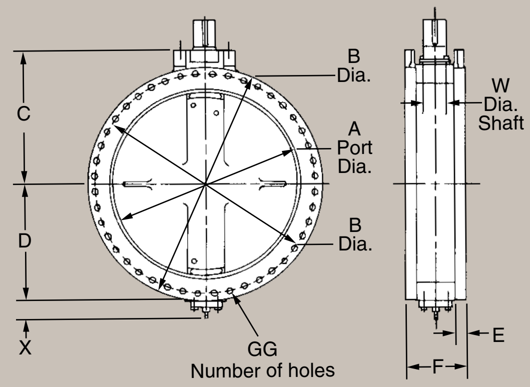


Figure 5: Condenser Partition Valve–Typical Installation

Standard Dimensions



Size	A	B	C	D	E	F	G	GG	W*	X
24	22.88	32.00	21.75	16.25	1.88	8.00	29.50	20	3.00	6.88
30	29.00	38.75	24.75	19.62	2.12	12.00	36.00	28	3.62	6.88
36	34.94	46.00	27.88	23.25	2.38	12.00	42.75	32	4.50	6.88
42	40.88	53.00	30.88	26.75	2.62	12.00	49.50	36	5.00	6.88
48	46.88	59.50	34.25	29.88	2.75	15.00	56.00	44	5.75	6.88
54	52.88	66.25	37.75	33.38	3.00	15.00	62.75	44	6.75	7.31
60	58.88	73.00	40.88	36.75	3.12	15.00	69.25	52	7.50	7.56
66	64.88	80.00	44.50	40.50	3.38	18.00	76.00	52	7.75	7.56
72	70.88	86.50	47.62	43.62	3.50	18.00	82.50	60	8.50	6.02
78	76.88	93.25	50.25	47.00	3.75	21.00	89.00	66	9.25	6.02
84	82.88	99.75	60.00	55.00	3.88	21.00	95.50	66	10.00	6.02
90	88.88	106.50	55.88	53.50	4.06	22.50	102.00	68	10.75	6.02
96	94.00	113.25	60.00	57.25	4.25	24.00	108.50	68	11.50	6.02

Valve may be installed with shaft in either the horizontal or vertical position.

*Shaft dimensions for 150B rating. Dimensions in inches.

Where Rubber-covered Butterfly Valves are Typically Used

- Circulating water service (Figure 4)
- Condenser partition (Figure 5)
- Condenser isolation
- Wet well service
- For control of saline and brackish water within the plant or intake structure.

Sizes–Pressure Classes–Testing

Sizes	Cast: 24", 30", 36", 42", 48", 54", 60", 66", 72", 78", 84", 90", 96", 108", 120" Fabricated: 24" and larger
Pressure Classes	25, 75, 150, 250 psi
Painting	High-build, high-solids epoxy
Testing	In accordance with AWWA C504 Optional MSS SP-67 available

Higher pressures available upon request.

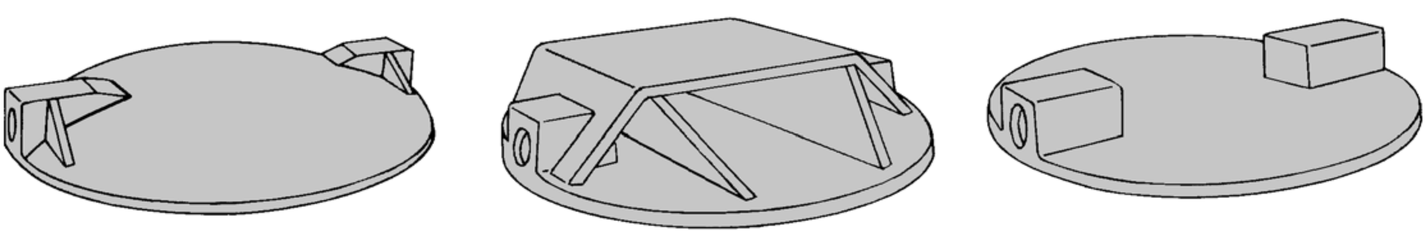
Disc Design: Domed, Flow-Through or Low-Profile

All disc configurations are offered with lock-in rubber seat, tangential pinning and full rubber covering.

Domed Disc: Constructed from ductile iron, the domed disc was developed to enhance the strength and improve the flow characteristics of cast valves.

Flow-Through: Constructed from fabricated steel, the Flow-Through disc features a rugged bridge truss and flow-through area easily accessible for rubber covering.

Low Profile: Constructed from fabricated steel, the Low Profile disc features a streamlined disc profile with heavy trunnions.



DOMED DISC   FLOW-THROUGH DISC   LOW PROFILE DISC

Figure 6: Disc Configurations

RODNEY HUNT®

Custom Engineered and Pre-Engineered Fabricated Streamseal® Butterfly Valves

24" and Larger

Custom engineered fabricated Streamseal Butterfly Valves are designed for a variety of plant services requiring special materials, sizes and end configurations.

- **In-house system analysis, design, and manufacturing experience.** Rodney Hunt has the hydraulic engineering expertise to analyze system requirements. Utilizing designs, data, and technical history acquired from Allis Chalmers, Rodney Hunt will recommend the appropriate valve for the application. The latest design technologies, including finite element analysis, facilitate the development of final custom designs.

- **Cost-effective flow control for a wide range of flows, pressures, temperatures and media.** Fabricated valves can be designed and manufactured to control flows with virtually unlimited pressure and temperature ranges. Liquids containing abrasive solids or entrained gas can be effectively handled.

- **Available in other than "standard" sizes.** Fabricated valves can be designed to meet equipment and space limitations.

- **Permits varied or mixed-end configurations.** Fabricated valves are custom engineered for each application, and can incorporate ANSI or metric flanges, wafer, weld ends, or other configurations to connect to adjacent equipment or piping.

- **Materials of construction flexibility.** Available in steel, stainless steel, or more sophisticated metals as required for specific service conditions.

- **Rubber coating available for corrosive service.** A dual rubber coating on all interior wetted areas is available to resist corrosion in brine, saline, or other aggressive services. Allis-Chalmers rubber-covered butterfly valves have been successfully used for power and desalination plant service since 1937.

Finite element analysis software enables the static and dynamic assessment of a product or component under various loading and stress conditions.

All Rodney Hunt welders meet AWS and ASME, Section IX qualifications.

Fabricated Streamseal butterfly valves can be manufactured to meet a variety of service conditions.

- **Total actuation availability.** Rodney Hunt has the expertise to analyze requirements, design, manufacture, mount, test, calibrate, and install all types of actuation systems: manual, electric, cylinder (pneumatic, hydraulic, or air/oil). Extension stems or extended bonnets for open/close or modulating service are also available.

Sample Specifications

24" and Larger Butterfly Valves

Butterfly valves shall be rubber-seated tight closing Streamseal Valves as manufactured by Rodney Hunt Company, and shall conform to AWWA Standard C504 latest revision.

The butterfly valve bodies shall be of cast iron ASTM A126 Class B. They shall have integral hubs for housing shaft bearings and seals. Body ends shall be either: flanged with facing and drilling in accordance with ANSI B16.1, Class 125, or mechanical joint in accordance with AWWA Standard C110.

Butterfly valve discs shall be of the "off-set" design to provide a full 360° uninterrupted seating surface. Discs shall be Ductile iron ASTM A536, Grade 65-45-12 with no external ribs transverse to the flow.

All cast discs shall be the uncored type so that all disc surfaces are exposed for easy inspection and/or measurement.

The resilient seat shall be synthetic rubber designed to provide tight shut-off at the pressures specified in the data table. Seat shall be incorporated on the valve disc edge and shall be mechanically retained by means of a corrosion-resistant ring, and stainless steel screws.

The resilient seat must be capable of mechanical adjustment in each direction without the use of special tools. It must also be capable of being replaced in the field without chipping, grinding, or burning out of the old seat, moving the valve disc along its shaft axis, or removing the valve from the line.

The mating seat surface shall be integral with the valve body and shall be stainless steel, Type 304. Sprayed or plated mating seat surfaces are not acceptable.

Valve shafts shall be of the two-piece type extending into the valve disc hubs for a distance of at least one and one-half shaft diameters. They shall be of stainless steel, Type 304.

Valve shafts shall be securely attached to the valve disc by means of taper pins located tangentially to the valve shafts. Taper pins shall be mechanically secured and shall be of corrosion-resistant material.

Shaft bearings shall be contained in the integral hubs of the valve body. They shall be of the self-lubricated, sleeve type.

The valve assembly shall be furnished with a factory-set two-way thrust bearing which is field adjustable.

Where the valve shaft projects through the body for the operator connection, a shaft seal shall be provided. The seal shall be of the type utilizing a stuffing box and pull down package gland so that the package can be adjusted or completely replaced without disturbing any part of the valve or operator assembly except the packing gland follower.

Actuator will be sized to operate the valve from full open to full closed at rated pressure with a maximum of 80 ft./lb. of input torque on a manual actuator. The valve manufacturer shall be responsible for sizing electric or cylinder operators based on flow and pressure conditions.

Coating shall be of two (2) layers (5 mils minimum each coat). First coat interior and exterior to be Amine Modified Polyamide Epoxy Amerlock 400, or approved equivalent. Second coat shall be the same as the first coat unless the valve is exposed to sunlight, in which case the second coat exterior shall be Aliphatic Polyurethane Amercoat 450 H.S. or approved equivalent.

Rubber-covered Butterfly Valves

NOTE: The following specifications apply only to rubber-covered butterfly valves. Refer to Standard Specifications found above for complete butterfly valve specifications.

When the valve is to be used in corrosive service, a multiply rubber covering shall be vulcanized to all interior wetted surfaces of the valve body, disc and end cover for corrosion protection. The rubber shall extend into all areas of the body and disc including hard-to-reach, close-tolerance locations such as shaft bores, thrust bearing recess, stuffing box, etc., so that all internal wetted surfaces are isolated from the corrosive flow medium without dependence upon dynamic O-Ring seals.

All surfaces to be rubber-covered shall first be thoroughly grit blasted to SSPC-SP5 (white metal blast) prior to coating. The layered rubber shall consist of a soft rubber or tie-gum underlayment of approximately 65 on the Shore A Durometer scale, and a hard rubber outer layer of approximately 43 to 70 on the Shore D Durometer scale. The rubber shall be bonded to the clean grit blasted base metal, then vulcanized to form a solid covering to face the corrosive flow medium, and to resist the absorption of water. Final lining thickness shall be 3/16" minimum when measured at any point. The coating shall be spark-tested at 20,000 volts to assure coating integrity. The body rubber covering shall terminate in a machined recess in the face of each flange, and shall be flush with the flange face.

When in the closed position, the resilient seat shall mate against a seating surface that is machined into the hard rubber body covering.

Manual or Power Actuation

Manual–In accordance with AWWA C504 Standard. Handwheel, chain-wheel, or operating nut input. Adjustable travel stops, and self locking feature.

Electric Motor–Available for open-close or throttling service, complete with limit switches and torque switch as required. Manual override is standard. Also available for modulating service with position feedback for continuously adjustable automatic controls. Complete accessories are available and include indicator lights, integral reversing starters, push buttons, potentiometers, space heaters, sensors, transmitters, transducer and other control features.

Cylinder–Pneumatic or hydraulic; suitable for plant air, water, or other operating media. Controls available for adjustable closure rates. Complete hydraulic power units are available. Control systems can be supplied for automatic fail-safe closure and valve positioning. Position sensors can also be provided.

Accessories

Extension Bonnet and Shaft–For locating actuator away from valve for easy access. Actuator (manual or power) is mounted on end of extension bonnet and coupled to the extended valve shaft.

Extended Actuator Input Shaft–Manual actuator is mounted on valve with valve shaft horizontal. Actuator input shaft may be extended to a floorstand with handwheel or electric actuator.

Extended Valve Shaft–Vertical valve shaft may be extended away from valve with couplings or universal joints and connected to a floorstand-mounted manual, electric or cylinder actuator.

Also available:

- Floorstands
- Wall Brackets
- Chain-wheel Sprocket and Guide
- Torque Tube
- Integral Disc Position Indicator
- Rodney Hunt Epoxy Coating
- Special Paint Requirements

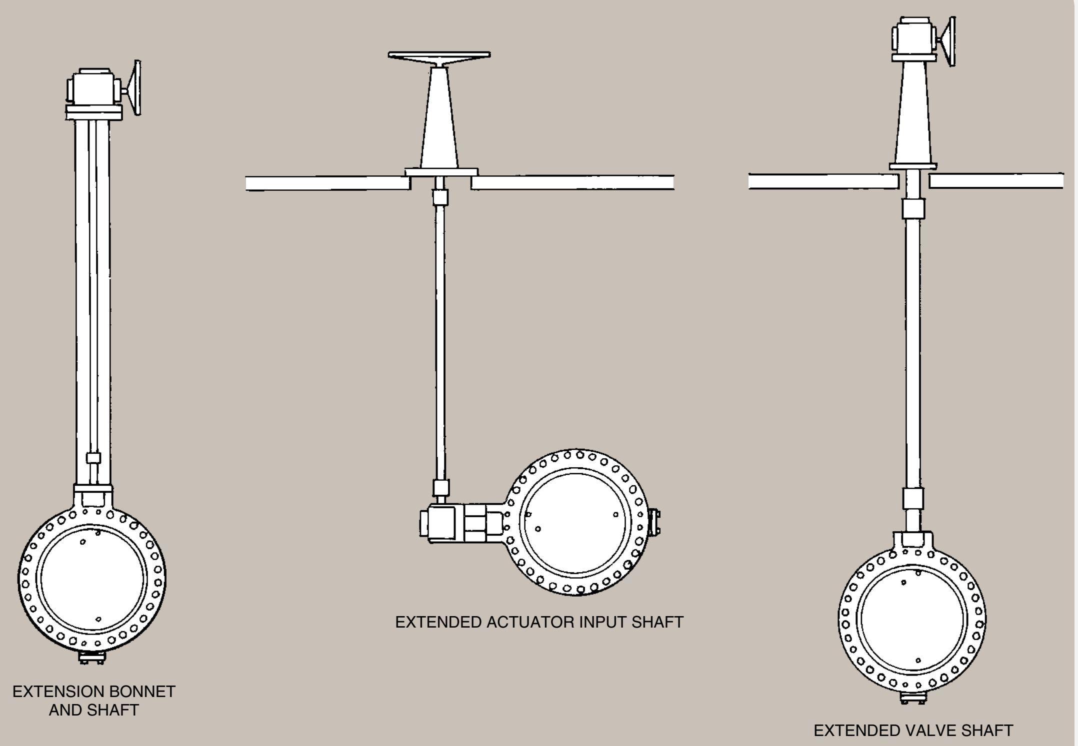


Figure 7: Valve Extensions

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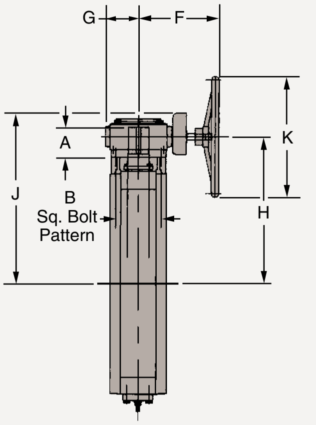
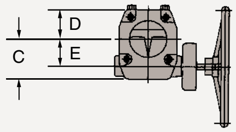
Manual Actuators



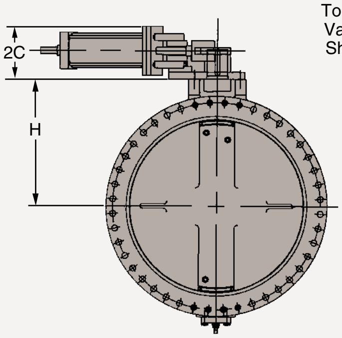
Actuator dimensions are approximate. Request certified drawings for space requirements.

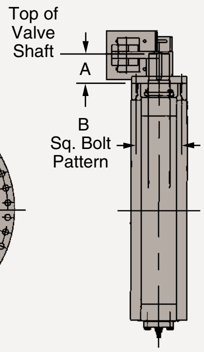


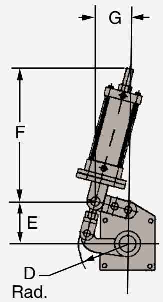
Dimensions in inches.

Size	A	B	C	D	E	F	G	H	J	K
24	6.50	6.25	6.75	3.50	4.25	11.50	3.50	25.00	28.75	24
30	6.50	9.88	9.10	6.00	5.50	14.50	6.75	28.88	33.50	24
36	6.50	9.88	9.10	6.00	5.50	16.75	6.75	32.00	37.38	24
42	6.50	9.88	9.50	7.10	6.75	16.75	6.75	35.00	40.38	24
48	8.88	12.25	11.25	8.50	8.10	17.75	7.75	38.65	44.00	24
54	8.88	12.25	12.75	8.50	9.10	19.75	9.25	42.50	49.75	24
60	8.88	12.25	15.75	9.75	11.50	23.00	10.75	48.60	53.38	24
66	10.00	14.62	19.50	11.38	14.00	29.38	14.75	54.10	60.10	24
72	10.00	14.62	19.50	11.38	14.00	29.38	14.75	57.25	63.25	30
78	10.00	17.50	19.50	11.38	14.00	29.38	14.75	58.38	64.38	36
84	12.00	17.50	22.38	11.75	16.00	33.75	15.25	70.00	79.88	36
90	12.00	18.50	24.75	15.50	18.00	36.38	16.75	66.75	76.50	36
96	12.00	20.00	24.75	15.50	18.00	36.38	16.75	71.00	80.75	36

Cylinder Actuators



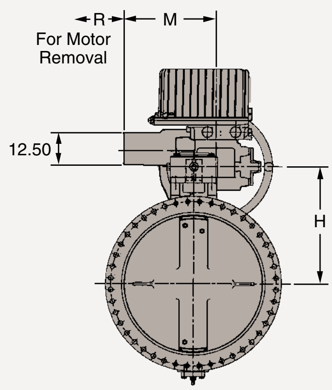


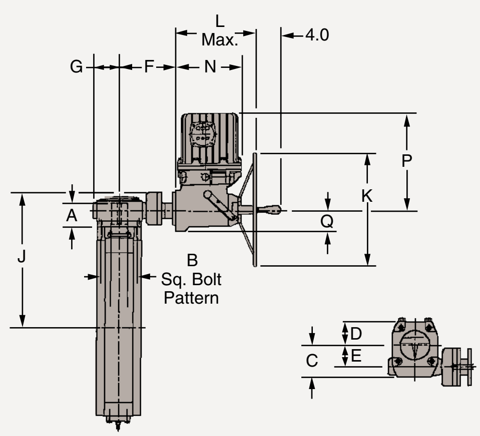


Dimensions in inches.

Size	A	B	C	D	E	F	G	H
24	6.50	6.25	2.50	10.12	9.19	25.00	7.13	21.75
30	6.50	9.88	2.50	10.12	9.19	25.00	7.13	24.75
36	6.50	9.88	2.50	10.12	9.19	25.00	7.13	27.88
42	6.50	9.88	2.50	10.12	9.19	25.00	7.13	30.88
48	8.88	12.25	3.75	17.38	15.56	34.00	12.56	34.25
54	8.88	12.25	3.75	17.38	15.56	34.00	12.56	37.75
60	8.88	12.25	3.75	17.38	15.56	34.00	12.56	40.88
66	10.00	14.62	4.25	24.12	20.96	45.00	18.19	44.50
72	10.00	14.62	4.25	24.12	20.96	45.00	18.19	47.62
78	10.00	17.50	4.25	24.12	20.96	45.00	18.19	50.25
84	12.00	17.50	5.25	31.38	27.63	74.00	23.25	60.00
90	12.00	18.50	5.25	31.38	27.63	74.00	23.25	60.00
96	12.00	20.00	5.25	31.38	27.63	74.00	23.25	60.00

Electric Actuators





Size	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R
24	6.50	6.25	6.75	3.50	4.25	11.50	3.50	25.00	28.75	12	12.10	14.25	10.62	15.13	2.50	2.50
30	6.50	9.88	9.10	6.00	5.50	14.50	6.75	28.88	33.50	12	12.10	14.25	10.62	15.13	2.50	2.50
36	6.50	9.88	9.10	6.00	5.50	16.75	6.75	32.00	37.38	12	12.10	14.25	10.62	15.13	2.50	2.50
42	6.50	9.88	9.50	7.10	6.75	16.75	6.75	35.00	40.38	18	13.60	16.00	11.00	16.13	3.50	2.50
48	8.88	12.25	11.25	8.50	8.10	17.75	7.75	38.65	44.00	18	13.60	16.00	11.00	16.13	3.50	2.50
54	8.88	12.25	12.75	8.50	9.10	19.75	9.25	42.50	49.75	18	14.00	18.90	11.00	16.75	3.50	2.50
60	8.88	12.25	15.75	9.75	11.50	23.00	10.75	48.60	53.38	18	15.50	31.13	10.13	16.75	4.13	4.00
66	10.00	14.62	19.50	11.38	14.00	29.38	14.75	54.10	60.10	18	15.50	31.13	10.13	16.75	4.13	4.00
72	10.00	14.62	19.50	11.38	14.00	29.38	14.75	57.25	63.25	18	15.75	32.25	10.75	18.13	6.75	4.00
78	10.00	17.50	19.50	11.38	14.00	29.38	14.75	58.38	64.38	18	15.75	32.25	10.75	18.13	6.75	4.00
84	12.00	17.50	22.38	11.75	16.00	33.75	15.25	70.00	79.88	24	19.38	39.50	12.25	27.88	9.25	4.00
90	12.00	18.50	24.75	15.50	18.00	36.38	16.75	66.75	80.38	24	19.38	39.50	12.25	27.88	9.25	4.00
96	12.00	20.00	24.75	15.50	18.00	36.38	16.75	71.00	80.75	24	19.38	39.50	12.25	27.88	9.25	4.00

Dimensions in inches.

RODNEY HUNT ®

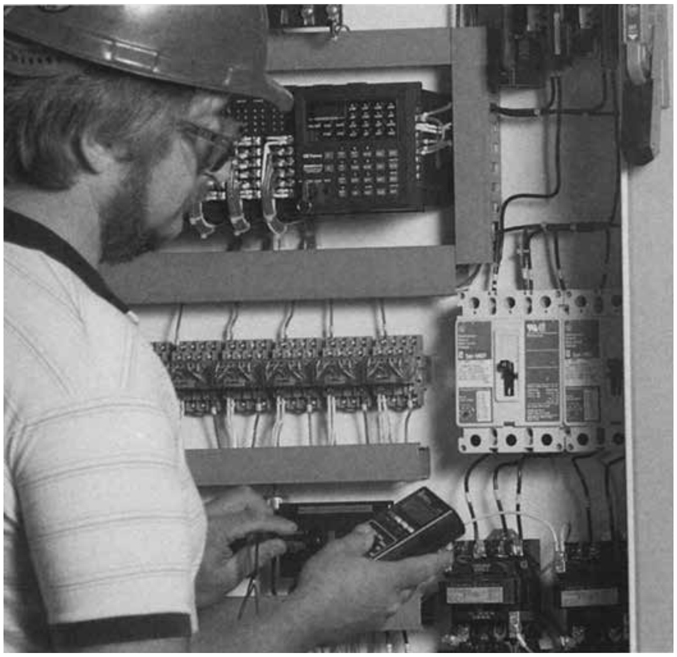
Hydraulic Actuation Systems for Valve Operation

Depending upon the application, Rodney Hunt hydraulic systems for valve control offer specific advantages and economies over manual and electric actuation. Where several valves are operated by a single hydraulic operating system, for example, considerable cost savings can result.

Rodney Hunt has the capability to design manufacture, and test hydraulic systems complete with associated electrical control panels. Start-up assistance is also available. These capabilities offer the consulting engineer, contractor, and end-user single-source responsibility for both the valve equipment and hydraulic actuation.

Advantages of Hydraulic Actuation

- **Inexpensive.** Hydraulic actuation is the most cost-effective type of actuation currently avail able (other than manual).
- **Standard components.** Pre-engineered cylinders are available for valve operation in any application.
- **Increased control**. Valve can be designed to open and close at different speeds, and to permit easy field adjustment of speed.
- **Less wear.** Hydraulic cylinders provide long, trouble-free service especially where valve opens/closes frequently, or for modulating service.
- **Flexible functions.** Systems can vary from a simple pushbutton station to sophisticated programmable positioning.
- **Emergency "fail-safe" operation.** Can be easily configured to open or close valve in the event of power failure, line break, or other emergency.
- **Added security.** Ideally suited for environments that require explosion-proof equipment. The hydraulic system can be housed in a remote location.



Hydraulic actuation system engineering includes development of hydraulic power units that respond to computer instructions for exact valve positions, continuous monitoring, and emergency operation.

Service and Support

Rodney Hunt field service engineers work with customers throughout the world in resolving mechanical, structural, and hydraulic issues associated with water control system design and construction.

The name Rodney Hunt has been associated with quality, reliability, and technical expertise for over 150 years. Consistent customer satisfaction comes from the ability to control all phases of product development and production, and to coordinate these phases with customer needs.

System Analysis. Interdisciplinary engineering skill, supported with the latest technological tools available, enables comprehensive analysis and equipment recommendation.

Product Design and Performance. Proven Allis-Chalmers design, operating effectively in the field for over 50 years.

Manufacturing Capability. Rodney Hunt has assembled one of the most flexible and comprehensive casting, metal fabrication and machining facilities in the industry.

Rodney Hunt representatives work with customers to develop, design, and install water management products and support systems.

Customer Service. Rodney Hunt sales and service personnel work with customers throughout the world to develop, design, and install water management products and support systems that are sensitive to local resources, regulations, and customs. Our goal is to effectively coordinate all phases of design and manufacturing to meet our customers' construction or outage needs.

Spare Parts and Service. On-line and hard-copy access to all current and historical (Allis Chalmers) manufacturing records enable the accurate and timely production of spare parts for all existing Allis Chalmers equipment. Butterfly valves can be repaired or refurbished either on-site or at Rodney Hunt.

Service professionals are available to respond to virtually any customer request or question.

Rodney Hunt Water Control Equipment

Rodney Hunt products have an unparalleled reputation for trouble-free operation in thousands of municipal, industrial, and power installations around the world. Rodney Hunt water control equipment covers a broad range of products and support systems.

- Sluice Gates
- Slide Gates
- Roller Gates
- Tainter Gates
- Hinged Crest Gates
- Gate Actuators
- SCUBA® Hydraulic Actuators
- Rotovalve® Cone Valves
- Howell-Bunger® Valves
- Streamseal® Butterfly Valves
- Rectangular Butterfly Valves
- Flap Valves
- Hydraulic Systems

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  - Fast Close – <60 seconds on 350,000 ft/lbs with standard actuators
  - Cleaner, less expensive option to Electro Hydraulic solutions
- Large butterfly & ball valves
  - Torques to 1,000,000 FT/LBS +
  - Significantly less backlash
  - Smaller actuator / same performance
- High torque / high thrust multi-turn applications (Y-pattern globe & gates)
  - Up to 70% base efficiency competitive in smaller less expensive packages where torque is 9,000 ft/lbs+
  - Thrust bases available to 2,000,000 lbs+
  - Temperature compensation
- Marine / sub sea service
  - Hyperbaric testing to 10,000 ft
  - Stainless / chrome hardware / shafts / housing (if necessary)
  - IP 67/68
  - ROV interface and indicator / feelicators
  - Buckets / panels
- Extreme temperature / environment
  - - 60˚C - 235˚C +
  - K-mass available

Values with "+" indicate current design limits.
Higher capabilities may be engineered.

- Quick delivery on high performance gears; high torque / fast close
- Reduce turns to close by up to 75%
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- Greatly improved torque capability and durability with significantly reduced backlash
- Rigorously tested and qualified – AWWA C504 & C540 Compliant
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- Custom solution

MaxTorque

What MaxTorque IS NOT

- Commodity, "price point" solution
- Competitor for "basic" gear box solutions

Unique Applications

- River / Sluice Gates
- Buried service
- De-clutch and partial stroke to 450,000 ft/lbs
- Remote / DC service (limited power availability)
- High cycle / high precision process control
- Custom engineered solutions
- Low volume, unique applications
- Specialty government work

MW3 Unit on Test Stand

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REV. 2 APRIL 1, 2005

MaxTorque

PERFORMANCE SPECIFICATIONS
MODERATE SERVICE FACTOR <10,000 LIFE CYCLES

Unit	Model	In-Lbs	Ft-Lbs	Max Base Ratio	Max Standard Bore	Max Standard Key	Stem Engage
LW SERIES	LW1	20,000	1,667	9.30	2.5″	3/4″ x 1/2″	3 1/4″
	LW2	40,000	3,333	18.30	3″	3/4″ x 12″	4″
	LW3	80.000	6,667	25.30	4″	1″ x 3/4″	5 3/8″
BW SERIES	BW1	160,000	13,333	20.25	5 1/2″	1 1/2″ x 1″	7 1/2″
	BW2	320,000	26,667	18.75	6 1/2″	1 1/2″ x 1″	8 3/8″
	BW3	480,000	40,000	22.75	9″	1″ x 1 1/2″	9 1/2″
	BW4	800,000	66,667	28.25	9″	2″ x 1 1/2″	10 1/4″
MW SERIES	MW1	1,200,000	100,000	21.75	10″	1 1/2″ x 2″	15 3/4″
	MW2	1,800,000	150,000	27.25	10″	2 1/2″ x 2″	15 3/4″
	MW3	2,400,000	200,000	30.75	10″	2 1/2″ x 2″	15 3/4″
	MW4	3,000,000	250,000	37.75	10″	2 1/2″ x 2″	15 3/4″
	MW5	3,600,000	300,000	42.75	10″	2 1/2″ x 2″	15 3/4″
	MW9	7,200,000	600,000	35.25	12″	2 1/2″ x 2″	15 3/4″
	MW14	11,199,996	933,333	43.75	14″	3 1/2″ x 2″	16 3/4″

* Low service / Manual ratings (< 1,000 life cycles) are approximately 120% of moderate factor.
* Multiple spur options available. Visit www.maxtorquegears.com for details. Spur options for LW + BW series include BS3, AX2.7 through AX12.6″. Spur options for MW series include WGR20.25, and HSS4-10, AX series spurs may be added to WGR 20.25 for additional ratio.

Double Enveloping Gear Set

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- We partner with you and your end customers to design custom solutions
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  +1-207-793-2289
  iagpat@rcn.com
- For more information, please visit www.maxtorquegears.com

1) MaxTorque, LLC reserves the right to modify or update technical data at any time. Please consult www.maxtorquegears.com for the most current specifications.

2) Efficiencies are based on dynamic performance after a reasonable break-in period.

3) Self locking characteristics are similar to those of other self-locking worm gearboxes. Specific environmental conditions such as high vibration may adversly affect self locking characteristics. If locking is required in this or other conditions, a separate brake should be utilized.

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REV. 2

APRIL 1, 2005

Moderate Service - <10,000 life cycles

Rev. 17 / 8-July-08

Usage:

- The LW Series utilizes "IP" spurs for additional ratio. Options are 2:1 and 3:1 and can be stacked. Additionally, on the LW3 unit there is the availability of a 3:1 spur which should be utilized at the higher end of it's torque rating.
- The BW series utilizes BS (base spur) and AX (auxilliary spur) spurs to add ratio. Either can be used directly on the BW series gears. However, BS units are more robust than the AX units. If stacking 2 spurs to get additional ratio, the first should be a BS model then the AX.
- Stacking AX spurs is not recommended without checking with MaxTorque engineering
- BS options are 3:1 and 2.05:1. AX options are 1.88, 2.29, 2.45, 2.63, 2.83, 3.06, 3.31, 3.60, 4.26, 4.55, 5.19, 5.55, 5.57, 5.95, 5.98, 6.39, 6.44, 6.88, 6.95, 7.39, 7.43, 7.53, 7.93, 8.04, 8.18, 8.51, 8.74, 9.17, 9.90, 10.72, 11.65, 12.6.
- MW Series "Standard" typically utilize a second worm gear as the primary spur. Most often this is a WGR1 (20.25:1) which is rated for 10,000 ft-lbs (13,500 Nm) BS and AX spurs can be added for additional ratio per the guidelines above on the BW Series.

A WGR2 (18.75:1) is standard on the MW5 and may be used on the other MW units. It's rating is 25,000 ft-lbs (33,900 Nm.)

MW Series "High Speed" utilize large spurs available in even ratios from 3:1 to 9:1

Insert RPM: 110 — Turns to Stroke: 66

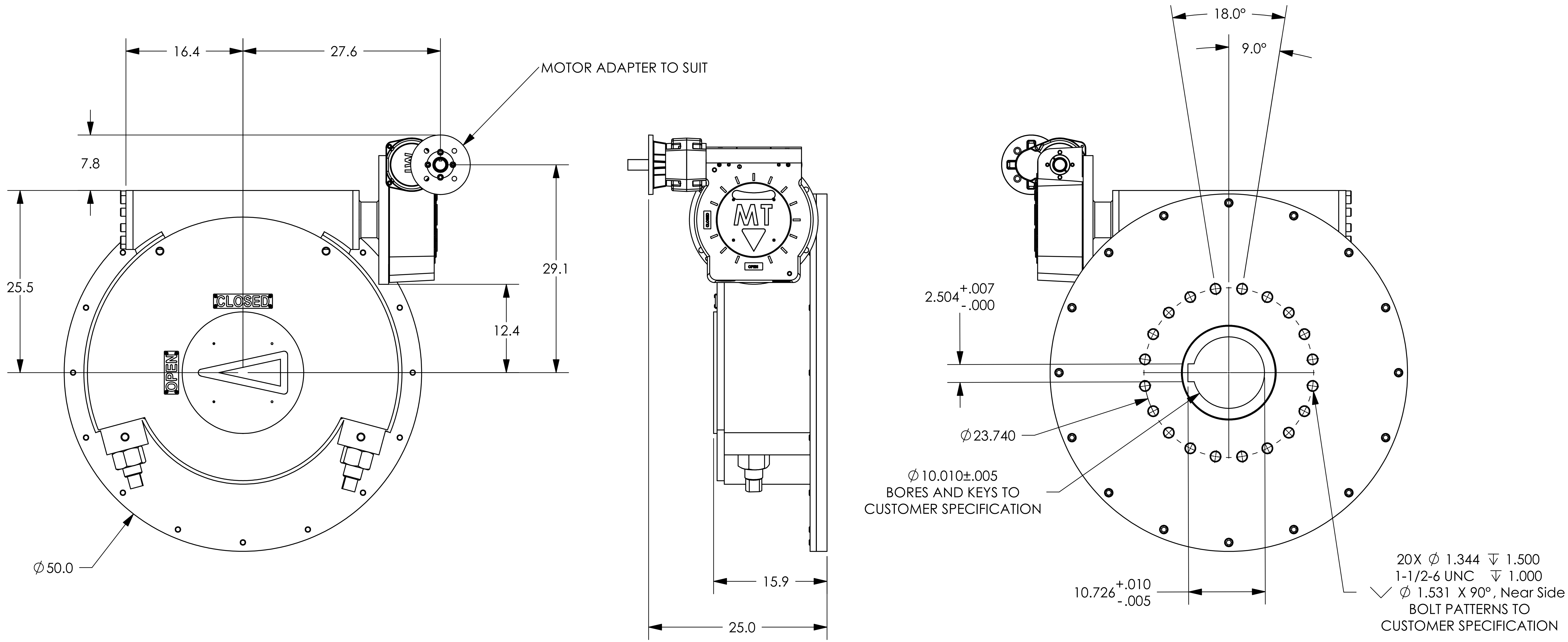
Series	Model	Max Output Moderate Service IN-Lbs	Max Output Moderate Service Ft-Lbs	Max Output Moderate Service Nm	Base Ratio	Spur 1 Ratio*	Spur 2 Ratio*	Final Ratio	Effic*	Mech Adv	Required Output Torque (Enter only one) IN-Lbs	Required Output Torque Ft-lbs	Required Output Torque Nm	Required Torque Input ft-lbs	Required Torque Input Nm	Turns to Open	Quarter Turn Seconds To Close @ 110	Multi-Turn Output RPM	Multi-TurnTime to Close (s)	One time Max Allowable Torque	Max Stndrd Bore	Max Standard Key	Max Stem Engagement
LW SERIES	LW1	30,500	2,550	3,457	24.33	1.00	1.00	24.3	0.61	15	1	1	1	0	0	6	3	4.52	876	416	2.75	.5" x .5"	3 1/2"
	LW2	60,000	5,000	6,779	24.33	1.00	1.00	24.3	0.61	15	1	1	1	0	0	6	3	4.52	876	815	3.25	.75" x .75"	4 1/2"
	LW3	96,000	8,000	10,846	25.3	1.00	1.00	25.3	0.55	14	1	1	1	0	0	6	3	4.35	911	1198	4"	1" x 3/4"	5 3/8"
BW SERIES	BW1	160,000	13,333	18,077	20.25	3.00	1.00	60.8	0.67	40.4	1	1	1	0	0	15	8	1.81	2187	825	5 1/2"	1 1/2" x 1"	7 1/2"
	BW2	320,000	26,667	36,155	18.75	3.00	1.00	56.3	0.67	37	1	1	1	0	0	14	8	1.96	2025	1782	6 1/2"	1 1/2" x 1"	8 3/8"
	BW3	560,000	46,667	63,271	22.75	3.00	1.00	68.3	0.67	45	1	1	1	0	0	17	9	1.61	2457	2571	9"	1 x 1 1/2"	9 1/2"
	BW4	800,000	66,667	90,387	28.25	3.00	1.00	84.8	0.67	56	1	1	1	0	0	21	12	1.30	3051	2957	9"	2" x 1 1/2"	10 1/4"
MW SERIES STANDARD	MW1	1,200,000	100,000	135,580	21.75	20.25	1.00	440.4	0.46	200	1	1	1	0	0	110	60	0.25	15856	1123	10"	2 1/2" x 2"	15 3/4"
	MW2	1,800,000	150,000	203,370	27.25	20.25	1.00	551.8	0.46	251	1	1	1	0	0	138	75	0.20	19865	1344	10"	2 1/2" x 2"	15 3/4"
	MW3	2,400,000	200,000	271,160	30.75	20.25	1.00	622.7	0.46	283		1	1	0	0	156	85	0.18	22417	1588	10"	2 1/2" x 2"	15 3/4"
	MW4	3,000,000	250,000	338,950	42.25	20.25	1.00	855.6	0.46	389	1	1	1	0	0	214	117	0.13	30800	1445	10"	2 1/2" x 2"	15 3/4"
	MW5	3,600,000	300,000	406,740	42.25	18.75	1.00	792.2	0.46	360	1	1	1	0	0	198	108	0.14	28519	1873	10"	2 1/2" x 2"	15 3/4"
MW SERIES *HIGH SPEED*	MW1	1,200,000	100,000	135,580	21.75	6.00	1.00	130.5	0.62	81	1	1	1	0	0	33	18	0.84	4698	2792	10"	2 1/2" x 2"	15 3/4"
	MW2	1,800,000	150,000	203,370	27.25	7.00	1.00	190.8	0.62	118	1	1	1	0	0	48	26	0.58	6867	2706	10"	2 1/2" x 2"	15 3/4"
	MW3	2,400,000	200,000	271,160	30.75	5.00	3.00	461.3	0.59	271	1	1	1	0	0	115	63	0.24	16605	1571	10"	2 1/2" x 2"	15 3/4"
	MW4	3,000,000	250,000	338,950	42.25	5.70	1.00	240.8	0.62	149	1	1	1	0	0	60	33	0.46	8670	3572	10"	2 1/2" x 2"	15 3/4"
	MW5	3,600,000	300,000	406,740	42.25	3.00	1.00	126.8	0.62	78	1	1	1	0	0	32	17	0.87	4563	8145	10"	2 1/2" x 2"	15 3/4"
MW SERIES	MW9	7,200,000	600,000	813,480	34.25	3.00	1.00	102.8	0.57	59	1	1	1	0	0	26	14	1.07	3699	20899	12"	2 1/2" x 2"	15 3/4"
	MW18	16,000,000	1,333,333	1,807,733	44.25	5.55	3.00	736.8	0.54	399	1	1	1	0	0	184	100	0.15	26523	6818	14"	3 1/2" x 2"	16 3/4"

1) MaxTorque reserves the right to update or modify technical data at anytim
2) Efficiencies are based on dynamic performance after a reasonable break in perio

Instructions:

1) Find the MaxTorque gear that meets your stem torque requirements
2) Input your required output in column highlighted in Blue. You can input In-lbs, Ft-lbs or Nm. (Input only one)
3) For multi-turn applications, enter turns to stroke in AE/13. (For quarter turn operation = .25)
3) This sheet has been designed so that you can change the ratio on the base spur or the auxiliary spur (Column highlighted in light green) to either decrease or increase the input torque requirement or change the turns to open of the opening & closing times.
4) For LW and BW series, the base spur options are is 2.05 :1 and 3:1. Auxiliary Spur (AX) options may be utilized on the gear alone or in combination with the BS3 for additional ratio on BW and MW series. AX options are 1.88, 2.29, 2.45, 2.63, 2.83, 3.06, 3.31, 3.60, 4.26, 4.55, 5.19, 5.55, 5.57, 5.95, 5.98, 6.39, 6.44, 6.88, 6.95, 7.39, 7.43, 7.53, 7.93, 8.04, 8.18, 5.51, 8.74, 9.17, 9.90, 10.72, 11.65, 12.6
5) MW series uses standard double worm reduction with a ratio of 20.25 (WGR). For faster close times high speed spurs for the MW series are available in 3:1, 4:1, 5:1, 6:1, 7:1, 8:1 , 9:1

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED



NOTES:

1. FINAL RATIO RAGE: : 1868 : 1
   BASE RATIO: 30.75 : 1, WORM GEAR REDUCER RATIO: 20.25, BASE SPUR RATIO: 3 : 1
2. MAX BORE AND KEY: Ø10.0" W/ 2 1/2" X 2" KEY
3. MAX STEM ENGAGEMENT: 15 3/4
4. APPROXIMATE WEIGHT: 3462 LBS
5. UNIT IS SHOWN IN THE "OPEN" POSITION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±1/32
ANGULAR: MACH±1/2
BEND ±1/2
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

MATERIAL: N/A

FINISH: PAINT

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JM	7/17/06
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

Monday, July 17, 2006 10:21:22 AM

MAXTORQUE ™

TITLE: MW3, WGR, BS3, GENERIC
1800K TO 2400K IN-LBS

SIZE B | DWG. NO. 300122 | REV.

SCALE: 1:14 | WT: 3462 lbs | SHEET 1 OF 1

FLOWSERVE

Limitorque MX

The Next Generation in Smart Multi-turn Actuation

Experience In Motion

FLOWSERVE

Flowserve Limitorque Actuation Systems

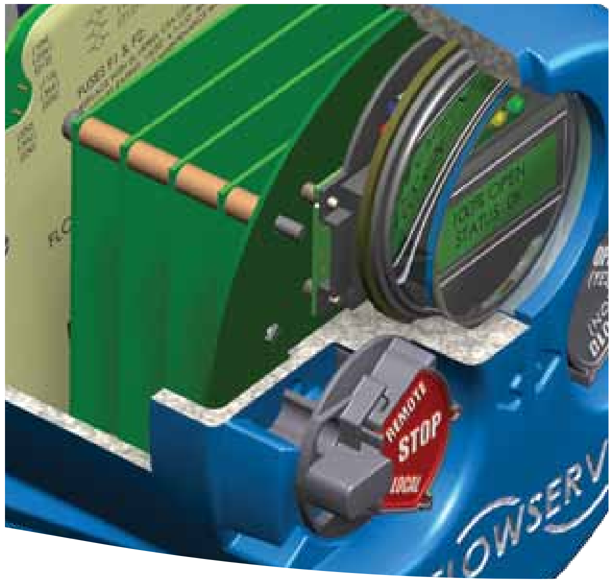
Limitorque is an operating unit of Flowserve, a $2+ billion-a-year company strongly focused on automation and support of the valve industry. Flowserve is the world's premier provider of flow management services.

Limitorque has evolved over 75 years since its strategic introduction of a "torque-limiting" design that changed an industry. Flowserve Limitorque offers solutions and automation choices for customers which provide:

- cost savings from field devices such as electric valve actuators.
- greater operating efficiencies from control room performance sequencing, interlocking, and continuous process optimization.
- competitive advantages derived from increased management visibility of databases and networks.

Limitorque is one of the primary reasons Flowserve is "Experience In Motion."

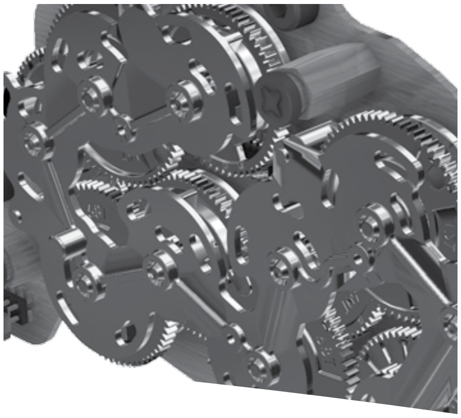
The MX speaks your language, whether it's management, technical, financial, operations, or service.



MX – Still "No Batteries Required"

Limitorque MX: smart multi-turn actuator that delivers what you want most — control, ease of use and "no batteries required."

Flowserve Limitorque introduced the MX electronic actuator in 1997 as the first smart actuator that provided uncompromised reliability and performance in a design that was easy to use. The MX innovations which were market firsts – unique absolute encoder that doesn't require battery back-up – Limigard™ technology – easy to use menus in six languages – the use of Hall effect devices to eliminate potentially troublesome reed switches – have been improved. The features Users have come to expect from Flowserve Limitorque are still standard, but the list of improvements and optional equipment permits improved reliability, functional performance and durability. The MX is the smart actuator design that is rigorous and easy to use. It is the only non-intrusive, double-sealed electronic actuator to display the Limitorque brand.



MX: The Next Generation in Smart Actuation

Speed, Precision and Simplicity

The MX control panel features an improved 32-character LCD screen that provides actuator status and diagnostics in an easy to use, easy to read, graphical format. The industry's first multilingual actuator is now capable of configuration in English, Spanish, German, French, Italian, Portuguese, Mandarin, Russian, Bahasa Indonesia and Katakana as standard configuration languages. In addition, the LCD can be rotated 180˚ for better field visibility.

Speed, precision, simplicity, and set-up speed are characteristics expected of a smart actuator. Users and valve OEMs demand quick set-up and easy to understand dialog in preferred languages. The ability to either upload new software or download diagnostics is also critical to improving a plant's efficiency. The MX provides customers with the essential tools for rapid installation and root cause diagnostics.

Precision is expected in a smart actuator. The MX was the first such device developed with an innovative absolute encoder that doesn't require troublesome and unpredictable battery back-up. Flowserve Limitorque's innovative absolute encoder has been improved to 18-bit resolution over 10,000 drive sleeve rotations and is 100% repeatable. It now has BIST (Built In Self Test) enhancements and redundancy.

When a device is designed for BIST, its methodology is such that much of the test functionality is embedded in the device itself. BIST design facilitates a critical component's ability to communicate its actual state to a CPU for comparison to the expected state. Any deviation from expected values will be reported to the User with correlation to the failed component or sub-system.

Simplicity is expected in a smart actuator. In fact, one of the reasons for using an electronic actuator is the simplicity of set-up, installation on a valve, and acquiring diagnostic information. The MX is the simplest and easiest to use electronic actuator.

Long Life and Protection

Long life is expected in a smart actuator. There are more than 1,000,000 Limitorque actuators installed around the globe, in every conceivable environment. Many have been functioning for over 50 years. Introduced in 1997, the MX is the Flowserve Limitorque smart actuator that inherits Limitorque's legendary longevity.

In order to last a long time in severe environments smart actuators must have unparalleled protection. The MX's IP68 enclosure rating is 15M for 96 hours, regardless of whether the unit is weatherproof or explosionproof. This is an industry leading feature. Add other certifications to the list – NEMA 4, 4X, 6 – and the MX is unsurpassed in unit protection.

The MX is double-sealed, which isolates the terminal compartment from the controls environment. Any leakage into the terminal compartment is contained in the compartment.

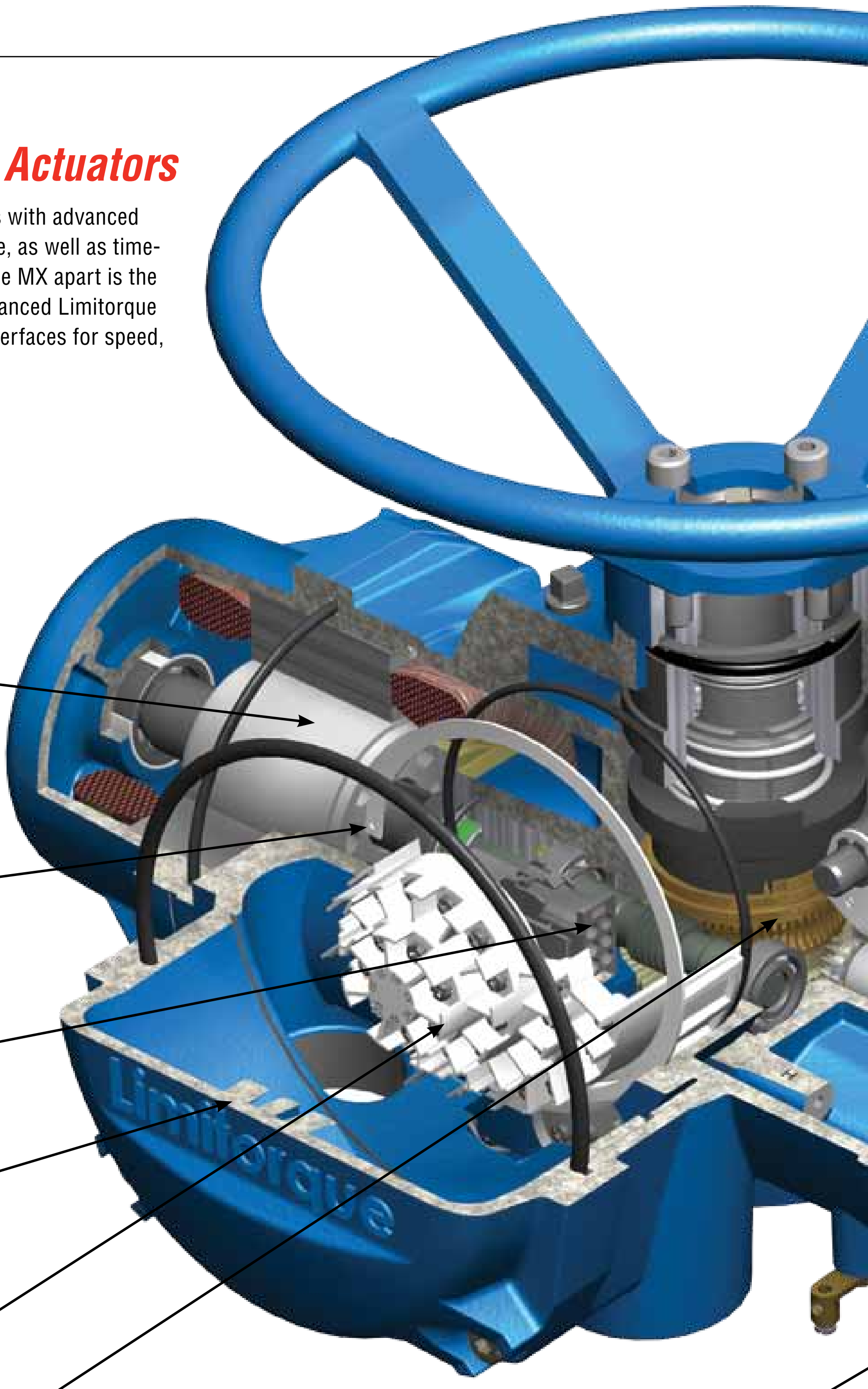
The MX is powder coated using a polyester resin in Dupont Blue Streak color, not only for aesthetics, but also for protection in severe corrosive environments.

Quality and Certifications

Flowserve Limitorque is a global leader in quality manufacturing. All Limitorque plants are certified to ISO 9001 standards, the recognized benchmark for quality all over the world. The same unexcelled use of certified materials is found in the MX as in Limitorque's naval and nuclear qualified electric actuators. The MX has used synthetic gear oils especially optimized for use with worm gear sets since the first unit was shipped in 1997. It was the first non-intrusive actuator to use rolled worms and electronic controls designed and produced using surface mount technology. A true globally certified device, MX meets all pertinent European Directives including ATEX, EMC, Machinery and Noise and displays the CE mark associated with such compliance.

Anatomy of MX Multi-turn Actuators

Limitorque MX actuators respond to customer needs with advanced features designed for ease of commissioning and use, as well as time- and money-saving operational benefits. What sets the MX apart is the combination of control and reliability enabled by advanced Limitorque technology, plus superior ergonomics and human interfaces for speed, comfort, and ease of use.



The reliable MX motor includes Class F insulation and thermal protection. It is designed specifically for valve actuator service, with a high starting torque and low inertia to reduce valve position overshoot. Class H is available as an option.

Motor gear attachment allows the motor to be removed in one assembly for fast, easy inspection, repair, and maintenance.

MX actuators feature a LimiGard™ circuit monitor that is designed for Fail/No-Action protection. LimiGard consists of dedicated circuitry that continually monitors the motor contactor, control relays, internal logic circuits, and external command signals to detect and alarm malfunctions. It now includes BIST with Frequency Domain Analysis (FDA) for true predictive maintenance.

Plug-in connectors permit quick and easy replacement of components.

Double-sealed design provides a termination chamber that is separate and sealed from the control chamber. Control components are never exposed to the elements during site wiring or because of a faulty cable connection.

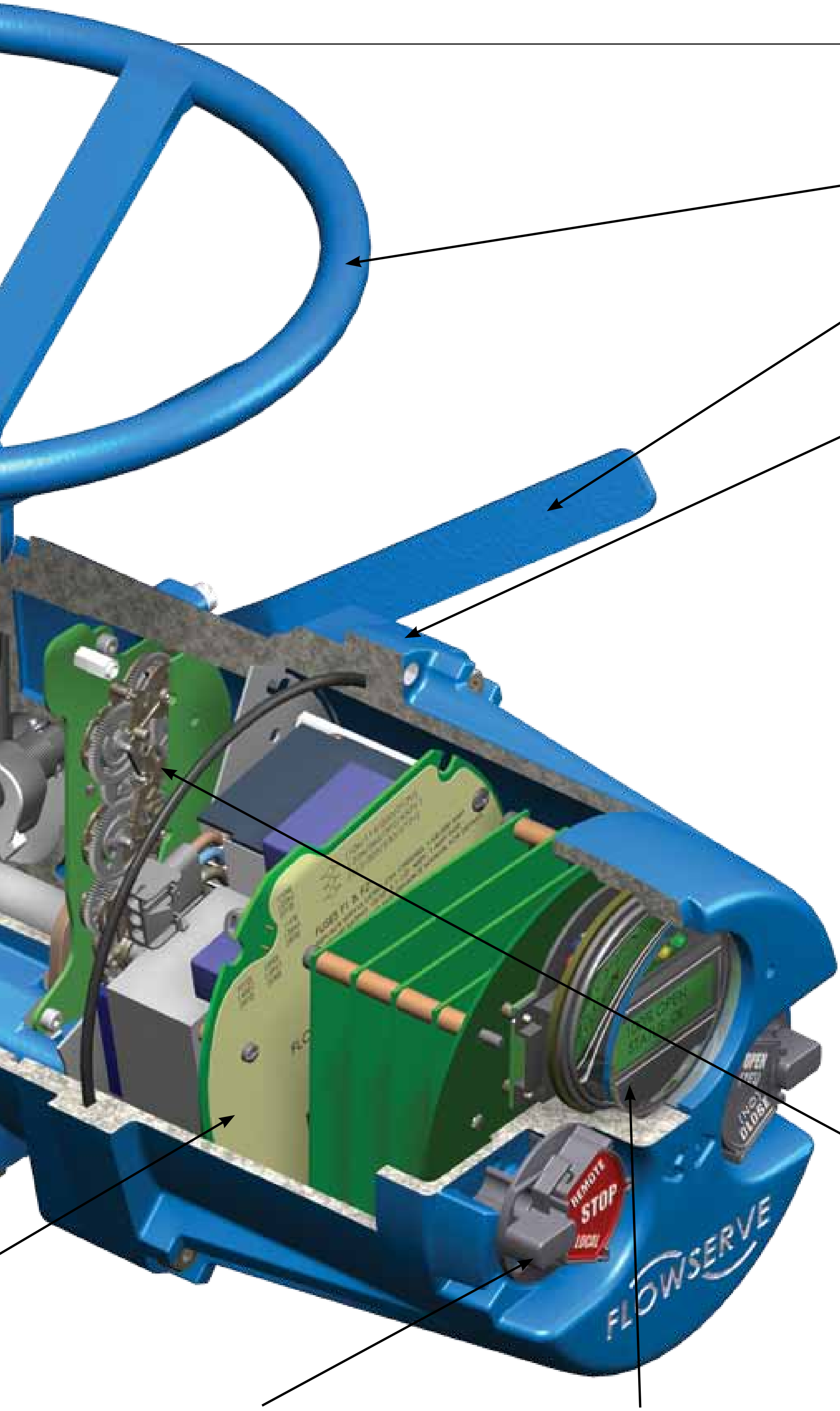
External connection block has three power terminals, a ground screw, and 54 control screw-type terminals to simplify commissioning and upgrades.

Long-life gear set consists of hardened alloy steel rolled worm and bronze worm gear immersed in an extended-life synthetic gear oil specifically developed for worm gear operation. It is completely bearing-supported.

Ductile iron thrust base is removable from main actuator housing for easier valve installation and maintenance.

High-strength, bronze alloy stem nut is removable for machining to suit the valve stem.

The control chamber includes an electronic control, monitoring, and protection module mounted on steel plate. Plug-in connectors allow fast, error-free removal and replacement of the module.



The MX heavy-duty handwheel provides backup for manual operation.

Declutch lever enables the MX actuator to be placed in manual, handwheel-drive operation. Lever automatically disengages when motor is energized and can be padlocked in the motor position.

Cast aluminum housing powder-coated for extreme environments. Optional coatings are available.

Optionally, controls may be powered from an external 24 VDC source as backup for AC power. Controls and display will remain active through loss of AC power.

Torque sensor derives output from motor speed, temperature, and voltage—and shuts off the motor to protect the actuator and valve if the set torque is exceeded. This method of torque scanning indicates Limitorque's commitment to be fully electronic.

Flowserve Limitorque's uncompromising commitment to "no batteries required" is enhanced with the addition of the optional MX Quik (MX-Q) uninterrupted power transfer when mains power is lost to the actuator. MX-Q powers the S/R contacts for updated status to the control room and also provides limited visibility of the LCD screen. It is configurable for "MX Quik time" and, once main power is restored, is available for the next unforeseen power outage.

The absolute encoder, a key that enables MX actuators to achieve 100% repeatable control, provides optical sensing of valve position with 18-bit resolution. The encoder measures valve position in both motor and handwheel operation. No battery or back-up power supply is required. It is now redundant, permitting up to a 50% fault tolerance, ensuring reliable performance in the unlikely event of component failure.

Local control switches make setup and calibration easy, using "yes" or "no" responses to straightforward questions, plus they provide the ability to open, stop, and close the actuator and to select remote or local preferences. These switches are magnetically coupled, solid state Hall effect devices, which eliminate troublesome and fragile reed switches.

The control panel display delivers instant, up-to-the-minute actuator status and valve position in ten languages. It also provides simple calibration and diagnostic information, including motor, identification, hardware data, as well as torque profile log reports.

The MX now offers Bluetooth technology as optional, up to 10 meters. When used with Flowserve Limitorque's Windows CE and Mobile 5 based graphical interface Dashboard™, diagnostic information, which includes FDA (frequency domain analysis) can be transferred easily to a PDA, laptop computer or smart cell phone.

MX Series Performance Ratings for Units 05 through 150

MX-05 through MX-40 (three-phase: 50 Hz/380, 400, 415, and 440 Volt: 60 Hz/208, 230, 380, 460, 525, 575 Volt)

MX-85 through MX-150 (three-phase: 50 Hz/380, 400, and 415 Volt: 60 Hz/380, 460, 575 Volt)* *380/50 multiply by 0.9

Output Speed (RPM)		MX-05		MX-10		MX-20		MX-40		MX-85		MX-140		MX-150	
		Rated Output Torque													
60 Hz	50 Hz	ft-lb	N m	ft-lb	N m	ft-lb	N m	ft-lb	N m	ft-lb	N m	ft-lb	N m	ft-lb	N m
18	15	55	75	125	170	225	305	440	597	N/A	N/A	N/A	N/A	N/A	N/A
26	22	55	75	125	170	225	305	440	597	850	1153	1500	2036	N/A	N/A
40	33	55	75	125	170	225	305	440	597	1225	1662	1700	2307	N/A	N/A
52	43	55	75	125	170	225	305	440	597	1150	1561	1600	2171	N/A	N/A
77	65	48	65	107	145	178	241	345	468	850	1153	1200	1628	N/A	N/A
100 131[1]	84 110[1]	39	53	89	121	148	201	286	388	600	814	815	1105	1500	2036
155 170[1]	127 143[1]	41	56	89	121	140	190	260	353	450	611	650	882	1150	1561
200	165	34	46	73	99	114	155	210	285	N/A	N/A	N/A	N/A	N/A	N/A

Note 1: MX-85, MX-140 and MX-150

	lb	kN	lb	kN	lb	kN	lb	kN	lb	kN	lb	kN	lb	kN
Thrust Ratings (lb/kN)	8000	35	15000	66	25000	111	36000	160	50000	222	75000	333	75000	333
B4 Base (Torque Only)	**lb**	**kg**	**lb**	**kg**	**lb**	**kg**	**lb**	**kg**	**lb**	**kg**	**lb**	**kg**	**lb**	**kg**
Weights (lb/kg)	52	24	65	29	109	49	133	60	250	114	300	136	431	182

A1 Base (Thrust Only) Weight	lb	kg
MX-05 & MX-10	9	4
MX-20 & MX-40	29	13
MX-85 w/ F16/FA16 base	72	33
MX-140/MX-150 w/ F25/FA25 base	111	50

Maximum Stem Capacity

Type A Couplings	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
Type A1	1.26	32	1.57	40	2.36	60	2.64	67	3.50	88	3.50	88	3.50	88
Type A1E (Extended Nut)	1.26	32	1.57	40	2.36	60	2.64	67	3.50	88	3.50	88	3.50	88
Type B Couplings (Torque Only)[2]	**in.**	**mm**	**in.**	**mm**	**in.**	**mm**	**in.**	**mm**	**in.**	**mm**	**in.**	**mm**	**in.**	**mm**
Type B4	1	25.4	1.25	30	1.94	50	2.2	55	2.88	73	2.88	73	2.625	65
Type B4E (Extended)	0.75	19	0.91	22	1.56	41	1.78	46	2.25	57	2.25	57	2.625	65
Type B1 (Fixed Bore)[3]	N/A	42	N/A	42	N/A	60	N/A	60	N/A	N/A	N/A	N/A	N/A	N/A
Type BL (Splined)	6 & 38 Splines		6 & 38 Splines		6 & 36 Splines		6 Splines		N/A	N/A	N/A	N/A	N/A	N/A
Maximum Bore and Keyway	**in.**	**mm**	**in.**	**mm**	**in.**	**mm**	**in.**	**mm**	**in.**	**mm**	**in.**	**mm**	**in.**	**mm**
Maximum Bore (B4)	1	25	1.25	30	1.94	50	2.2	55	2.75	65	2.65	65	2.625	65
Maximum Keyway	¼ sq.	8 x 7	¼ sq.	10 x 8	½ x ⅜	14 x 9	½ x ⅜	16 x 10	⅝ x 7/16	18 x 11	⅝ x 7/16	18 x 11	⅝ x 7/16	18 x 11
Maximum Bore (B4E)	.75	18	0.91	22	1.56	41	1.78	46	2.25	56	2.25	56	2.5	65
Maximum Keyway	3/16 sq.	6 x 6	¼ sq.	8 x 7	⅜ sq.	12 x 8	½ x ⅜	14 x 9	½ x ⅜	16 x 10	½ x ⅜	16 x 10	0.625 sq.	18 x 11

Note 2: Maximum bores for Type B couplings may require rectangular keys.

Note 3: Available in ISO base only.

	MX-05	MX-10	MX-20	MX-40	MX-85	MX-140	MX-150
Mounting Base (MSS SP-102/ISO 5210)	FA10/F10	FA10/F10	FA14/F14	FA14/F14	FA16/F16	FA25/F25	FA25/F25
Handwheel Ratio (STD/Optional)	Direct	Direct/8:1	Direct/12:1	Direct/24:1	16/48	16/48	16/48
Side-Mounted Handwheel Efficiencies	N/A	52%	54%	51%	53%/51%[4]	53%/51%[4]	53%/51%[4]

Note 4: Efficiencies for MX-85, MX-140 and 150 are 51% with SGA and 53% without SGA.

FLOWSERVE

MX Standard & Optional Features

Limitorque MX electronic valve actuators are designed for the operation of ON-OFF and modulating valves. They include a three-phase electric motor, worm gear reduction, absolute encoder, electronic torque sensor, reversing motor contactor, electronic control, protection and monitoring package, handwheel for manual operation, valve interface bushing, 32-character LCD, and local control switches—all contained in an enclosure sealed to NEMA 4, 4X, 6, and IP68. Explosionproof (XP) enclosures can also be provided when required. All MX actuators comply with applicable European Directives and exhibit the CE mark.

Power transmission and lubrication

All mechanical gearing components are bearing supported, and final drive (output) consists of a hardened alloy steel worm and alloy worm gear. All gears are immersed in an oil-bath lubricated with a synthetic oil designed specifically for extreme pressure worm and worm gear transmission service. Special lubricants are available for operation in temperatures of less than -30°C. Consult factory.

LUBRICATION & TEMPERATURE RANGE	SYNTHETIC BRAND
Standard Lubrication, -30ºC to +70ºC	Mobil SHC 323
Optional Food Grade Lubrication, -30ºC to +70ºC	Dow Molykote

Motor

The MX motor is a 3-phase squirrel cage designed for electronic valve actuators. It is specifically designed for the MX actuator and complies with IEC 34, S2-33 percent duty cycle at 33 percent of rated torque. The motor is a true bolt-on design with a quick-disconnect plug that can be changed rapidly without sacrificing motor leads. It is equipped with a solid-state motor thermistor to prevent damage due to temperature overloads.

ON-OFF MODULATING
Standard insulation class is F to IEC 34, S2-33% for stated operating times 100-600 starts per hour
600-1200 starts per hour, IEC 34, S4_33%_1200 S/H

The MX motor permits a global range of 3-phase voltages to be connected without modification. The motor can energize, provided either of the listed voltages are connected:

Phase/Frequency	Application Voltage
3ph - 60 Hz	208, 220, 230, 240, 380, 440, 460, 480, 550, 575, 600
3ph - 50 Hz	380, 400, 415, 440, 525

Electronic control modules

Non-intrusive

The MX is non-intrusive, which means that all calibration/configuration is possible without removing any covers and without the use of any special tools. All calibration is performed in clear text languages; no icons are used. All configuration is performed by answering the “YES” and “NO” questions displayed on the LCD. “YES” is signaled by using the OPEN switch and “NO” by using the CLOSE switch, as indicated adjacent to the switches.

Double-sealed terminal compartment and terminal block

All customer connections are located in a terminal chamber that is separately sealed from all other actuator components. Site wiring doesn’t expose actuator components to the environment. The internal sealing within the terminal chamber is suitable for NEMA 4, 6, and IP68 to 15M for 96 hours. The terminal block includes screw-type terminals; three for

power and 54 for control. Customer connections are made via conduits located in the terminal housing.

Three Standard Conduit Openings (NPT threads standard, M optional)
(2) – 1.25" NPT or M32 (optional) (1) – 1.5" NPT (standard) or M38 (optional)

Controls

The controls are all solid state and include power and logic circuit boards and a motor controller that performs as the motor reverser, all mounted to a steel plate and attached in the control compartment with captive screws. All internal wiring is flame resistant, rated 105°C, and UL/CSA listed.

The controls are housed in the ACP (Actuator Control Panel) cover, and the logic module uses solid-state Hall-effect devices for local communication and configuration. A 32-character, graphical LCD is included to display valve position as a percent of open, 0-100% and current actuator status. Red and green LEDs are included to signal 'Opened' and 'Closed,' and are reversible, and a yellow LED to indicate 'Valve Moving.' A blue LED is included when the Bluetooth option is ordered. A padlockable LOCAL-STOP-REMOTE switch and an OPEN-CLOSE switch are included for local valve actuator control

Using the knobs and LCD screen the MX is configurable in 10 languages: English, Spanish, French, German, Portuguese, Italian, Mandarin, Russian, Bahasa Indonesia and Katakana.

S contacts for remote indication

As standard, two pairs of latched status contacts rated 125 VAC, 0.5 A and 30 VDC, 2 A are provided for remote indication of valve position, configured as 1-N/O and 1-N/C for both the open and closed positions. Two contacts may be configured to represent any other actuator status and the other two will be complementary. The contacts may be configured in any of the selections depicted in the "Actuator Status Message" column.

"S" Contact AC	"S" Contact DC
0.5 Amps @ 125 VAC	1A @ 50 VDC, 2A @ 30 VDC (Resistive)

Actuator Status Message	Function
"CLOSED"	– valve closed "(0% OPEN)"
"OPENED"	– valve open "(100% OPEN)"
"CLOSING"	– valve closing
"OPENING"	– valve opening
"STOPPED"	– valve stopped in mid-travel
"VALVE MOVING"	– either direction
"LOCAL SELECTED"	– red selector knob in "LOCAL"
"MOTOR OVERTEMP"	– thermistor range exceeded
"OVERTORQUE"	– torque exceeded in mid-travel
"MANUAL OVERRIDE"	– actuator moved by handwheel
"VALVE JAMMED"	– valve can't move
"CLOSE TORQUE SW"	– torque switch trip at "CLOSED"
"OPEN TORQUE SW"	– torque switch trip at "OPEN"
"LOCAL STOP/OFF"	– red selector knob at "STOP"
"LOST PHASE"	– one or more of the incoming supply lost
"ESD SIGNAL"	– signal active
"CLOSE INHIBIT"	– close inhibit signal active
"OPEN INHIBIT"	– open inhibit signal active
"ANALOG IP LOST"	– 4-20 mA not present
"REMOTE SELECTED"	– red selector in "REMOTE"
"HARDWARE FAILURE"	– indication
"NETWORK CONTROLLED"	– permits relay control via DDC, FF, or other network driver
"FUNCTION"	– LimiGuard circuit protection activated
"MID-TRAVEL"	– valve position, 1-99% open
"CSE CONTROL"	– CSE station in LOCAL or STOP and controls actuator

This calculation is to compute the actuator requirements for the 120" Butterfly Valve. Values are assumed at this point. Assumptions are based on the equipment used for the Dorina valve installation. Generally the BF valve will be operated by three pieces of equipment. First a primary worm gear operator mounted on the BF valve shaft. Second a seconary worm gear operator mounted on the input shaft of the primary worm gear operator. Finally, an multi-turn electric gear operator mounted on the input shaft of the secondary worm gear operator.

Variables

$T_{valve} := 2400 in \cdot kip$ — Torqure required to operate the butterfly valve.

$R_{wgr1} := 30.75$ — Ratio of the primary worm gear operator.

$R_{wgr2} := 20.26$ — Ratio of the secondary worm gear operator.

$Eff_{wgr} := .68$ — Efficiency of worm gear reducers. The published data is for the combination of primary and secondary. This is the assumed efficiency of each individual.

$RPM_{mot} := 77$ — Motor operator speed.

Calculations

$$T1_{in} := \frac{T_{valve}}{R_{wgr1} \cdot Eff_{wgr}} \qquad T1_{in} = 114.778 \, in \cdot kip$$

Input torque requirements for the primary worm gear operator.

$$T2_{in} := \frac{T1_{in}}{R_{wgr2} \cdot Eff_{wgr}} \qquad T2_{in} = 8.331 \, in \cdot kip \qquad T2_{in} = 694.269 \, ft \cdot lbf$$

Input torque requirements for the secondary worm gear operator. This is the torque requirement for the motor operator as well

$$RPM_2 := \frac{RPM_{mot}}{R_{wgr2}} \qquad RPM_2 = 3.801$$

Output speed of the secondary worm gear operator.

$RPM_1 := \frac{RPM_2}{R_{wgr1}}$	$RPM_1 = 0.124$		Output Speed of the primary worm gear operator.
$T_{rev} := \frac{1}{RPM_1}$	$T_{rev} = 8.091$	(minutes)	Time required for 1 revolution of the primary operator. (minutes)
$T_{close} := \frac{T_{rev}}{4}$	$T_{close} = 2.023$	(minutes)	Time required to operate the butterfly valve at 1/4 turn. (minutes)

The motorized gear operator requirements are 694.26 ft-lb torque at an speed of 77 RPM.This is consistant with a Limitorque MX-85 multi-turn operator. Its capabilities are1150 ft-lb at 77 RPM.

This calculation is to check the bending and shear capacity of the wheel axle for the Dalles EFL AWS emergency closure gate.

Variables

$W_{gate} := 14.5ft$		Width of the Gate
$H_{gate} := 14.5ft$		Height of theGate
$D_{water} := 50ft$		Depth of water at Gate invert.
$s1_{axle} := 3in$		Span between wheel and first reaction.
$s2_{axle} := 24in$		Span between first and second reaction in the wheel axle.
$d_{axle} := 6in$		Diamter of the wheel Axle.
$S_y := 50ksi$		Yield strength of the axle material.
$N_{axle} := 10$		Number of wheels per gate
$Density := 62.4\frac{lbf}{ft^3}$		Density of water

Calculations

$A_{gate} := W_{gate} \cdot H_{gate}$	$A_{gate} = 210.25 \cdot ft^2$	Area of the gate
$F_{gate} := A_{gate} \cdot D_{water} \cdot Density$	$F_{gate} = 6.56 \times 10^5 \cdot lbf$	Total water force on the gate
$P_{axle} := \frac{F_{gate}}{N_{axle}}$	$P_{axle} = 6.56 \times 10^4 \cdot lbf$	Force acting on each wheel
$Ra := \frac{P_{axle} \cdot (s1_{axle} + s2_{axle})}{s2_{axle}}$	$Ra = 7.38 \times 10^4 \cdot lbf$	Reaction at plate nearest to the wheel.
$Rb := Ra - P_{axle}$	$Rb = 8.2 \times 10^3 \cdot lbf$	Reaction at plate farthest from wheel.
$V_{max} := max(Ra, Rb)$	$V_{max} = 7.38 \times 10^4 \cdot lbf$	Maximum shear in axle
$M_{max} := Ra \cdot s1_{axle}$	$M_{max} = 221.393 \cdot in \cdot kip$	Maximum moment in axle

$r_{axle} := \frac{d_{axle}}{2}$	$r_{axle} = 3 \cdot in$	Radius of axle
$S_{axle} := \frac{\pi \, r_{axle}^{3}}{4}$	$S_{axle} = 21.206 \cdot in^{3}$	Section modulus of axle
$fb_{axle} := \frac{M_{max}}{S_{axle}}$	$fb_{axle} = 10.44 \cdot ksi$	Bending stress in axle.
$A_{axle} := \pi \cdot r_{axle}^{2}$	$A_{axle} = 28.274 \cdot in^{2}$	Cross section area of axle
$fv_{axle} := \frac{V_{max}}{A_{axle}}$	$fv_{axle} = 2.61 \cdot ksi$	Shear stress in axle.
$f_{vm} := \sqrt{\left(fb_{axle}^{2} + 3 \cdot fv_{axle}^{2}\right)}$	$f_{vm} = 11.377 \cdot ksi$	Von Mises stress in axle
$FS := \frac{S_y}{f_{vm}}$	$FS = 4.395$	Factor of safety in axle

This calculation is to determine the size requirements for the cross beams for the trash rack rake

Variables

$P_w := 22.8 \frac{lbf}{ft^2}$	Pressure exterted by water flowing through the rake
$L_{rake} := 22ft$	length of the rake
$S_{beam} := 1.75ft$	Beam spacing for rake support
$S_y := 50ksi$	Yield strength of beam material.

Calculations

$W_{beam} := P_w \cdot S_{beam}$	$W_{beam} = 39.9 \cdot \frac{lbf}{ft}$	Beam load
$F_{beam} := W_{beam} \cdot L_{rake}$	$F_{beam} = 877.8 \cdot lbf$	Total force on each beam
$V_{beam} := \frac{F_{beam}}{2}$	$V_{beam} = 438.9 \cdot lbf$	Maximum shear in beam
$M_{beam} := V_{beam} \cdot \frac{L_{rake}}{4}$	$M_{beam} = 28.967 \cdot in \cdot kip$	Bending moment in beam
$F_{allow} := S_y \cdot .6$	$F_{allow} = 30 \cdot ksi$	Allowable Stress in beam
$S_{req} := \frac{M_{beam}}{F_{allow}}$	$S_{req} = 0.966 \cdot in^3$	Required Section modulus for the beam.

A section modulus this small calls for a beam that is smaller than required to support the wheel axles. As a result the trash rake beams are not stress controlled. The beam is geometry controlled and will result in a beam depth that is much stronger than necessary for the applied load.

This worksheet is to calculate the force required to rotate gate wheels against friction forces while the gate is under flow.

Variables

$H_1 := 50ft$	Depth of the bottom of the gate below water surface
$Height_g := 14ft$	Height of the gate
$Width_g := 14ft$	Width of the gate
$Num_w := 8$	Number of wheels
$Wheel_{od} := 12in$	Outside diameter of the wheel
$Wheel_{sp} := 9in$	Diameter of the spherical sliding surface of the wheel
$mu_s := .1$	Coefficient of sliding friction of the sliding surface.
$rho_{wat} := 62.4\frac{lbf}{ft^3}$	Density of water

Calculations

$A_{gate} := Height_g \cdot Width_g$ $\quad A_{gate} = 196 \cdot ft^2$ — Area of the gate

$P0_{gate} := \left(H_1 - Height_g\right) \cdot rho_{wat}$

$P0_{gate} = 2.246 \times 10^3 \cdot psf$ — Pressure at the top of the gate

$Pb_{gate} := H_1 \cdot rho_{wat}$ $\quad Pb_{gate} = 3.12 \times 10^3 \cdot psf$ — Pressure at the bottom of the gate.

$Space_{wh} := \frac{Height_g}{\left(\frac{Num_w}{2}\right)}$ $\quad Space_{wh} = 3.5 \cdot ft$ — Wheel spacing

$Force_b := Pb_{gate} \cdot Width_g \cdot Space_{wh} \cdot .5$

$Force_b = 7.644 \times 10^4 \cdot lbf$ — Force on each of the bottom pair of wheels

$M_{frictm} := Force_b \cdot mu_s \cdot \frac{Wheel_{sp}}{2}$

$M_{frictm} = 3.44 \times 10^4 \cdot in \cdot lbf$ — Max Moment required to turn each wheel under load

$F_{wheelm} := \frac{M_{frictm}}{\left(\frac{Wheel_{od}}{2}\right)}$ | $F_{wheelm} = 5.733 \times 10^{3} \cdot lbf$ | Max Force applied to wheel OD required to turn wheel

$F_{const} := P0_{gate} \cdot A_{gate}$ | $F_{const} = 4.403 \times 10^{5} \cdot lbf$ | Total constant force on gate

$F_{grad} := A_{gate} \cdot \frac{\left(Pb_{gate} - P0_{gate}\right)}{2}$

$F_{grad} = 8.561 \times 10^{4} \cdot lbf$ | Total force on gate due to gradient.

$F_{tot} := F_{const} + F_{grad}$ | $F_{tot} = 5.259 \times 10^{5} \cdot lbf$ | Total force acting on gate due to water pressure.

$F_{avg} := \frac{F_{tot}}{Num_{w}}$ | $F_{avg} = 6.574 \times 10^{4} \cdot lbf$ | Average force acting on each wheel

$M_{fricta} := F_{avg} \cdot mu_{s} \cdot \frac{Wheel_{sp}}{2}$

$M_{fricta} = 2.958 \times 10^{4} \cdot in \cdot lbf$ | Avg Moment requred to turr each wheel under load.

$F_{wheela} := \frac{M_{fricta}}{\left(\frac{Wheel_{od}}{2}\right)}$ | $F_{wheela} = 4.93 \times 10^{3} \cdot lbf$ | Avg Force applied to wheel OD required to turn wheel

$F_{frict\_total} := F_{wheela} \cdot Num_{w}$

$F_{frict\_total} = 3.944 \times 10^{4} \cdot lbf$ | Total downward force required to turn wheels under load.

For absorbing concentrated pipe movement

NOTE:
See Page 2 for Style 63 ordering information

Style 63 Expansion Joints

Dresser offers the broadest line of **Style 63 Expansion Joints** including single-end (Type 1 and Type 3 shown below), and double-end (Type 2 & 4), limited-movement types, flanged, lock coupled, or weld ends. Aggressive wear and pipe wall failure caused by fatigue of the convoluted surfaces present in rubber accordion or metal bellows types is eliminated with Dresser expansion joints. There is no need for expensive pipe loop systems.

Dresser expansion joints are built to order and are available up to 120" in diameter. Provided with rugged welded steel construction, the Style 63 is available in stainless or carbon steel, monel or other alloys for special applications. Single-end expansion joints permit up to 10" of concentrated pipe movement. Larger amounts of movement are available per application.

Special packing and lubrication requirements are custom-matched to specific fluid processes or application requirements. Temperature ratings to 800°F and pressure ratings to 1200 psi.

Available with Dresser AL-CLAD™ coating for optimum protection against aggressive water conditions and for handling brine, brackish water, coke oven gas, petroleum and other line content.

Materials of Construction

Body: AISI C1006, C1010, C1015, C1025 or ASTM A513 Carbon Steel

Follower: AISI C1012, C1021, ASTM A20 or A36 Carbon Steel

Slip Pipe: Chrome plated

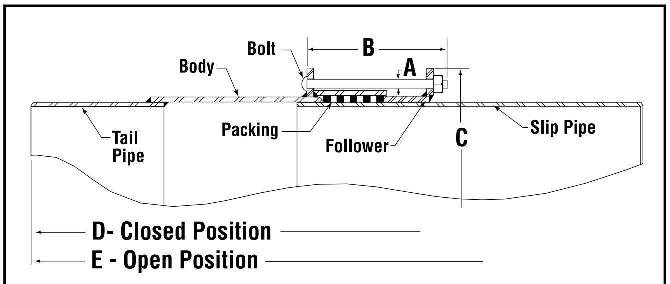
Tail Pipe: AISI C1006, C1010, C1015, C1025 or ASTM A513 Carbon Steel

Bolts & Nuts: ANSI/AWWA C111/ANSI A21.11

Packing: Standard packing is alternate rings of Buna-S and lubricating split jute

Style 63 Type 1 Sizes and Specifications

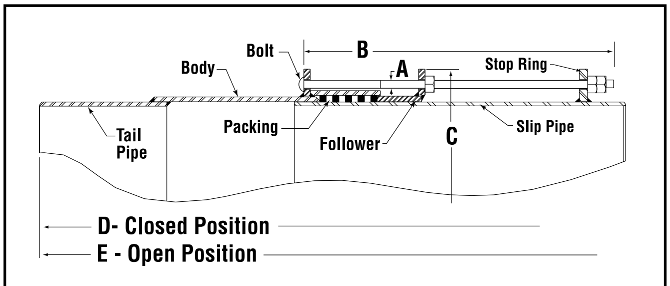
Pipe Nominal Size (In)	Outside Diameter (OD)	Bolts No./Diam. x Length (A&B)	Overall Dimensions Diam. (C)	Overall Dimensions Length (D) (E)	Weight Per Joint (Lbs)
3	3.500	4–5/8 x 11	8-1/2	CONSULT FACTORY PER ORDER	65
4	4.500	4–5/8 x 11	9-1/2		75
5	5.563	4–5/8 x 11	10-5/8		110
6	6.625	6–5/8 x 11	11-3/4		130
8	8.625	6–5/8 x 11	13-3/4		180
10	10.750	8–5/8 x 11	15-7/8		250
12	12.750	8–5/8 x 11	17-7/8		315
	14.000	8–5/8 x 11	19-1/2		340
	16.000	10–5/8 x 11	21-1/2		380
	18.000	10–5/8 x 11	23-1/2		415
	20.000	12–5/8 x 11	25-1/2		470
	22.000	14–5/8 x 11	27-1/2		525
	24.000	14–5/8 x 11	29-1/2		565



Type 1 is a single-end expansion joint permitting up to 10" of concentrated pipe movement. Standard packing consists of alternate layers of split resilient sealing rings and jute lubricating rings. Other packing for special conditions can be supplied.

Style 63 Type 3 Sizes and Specifications

Pipe Nominal Size (In)	Outside Diameter (OD)	Bolts No./Diam. x Length (A&B)	Overall Dimensions Diam. (C)	Overall Dimensions Length (D) (E)	Weight Per Joint (Lbs)
3	3.500	4–5/8 x 24	8-1/2	CONSULT FACTORY PER ORDER	80
4	4.500	4–5/8 x 24	9-1/2		90
5	5.563	4–5/8 x 24	10-5/8		125
6	6.625	6–5/8 x 24	11-3/4		155
8	8.625	6–5/8 x 24	13-3/4		205
10	10.750	8–5/8 x 24	15-7/8		285
12	12.750	8–5/8 x 24	17-7/8		350
	14.000	8–5/8 x 24	19-1/2		385
	16.000	10–5/8 x 24	21-1/2		430
	18.000	10–5/8 x 24	23-1/2		470
	20.000	12–5/8 x 24	25-1/2		530
	22.000	14–5/8 x 24	27-1/2		590
	24.000	14–5/8 x 24	29-1/2		635



Type 3 is a single-end expansion joint equipped with a limited movement feature to limit the maximum amount of pipe withdrawal. Slip pipes are regularly furnished for Type 3 expansion joints.

The New Timken® Spherical Roller Bearing

TIMKEN
Where You Turn

Timken's spherical roller bearings are available with stamped steel or machined brass cages.

Designs: *EJ/EM/EMB*

Common Applications:

- *Casters (metal mills)*
- *Conveyors*
- *Felt and Wire Rolls (paper)*
- *Gear Drives*
- *Shaker Screens*

Top Performance, Longer Life and Cooler Running

For the new Timken® spherical roller bearing top performance is in the details. With our one-of-a-kind slotted-cage, unique internal geometries and enhanced surface textures, our spherical roller bearing line reaches the highest performance levels in the industry.

In fact, this product offers an 18 percent increase in capacity resulting in a 75 percent design life improvement over our former spherical roller bearing offering. Engineered for enhanced durability, the new spherical roller bearing from Timken also runs cooler and has a longer design life – for greater reliability.

Innovative Design

Advanced Internal Geometries

- Optimized internal geometries balance the need for increasing load-carrying capability while lowering operating temperatures.
- Axial roller guidance improves lubricant distribution and positive roller guidance, which translates into lower operating temperatures and improved performance.
- Circumferential roller guidance generates positive hydrodynamic contact, contributing to better roller/cage interaction.

Surface Finishes

- Improved surface finishes help lower operating temperatures and increase speed capabilities.

Cage Options

Stamped Steel Cage (EJ)

+ Two-piece land riding
+ Surface hardened
+ Slotted for more efficient lubrication distribution
+ Ideal for increased speeds

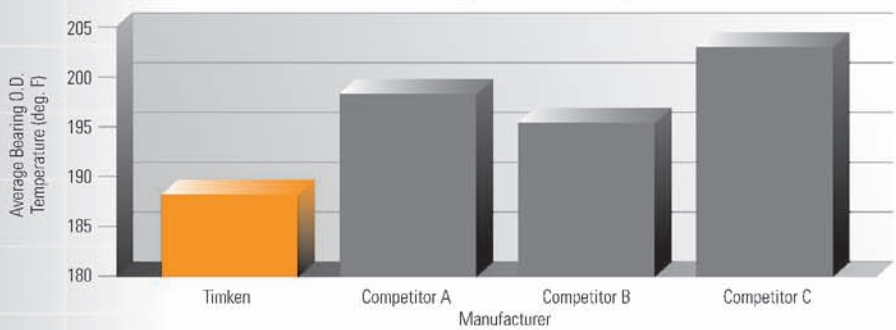
Machined Brass Cage (EM/EMB)

+ Type EM is roller riding
+ Type EMB is land riding
+ Ideal for extreme operating environments

Cooler Than the Competition

Timken spherical roller bearings are designed to run cooler in heavy-duty applications subject to high temperatures. These bearings are engineered for maximum load capacity and are able to support combinations of radial and axial loading, even under significant misalignment conditions.

Actual Average Bearing O.D. Temperature Comparison: 22322 Spherical Roller Bearings



The bearing outside diameter (O.D.) temperature shown here is an average of the temperatures measured at the bearing O.D. of four competing bearings included in the test. Timken spherical roller bearings ran up to 14°F cooler than the competition.

From Design to Maintenance

Timken spherical roller bearings allow manufacturers and end-users to build and operate leaner, more reliable equipment while reducing their total cost of operation. Our power-dense bearings allow original equipment manufacturers to downsize their designs and still improve customer satisfaction. For operators, high bearing quality and reliability means less maintenance, while cooler operating temperatures help lengthen service life. It all adds up to greater uptime and a positive impact on your bottom line.

The Timken Difference

The Timken brand stands for high quality and outstanding performance. Using our capabilities in bearing technology, manufacturing, application knowledge and engineering, we provide our customers with smart, cost-effective friction management and power transmission solutions that improve total system performance and help outperform the competition. We also strive to deliver and excel in the moments that build your trust and confidence in our products.

Designed to Last

Our global engineering team collects performance requirements from around the world and designs bearings to meet the specifications our customers demand.

High Material Quality

Timken is the only premium bearing manufacturer in the world to produce clean, high-alloy steel. Our steel manufacturing knowledge helps ensure quality materials are used in our bearings.

Manufacturing Excellence

Timken worldwide quality standards are implemented in every manufacturing facility, so each Timken® bearing meets the same performance standards – no matter where in the world it is manufactured.

Timken Experts are Your Experts

Every Timken bearing is backed by our team of experts, providing you with the industry's best design, application and 24/7 field-engineering support.

A Full Range of Products

Timken continues to expand its line of spherical bearings to meet customer size and configuration demands. With our wide range of tapered, cylindrical and spherical bearings, you can make Timken your single-source bearing provider.

Timken Spherical Bearing Nomenclature

2	23	40	K	EJ	W507	C08	C3

EJ → Cage Type

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Bearings • Steel •
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The Dalles East Fish Ladder Auxiliary Water Backup System

90 Percent Design Documentation Report

APPENDIX F

Geotechnical

US Army Corps
of Engineers®
Walla Walla District

90 Percent (Preliminary)

THE DALLES LOCK AND DAM
Columbia River

East Fish Ladder
Auxiliary Water Supply Backup System

January 2014

Preliminary Geotechnical Data Report

FOR OFFICIAL USE ONLY

ACRONYMS AND INITIALISMS

ASTM	American Society for Testing and Materials
AWC	auxiliary water conduit
AWS	auxiliary water supply
AWSC	auxiliary water supply chamber
cfs	cubic feet per second
DDR	Design Documentation Report
EDR	Engineering Documentation Report
EFL	east fish ladder
EM	Engineering Manual
ER	Engineering Regulation
FAC	fish lock approach channel
FCC	fish collection channel
fps	feet per second
fps	feet per second
ft	feet
FTC	fish transportation channel
GDR	Geotechnical Data Report
gpm	gallons per minute
HDC	Hydroelectric Design Center
hp	horsepower
JBS	juvenile bypass system
kips	kilo pounds
kV	kilovolt
kVA	kilovolt-ampere
kW	kilowatt
MCE	Maximum Credible Earthquake
MDE	Maximum Design Earthquake
msl	mean sea level
NWP	USACE, Portland District
NWW	USACE, Walla Walla District
O&M	Operations and Maintenance
OBE	Operating Basis Earthquake
PCF	pounds per cubic foot
PGA	peak ground acceleration
psi	pounds per square inch
V	volt
UFC	Unified Facilities Criteria
USACE	U.S. Army Corps of Engineers

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Attachment A	–	Plan View of Conduit Alignment
Attachment B	–	Profiles of Conduit Alignment
Attachment C	–	Information Pages:
		Geologic Sections
		Boring Plans
		Boring Logs
		Structures
		Utilities

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CHAPTER 1 – PURPOSE AND INTRODUCTION

1.1 PURPOSE

Auxiliary water supply (AWS) systems augment flows at fish ladders, which provide for better fish attraction. Providing backup auxiliary water for the East Fish Ladder (EFL) is critical to the overall success of adult fish passage at The Dalles Lock and Dam.

A variety of backup AWS systems have been considered since the 1990s, though none has been constructed. In 2008 a failure risk analysis report for the fish turbines – key components of the existing AWS system – confirmed that after more than 50 years in service, the probability of a failure within 10 years is elevated. This elevated risk of turbine failure, and the potential consequences for fish migration provide the impetus for construction of a backup auxiliary water supply system.

The planned AWS Backup System consists of a gravity flow conduit that can provide 1,400 cfs of water to the East Fish Ladder when the existing AWS is out of service. The conduit will be a large-diameter steel pipe. It will extend from its inlet in the forebay, through the dam; then underground across the main access road and a small parking area; under the EFL; across the junction pool, to its discharge point in the end pool of the existing AWS conduit. The water then flows back under the partition wall and upwells into the junction pool, and then drains to the river.

1.2 SCOPE

This Preliminary Geotechnical Data Report (GDR) documents available surface and subsurface information used for development of geotechnical recommendations presented in the 90% EDR for the planned system.

CHAPTER 2 SITE AND PROJECT DESCRIPTION

2.1 EXISTING SITE FEATURES

2.1.1 The Dam

The first 50 feet of the AWS backup system will extend through an 11 ft diameter tunnel mined through the concrete of Monolith 5 of the East Non-Overflow Dam (ENOD). For constructability, the tunnel will be near surface grades at the downstream face of the monolith.

2.1.2 The Upstream Portion of the EFL

The upstream portion of the EFL is an above-grade concrete structure that extends parallel to the dam and is overhead near Sta 0+55. The alignment is approximately centered between monolith expansion joints, and this coincides with being nearly centered between the EFL supports. The south edge of the EFL creates an overhead restriction approximately 30 feet above the ground surface, near Elevation 141 ft. Plan information identifies this portion of the EFL with a structure index of “M.”

2.1.3 Access Road, Railroad, and Parking Area

The buried portion of the conduit extends across the main access road, which has a railroad track along its centerline, and the paved parking area to the southwest. Construction of this portion of the alignment will affect many existing utilities and several issues need to be clarified:

- A portion of the existing railroad will be removed for excavations to install the conduit. The affected portion of railroad will not be restored.

- Based on Plan information, excavations will encounter service air and water lines, as well as an 8 inch diameter water line. These, and other miscellaneous pressure lines or utilities will need to be repaired, tested, and restored to service.

- Plan information indicates a 4 inch diameter concrete sewer pipe will be encountered near Sta 0+70. During a site visit, what appeared to be a 6 inch diameter pvc sewer cleanout was observed, and it appears to be coincident with the line indicated on Plans. (It seems unlikely that any pvc was used for drain pipe in 1957.) If these gravity drains are relatively shallow where the conduit alignment crosses, it may be possible to lower the conduit to allow the gravity flow sewer drain to be simply repaired.

- Plan information also indicates a 2 inch diameter pressure sewer pipe will be encountered. It appears likely that temporary facilities will be needed to preserve sewer system operation during construction.

- Plans also show the network of storm drains in the paved parking area. The westernmost drain will be isolated from the network by the conduit. A new drain line and discharge point may be needed, or perhaps surface grades can be reconstructed to eliminate the storm drain.

2.1.4 The Downstream Portion of the EFL

Near Sta 2+00, the conduit alignment turns south, and extends under the portion of the EFL that identified on Plans with a structure index of “K.” Design, construction methods, and bids need to consider all of the following:

- The overhead clearance along the support frames is approximately 14 feet. The elevation of the restricting concrete surface is near Elevation 124 ft.
- There is approximatley 25-feet between pairs of vertical supports. Excavations for the wye and downstation pair of conduits will be relatively wide. The EFL could be obstacles for excavation operations. Additionally, to limit horizontal forces on the columns, it will not be permissible to excavate more than 1 column diameter lower on the trench side/inside of the columns, than on the outside.
- Surface evidence indicates 8 to 10 inches of surface subsidence has occurred in fill under the fish ladder. This area is near the junction pool wall and while it may have been backfilled with particular material that should be well suited to the application, it is almost certain the fill is poorly compacted. The total depth of fill appears to exceed 25 to 30 feet in this area, so poorly compacted fill extends well below anticipated depths of excavation. While the conduit represents a substantial decrease in soil loads (even full of water), explorations are needed to confirm there is no risk that the addition of water can cause ground subsidence that could affect the pipe alignment, welds, wall penetrations, or surface grades.

2.1.5 After the AWS Conduit

The AWS Backup System conduit discharges into the pool at the end of the AWS conduit. Water in that pool drains under the partition wall and upwells into the junction pool. From there, it flows to the fish ladder inlet.

2.2 PLANNED CONDUIT FEATURES

The planned AWS Backup System consists of a 10 ft diameter, gravity flow conduit that can provide 1,400 cfs of water to the East Fish Ladder when the existing AWS is out of service. The conduit will extend from its inlet in the forebay, through the Dam; then underground across the main access road and a small parking area; under the East Fish Ladder (EFL) to a wye, where it splits into two 7.5 ft diameter pipes; and across the junction pool where it discharges in the existing AWS conduit. The alignment is shown in the Plan View of Conduit Alignment, Attachment A.

2.2.1 Approximate Alignment

The Plan View of Conduit Alignment presented in Attachment A shows stationing. This stationing is approximate and is based on the conduit alignment used for hydraulic design. The alignment used for hydraulic design continued beyond the wye along the left 7.5 ft diameter pipe, whereas the alignment in Attachment A extends between the pipes. It will be necessary for the PDT to establish a single alignment to facilitate further design.

2.2.2 Features Along the Conduit

- Sta 0+00 – The planned Inlet Gate for the conduit will be located under water in the forebay, against the upstream face of the Monolith. The gate will be closed, except for testing or during emergencies. It will seal against the concrete of the dam, and will be operated from the top of the dam, using a mobile crane.

- Sta 0+50 – A secondary closure will be provided by a hydraulically actuated butterfly valve that will be attached to the downstream face of the Monolith.

- Sta 0+55 – Downstation of the butterfly valve, vertical bends will transition the conduit to approximately 2 feet below grade.

- Sta 0+60 to Sta 0+90 – The conduit extends underground, approximately 2 feet below grade, across the alignment of the existing main access road, which has a rail line extending along its centerline. Several issues require consideration:

    - Portions of the railroad removed for construction will not be replaced.

    - With only 2 feet of cover, conventional traffic loads, including HS-20 truck traffic, is not expected to cause damage to the steel conduit. However, extreme loads caused by heavy equipment transport (e.g. transformers or turbine runners) could cause excessive surface deflections that could damage pavements. If the presence of the conduit contributes to a more flexible pavement surface, minor deflections due to traffic could also contribute to abbreviated pavement life. Placement of a CDF (controlled density fill) cap over the conduit in roadway areas may be appropriate to limit deflections and extend pavement life.

    - It is expected that cranes of only moderate size could, during a pick, create unacceptable surface deflections where outriggers are on the surface above the conduit. Point loads of this type may be acceptable provided the loads are analyzed and their application is monitored. The effect of this requirement will be a crane exclusion zone along the alignment.

- Sta 0+90 – The buried conduit extends southeast, beneath the existing parking area, toward the fish lock approach channel.

- Sta 2+00 – The alignment turns south and extends under the EFL.
- Sta 2+20 – Under the EFL, a wye connection transitions from a single 10 ft diameter pipe to a pair of 7.5 ft diameter pipes. The transition preserves the vertical alignment of pipe centerline, not its flowline.
- Sta 2+50 – The conduits penetrate the east wall of the junction pool.
- The end of the excavation under the EFL will also serve as the construction access and staging area for the pipe extending across the junction pool. Workers, round steel pipe, and equipment will be crowded into the available space at the two wall penetrations. Trench safety and fall protection safety issues will require simultaneous attention.
- Sta 2+80 – The conduits penetrate the west wall of the junction pool and vertical bends direct discharge downward, into the end of the existing AWS conduit. (The existing AWS conduit is a rectangular concrete channel, not a pipe.)

CHAPTER 3 SUBSURFACE CONDITIONS

3.1 GEOLOGIC CONDITIONS

3.1.1 General Geology

The Dalles Lock and Dam is located at the western edge of the Columbia Basin, in the eastern foothills of the Cascade Mountain Range. Geologic conditions are controlled by Columbia River Basalts (which extend downstream all the way to the Pacific Ocean) and the Missoula Floods (which occurred in the Pleistocene some 13,000 to 17,000 years ago). These floods involved hundreds of feet of water, carried a tremendous volume of sediment, and scoured the river channel leaving channeled scabland topography.

The Columbia River Basalt Group consists of multiple flow-on-flow layers with little or no intervening soil horizons. The basalt at the site includes Grande Ronde and Wanapum basalt groups. The foundation of the dam is constructed on Grande Ronde basalt.

Individual basalt flows range from 60 to 100 feet in thickness. Typically, the uppermost zone of a basalt flow cools and solidifies while the material is still moving. The solidified crystalline rock is fractured and disturbed, creating a layer of breccia. Breccia can also form along the bottom surface of a flow, where contact with the ground accelerates cooling and the solidified material is disturbed by flow. Where the hot interior mass of the flow cools after the flow stops, crystalline microstructure and shrinkage cracking create the easily recognized columnar basalt zones.

Columnar basalts are typically more dense, more erosion resistant, and less permeable than breccias. Where fractures are closed or completely infilled, basalt can be quite strong. In contrast, breccias typically have disturbed particles with closely spaced fractures and this reduces strength, as well as erosion resistance. Gas bubbles that form as molten rock solidifies create vesicles in the solid rock and these contribute voids that directly reduce rock mass density and strength. Vessicular basalt and breccia can be hard, resistant bedrock, but this usually involves secondary mineralization or other processes that fill cracks and voids.

3.1.2 Seismicity

There are several faults mapped at, near, and crossing beneath the Dam. Three faults have been identified at the site. Displacement on these faults range between 50 to 300 feet. The faults have brecciated the rock forming weak zones where the river has eroded deep channels. These faults include:

1.) Three Mile Rapids fault located immediately downstream of the navigation lock,

2.) Signal Butte fault located south of the powerhouse, and

3.) Big Eddy fault, which passes beneath the closure dam.

4.) Additionally, there are several minor faults and shear zones throughout the foundation. Most are low-angle faults with displacements of a few inches and no fault breccia.

Complex uplift, shearing, and faulting are described and discussed in the 2013 Seismic Safety Review, which is 95% complete. Ground motions and other design considerations for the site are also presented.

3.1.3 Bedrock at the Site

The regulated river hides the scabland topography the dam was built on. In March of 1957, when the Dam was completed and the spill gates closed, Celilo Falls – 13 miles upstream – was submerged within hours. Almost all of the exposed rock of what was “the Dalles of the Columbia” remains submerged. Two prominent features of the Dalles were the “Short Narrows” and the “Long Narrows.” The photos below show the eroded scabland basalt surface at the upstream end of the Long Narrows, which ends just upstream of the damsite.

Mt Hood in the background confirms the camera was pointed southwest. What appear to be buildings in the distance would have been portions of the Town of The Dalles, so the view looks across the damsite.

The Dam was built on rugged, eroded basalt of the Grande Ronde formation. The lowland areas now submerged in the forebay were, “…fluted, channeled, and potholed surfaces that formed long anastomosing tracts of scabland separated by islands of softly rounded hills of windblown sand.” The “anastomosing tracts” are contiguous areas of the rock surface within a network of incised erosion channels and potholes. It appears erosion in the river channel cut bedrock to the elevation of a resistant layer in the flow basalt, exposing its relatively flat top surface.

Rare catastrophic flood flows also carved the complex network of channels and scabland topography – and the Long and Short Narrows – by a combination of extreme erosion conditions and zones of variable erosion resistance in the bedrock layers. Exposed breccia and other less resistant materials would have been stripped away. The resulting topography is characterized by the pattern of partially infilled channels with steep sideslopes. It seems likely that infilled erosion channels were exposed in foundation excavations, though this is speculation.

3.1.4 Bedrock Test Data

The Dam was constructed on basalt bedrock. Results from unconfined compressive strength tests vary from 6 to 25 ksi with an average of 15 ksi.

3.1.5 Soil Conditions

3.1.5.1 General

The Missoula floods created a channeled scabland topography along the river. During receding phases of each flood, scattered irregular deposits of sand, gravels, and boulders were left behind in protected areas.

While zones of cobbles, sandy gravel, and boulders are common – either alluvial or as localized talus – surficial soils are predominantly alluvial and fluvial sands and silty sands. Some of the fine sand deposits are aeolian (windblown). There are also minor amounts of low plasticity sandy materials. Ashfall, and other materials deposited prior to catastrophic floods were scoured out.

3.1.5.2 Riverbed Soils

The irregularly incised river channel still contains boulder, cobble, gravel, and sand deposited as Plestocene floods receded. Generally, these materials would be expected in deeper erosion pits and less active areas along the river. The bedload materials along the river are expected to be dominated by silty sand with gravel.

3.1.5.3 Upland Areas

The right bank slopes upward to the north, away from the river, at a net slope on the order of 5%. Steeper slopes of 15% to 50% occur at localized rock outcrops. The steepest areas appear to be along the River. Much of the surface is capped with more than 5 feet of sandy loam and fine to medium sand over the underlying bedrock.

The slopes on the left bank are typically steeper, at 5% to 25%. There are more rock scarps and outcrops are more prominent, taller, and steeper, with some vertical rock faces. In general, soils are less than 5 feet in thickness.

3.1.5.4 Site Soils

Site soils are fill that is expected to vary in depth from 15 to more than 30 feet in depth. The depth to bedrock increases with distance away from the monolith and drops steeply before the alignment extends under the East Fish Ladder. Based on limited information, the fill is considered sand and gravel with some cobbles. Construction debris; including wood, metal, and concrete debris; and broken stone waste materials could be present, but are not expected.

Excavations for the pipe will extend into the wall backfill zone of the junction pool wall. Only sand and gravel is expected in wall backfill, and crushed rock could be encountered as well. Boulders and debris are not expected within tens of feet of retaining walls or fish ladder support columns, though this is speculation.

Additional explorations are needed to confirm soil conditions and depth to bedrock along the pipe alignment.

3.1.6 Subsurface Geometry

Based on available Plan information and the preliminary alignment, it appears the trench excavation along the 10 ft diameter conduit will be 13 feet in depth. The overburden soils are expected to be granular materials 6 to 10 feet in depth. The remainder of the excavation will be in dense, resistant basalt bedrock.

Beyond Sta 2+20, the bedrock surface slopes down and bedrock will not be encountered in excavations. Information from geologic cross sections, bore hole logs, and Plans, Profiles of the Conduit Alignment were developed and are presented in Attachment B.

CHAPTER 4 INFORMATION NEEDS

4.1 GENERAL

Substantial amounts of information can be gleaned from available Plans. Location and geometry information appears reliable. Obviously, there is a risk that changes, modifications, or deterioration could invalidate original construction as-built information, though this is not expected to be an issue.

Plan information relevant to subsurface material types and properties is both less reliable, and less useful than location and geometry information. Plan information about fill on the site includes several material descriptors that are probably both accurate and useful. Crushed stone, bituminous surface treatment, base, granular topping, and other types of fill were controlled products placed with specific Plan location and geometry. Embankment – another descriptor on the Plans – is certainly accurate, but hardly useful for evaluating material properties.

Basing geotechnical recommendations on soil conditions inferred from loads at the site and vague soil descriptions from the 1950s does not meet the standards of engineering practice in this area. Additional explorations are needed to identify the fill soils at the site. Additional site information is needed to confirm assumptions and evaluate conditions to address specific construction issues.

4.1.1 Assumptions About Fill

Material properties and recommendations presented in the 90% EDR were based on assumptions and inferred information that should be confirmed.

4.1.1.1 Granular Materials Are Expected

For several reasons, silty soils are not expected in fill along the conduit alignment:

- Granular materials with more than 10% fines (silts or clays) do not provide good drainage. This would be undesirable in fill at both ends of the conduit alignment. At the downstream end, wall backfill should provide good drainage. At the upstream end, the fill is subject to heavy traffic loads for the access road, and especially the railroad.
- Descriptions of the geology at the site include native soil caps across portions of the damsite. These materials are described as windblown silt, though the geologic map (Attachment C) appears to classify the material as fine sand. In any case, geologic mapping appears to indicate exposed bedrock rather than sand at the surface, so native soils are not expected.
- Concrete production and material processing to create zoned fill materials for use in earthen dam sections would have yielded vast quantites of sand and gravel that would perform well at the site.

4.1.1.2 Existing Fill Will Provide Adequate Support

Wall backfill at the junction pool (under the EFL) is expected to be gravel that drains well. Based on 8 to 10 inches of surface subsidence in this area, the materials were poorly compacted. It is worth noting that this is not consistent with the complete lack of subsidence evidence along the fish lock approach channel. (The several concrete valve control vaults would act as effective telltales.)

The wye and the 7.5 ft diameter conduit segments will be constructed on more than 15 feet of the poorly compacted fill. Explorations are needed to identify the material type, determine its density, and verify that additional settlements are not expected.

Construction waste or debris, boulder fill, concrete debris, and refuse are not expected. Similarly, subsurface contamination is not expected. Explorations are needed to confirm conditions.

4.1.2 Bedrock Characterization

It is likely the bedrock that will be encountered in the trench for the 10 ft diameter conduit can be excavated with a large track-mounted excavator. A combination of a hydraulic ram and specialized teeth on a rock bucket should be effective, if slow, for rock breakup and removal. However, based on site geology, near surface bedrock could be hard, intact rock that could be quite difficult to excavate with conventional equipment.

The excavatability of the bedrock needs to be evaluated. Without additional information, estimates and schedules must be based on specialized methods that are both costly, and relatively slow. For the 90% EDR, rock breakup was based on use of drilled holes and expansive grout. This is a bidability issue and substantially affects how Contractors schedule and bid the project.

4.1.3 Groundwater Conditions

A 14 inch diameter well and several smaller monitor wells were constructed along the alignment during dam construction. Additional research is needed to determine whether soil or groundwater information is available.

4.1.4 Additional Civil Design Issues

- The conduit will interfere with gravity sewers. Utility locate surveys need to include the sanitary sewer lines. It appears project design will need to incorporate facilities for preserving operation of the sewer system during construction.

- It also appears one of the existing storm drain inlets will be cut off from the storm drain system. This will require evaluation during design.

- Groundwater elevations and the potential for uplift forces on the pipe need to be evaluated. Information from monitor wells should be evaluated and the need for new monitor wells should be considered.

- The wye will need some kind of drain to prevent water ponding at the transition to the 7.5 ft diameter pipe.

- Where traffic crosses over the pipe, deflections due to increased flexibility of the subgrade could result in abbreviated pavement life. Additional analyses is needed to confirm the value of a CDF zone in the fill across the top of the conduit.

4.2 RECOMMENDED EXPLORATIONS

4.2.1 Test Pits

Test pit explorations are needed to explore overburden soils; expose bedrock along the alignment; and directly evaluate its excavatability using a large track-mounted excavator. At a minimum, the performance of a hydraulic ram and a rock bucket should be evaluated.

It appears that only 1 or 2 pits will be practicable.

4.2.2 Borings

Conventional hollow-stem auger borings are needed to explore the deep fill beneath the fish ladder. Conventional SPT testing is an obvious choice for confirming the wall backfill at the junction pool is dense compacted gravel and additional settlements are not expected – especially the deeper materials below the planned trench depth.

If geophysical surveys will *not* be completed, then borings should be completed along the alignment at relatively close intervals to explore conditions and determine the depth to bedrock. Some coring of bedrock should also be completed to explore conditions and extract samples for testing. Conventional unconfined compression test results can be correlated to different measures of excavatability using the Caterpillar Performance Handbook.

4.2.3 Geophysical Surveys

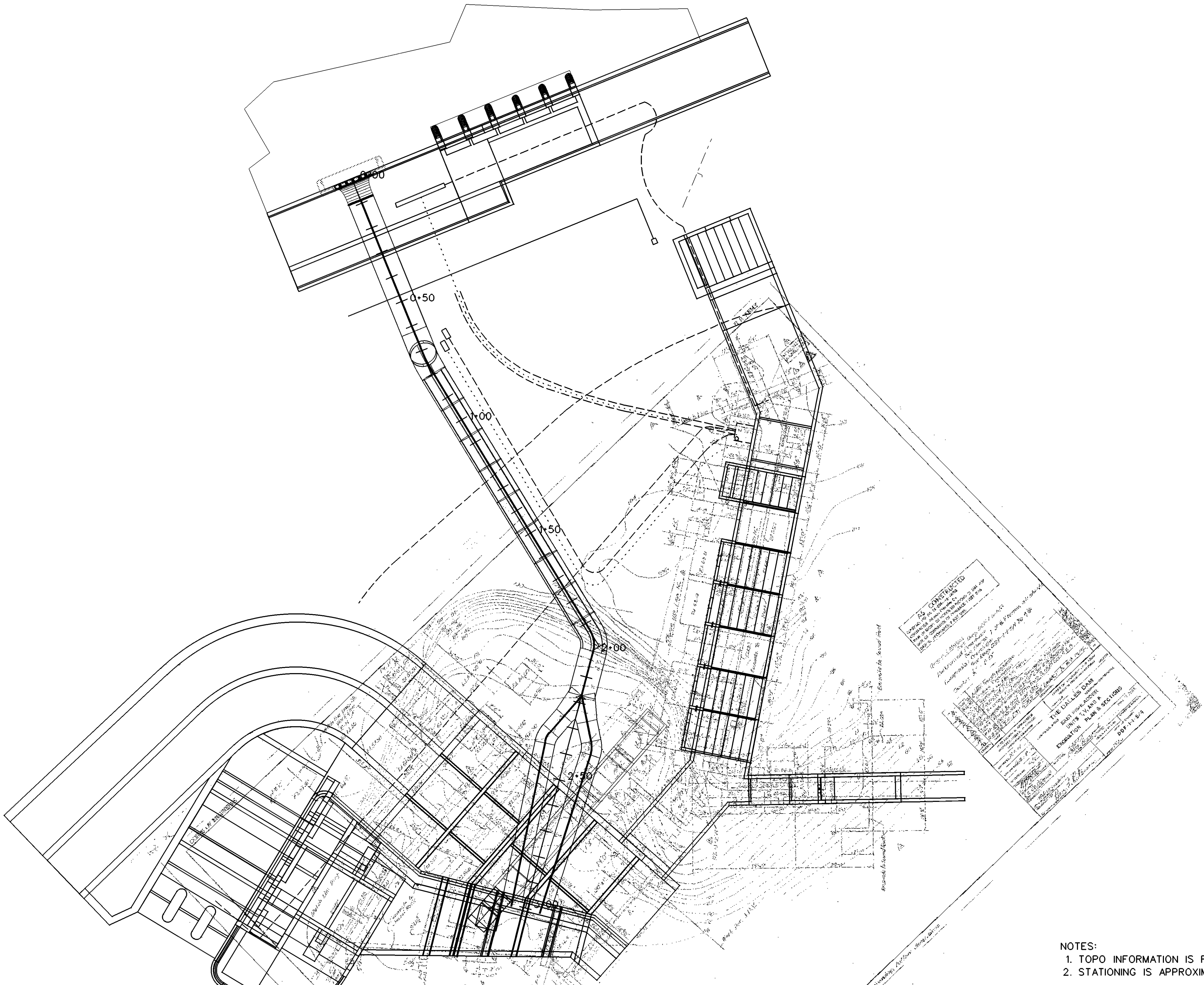
Conventional refraction seismic geophysical surveys should be completed to map subsurface velocity profiles and the depth to bedrock along the alignment. The shear wave velocities can also be correlated with measures of excavatability using the Caterpillar Performance Handbook.

The Dalles EFL AWS Backup System

Preliminary Geotechnical Data Report

ATTACHMENT A

Plan View of Conduit Alignment



A SITE PLAN WITH AS-BUILT SURFACE CONTOURS

0' 20' 40'

NOTES:
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2. STATIONING IS APPROXIMATE

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WALLA WALLA, WASHINGTON

DESIGNED BY: G4EDDDFP
DWN BY: G4EDDDFP
CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE
PLOT DATE: 08-JAN-2014
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

PLAN VIEW OF
CONDUIT ALIGNMENT
WITH AS-BUILT TOPOGRAPHY

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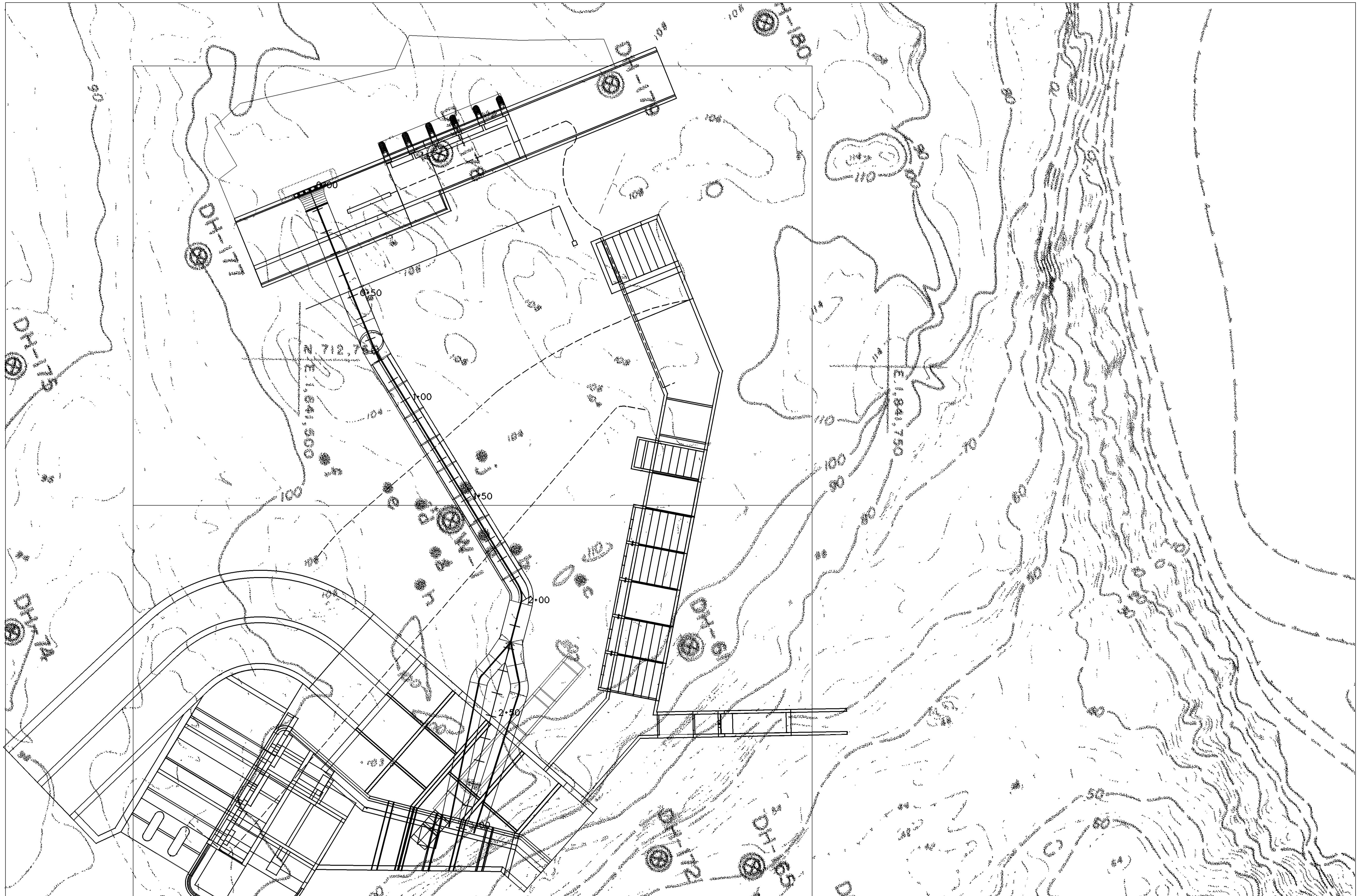

A SITE PLAN WITH AS-BUILT SURFACE CONTOURS

0' 20' 40'

NOTES:
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DWN BY: G4EDDDFP	CKD BY: CKD BY	SOLICITATION NO.: SOLICITATION NUMBER
SUBMITTED BY: SUBMITTER'S NAME		CONTRACT NO.: CONTRACT NUMBER
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THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

PLAN VIEW OF
CONDUIT ALIGNMENT
WITH FIO TOPOGRAPHY

SHEET IDENTIFICATION
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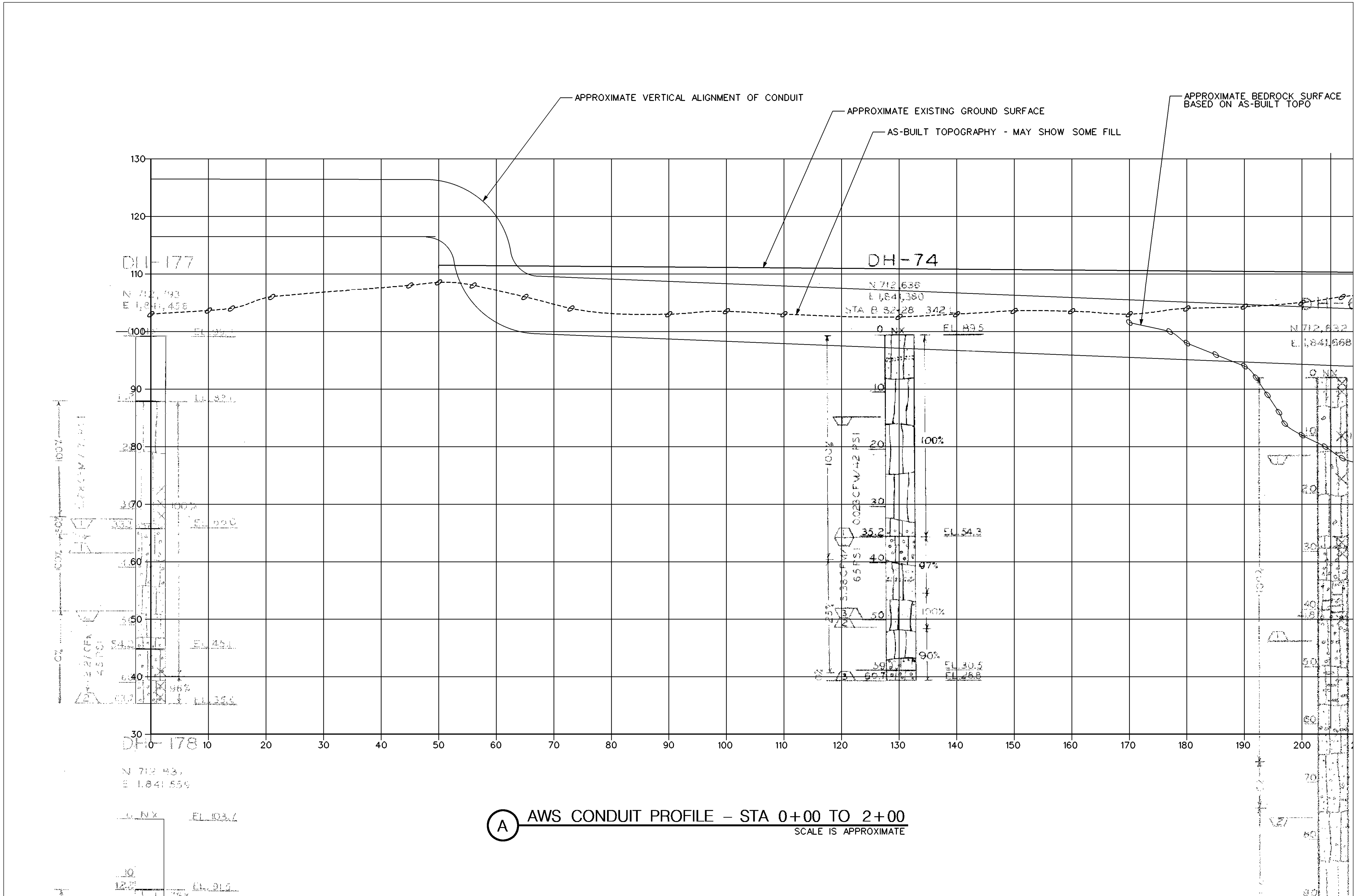
The Dalles EFL AWS Backup System

Preliminary Geotechnical Data Report

ATTACHMENT B

Profiles of Conduit Alignment



A AWS CONDUIT PROFILE – STA 0+00 TO 2+00

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DWN BY: MRS
CKD BY:
SUBMITTED BY: MRS
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THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

PROFILES OF
CONDUIT ALIGNMENT
WITH BORINGS

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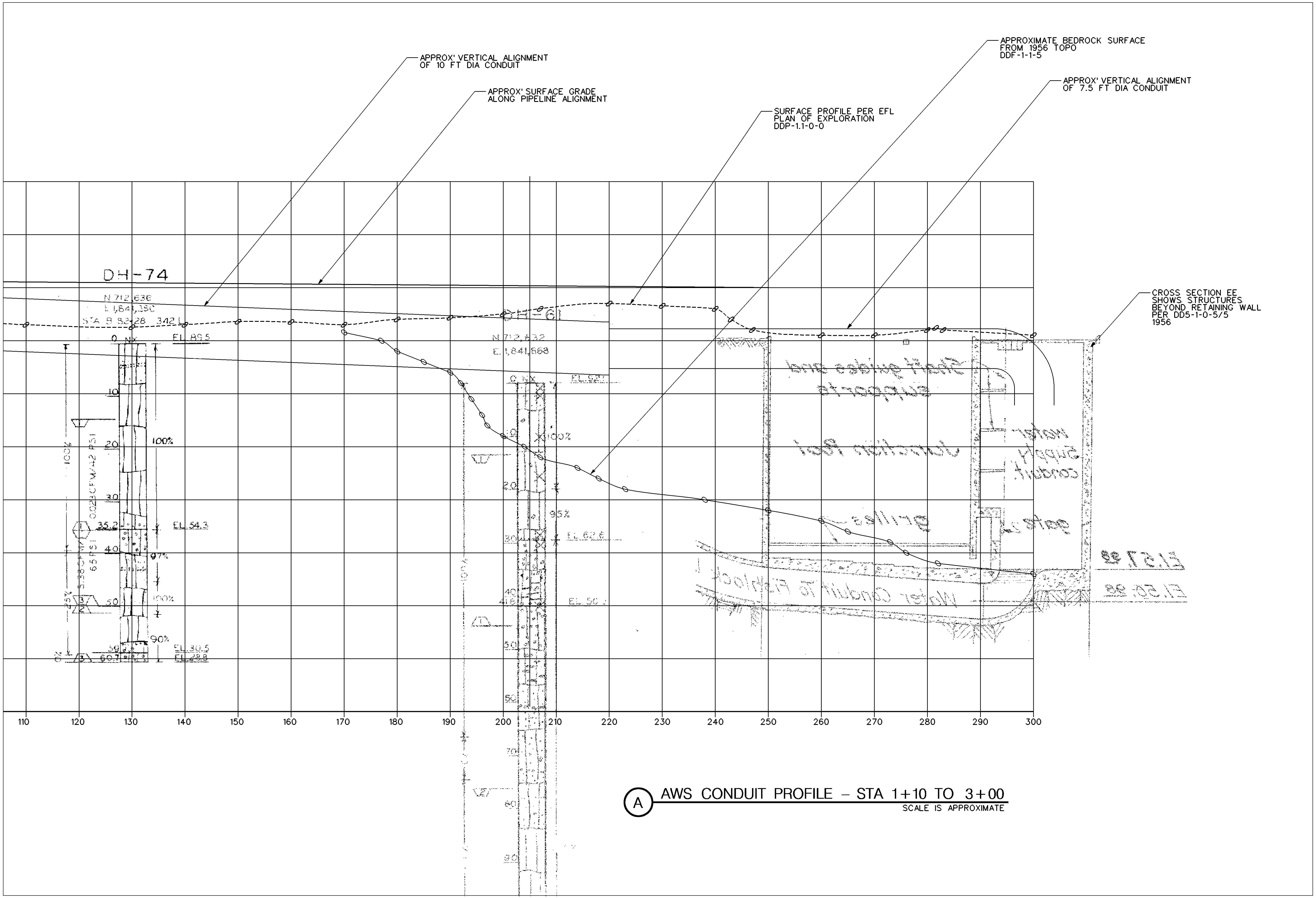

A AWS CONDUIT PROFILE – STA 1+10 TO 3+00

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WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

PROFILES OF CONDUIT ALIGNMENT WITH BORINGS

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B-002

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The Dalles EFL AWS Backup System

Preliminary Geotechnical Data Report

ATTACHMENT C

Information Pages:

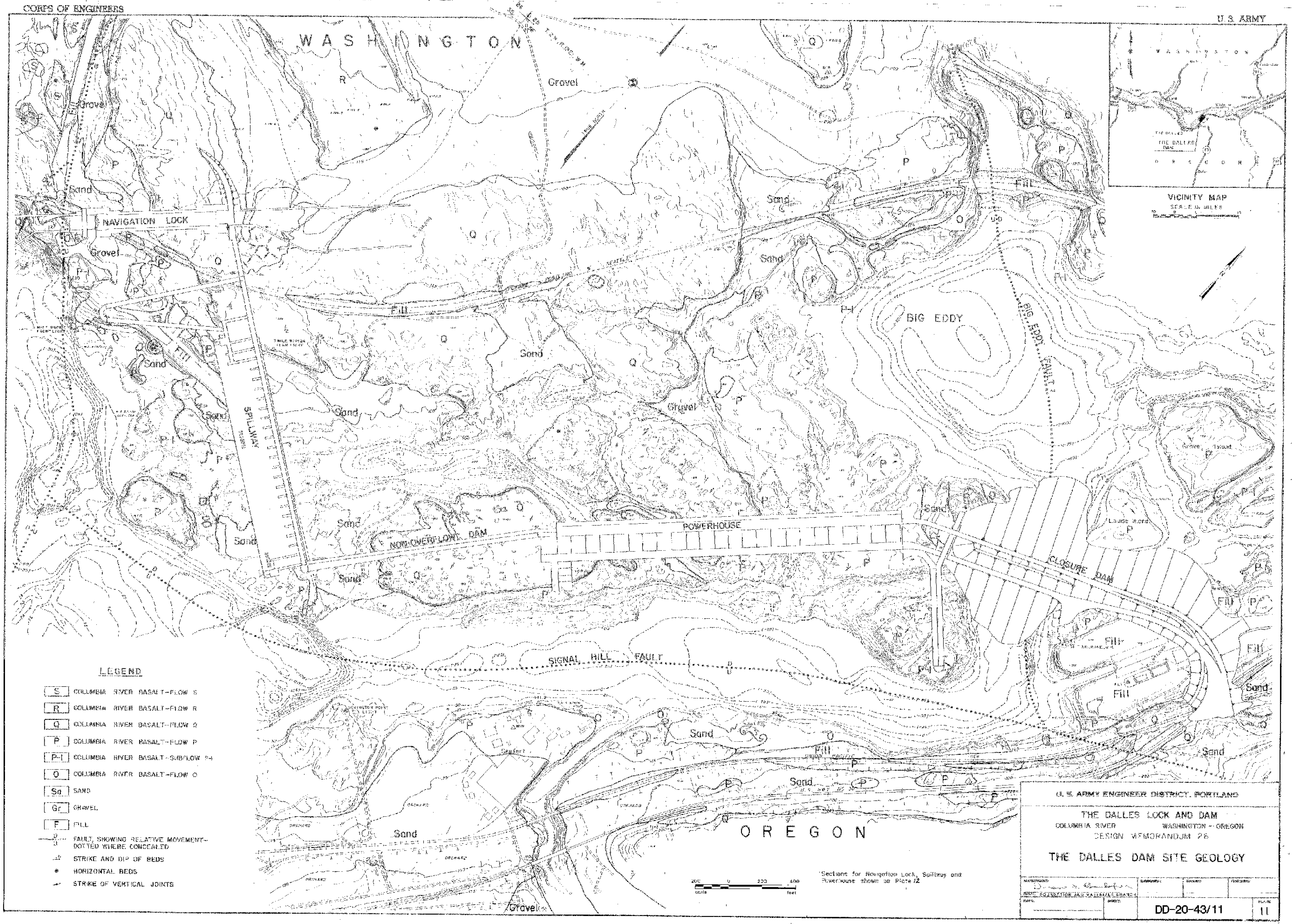
Geologic Sections

Boring Plans

Boring Logs

Structures

Utilities



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THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

THE DALLES
DAM SITE GEOLOGY

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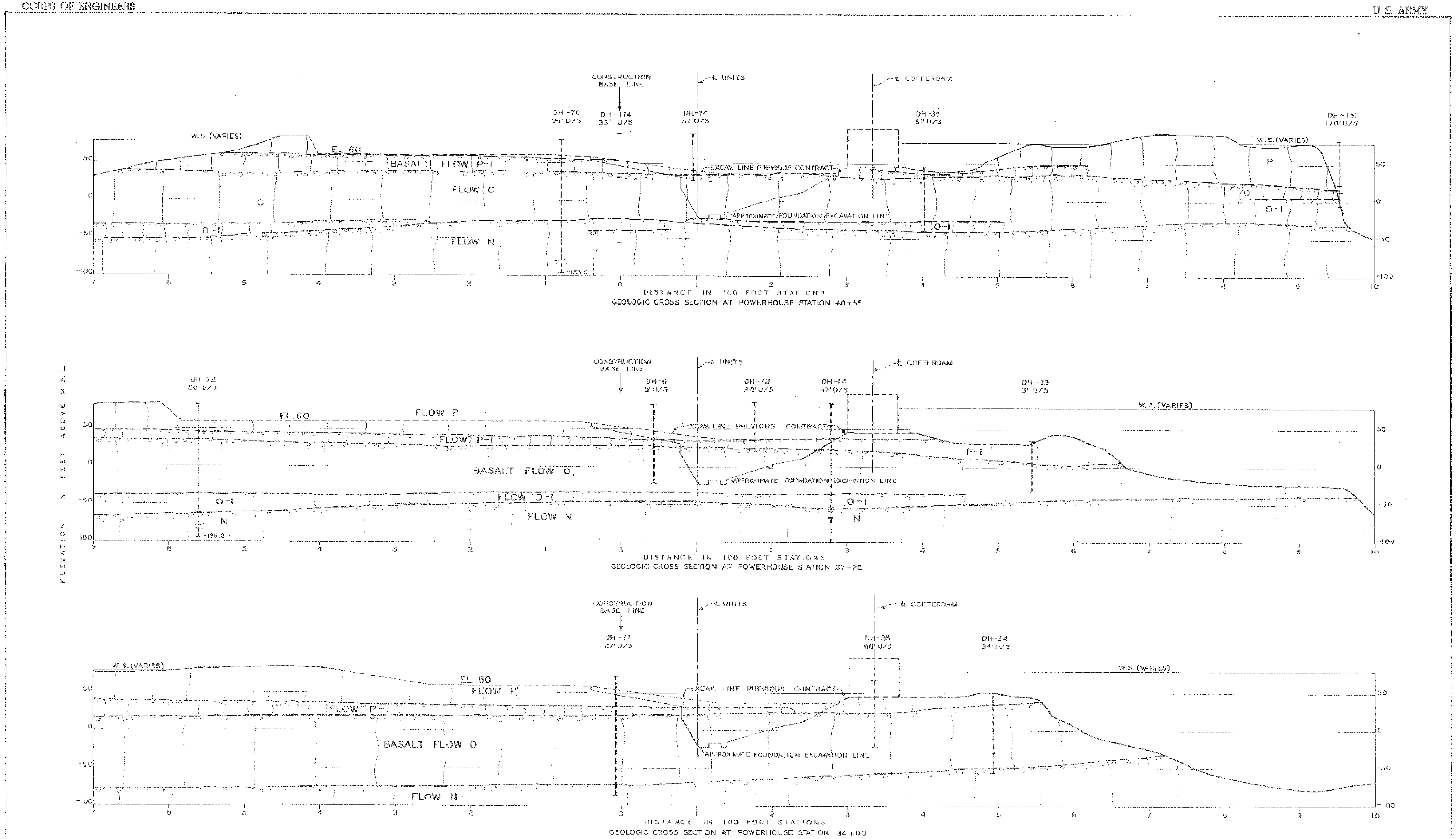

LEGEND

O3 OVERBURDEN, SILT, SAND OR GRAVEL

DH-70 96' D/S — CORE DRILL HOLE WITH OFFSET SHOWN

APPROXIMATE BASALT FLOW CONTACTS

FLOW P — COLUMBIA RIVER BASALT

NOTE:
IT IS UNDERSTOOD THAT THE INTERPRETATION OF SUBSURFACE CONDITIONS AS CONTAINED IN THIS DRAWING IS ONLY A DIAGRAM OF ASSUMED GEOLOGIC CONDITIONS AND SHOULD NOT BE USED BY THE CONTRACTOR AS RELIABLE FOR THE BASIS OF ESTIMATES.

AS CONSTRUCTED

SCALES AS SHOWN

CORPS OF ENGINEERS, U.S. ARMY
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THE DALLES DAM
COLUMBIA RIVER, WASHINGTON - OREGON
GEOLOGIC INVESTIGATIONS
POWERHOUSE-PHASE III
GEOLOGIC SECTIONS - UNITS 15-22

CHIEF, GEOLOGY SECTION
CHIEF, FOUNDATION & MATERIALS BRANCH

DDP-1J-0-0/2

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THE DALLES LOCK AND DAM NORTH-EAST FISHLADDER BACKUP AUXILIARY WATER SUPPLY

GEOLOGI INVESTIGATIONS POWERHOUSE-PHASE III GEOLOGIC SEC UNITS 15-22

SHEET IDENTIFICATION FIO-102

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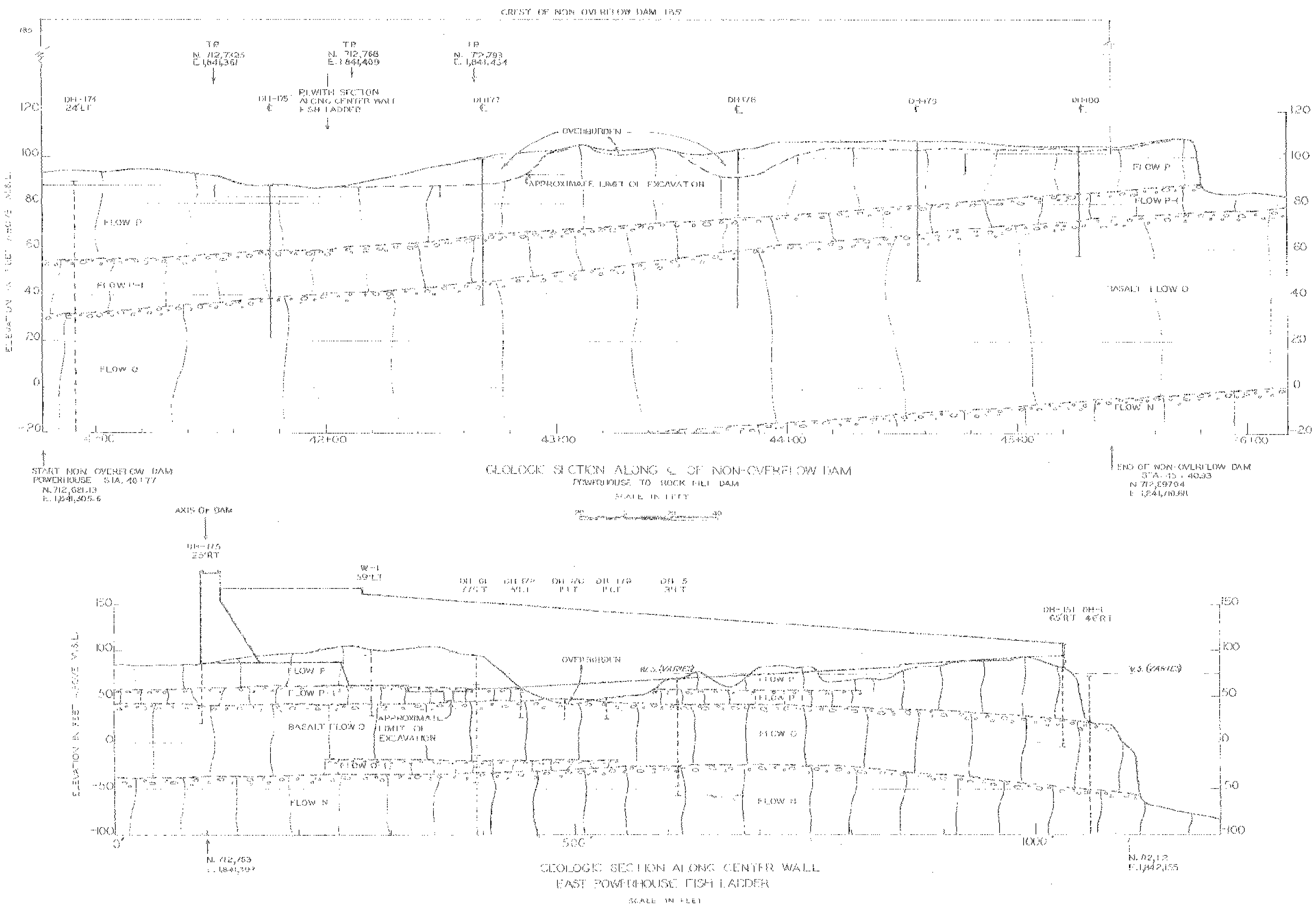

GEOLOGIC SECTION ALONG ℄ OF NON-OVERFLOW DAM
POWERHOUSE TO ROCK FILL DAM
SCALE IN FEET

GEOLOGIC SECTION ALONG CENTER WALL
EAST POWERHOUSE FISH LADDER
SCALE IN FEET

NOTE:
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LEGEND

CORE DRILL HOLE WITH OFFSET SHOWN

APPROXIMATE GEOLOGIC CONTACT

OVERBURDEN — SAND, GRAVEL W/ BASALT BOULDERS

FLOW P — COLUMBIA RIVER BASALT

AS CONSTRUCTED
CONTRACT NO. DA 35-026 eng-2070
DATE OF RECEIPT OF NOTICE TO PROCEED: 21 JAN. 1954
DATE OF COMPLETION OF CONTRACT: 1 JULY 1956
DATE OF ACCEPTANCE: 2 JULY 1956

REVISION	DATE	DESCRIPTION	BY

CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND OREGON

DRAWN: W.A.C.
TRACED: B.L.B.
CHECKED: B.L.S.

THE DALLES DAM
COLUMBIA RIVER, WASHINGTON - OREGON
GEOLOGIC INVESTIGATIONS
EAST FISH LADDER AND NON-OVERFLOW DAM
GEOLOGIC SECTIONS

SCALE: AS SHOWN
DDP-11-0-0/4

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DATE: 08-JAN-2014
FILE NAME: DDP-11-0-0/4

THE DALLES LOCK AND DAM NORTH-EAST FISHLADDER BACKUP AUXILIARY WATER SUPPLY
GEOLOGIC INVESTIGATIONS EAST FISH LADDER AND NON-OVERFLOW DAM

SHEET IDENTIFICATION
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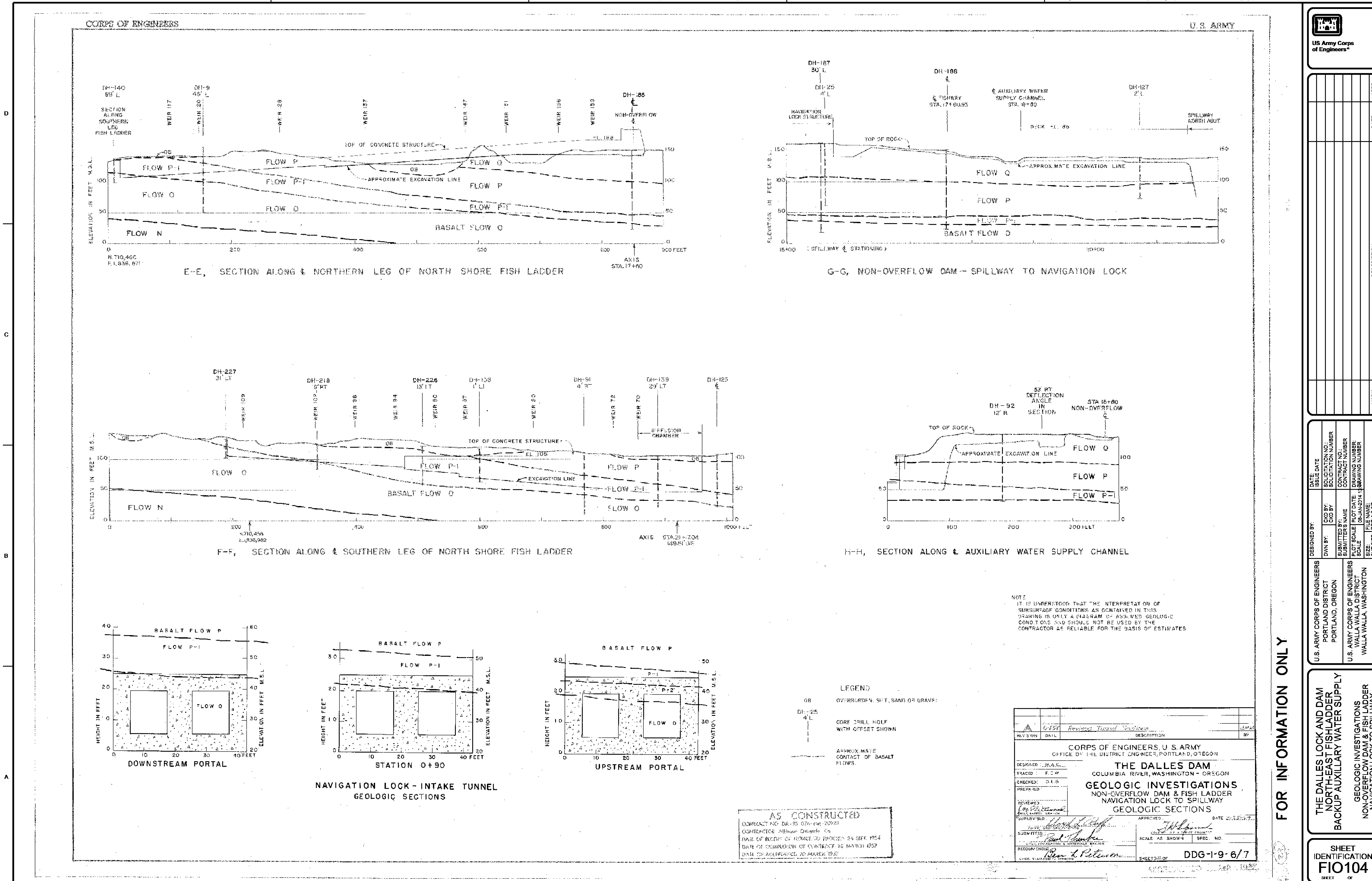
CORPS OF ENGINEERS
U.S. ARMY
E-E, SECTION ALONG ℄ NORTHERN LEG OF NORTH SHORE FISH LADDER
G-G, NON-OVERFLOW DAM — SPILLWAY TO NAVIGATION LOCK
F-F, SECTION ALONG ℄ SOUTHERN LEG OF NORTH SHORE FISH LADDER
H-H, SECTION ALONG ℄ AUXILIARY WATER SUPPLY CHANNEL
DOWNSTREAM PORTAL
STATION 0+90
UPSTREAM PORTAL
NAVIGATION LOCK - INTAKE TUNNEL
GEOLOGIC SECTIONS
NOTE
IT IS UNDERSTOOD THAT THE INTERPRETATION OF SUBSURFACE CONDITIONS AS CONTAINED IN THIS DRAWING IS ONLY A DIAGRAM OF ASSUMED GEOLOGIC CONDITIONS AND SHOULD NOT BE USED BY THE CONTRACTOR AS RELIABLE FOR THE BASIS OF ESTIMATES.
LEGEND
OB OVERBURDEN, SILT, SAND OR GRAVEL
DH-25 4' L CORE DRILL HOLE WITH OFFSET SHOWN
APPROXIMATE CONTACT OF BASALT FLOWS
AS CONSTRUCTED
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON
THE DALLES DAM
COLUMBIA RIVER, WASHINGTON - OREGON
GEOLOGIC INVESTIGATIONS
NON-OVERFLOW DAM & FISH LADDER
NAVIGATION LOCK TO SPILLWAY
GEOLOGIC SECTIONS
DDG-1-9-6/7
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U.S. ARMY CORPS OF ENGINEERS WALLA WALLA DISTRICT WALLA WALLA, WASHINGTON
THE DALLES LOCK AND DAM NORTH-EAST FISHLADDER BACKUP AUXILIARY WATER SUPPLY
GEOLOGIC INVESTIGATIONS NON-OVERFLOW DAM & FISH LADDER NAVIGATION LOCK TO SPILLWAY
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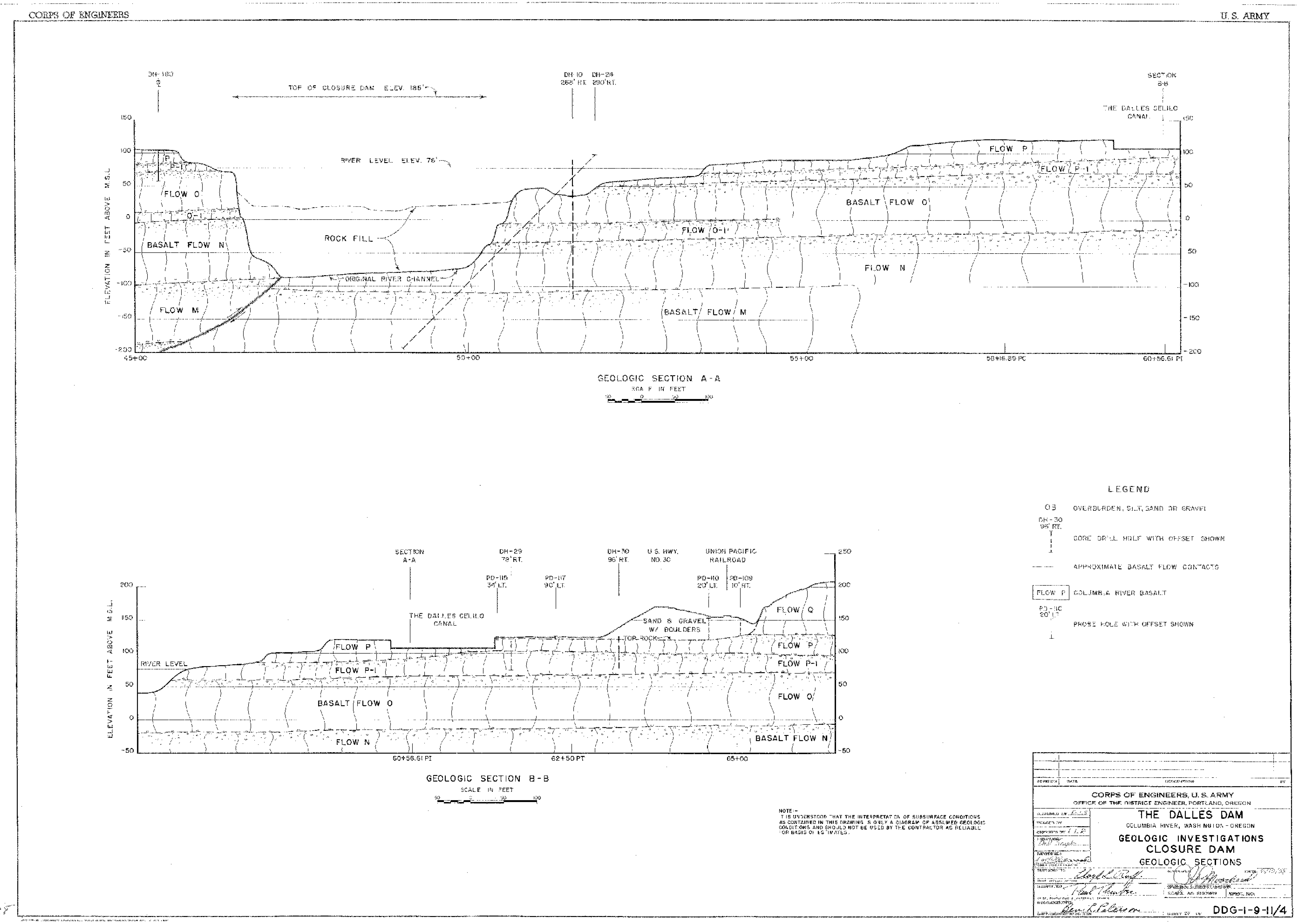

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WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

GEOLOGIC INVESTIGATIONS
CLOSURE DAM

SHEET IDENTIFICATION
FIO-105

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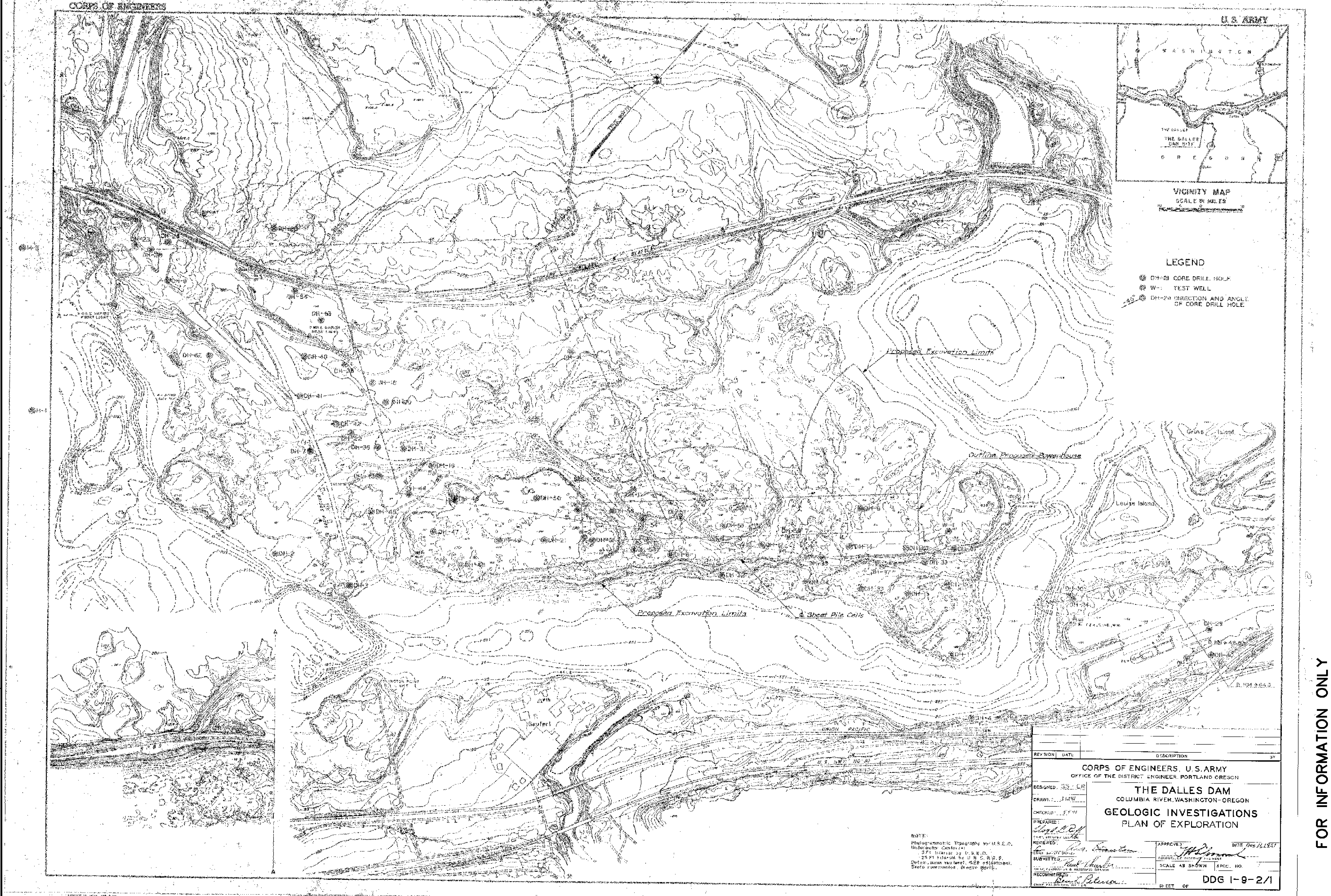


FOR INFORMATION ONLY

US Army Corps of Engineers

MARK	DESCRIPTION	DATE	APPR

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: | DWN BY: | CKD BY: | SUBMITTED BY: SUBMITTER'S NAME | PLOT SCALE: SCALE | PLOT DATE: 08-JAN-2014 | SIZE: SHT SIZE | FILE NAME: DDG-1-9-2/1 | DATE: ISSUE DATE | SOLICITATION NO.: SOLICITATION NUMBER | CONTRACT NO.: CONTRACT NUMBER | DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GEOLOGIC INVESTIGATIONS
PLAN OF EXPLORATIONS

SHEET IDENTIFICATION
FIO-201
SHEET OF

DESIGN FILE: $PWDIR$

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:$TIME | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$

FOR INFORMATION ONLY

US Army Corps of Engineers

MARK	DESCRIPTION	DATE	APPR

DESIGNED BY: | DWN BY: | CKD BY: | SUBMITTED BY: | PLOT SCALE: | PLOT DATE: 08-JAN-2014 | SIZE: | FILE NAME: DDG-1-9-11/3 | DATE: | SOLICITATION NO.: | CONTRACT NO.: | DRAWING NUMBER:

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

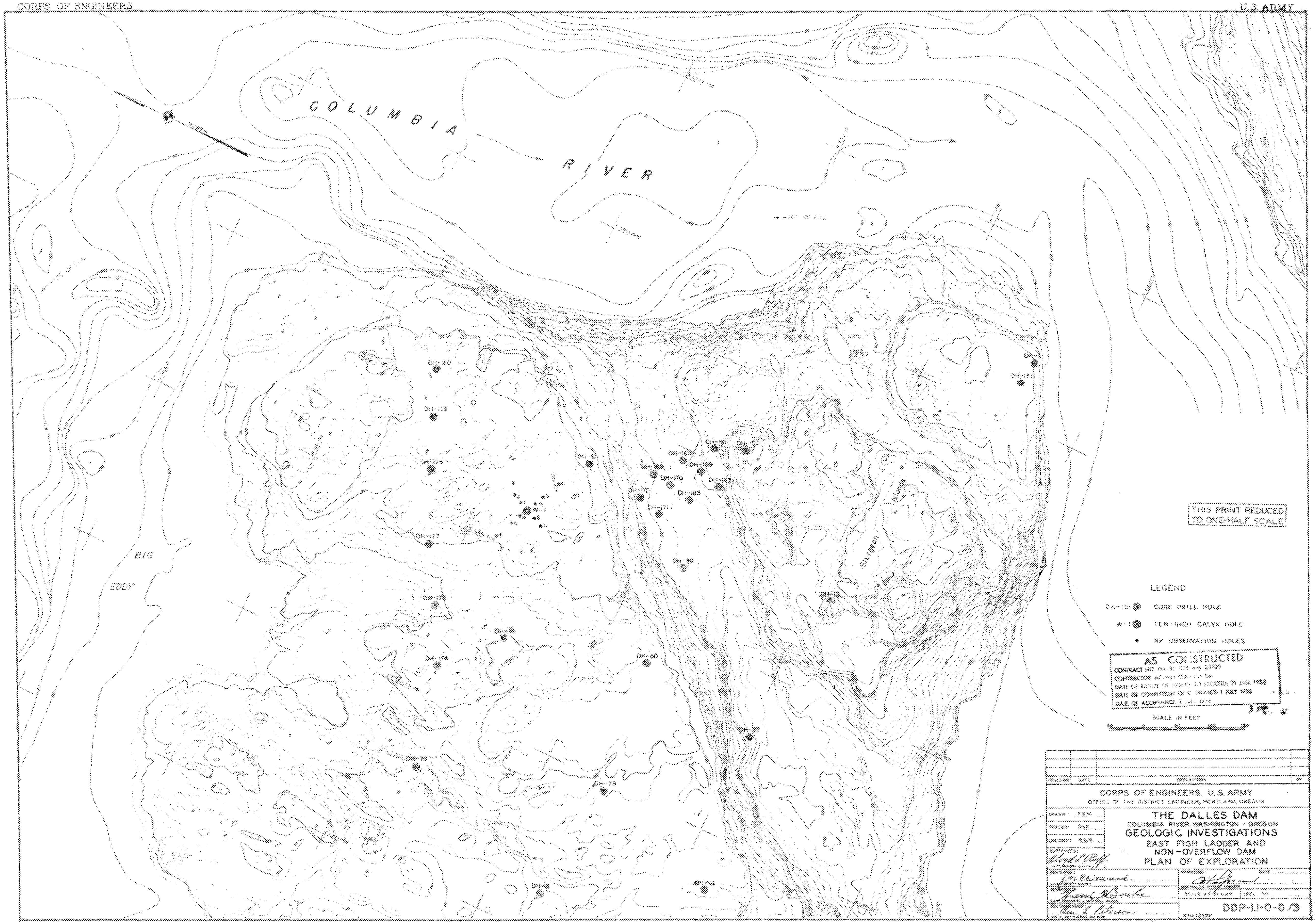
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GEOGRAPHIC INVESTIGATIONS
CLOSURE DAM
PLAN OF EXPLORATIONS

SHEET IDENTIFICATION
FIO-202

DESIGN FILE: $PWDIR$

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:$TIME | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$



FOR INFORMATION ONLY

US Army Corps of Engineers

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: | DATE: ISSUE DATE
DWN BY: | CKD BY: CKD BY | SOLICITATION NO.: SOLICITATION NUMBER
SUBMITTED BY: SUBMITTER'S NAME | CONTRACT NO.: CONTRACT NUMBER
PLOT SCALE: SCALE | PLOT DATE: 08-JAN-2014 | DRAWING NUMBER: DRAWING NUMBER
SIZE: SHT SIZE | FILE NAME: DDDP-1.1-0-0/3

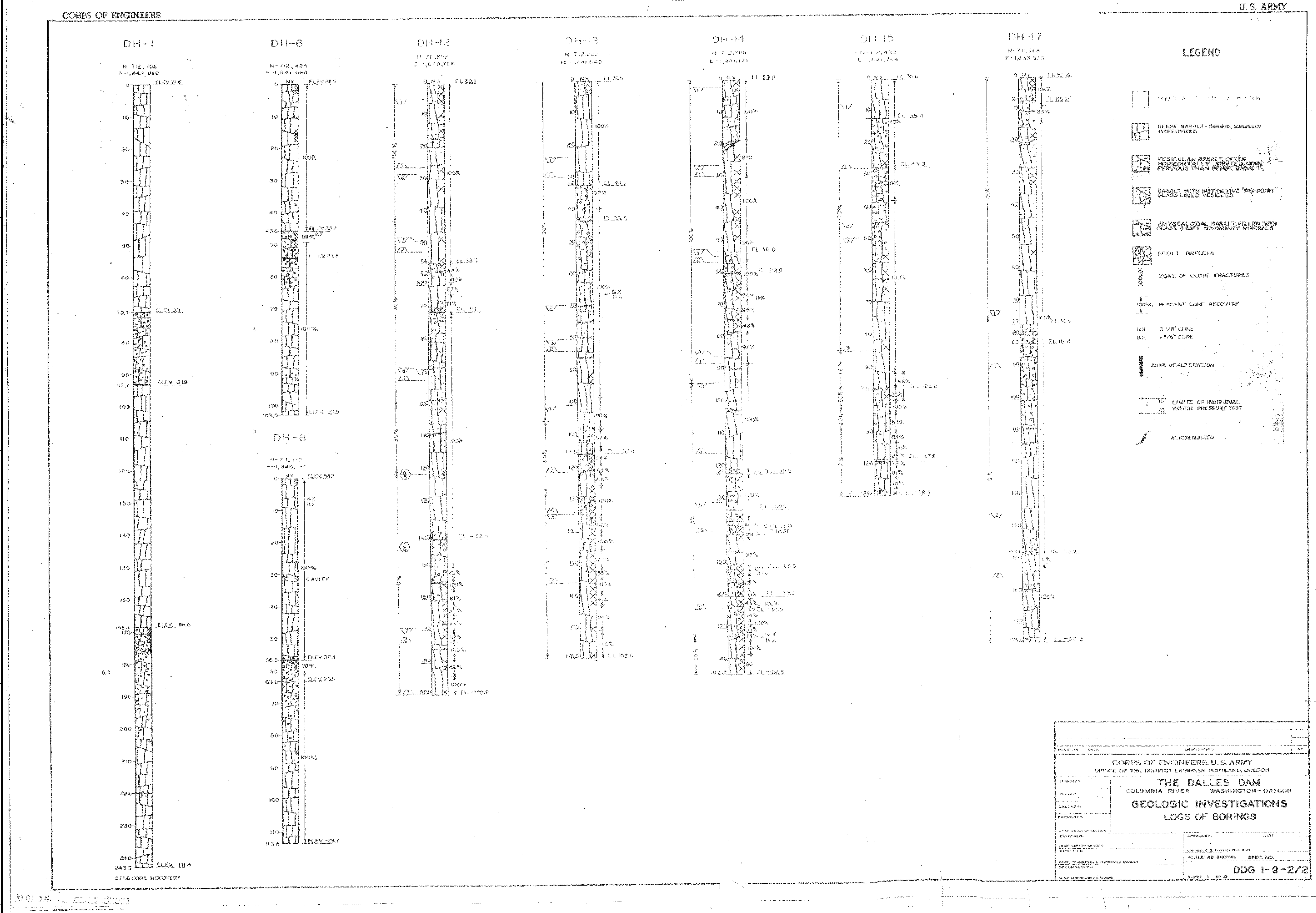
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GEOLOGIC INVESTIGATIONS
EAST FISH LADDER & NON-OVERFLOW DAM
PLAN OF EXPLORATION

SHEET IDENTIFICATION
FIO-203
SHEET OF

DESIGN FILE: $PWDIR$

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:$TIME | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$



FOR INFORMATION ONLY

US Army Corps of Engineers

MARK	DESCRIPTION	DATE	APPR

DESIGNED BY: | DWN BY: | CKD BY: | SUBMITTED BY: SUBMITTERS NAME | PLOT SCALE: SCALE | PLOT DATE: 08-JAN-2014 | SIZE: SHT SIZE | FILE NAME: DDG-1-9-2/2 | DATE: ISSUE DATE | SOLICITATION NO.: SOLICITATION NUMBER | CONTRACT NO.: CONTRACT NUMBER | DRAWING NUMBER: DRAWING NUMBER

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

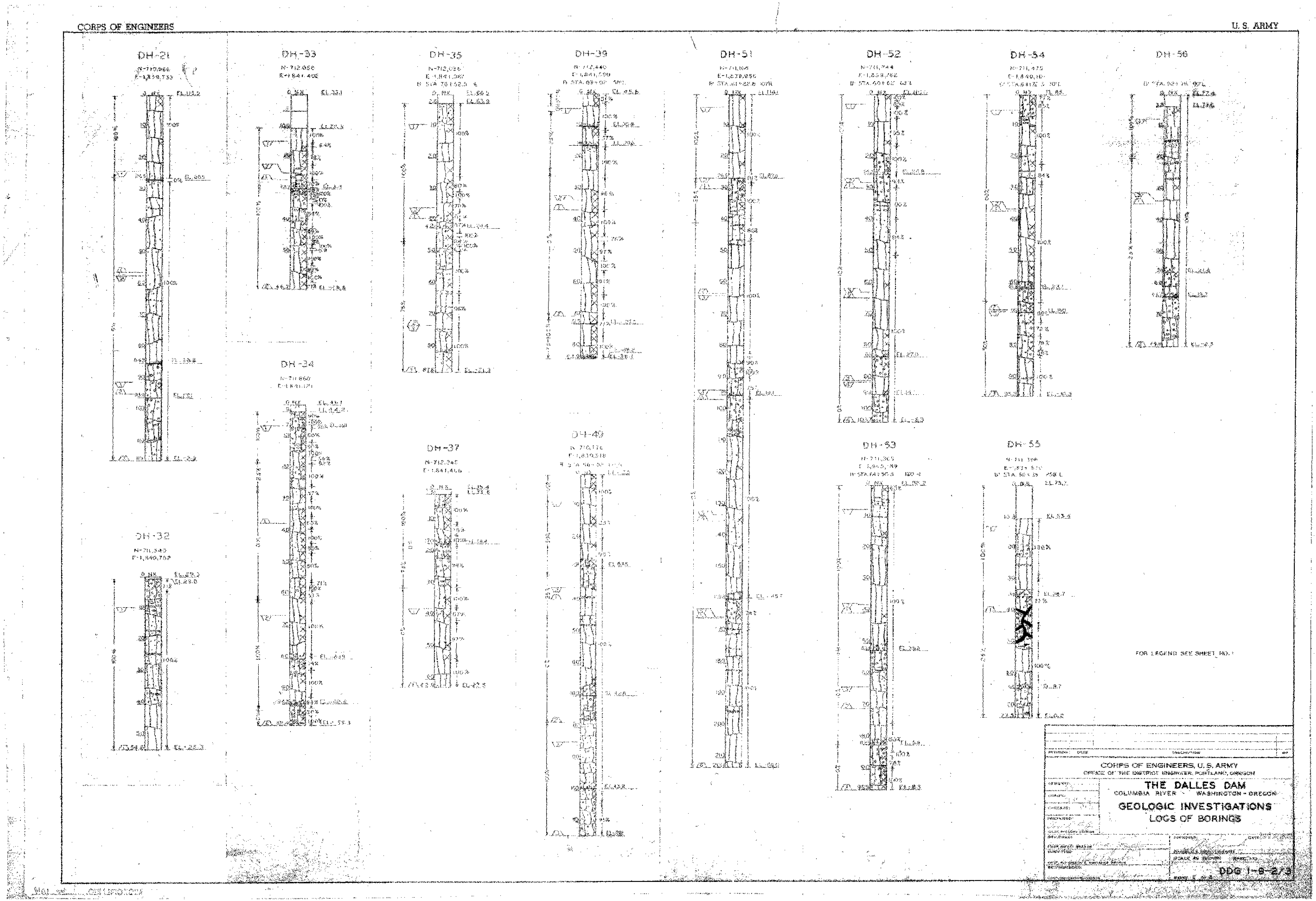
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GEOGRAPHIC INVESTIGATIONS
LOGS OF BORING

SHEET IDENTIFICATION
FIO-301
SHEET OF

DESIGN FILE: $PWDIR$

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:$TIME | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$



FOR INFORMATION ONLY

US Army Corps of Engineers

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: | DATE: ISSUE DATE | SOLICITATION NO.: SOLICITATION NUMBER
DWN BY: | CKD BY: CKD BY | CONTRACT NO.: CONTRACT NUMBER
SUBMITTED BY: SUBMITTERS NAME
PLOT SCALE: SCALE | PLOT DATE: 08-JAN-2014 13:49 | DRAWING NUMBER: DRAWING NUMBER
SIZE: SHT SIZE | FILE NAME: DDG-1-9-23

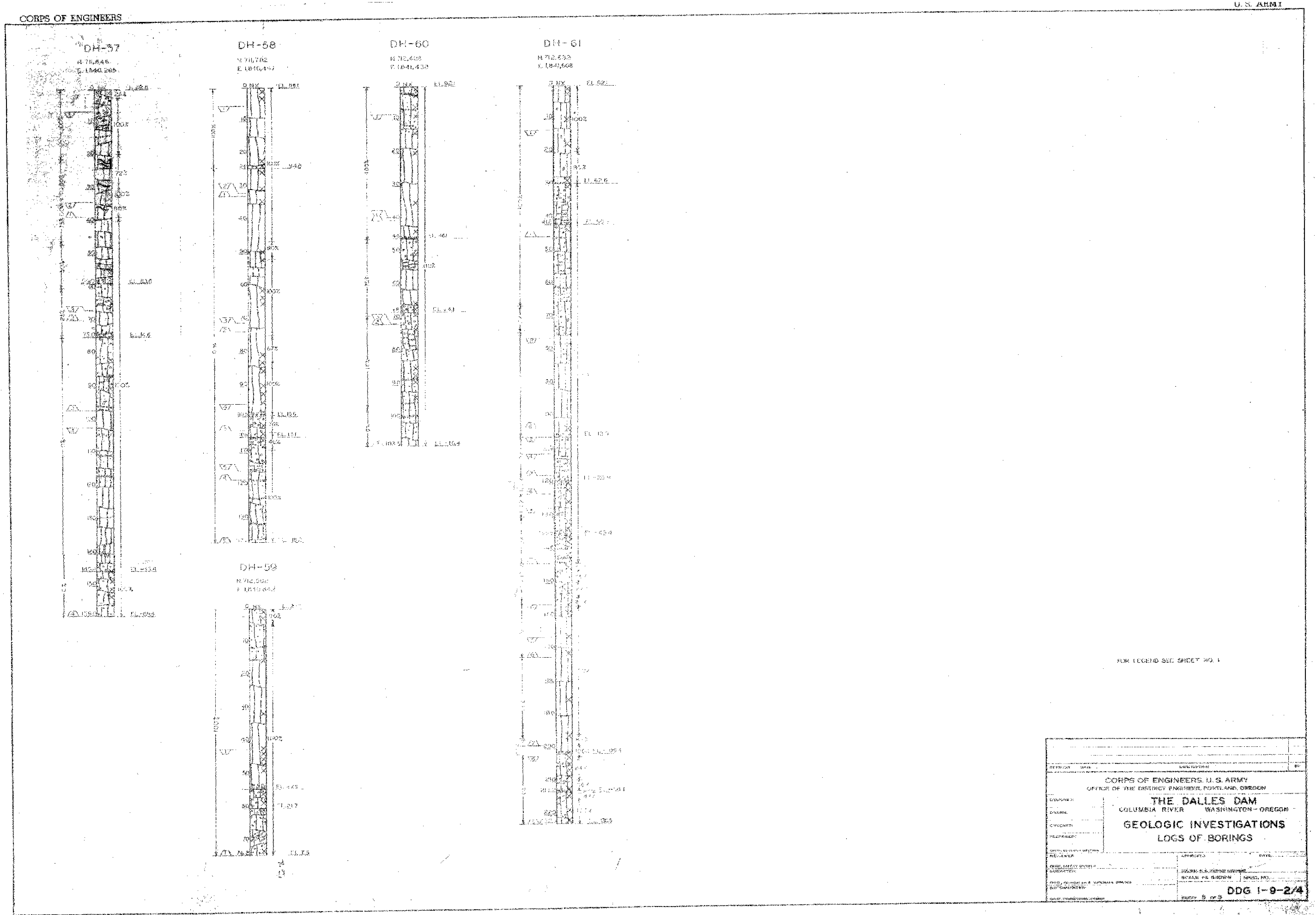
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GEOLOGICAL INVESTIGATIONS
LOGS OF BORINGS

SHEET IDENTIFICATION
FIO-302
SHEET OF

DESIGN FILE: $PWDIR$

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:49 $TIME | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$



FOR INFORMATION ONLY

US Army Corps of Engineers

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: | DWN BY: | CKD BY: | SUBMITTED BY: SUBMITTER'S NAME | PLOT SCALE: SCALE | PLOT DATE: 08-JAN-2014 13:... | SIZE: SHT SIZE | FILE NAME: DDG-1-9-24 | DATE: ISSUE DATE | SOLICITATION NO.: SOLICITATION NUMBER | CONTRACT NO.: CONTRACT NUMBER | DRAWING NUMBER: DRAWING NUMBER

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GEOLOGIC INVESTIGATIONS
LOG OF BORINGS

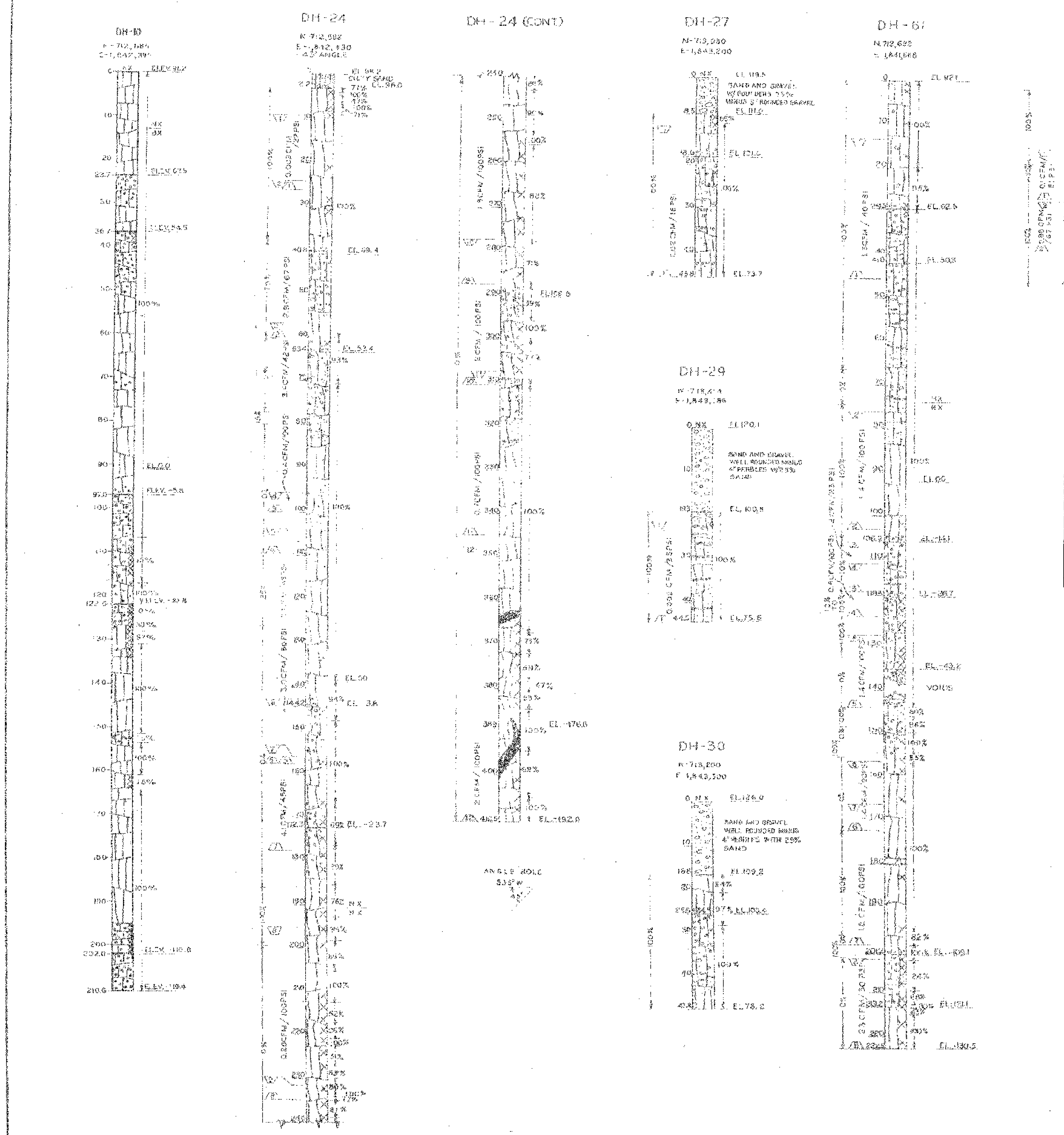
SHEET IDENTIFICATION
FIO-303
SHEET OF

DESIGN FILE: $PWDIR$

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:48 $TIME | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$

CORPS OF ENGINEERS

U.S. ARMY



LEGEND

- SILTY SAND (AEOLIAN)
- SAND AND GRAVEL, CONTAINING SOME BOULDERS
- SANDY CLAY, CONTAINING A FEW BOULDERS
- DENSE BASALT - SOUND, USUALLY IMPERVIOUS
- VESICULAR BASALT, OFTEN HORIZONTALLY JOINTED, MORE PERVIOUS THAN DENSE BASALT
- BASALT WITH DISTINCTIVE "PIN POINT" GLASS LINED VESICLES
- AMYGDALOIDAL BASALT, FILLED WITH GLASS & SOFT SECONDARY MINERALS
- FAULT BRECCIA
- BASALTIC GLASS, SOMETIMES DEVITRIFIED AND/OR SOFT.
- NX 2⅛ INCH CORE
- BX 1⅝ INCH CORE
- ZONE OF CLOSE-FRACTURING OF BEDROCK.
- LIMITS OF INDIVIDUAL WATER PRESSURE TESTS, WITH WATER INTAKE, IN CUBIC FEET PER MINUTE, AT POUNDS PER SQUARE INCH PRESSURE AS SHOWN.
- CORE RECOVERY, % OF FOOTAGE DRILLED.
- DRILLING WATER RETURN, % OF INPUT
- ZONE OF ALTERATION
- BASALT FLOW CONTACTS

PROBE HOLE INFORMATION

HOLE NO.	"A" STATION	OFFSET	GROUND ELEV.	INDICATED DEPTH OF OVERBURDEN	INDICATED BEDROCK ELEV.
PD-107	24+94	80' LT	150.6	25.0	125.6
PD-108	65+01	20' LT	150.8	23.4	127.4
PD-109	22+06	10' RT	151.6	23.5	128.4
PD-110	64+57	20' RT	152.6	33.5	118.1
PD-111	64+44	60' LT	147.9	29.5	118.4
PD-112	64+17	170' LT	144.7	24.5	119.7
PD-113	61+37	126' LT	124.5	3.4	121.2
PD-114	61+58	26' LT	120.3	1.0	119.3
PD-115	61+30	46' LT	123.5	3.3	120.2
PD-116	61+44	6' RT	——	2.5	——
PD-117	62+30	90' LT	125.2	4.0	121.2
PD-118	62+30	140' LT	125.1	5.0	120

CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

THE DALLES DAM
COLUMBIA RIVER, WASHINGTON - OREGON
GEOLOGIC INVESTIGATIONS
CLOSURE DAM
LOGS OF DRILL HOLES

DDG-1-9-11/5

FOR INFORMATION ONLY

US Army Corps of Engineers

DESIGNED BY:	DATE: ISSUE DATE
DWN BY:	CKD BY: CKD BY
SUBMITTED BY: SUBMITTERS NAME	SOLICITATION NO.: SOLICITATION NUMBER
PLOT SCALE: SCALE	CONTRACT NO.: CONTRACT NUMBER
PLOT DATE: 08-JAN-2014 13:38	DRAWING NUMBER: DRAWING NUMBER
SIZE: SHT SIZE	FILE NAME: DDG-1-9-11/5

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

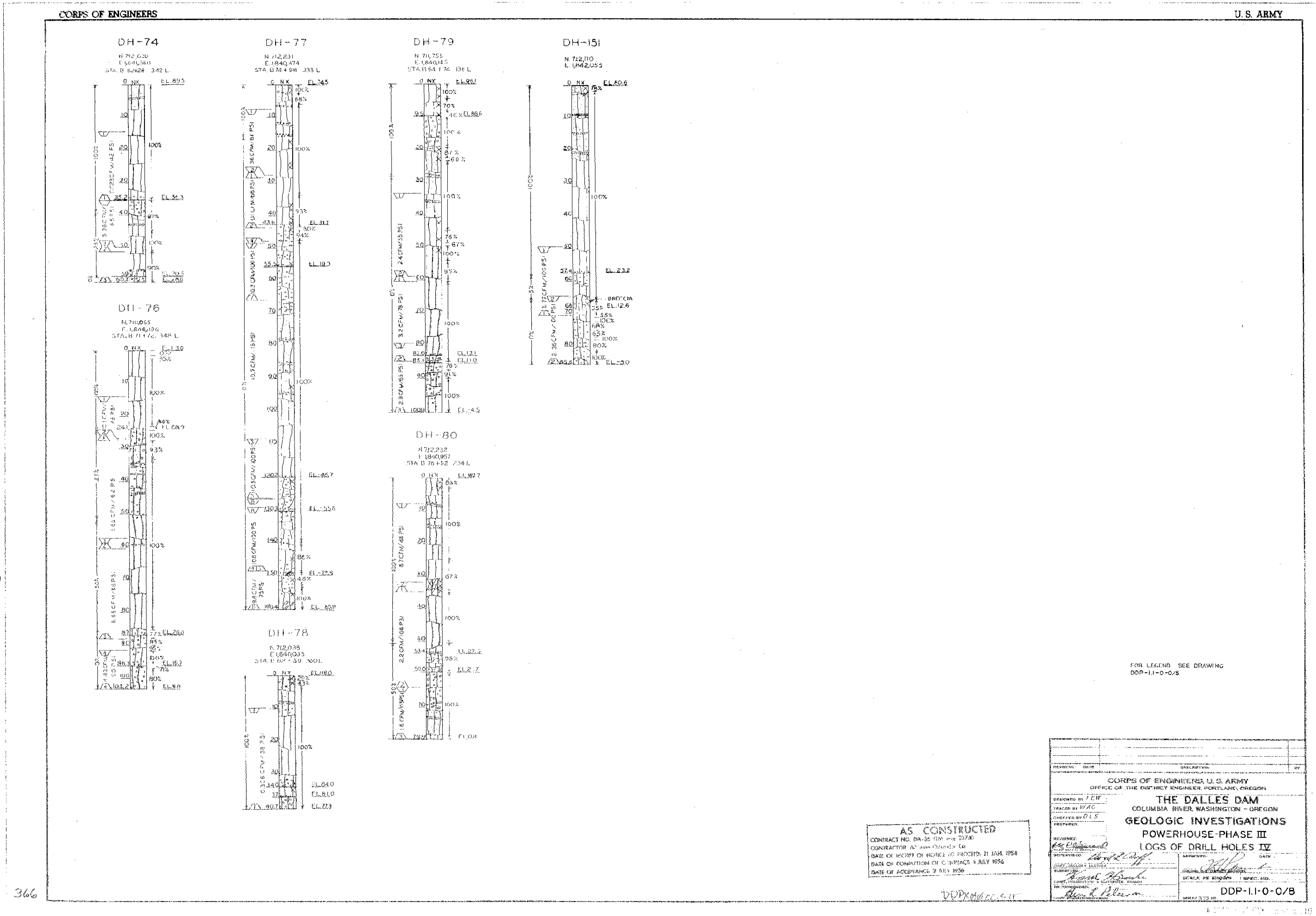
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GEOLOGIC INVESTIGATIONS
CLOSURE DAM
LOGS OF DRILL HOLES

SHEET IDENTIFICATION
FIO-304

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:38 | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$ | DESIGN FILE: $PWDIR$



FOR INFORMATION ONLY

US Army Corps of Engineers

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: | DWN BY: | CKD BY: | SUBMITTED BY: | PLOT SCALE: | PLOT DATE: 08-JAN-2014 | SIZE: | FILE NAME: DDP-1.1-0-0/8

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

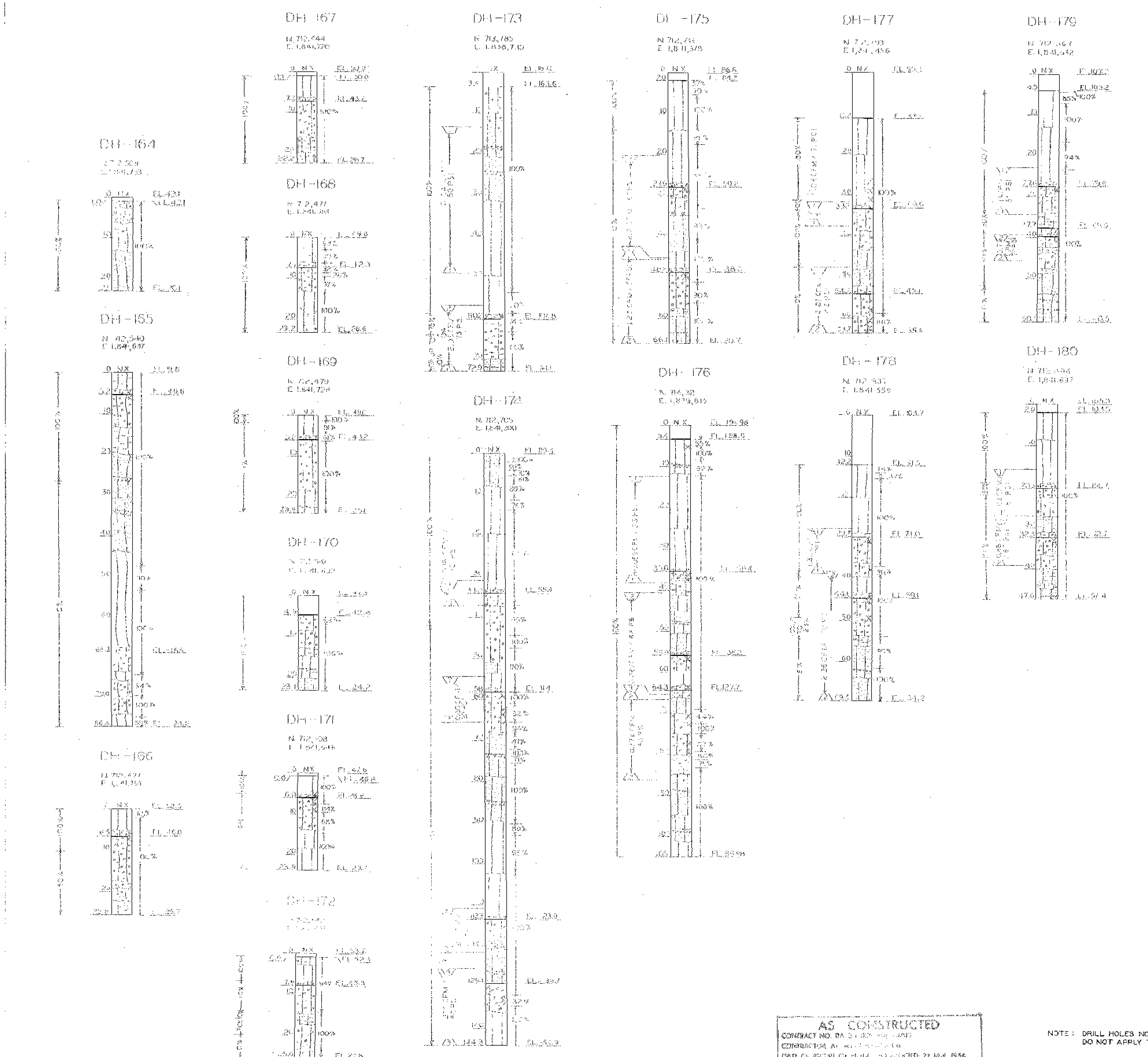
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

GEOLOGIC INVESTIGATIONS
POWERHOUSE-PHASE III
LOGS OF DRILL HOLES IV

SHEET IDENTIFICATION
FIO-305

CORPS OF ENGINEERS — U.S. ARMY



FOR LEGEND SEE DRAWING DDP-1.1-0-0/5

NOTE: DRILL HOLES NO. DH-173 AND DH-176 DO NOT APPLY TO THIS CONTRACT

AS CONSTRUCTED
CONTRACT NO. DA 3[illegible]
CONTRACTOR [illegible]
DATE OF RECEIPT OF NOTICE TO PROCEED: 21 JAN. 1956
DATE OF COMPLETION OF CONTRACT: 1 JULY 1956
DATE OF ACCEPTANCE: 2 JULY 1956

DDPXØØ26.CIT

REVISION	DATE	DESCRIPTION	BY

CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

DESIGNED: B.B.
TRACED: M.A.C.
CHECKED: O.L.S.
PREPARED:

THE DALLES DAM
COLUMBIA RIVER WASHINGTON - OREGON
GEOLOGIC INVESTIGATIONS
EAST FISH LADDER & NON-OVERFLOW DAM
LOGS OF DRILL HOLES

REVIEWED: CHIEF, SAFETY BRANCH
SUPERVISED: Lloyd L. Ruff — CHIEF, GEOLOGY SECTION
SUBMITTED: CHIEF, FOUNDATION & MATERIALS BRANCH
RECOMMENDED: CHIEF, ENGINEERING DIVISION
APPROVED: COLONEL, C.E. DISTRICT ENGINEER — DATE:
SCALE AS SHOWN — SPEC. NO.
SHEET 9 OF
DDP-1.1-0-0/9

FOR INFORMATION ONLY

US Army Corps of Engineers

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: | DATE: ISSUE DATE
DWN BY: | CKD BY: | SOLICITATION NO.: SOLICITATION NUMBER
SUBMITTED BY: SUBMITTERS NAME | CONTRACT NO.: CONTRACT NUMBER
PLOT SCALE: SCALE | PLOT DATE: 08-JAN-2014 13:... | DRAWING NUMBER: DRAWING NUMBER
SIZE: SHT SIZE | FILE NAME: DDP-1.1-0-0/9

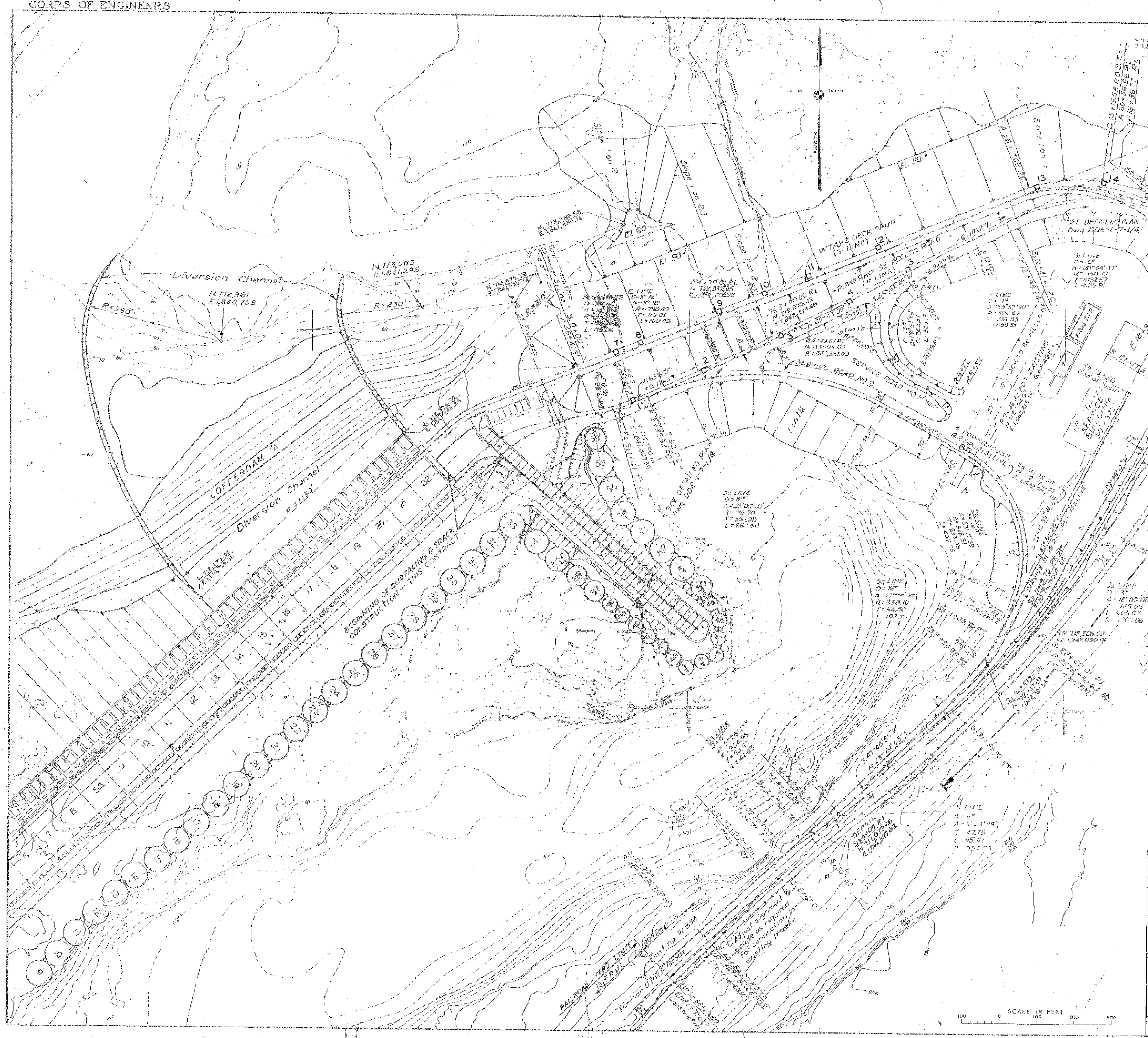
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GEOLOGIC INVESTIGATIONS
EAST FISHLADDER AND NON-OVERFLOW DAM
LOGS OF DRILL HOLES

SHEET IDENTIFICATION
FIO-306

DESIGN FILE: $PWDIR$

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:$TIME | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$



GENERAL NOTES

1. Underwater topography developed from soundings which were taken from depth finder hydrograph in August 1950, and indicate elevations above and below mean sea level, 1929 datum.
2. Road and railroad curves have been computed according to the arc definition.

8 □ Settlement Plates

Location of settlement plates:

1.	46+50	129 ft Right of ℄
2.	48+50	120 " " " "
3.	50+75	110 " " " "
4.	52+75	90 " " " "
5.	54+50	70 " " " "
6.	54+20	575 " " " "
7.	46+50	18 " Left " "
8.	47+20	18 " " " "
9.	49+50	18 ft Left of ℄
10.	50+75	" " " " "
11.	52+00	" " " " "
12.	54+00	" " " " "
13.	58+50	" " " " "
14.	60+50	" " " " "
15.	61+50	" " " " "

△1 The offsets are as listed. The plates should be placed on an offset location affording minimum interference with traffic.

The plates are to be placed at least two feet below the finished grade of the location.

The risers are to be plainly marked and protected.

REVISION	DATE	DESCRIPTION	BY
△1	4-4-57	Set. offsets revised as installed.	

CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

THE DALLES DAM
COLUMBIA RIVER WASHINGTON - OREGON
CLOSURE DAM AND ADMINISTRATION AREA
SETTLEMENT PLATES

DESIGNED / TRACED / CHECKED / REVIEWED / SUPERVISED / SUBMITTED / RECOMMENDED / APPROVED DATE

SCALE AS SHOWN | SPEC NO.

SHEET OF | DDE-1-0-1/6

FOR INFORMATION ONLY

US Army Corps of Engineers®

U.S. ARMY CORPS OF ENGINEERS PORTLAND DISTRICT PORTLAND, OREGON
U.S. ARMY CORPS OF ENGINEERS WALLA WALLA DISTRICT WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM NORTH-EAST FISHLADDER BACKUP AUXILLARY WATER SUPPLY

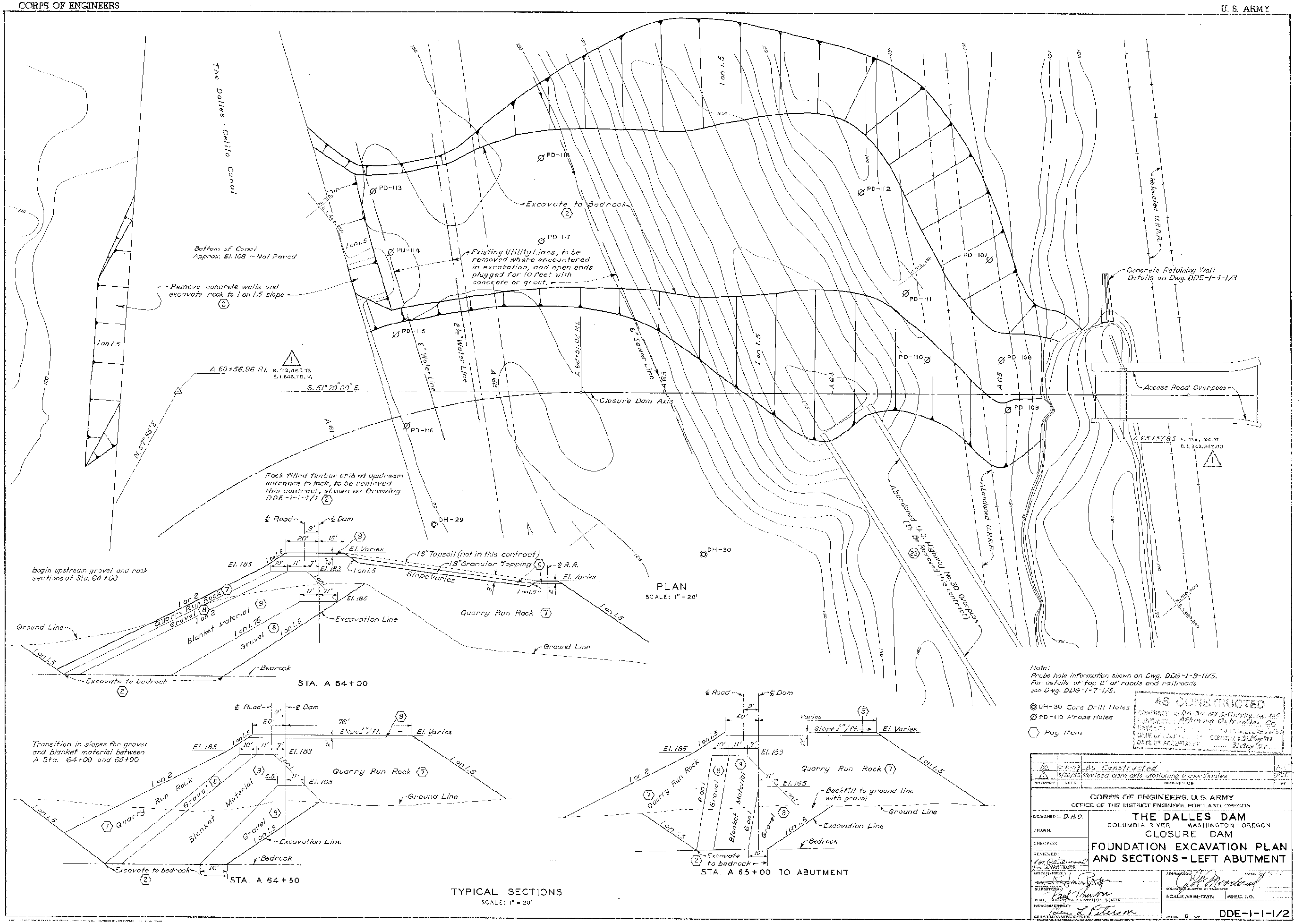
CLOSURE DAM AND ADMINISTRATION AREA SETTLEMENT PLATES

SHEET IDENTIFICATION
FIO-401

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 $TIME | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$

CORPS OF ENGINEERS

U. S. ARMY



FOR INFORMATION ONLY

US Army Corps of Engineers

U.S. ARMY CORPS OF ENGINEERS PORTLAND DISTRICT PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS WALLA WALLA DISTRICT WALLA WALLA, WASHINGTON

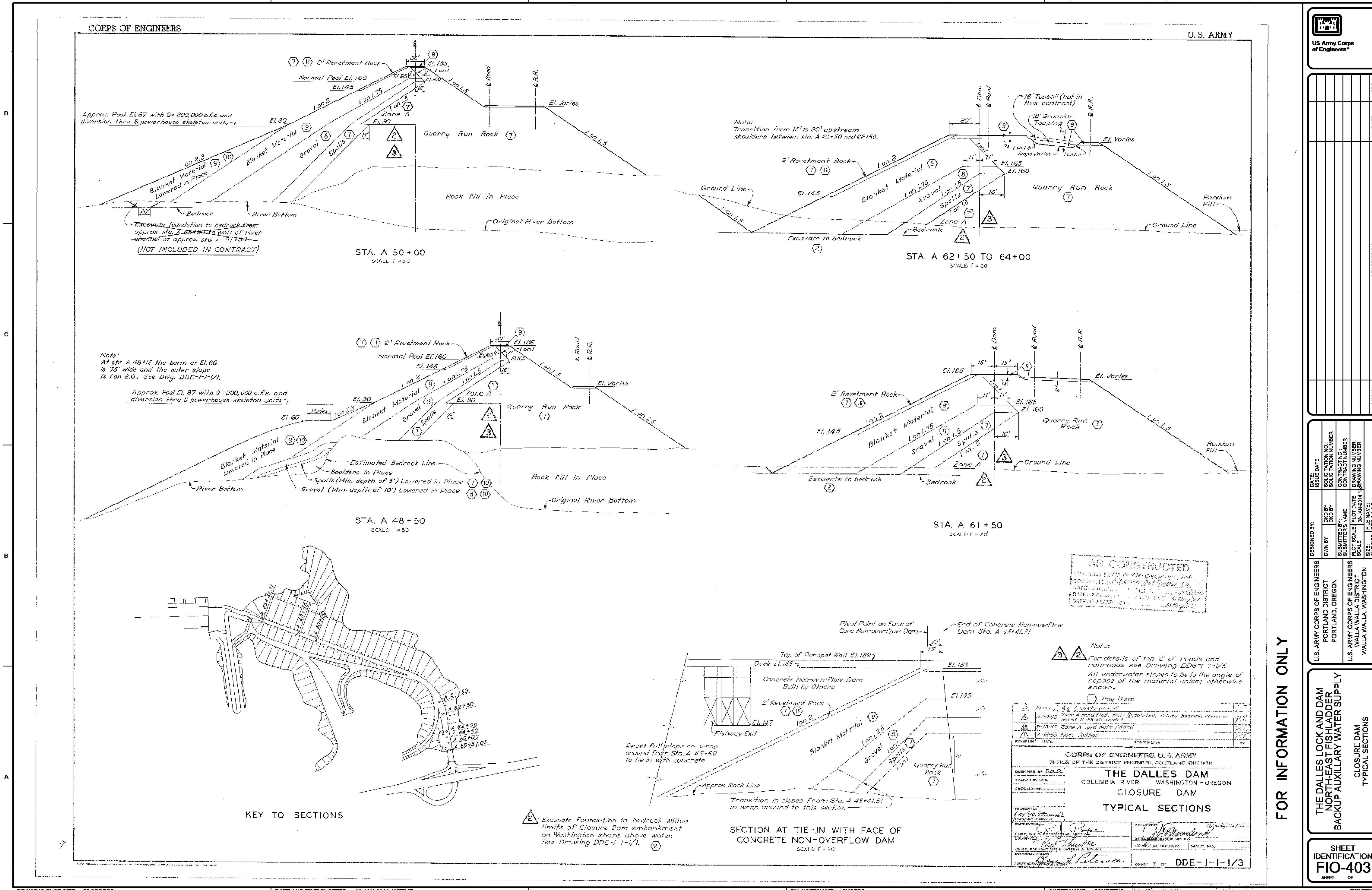
THE DALLES LOCK AND DAM NORTH-EAST FISHLADDER BACKUP AUXILIARY WATER SUPPLY

CLOSURE DAM FOUNDATION EXCAVATION PLAN AND SECTIONS-LEFT ABUTMENT

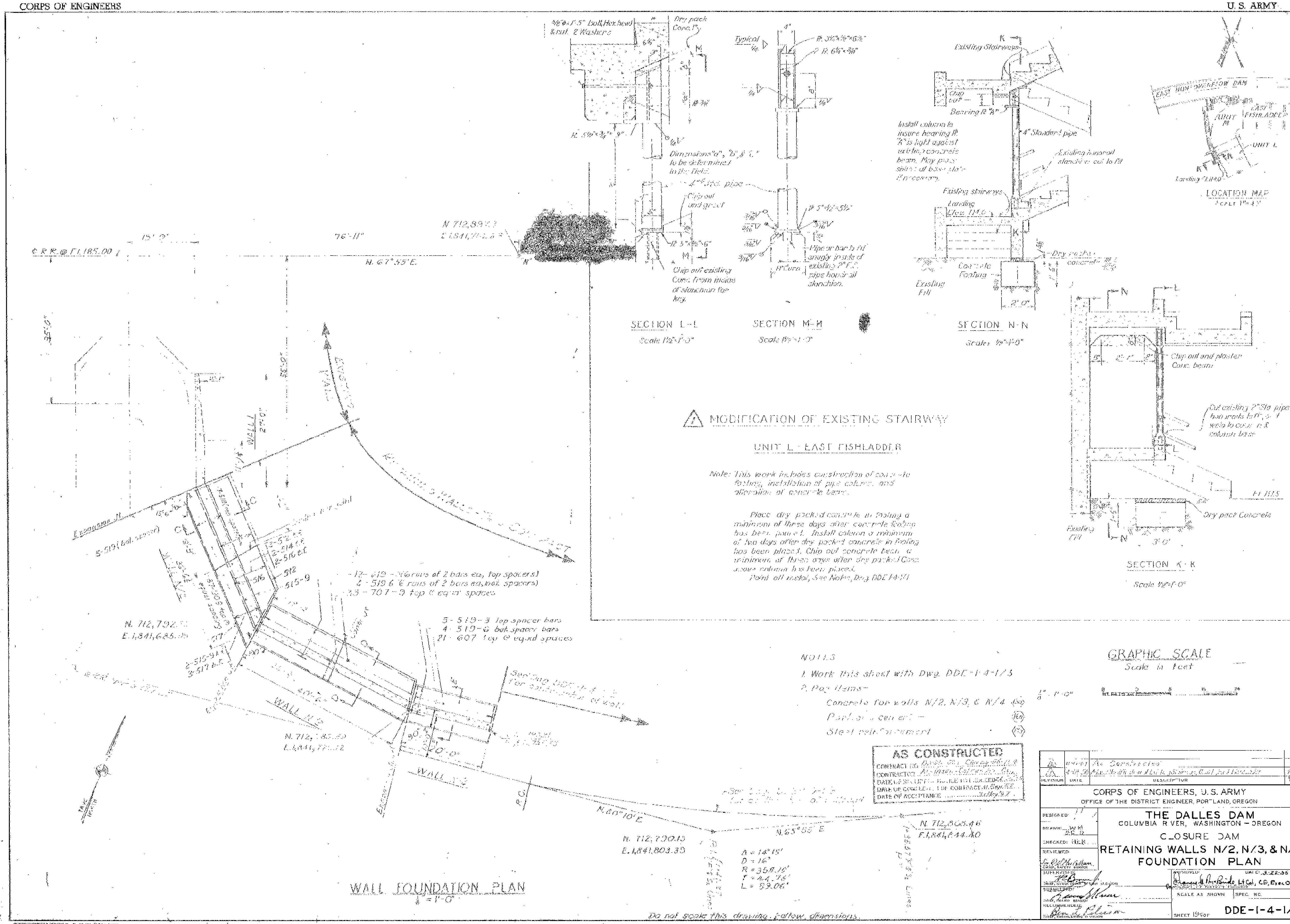
SHEET IDENTIFICATION FIO-402

DESIGN FILE: $PWDIR$

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:48 | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$


CORPS OF ENGINEERS
U. S. ARMY
STA. A 50 + 00
SCALE: 1" = 50'
Normal Pool El. 160
2' Revetment Rock
El. 185
1 on 1
El. 145
1 on 2
1 on 1.75
1 on 1.5
Zone A
El. 90
El. 30
Approx. Pool El. 87 with Q = 200,000 c.f.s. and diversion thru 8 powerhouse skeleton units
Quarry Run Rock
El. Varies
Blanket Material Lowered in Place
Blanket Material
Gravel
Spoils
Rock Fill in Place
Original River Bottom
Bedrock
River Bottom
Excavate foundation to bedrock from approx. sta. A 48+50 to wall of river channel at approx. sta. A 51+50
(NOT INCLUDED IN CONTRACT)
STA. A 62 + 50 TO 64 + 00
SCALE: 1" = 20'
Note: Transition from 15' to 20' upstream shoulders between sta. A 61+50 and 62+50.
18" Topsoil (not in this contract)
18" Granular Topping
Slope Varies
El. 165
El. 160
Ground Line
Random Fill
Excavate to bedrock
STA. A 48 + 50
SCALE: 1" = 50'
Note: At sta. A 48+15 the berm at El. 60 is 75' wide and the outer slope is 1 on 2.0. See Dwg. DDE-1-1-1/1.
Approx. Pool El. 87 with Q = 200,000 c.f.s. and diversion thru 8 powerhouse skeleton units
El. 60
Varies
1 on 2.3
Estimated Bedrock Line
Boulders in Place
Spoils (Min. depth of 5') Lowered in Place
Gravel (Min. depth of 10') Lowered in Place
STA. A 61 + 50
SCALE: 1" = 20'
KEY TO SECTIONS
SECTION AT TIE-IN WITH FACE OF CONCRETE NON-OVERFLOW DAM
SCALE: 1" = 20'
Pivot Point on Face of Conc. Non-overflow Dam
End of Concrete Non-overflow Dam Sta. A 45+41.31
Top of Parapet Wall El. 189
Deck El. 185
Concrete Non-overflow Dam Built by Others
El. 147
Fishway Exit
Revet full slope on wrap around from Sta. A 45+50 to tie-in with concrete
Approx. Rock Line
Transition in slopes from Sta. A 45+41.31 in wrap around to this section
Excavate foundation to bedrock within limits of Closure Dam embankment on Washington shore above water. See Drawing DDE-1-1-1/1.
Note:
For details of top 2' of roads and railroads see Drawing DDG-1-1-1/3.
All underwater slopes to be to the angle of repose of the material unless otherwise shown.
Pay Item
AS CONSTRUCTED
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON
THE DALLES DAM
COLUMBIA RIVER WASHINGTON - OREGON
CLOSURE DAM
TYPICAL SECTIONS
DDE-1-1-1/3
FOR INFORMATION ONLY
US Army Corps of Engineers
U.S. ARMY CORPS OF ENGINEERS PORTLAND DISTRICT PORTLAND, OREGON
U.S. ARMY CORPS OF ENGINEERS WALLA WALLA DISTRICT WALLA WALLA, WASHINGTON
THE DALLES LOCK AND DAM NORTH-EAST FISHLADDER BACKUP AUXILLARY WATER SUPPLY
CLOSURE DAM TYPICAL SECTIONS
SHEET IDENTIFICATION
FIO-403
DRAWING PLOT SIZE: $BORDER$
DATE AND TIME PLOTTED: 08-JAN-2014 13:47
BY USERNAME: $USER$
SHEET NAME: $SHEET$

CORPS OF ENGINEERS U. S. ARMY



AS CONSTRUCTED

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

THE DALLES DAM
COLUMBIA RIVER, WASHINGTON - OREGON
CLOSURE DAM
RETAINING WALLS N/2, N/3, & N/4
FOUNDATION PLAN

DDE-1-4-1/4

US Army Corps of Engineers

U.S. ARMY CORPS OF ENGINEERS PORTLAND DISTRICT PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS WALLA WALLA DISTRICT WALLA WALLA, WASHINGTON

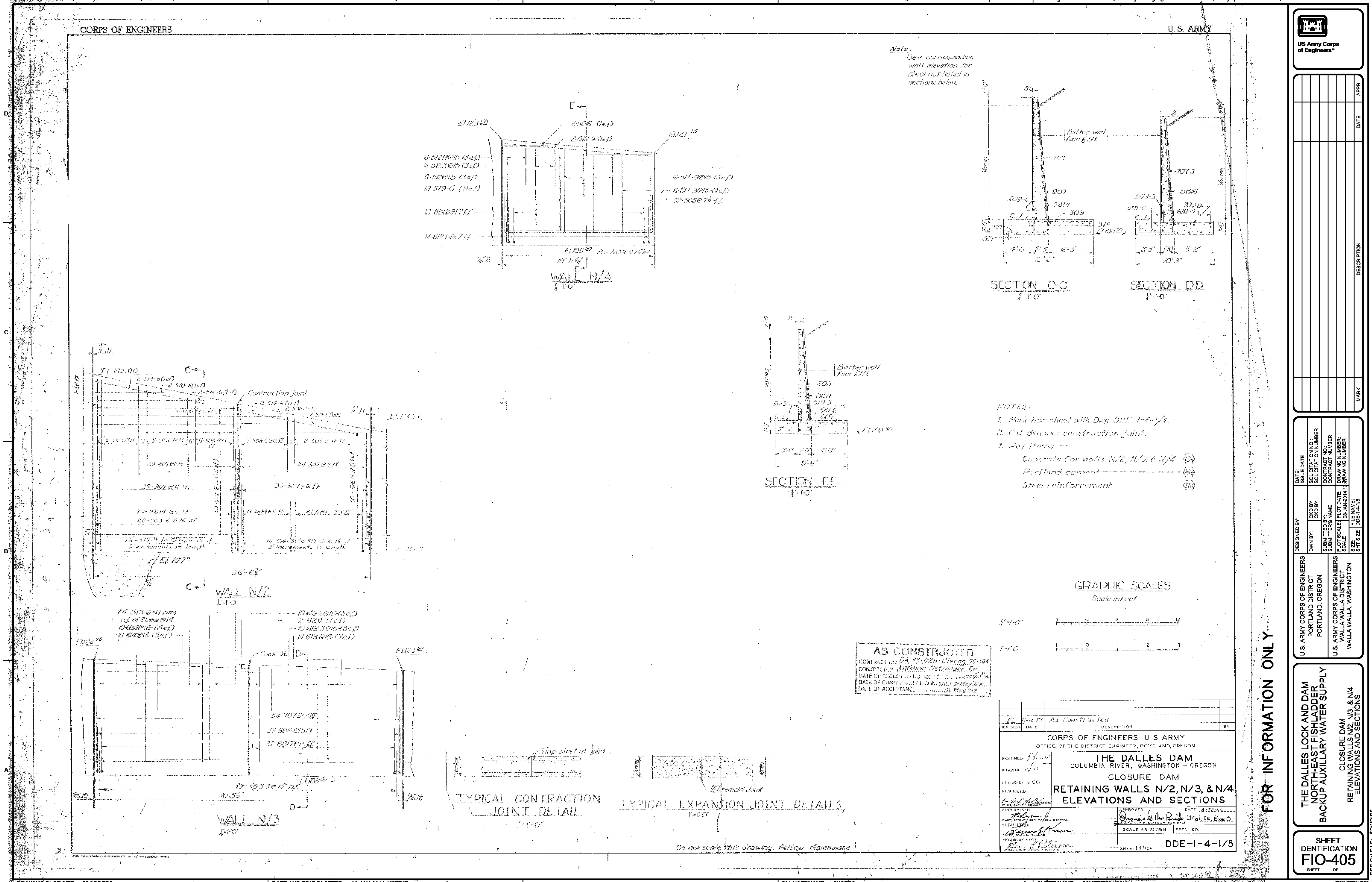
THE DALLES LOCK AND DAM NORTH-EAST FISHLADDER BACKUP AUXILIARY WATER SUPPLY

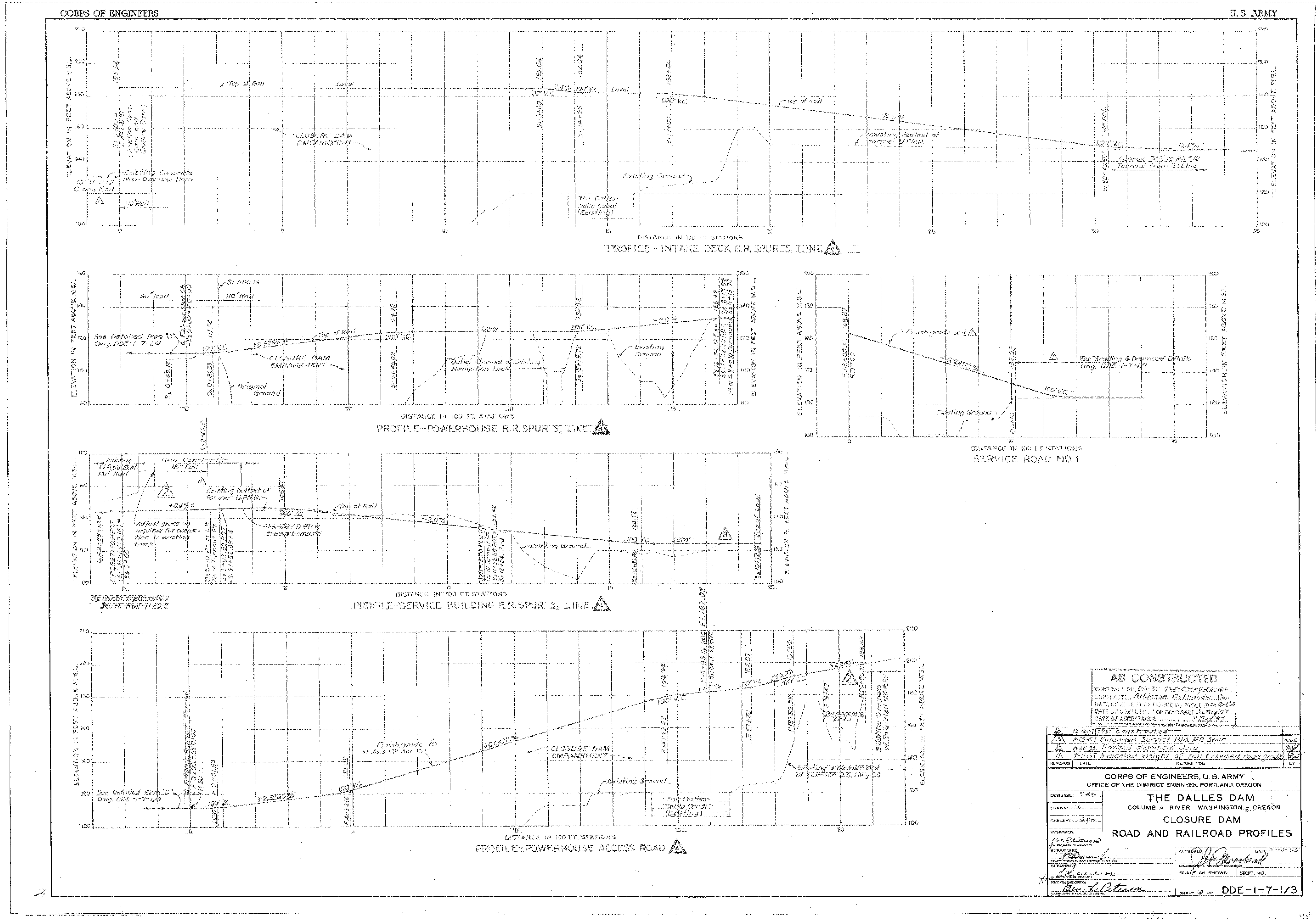
CLOSURE DAM RETAINING WALLS N/2, N/3, & N/4 FOUNDATION PLAN

FOR INFORMATION ONLY

SHEET IDENTIFICATION
FIO-404

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:47 | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$


CORPS OF ENGINEERS
U. S. ARMY
WALL N/4
WALL N/2
WALL N/3
SECTION C-C
SECTION D-D
SECTION E-E
NOTES:
1. Work this sheet with Dwg DDE-1-4-1/4.
2. C.J. denotes construction joint.
3. Pay items
Concrete for walls N/2, N/3, & N/4
Portland cement
Steel reinforcement
GRAPHIC SCALES
Scale in feet
AS CONSTRUCTED
TYPICAL CONTRACTION JOINT DETAIL
TYPICAL EXPANSION JOINT DETAILS
Do not scale this drawing. Follow dimensions.
CORPS OF ENGINEERS U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON
THE DALLES DAM
COLUMBIA RIVER, WASHINGTON – OREGON
CLOSURE DAM
RETAINING WALLS N/2, N/3, & N/4
ELEVATIONS AND SECTIONS
DDE-1-4-1/5
FOR INFORMATION ONLY
US Army Corps of Engineers
U.S. ARMY CORPS OF ENGINEERS PORTLAND DISTRICT PORTLAND, OREGON
U.S. ARMY CORPS OF ENGINEERS WALLA WALLA DISTRICT WALLA WALLA, WASHINGTON
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY
CLOSURE DAM
RETAINING WALLS N/2, N/3, & N/4
ELEVATIONS AND SECTIONS
SHEET IDENTIFICATION
FIO-405
DATE AND TIME PLOTTED: 08-JAN-2014



FOR INFORMATION ONLY

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: | DWN BY: | CKD BY: | SUBMITTED BY: | PLOT SCALE: | PLOT DATE: 08-JAN-2014 | SIZE: | FILE NAME: DDE-1-7-1/3 | DATE: | SOLICITATION NO.: | CONTRACT NO.: | DRAWING NUMBER:

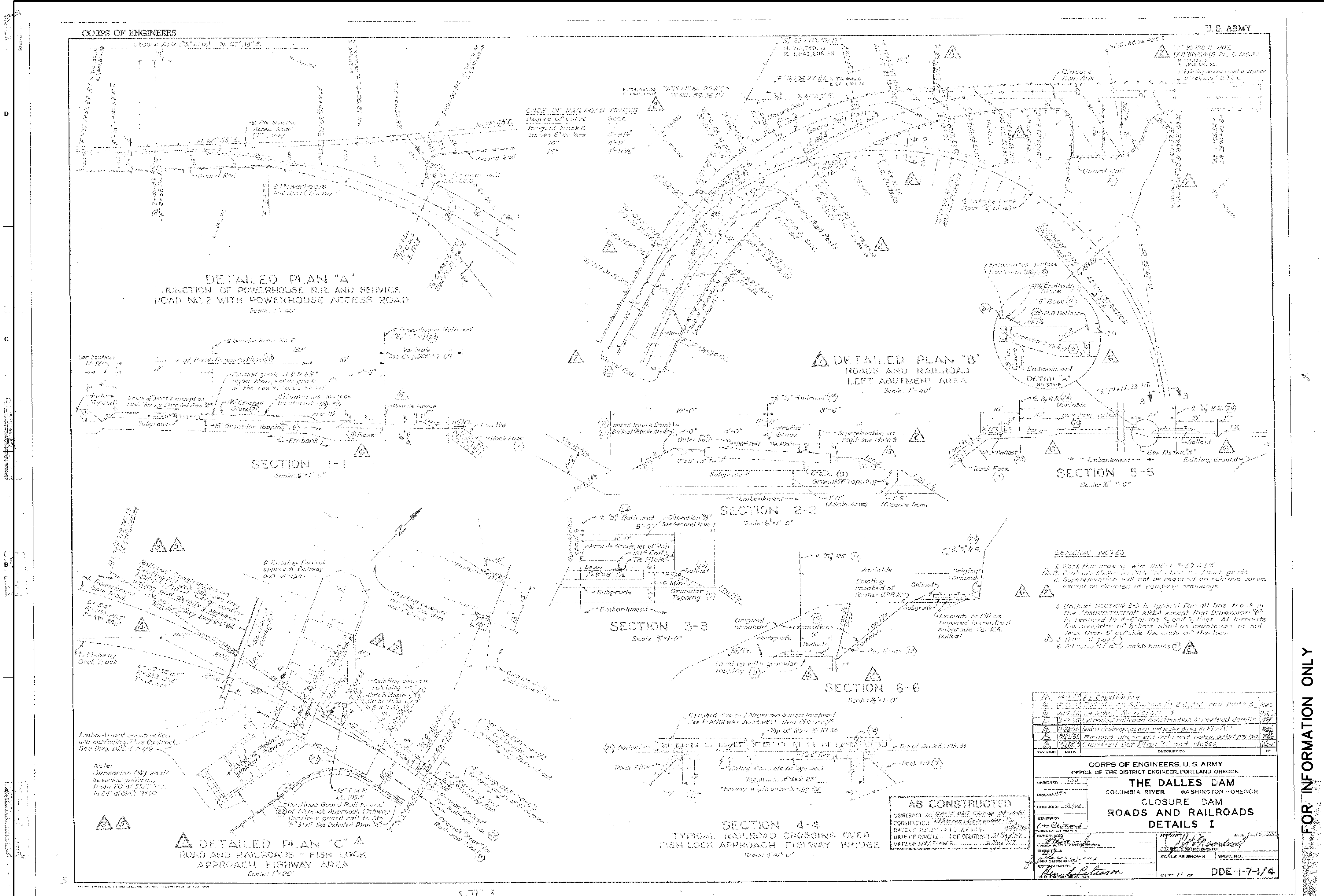
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

CLOSURE DAM
ROAD ANDE RAILROAD PROFILES

SHEET IDENTIFICATION
FIO-406

DESIGN FILE: $PWDIR$

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:47 | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$



FOR INFORMATION ONLY

US Army Corps of Engineers

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: | DWN BY: | CKD BY: | SUBMITTED BY: SUBMITTER'S NAME | PLOT SCALE: SCALE | PLOT DATE: 08-JAN-2014 | SIZE: SHT SIZE | FILE NAME: DDE-1-7-1/4 | DATE: ISSUE DATE | SOLICITATION NO.: SOLICITATION NUMBER | CONTRACT NO.: CONTRACT NUMBER | DRAWING NUMBER: DRAWING NUMBER

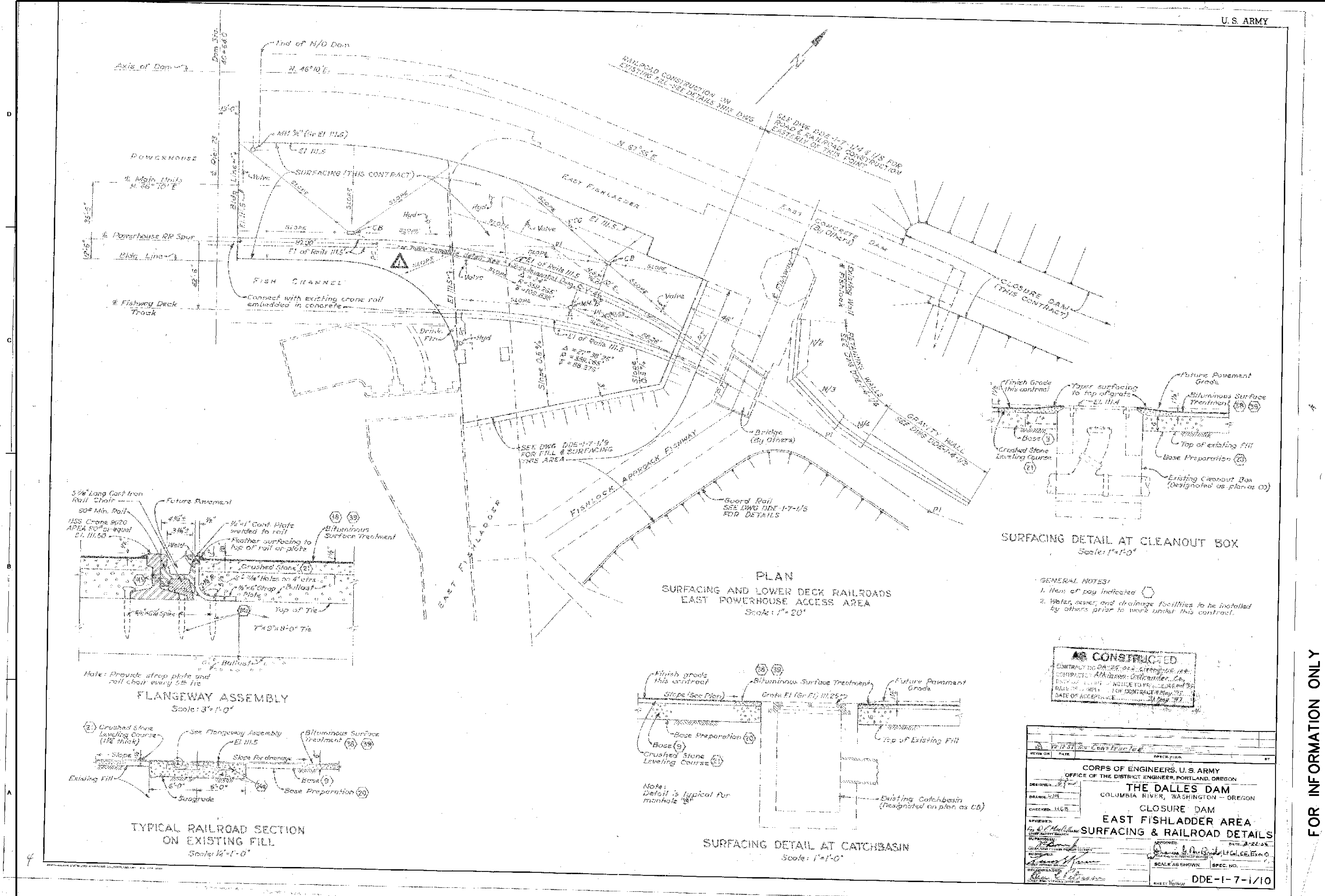
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

CLOSURE DAM
ROAD AND RAILROADS
DETAILS I

SHEET IDENTIFICATION
FIO-407

DESIGN FILE: $PWDIR$

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:47 | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$



US Army Corps of Engineers

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

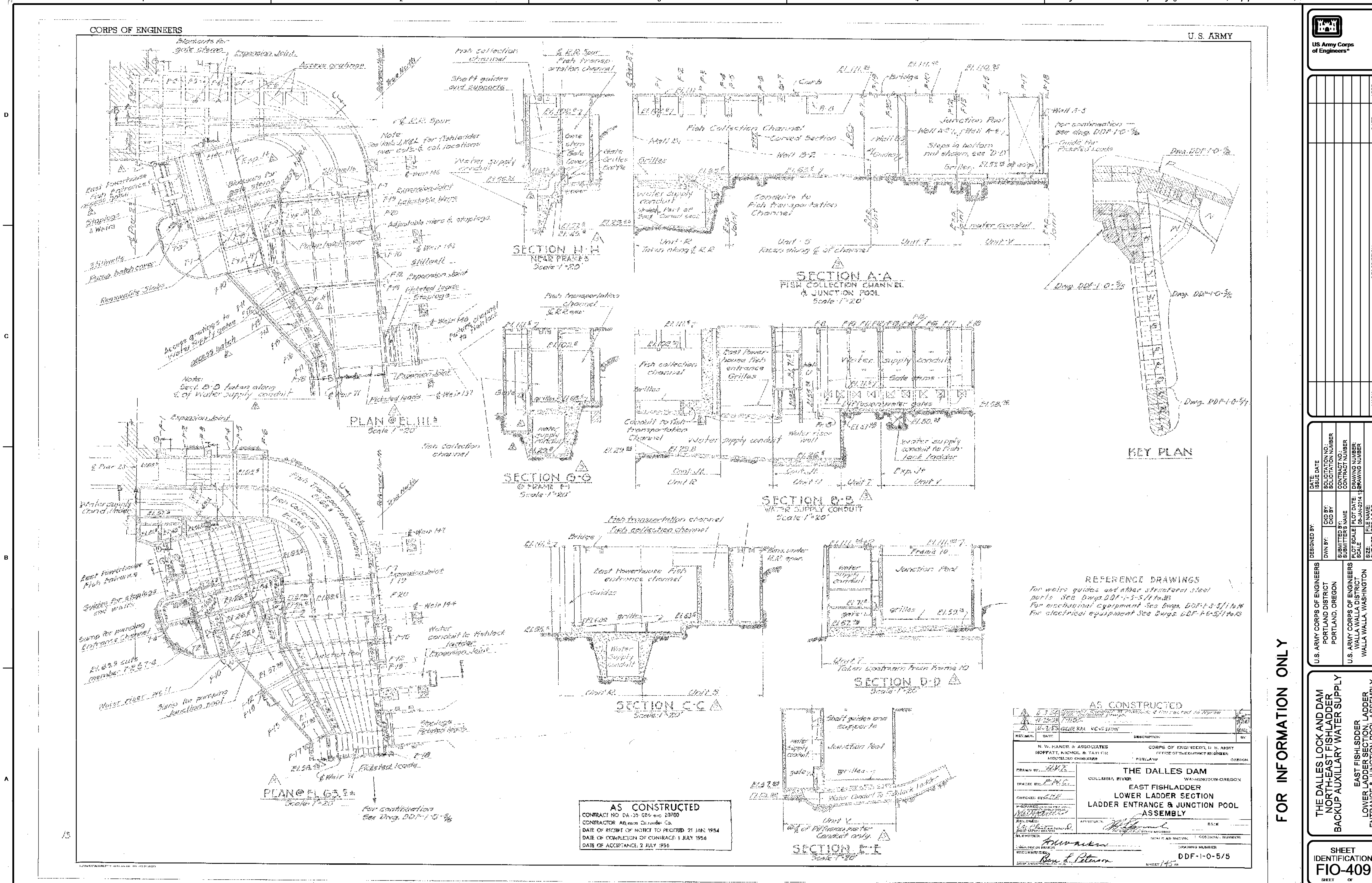
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

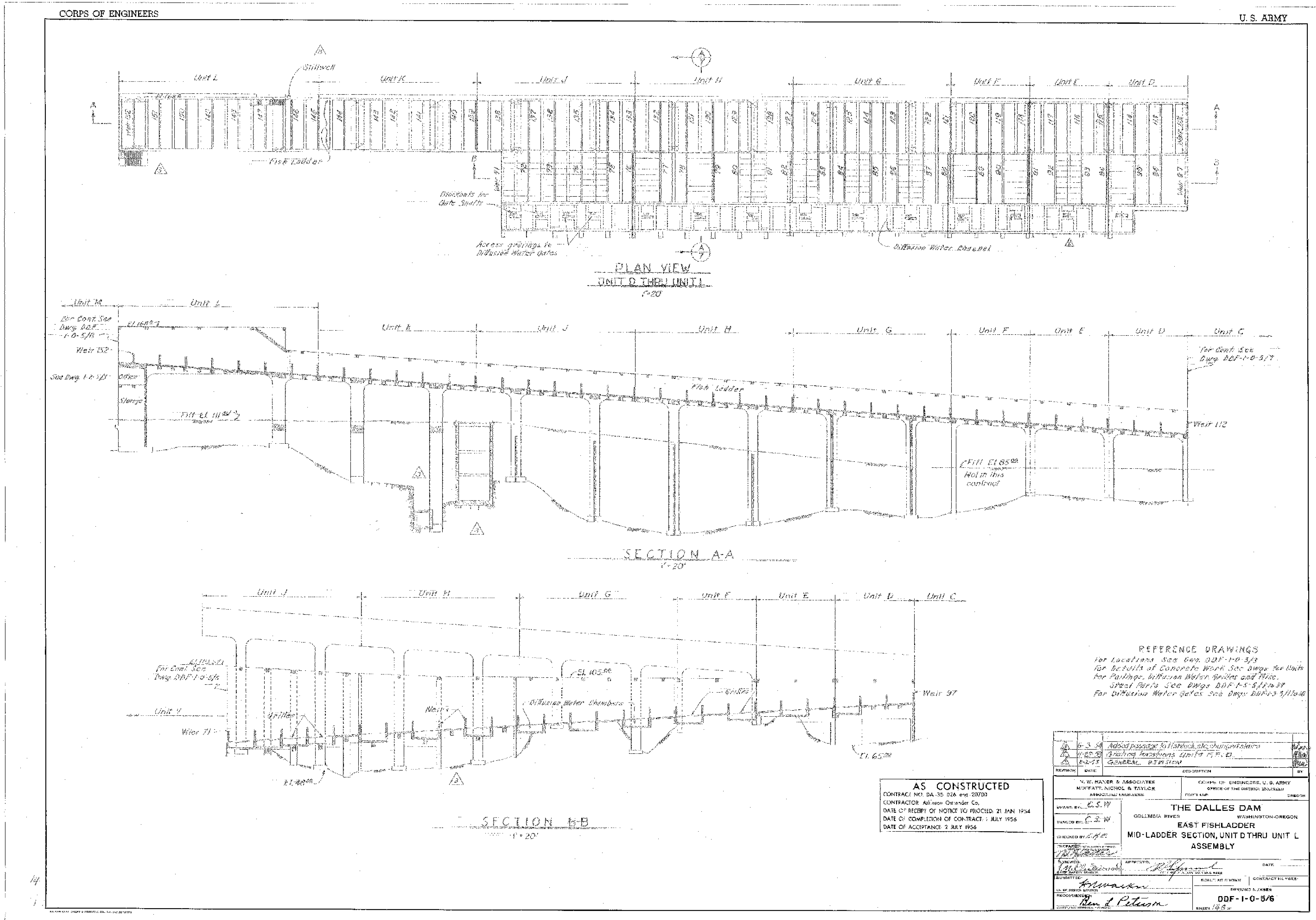
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

CLOSURE DAM
EAST FISHLADDER AREA
SURFACING & RAILROAD DETAILS

SHEET IDENTIFICATION
FIO-408

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:47 | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$


CORPS OF ENGINEERS
U. S. ARMY
PLAN @ EL. 111.5
PLAN @ EL. 63.5
SECTION H-H
SECTION A-A
FISH COLLECTION CHANNEL & JUNCTION POOL
SECTION G-G
SECTION B-B
WATER SUPPLY CONDUIT
SECTION C-C
SECTION D-D
SECTION E-E
KEY PLAN
REFERENCE DRAWINGS
AS CONSTRUCTED
CONTRACT NO. DA-35-026-eng-20700
DATE OF RECEIPT OF NOTICE TO PROCEED 21 JAN 1954
DATE OF COMPLETION OF CONTRACT 1 JULY 1956
DATE OF ACCEPTANCE 2 JULY 1956
THE DALLES DAM
EAST FISHLADDER
LOWER LADDER SECTION
LADDER ENTRANCE & JUNCTION POOL
ASSEMBLY
DDF-1-0-5/5
FOR INFORMATION ONLY
US Army Corps of Engineers
U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY
EAST FISHLSDDER
LOWER LADDER SECTION, LADDER
ENTRANCE & JUNCTION POOL ASSEMBLY
SHEET IDENTIFICATION
FIO-409
DRAWING PLOT SIZE: $BORDER$
DATE AND TIME PLOTTED: 08-JAN-2014
BY USERNAME: $USER$
SHEET NAME: $SHEETN$



US Army Corps of Engineers

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

EAST FISHLADDER
MID-LADDER SECTION, UNIT D THRU L
ASSEMBLY

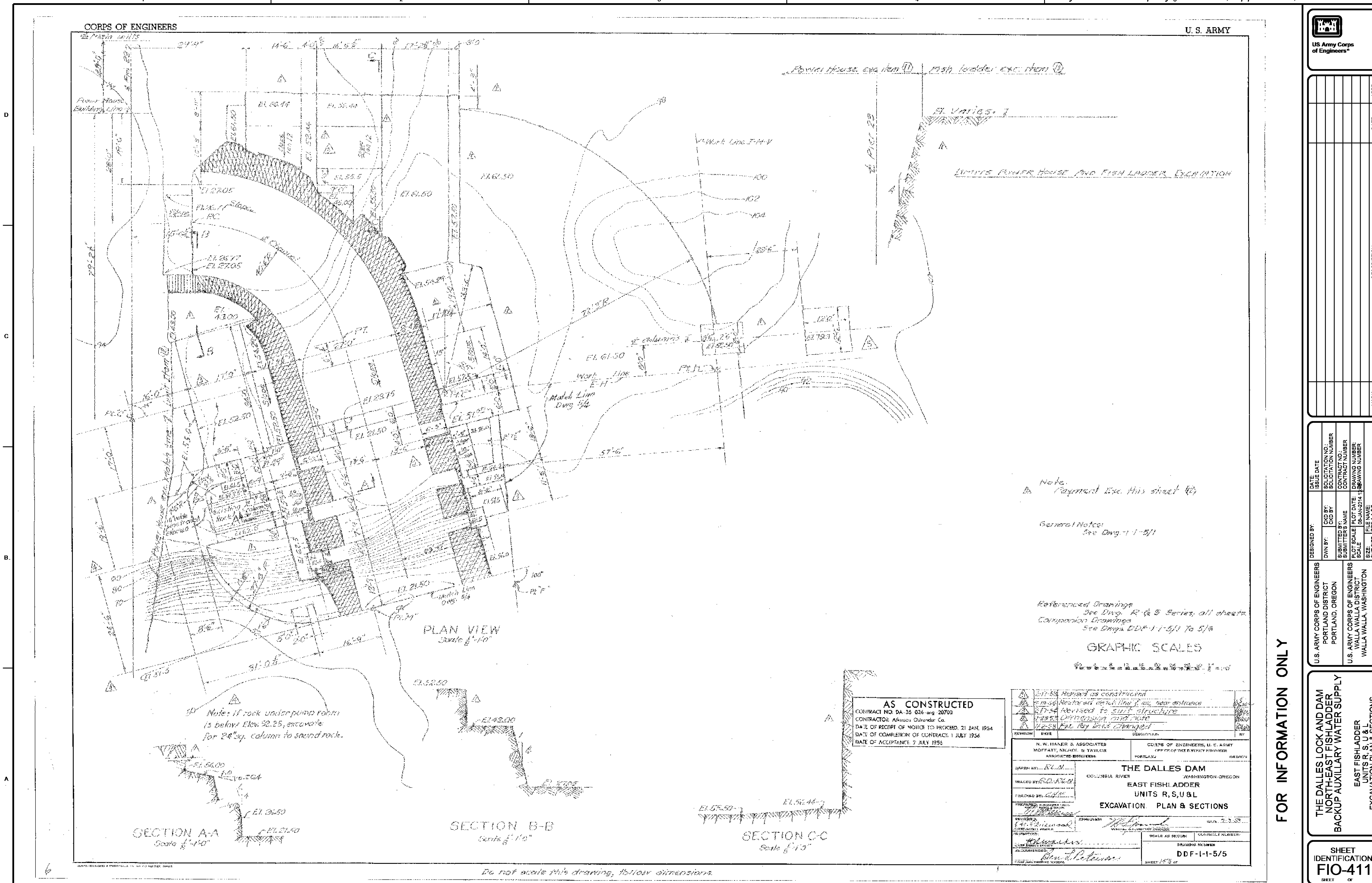
U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

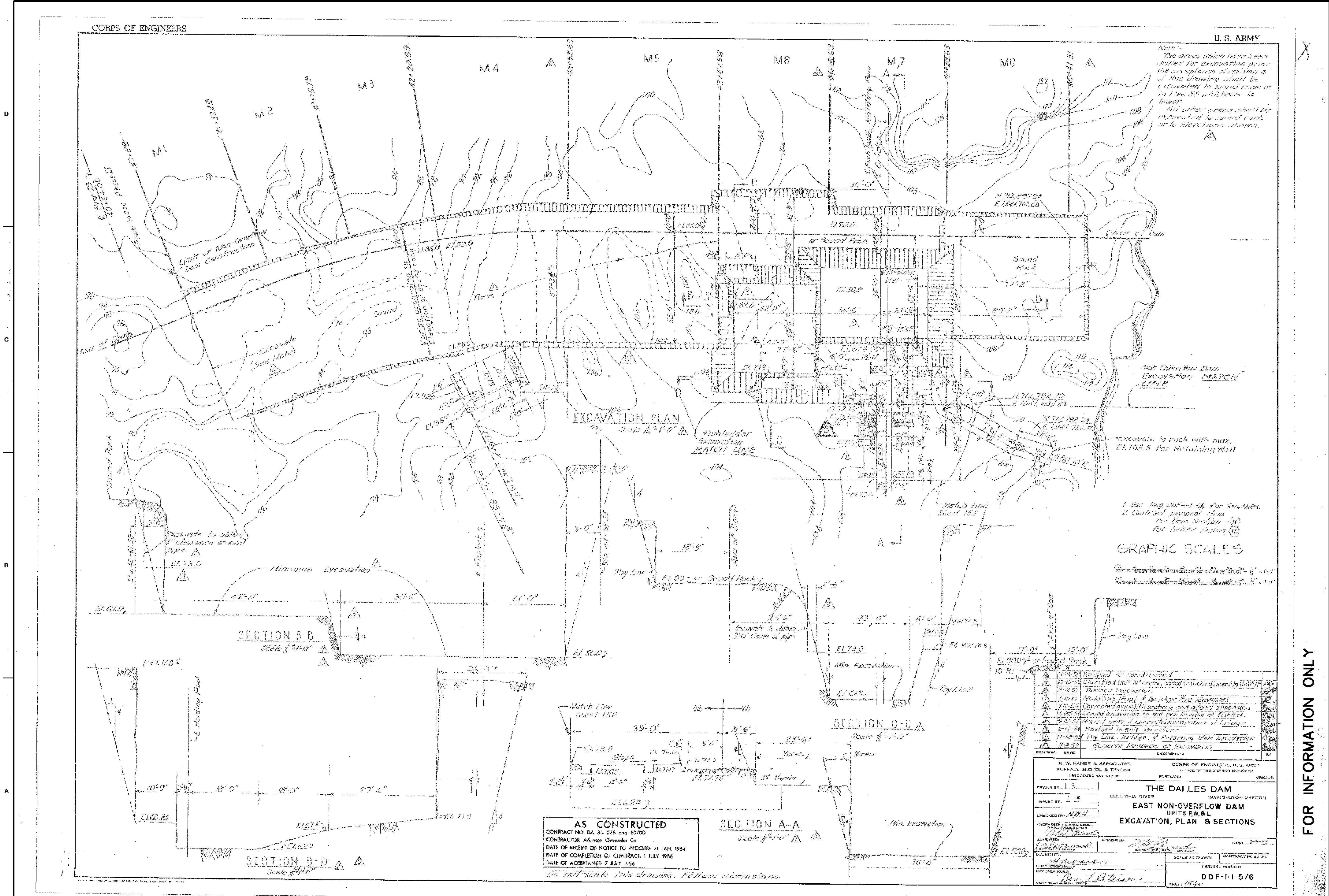
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

FOR INFORMATION ONLY

SHEET IDENTIFICATION
FIO-410

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:48 | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$


CORPS OF ENGINEERS
U. S. ARMY
Power House exc item 11 | Fish ladder exc item 12
El. Varies
Limits Power House and Fish Ladder Excavation
PLAN VIEW
Scale 1/8"=1'-0"
Note: If rock under pump room is below Elev. 52.25, excavate for 24" sq. column to sound rock.
SECTION A-A
Scale 1/8"=1'-0"
SECTION B-B
Scale 1/8"=1'-0"
SECTION C-C
Scale 1/8"=1'-0"
Note: Payment Exc. this sheet 12
General Notes: See Dwg. 1-1-5/1
Referenced Drawings: See Dwg. R-G & S Series, all sheets.
Companion Drawings: See Dwgs. DDF-1-1-5/1 To 5/6
GRAPHIC SCALES
AS CONSTRUCTED
CONTRACT NO. DA-35 026-eng-20700
CONTRACTOR Atkinson Ostrander Co.
DATE OF RECEIPT OF NOTICE TO PROCEED 21 JAN. 1954
DATE OF COMPLETION OF CONTRACT 1 JULY 1956
DATE OF ACCEPTANCE 2 JULY 1956
Revised as constructed
Restored centerline exc. near entrance
Revised to suit structure
Dimension and note
Exc. Pay lines changed
REVISION DATE DESCRIPTION BY
N. W. HANER & ASSOCIATES
MOFFATT, NICHOL & TAYLOR
ASSOCIATED ENGINEERS
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
PORTLAND OREGON
THE DALLES DAM
COLUMBIA RIVER WASHINGTON-OREGON
EAST FISHLADDER
UNITS R, S, U & L
EXCAVATION PLAN & SECTIONS
SCALE AS SHOWN
DRAWING NUMBER
DDF-1-1-5/5
Do not scale this drawing, follow dimensions.
US Army Corps of Engineers
FOR INFORMATION ONLY
U.S. ARMY CORPS OF ENGINEERS PORTLAND DISTRICT PORTLAND, OREGON
U.S. ARMY CORPS OF ENGINEERS WALLA WALLA DISTRICT WALLA WALLA, WASHINGTON
THE DALLES LOCK AND DAM NORTH-EAST FISHLADDER BACKUP AUXILLARY WATER SUPPLY
EAST FISHLADDER UNITS R, S, U & L EXCAVATION PLAN & SECTIONS
SHEET IDENTIFICATION
FIO-411
DRAWING PLOT SIZE: $BORDER$
DATE AND TIME PLOTTED: 08-JAN-2014
BY USERNAME: $USER$
SHEET NAME: $SHEETN$



FOR INFORMATION ONLY

US Army Corps of Engineers

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: | DWN BY: | CKD BY: | SUBMITTED BY: | PLOT SCALE: | PLOT DATE: 08-JAN-2014 | SIZE: | FILE NAME: DDF-1-1-5/6

DATE: | ISSUE DATE | SOLICITATION NO.: | CONTRACT NO.: | DRAWING NUMBER:

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

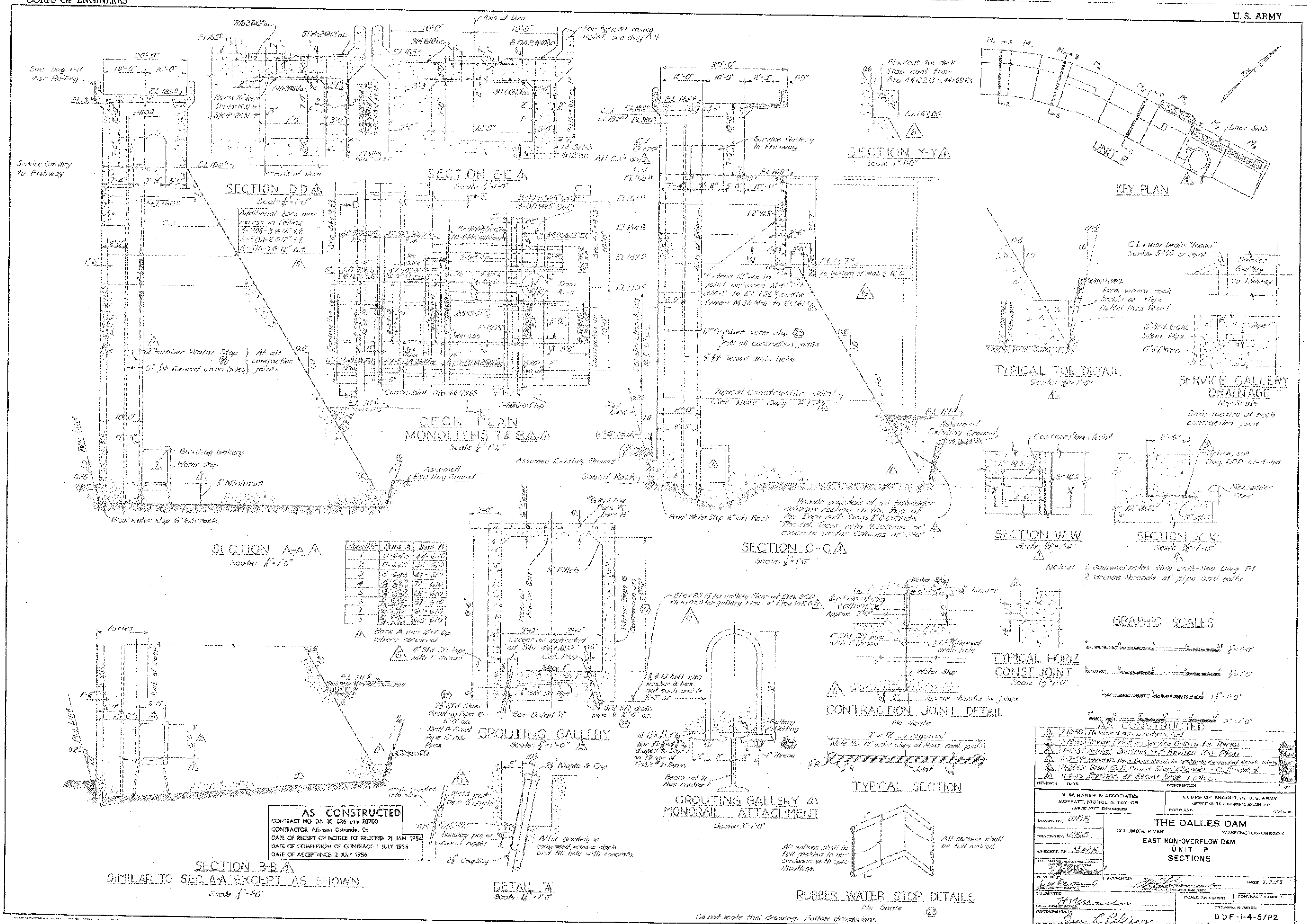
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

EAST NON-OVERFLOW DAM
UNITS P, W, & L
EXCAVATION PLAN & SECTIONS

SHEET IDENTIFICATION
FIO-412
SHEET OF

DESIGN FILE: $PWDIR$



FOR INFORMATION ONLY

US Army Corps of Engineers

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

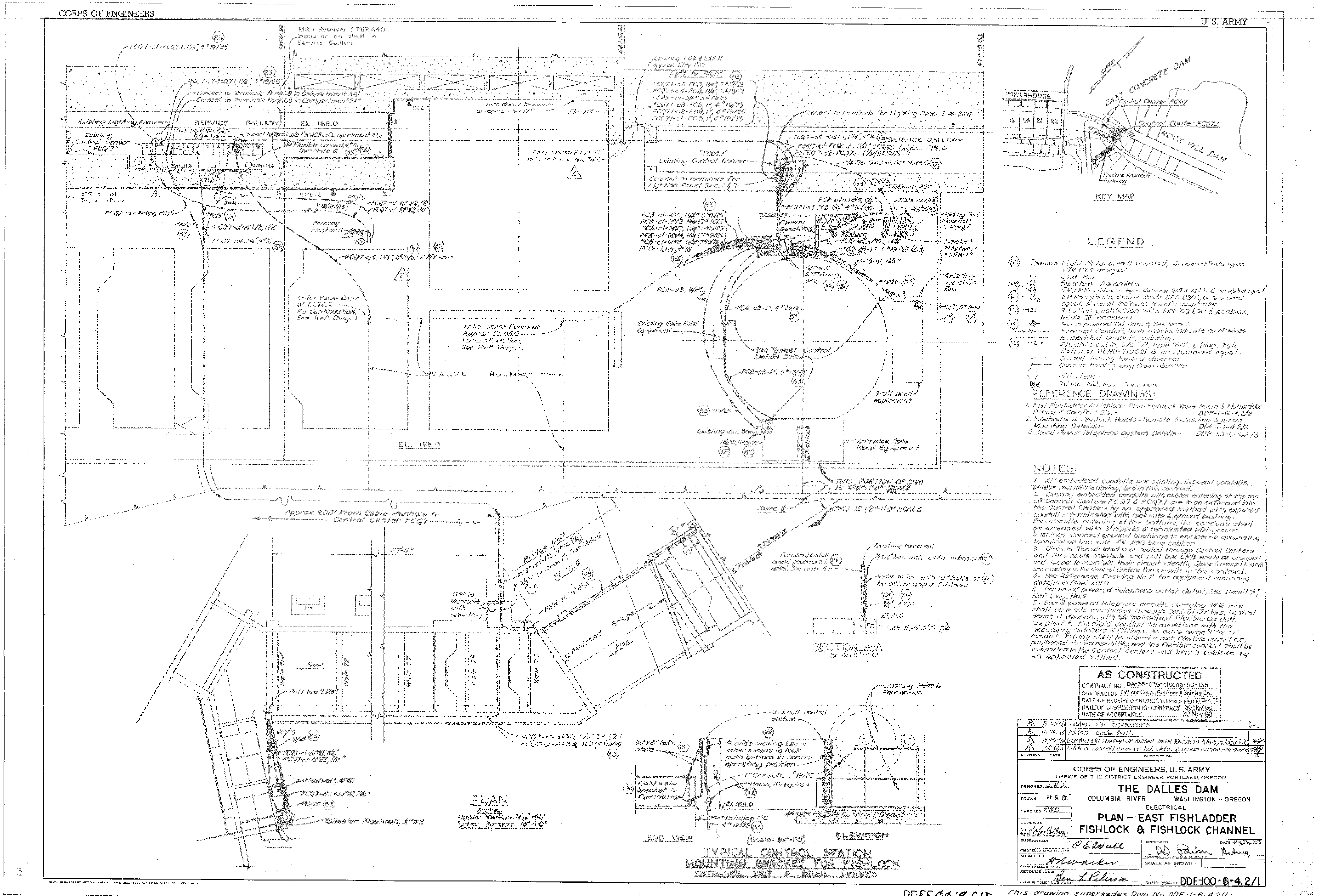
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

EAST NON-OVERFLOW DAM
UNIT P
SECTIONS

SHEET IDENTIFICATION
FIO-413

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:48 | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$



FOR INFORMATION ONLY

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: | DWN BY: | CKD BY: | SUBMITTED BY: | PLOT SCALE: | PLOT DATE: 08-JAN-2014 | SIZE: | FILE NAME: DDF-100-6-4.2/1
DATE: | SOLICITATION NO.: | CONTRACT NO.: | DRAWING NUMBER:

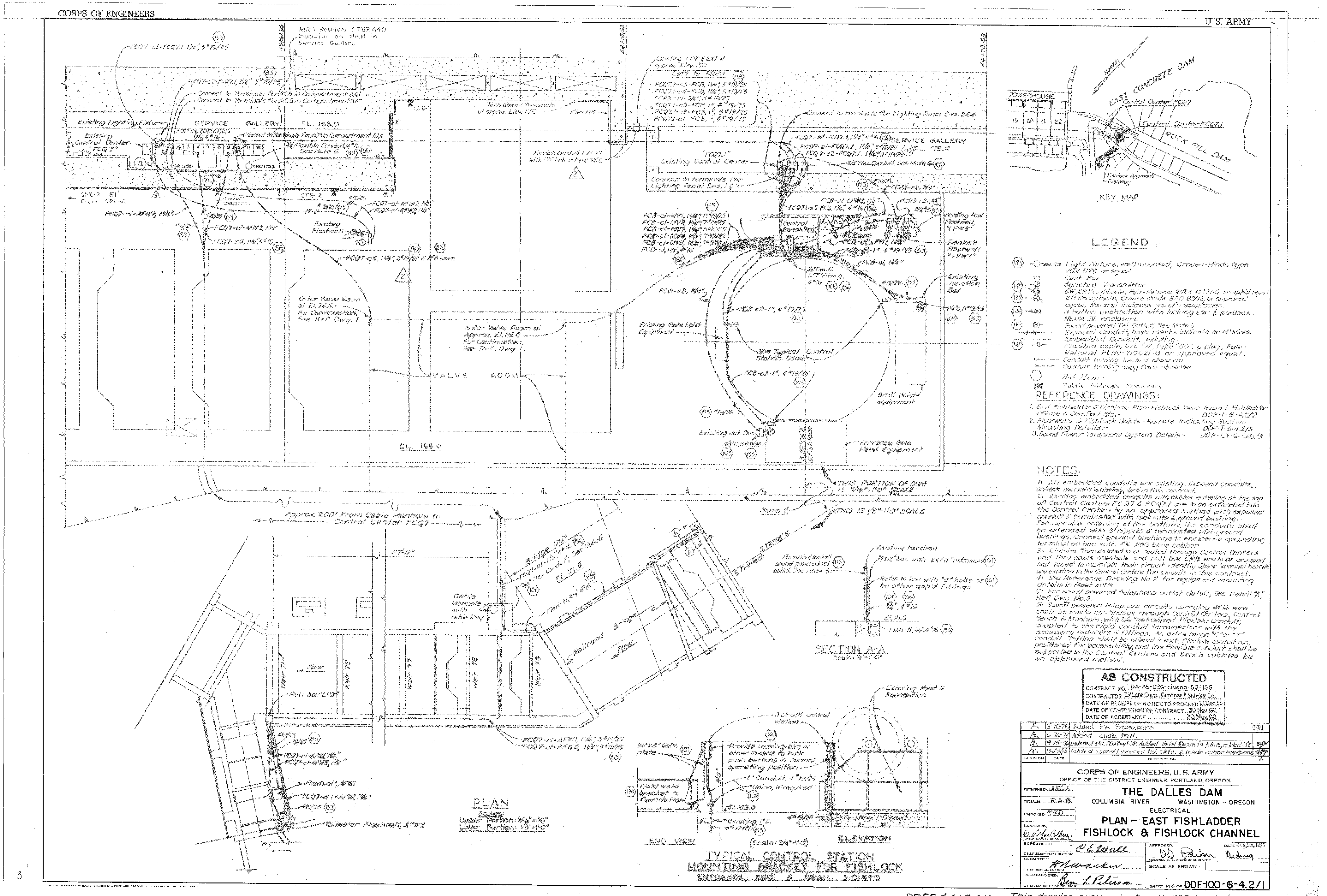
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

PLAN-EAST FISHLADDER
FISHLOCK & FISH LOCK CHANNEL

SHEET IDENTIFICATION
FIO-414

DESIGN FILE: $PWDIR$

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:$TIME | BY USERNAME: $USER$ | SHEET NAME: $SHEET$



FOR INFORMATION ONLY

US Army Corps of Engineers®

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

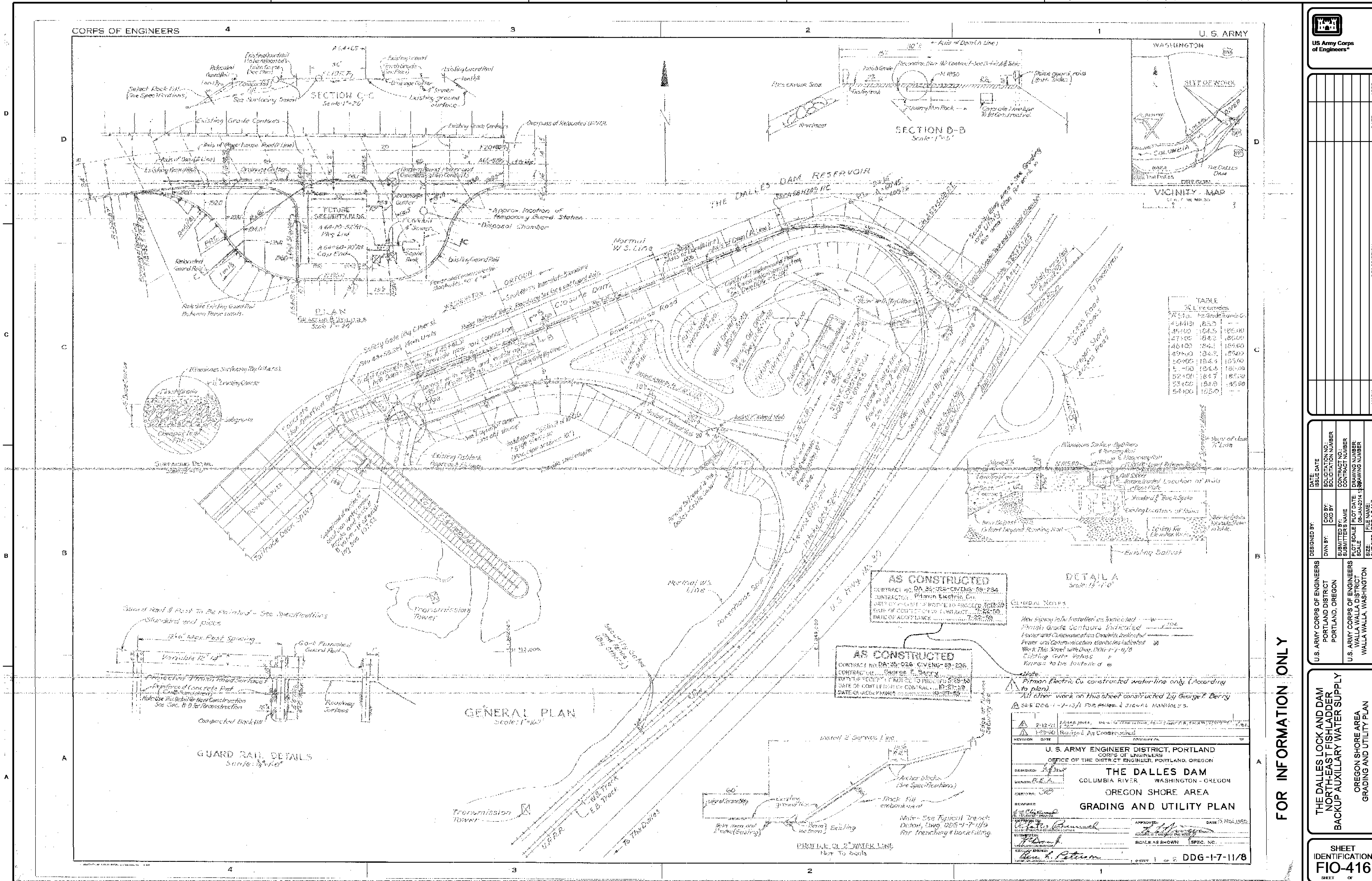
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

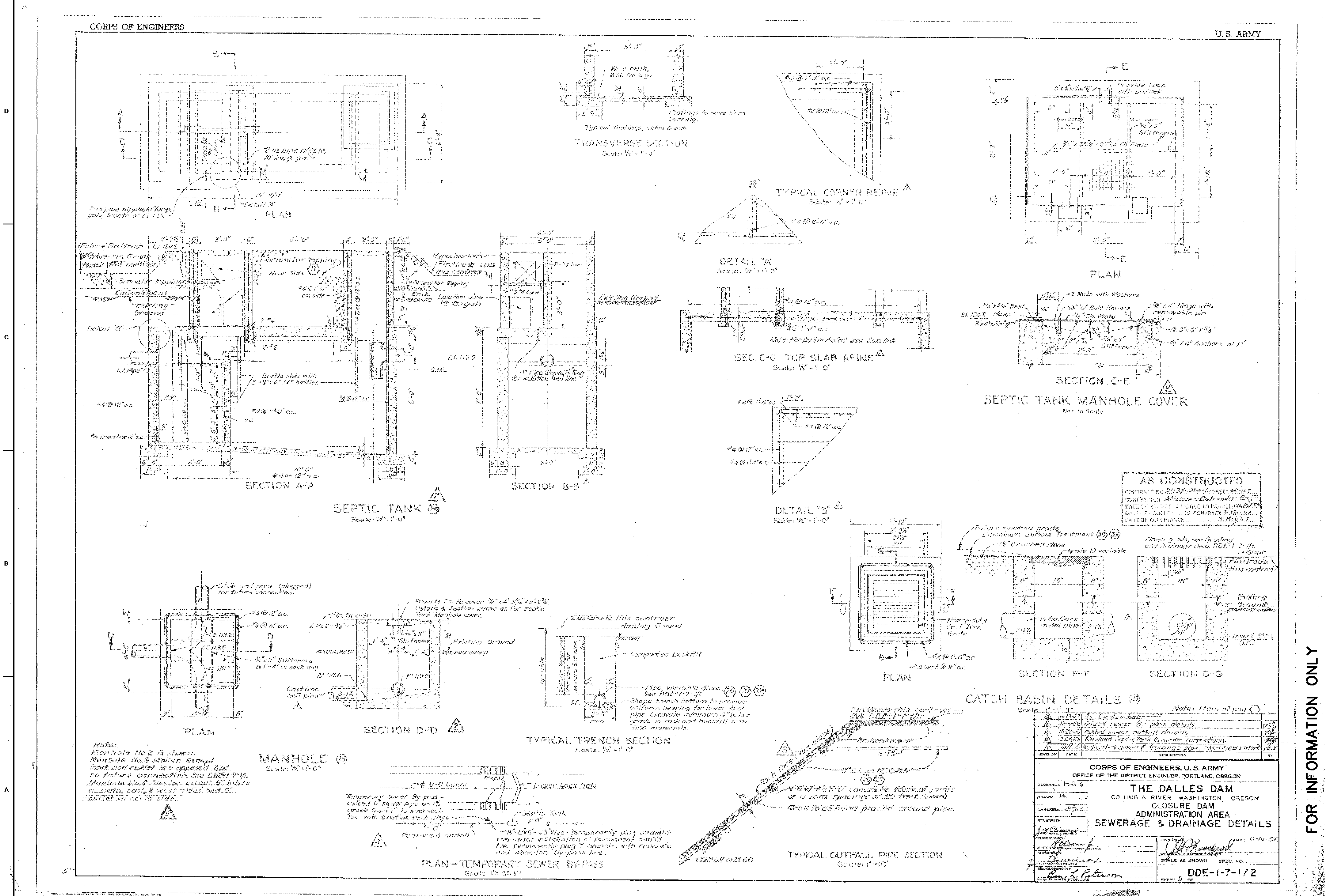
PLAN-EAST FISHLADDER
FISHLOCK & FISH LOCK CHANNEL

SHEET IDENTIFICATION
FIO-415

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13$TIME | BY USERNAME: $USER$ | SHEET NAME: $SHEET$



Sta.	Fin. Grade	Roadway Cr.
45+13	185.0	—
46+00	184.5	185.00
47+00	184.2	185.00
48+00	184.1	185.00
49+00	184.2	185.00
50+00	184.4	185.00
51+00	184.4	185.00
52+00	184.7	185.00
53+00	184.9	185.00
54+00	185.0	—



US Army Corps of Engineers

MARK | DESCRIPTION | DATE | APPR.

DESIGNED BY: | DWN BY: | CKD BY: | SUBMITTED BY: | PLOT SCALE: | PLOT DATE: 08-JAN-2014 | SIZE: | FILE NAME: DDE-1-7-1/2

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

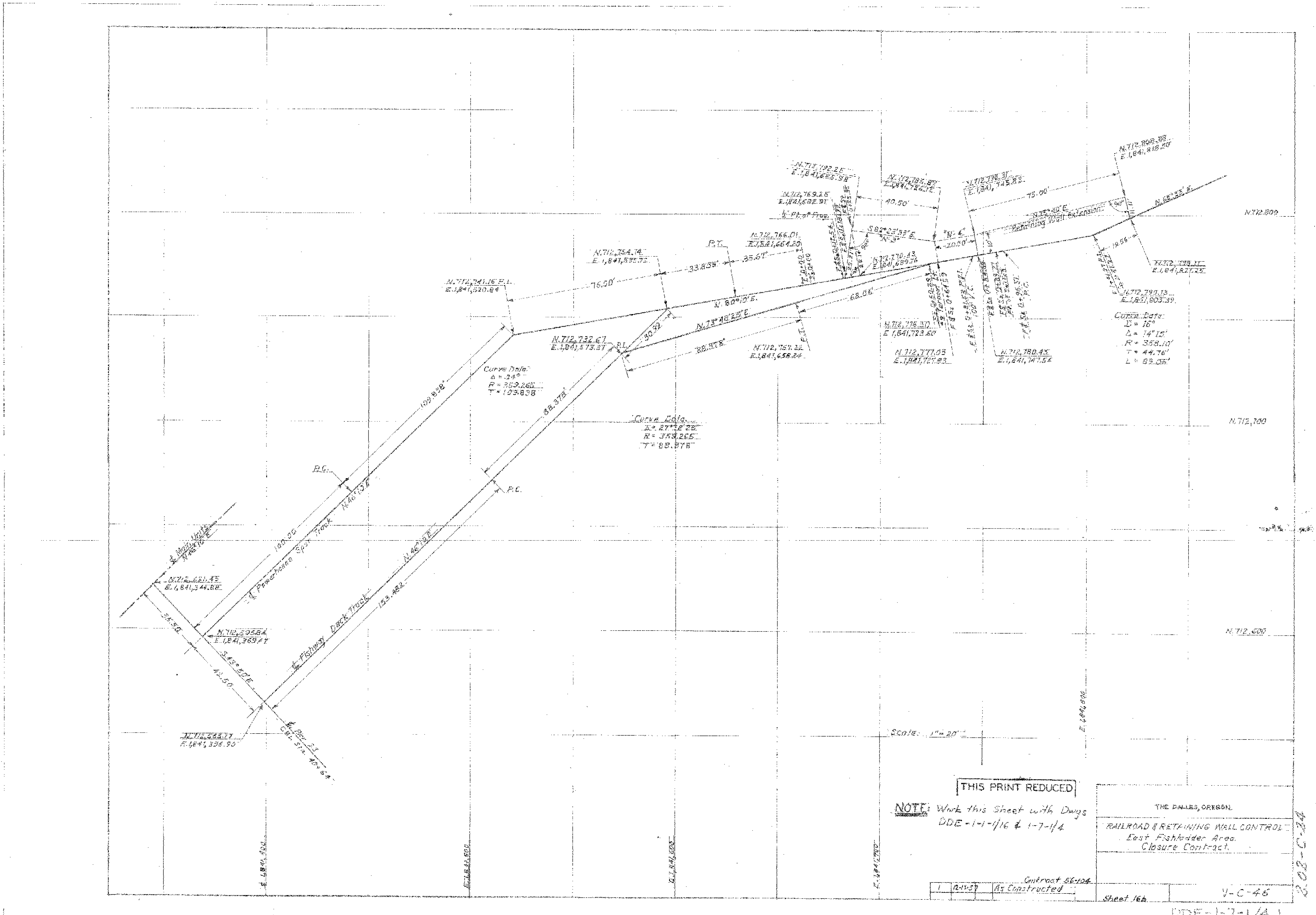
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

CLOSURE DAM
ADMINISTRATION AREA
SEWERAGE & DRAINAGE DETAILS

SHEET IDENTIFICATION
FIO-501

DESIGN FILE: $PWDIR$



FOR INFORMATION ONLY

US Army Corps of Engineers

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

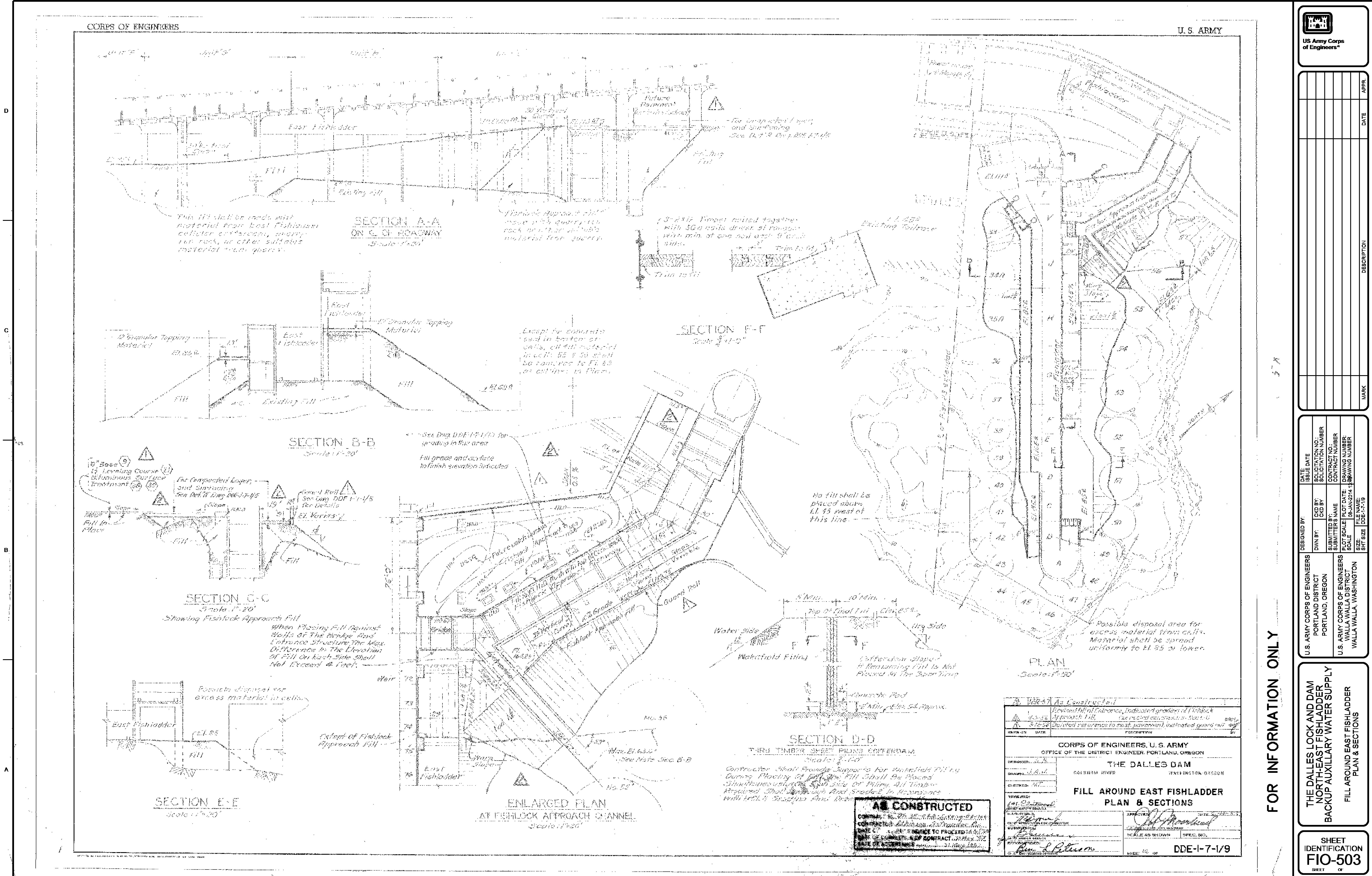
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

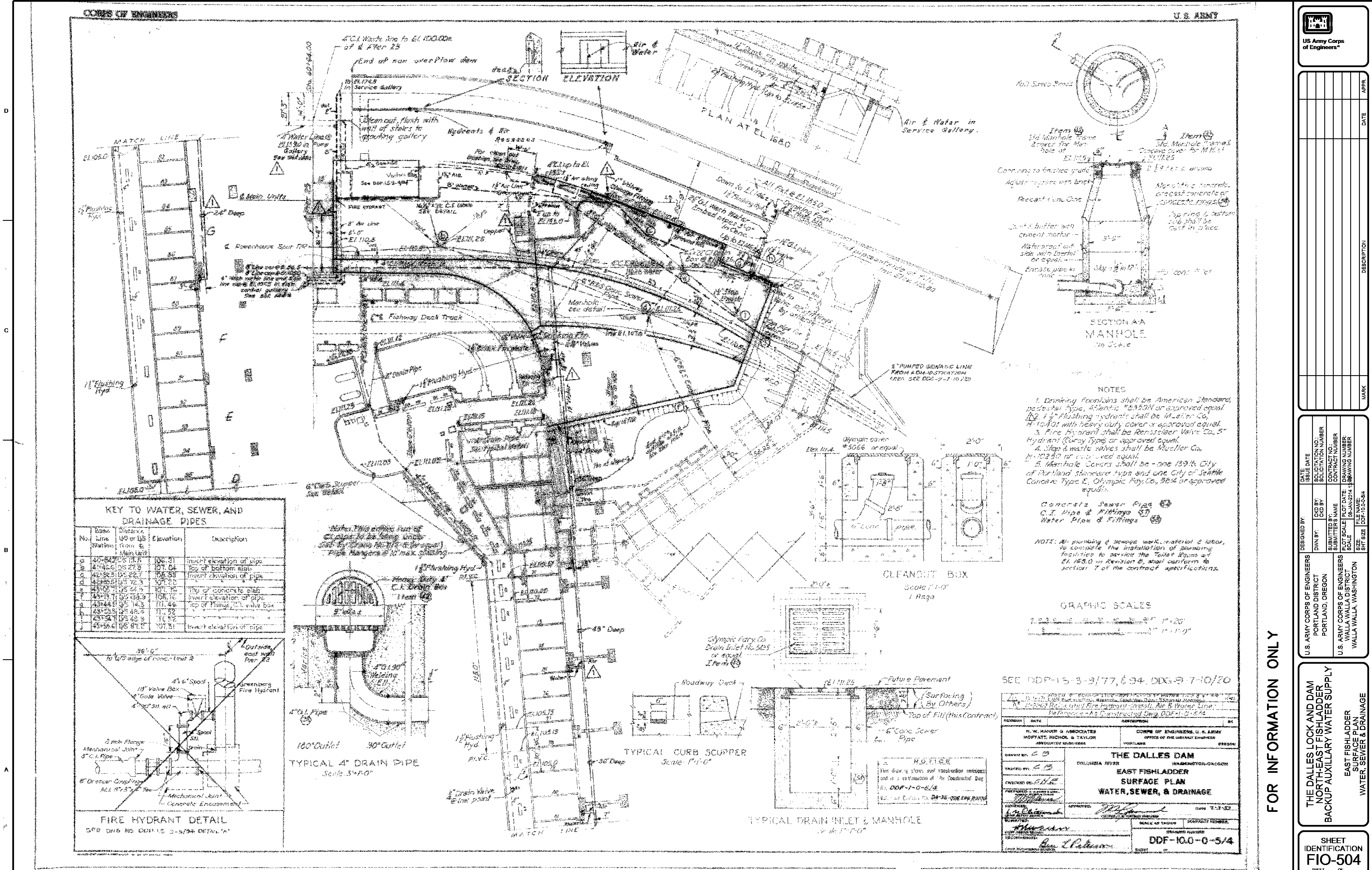
RAILROAD & RETAINING WALL CONTROL
EAST FISHLADDER AREA
CLOSURE CONTRACT

SHEET IDENTIFICATION
FIO-502

DRAWING PLOT SIZE: $BORDERS$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:$TIME | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$



CORPS OF ENGINEERS
U. S. ARMY
SECTION A-A
ON ℄ OF ROADWAY
SECTION B-B
SECTION C-C
Showing Fishlock Approach Fill
SECTION D-D
THRU TIMBER SHEET PILING COFFERDAM
SECTION E-E
SECTION F-F
ENLARGED PLAN
AT FISHLOCK APPROACH CHANNEL
PLAN
East Fishladder
Existing Tailrace
Possible disposal area for excess material from cells. Material shall be spread uniformly to El. 85 or lower.
No fill shall be placed above El. 85 west of this line.
AS CONSTRUCTED
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON
THE DALLES DAM
COLUMBIA RIVER
WASHINGTON-OREGON
FILL AROUND EAST FISHLADDER
PLAN & SECTIONS
DDE-I-7-1/9
FOR INFORMATION ONLY
US Army Corps of Engineers
U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY
FILL AROUND EAST FISHLADDER
PLAN & SECTIONS
SHEET IDENTIFICATION
FIO-503
DRAWING PLOT SIZE: $BORDER$
DATE AND TIME PLOTTED: 08-JAN-2014 13$TIME
BY USERNAME: $USER$
SHEET NAME: $SHEETN$
DESIGN FILE: $PWDIR$

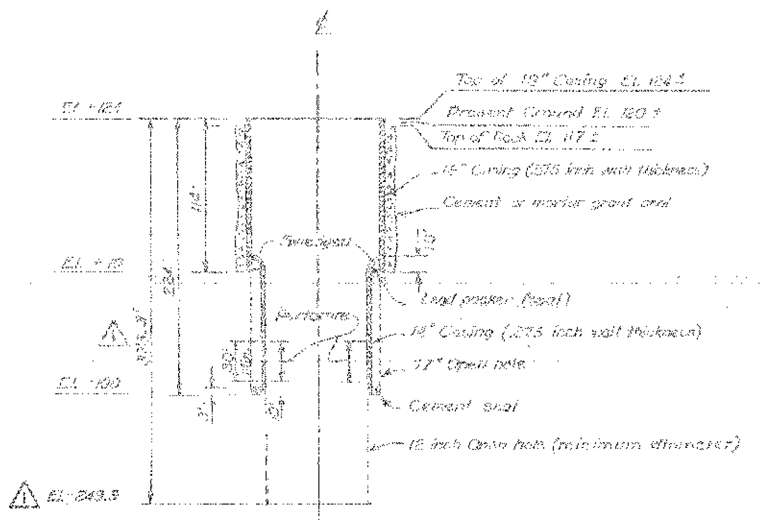


KEY TO WATER, SEWER, AND DRAINAGE PIPES

No.	Base Line Station	Distance U/S or D/S from ℄ Main Unit	Elevation	Description
a	42+84.7	U/S 13.5	106.31	Invert elevation of pipe
b	41+42.6	D/S 27.8	107.64	Top of bottom slab
c	42+92.5	D/S 22.7	106.53	Invert elevation of pipe
d	42+85.5	U/S 72.3	107.22	" " " "
e	43+02.7	U/S 64.5	107.16	Top of concrete slab
f	45+13.7	U/S 138.9	105.16	Invert elevation of pipe
g	43+44.5	D/S 14.3	111.46	Top of flange, C.I. valve box
h	43+53.5	D/S 48.4	111.52	" " " "
i	43+54.7	D/S 48.9	111.52	" " " "
j	45+56.6	D/S 81.2	107.51	Invert elevation of pipe

CORPS OF ENGINEERS

U. S. ARMY

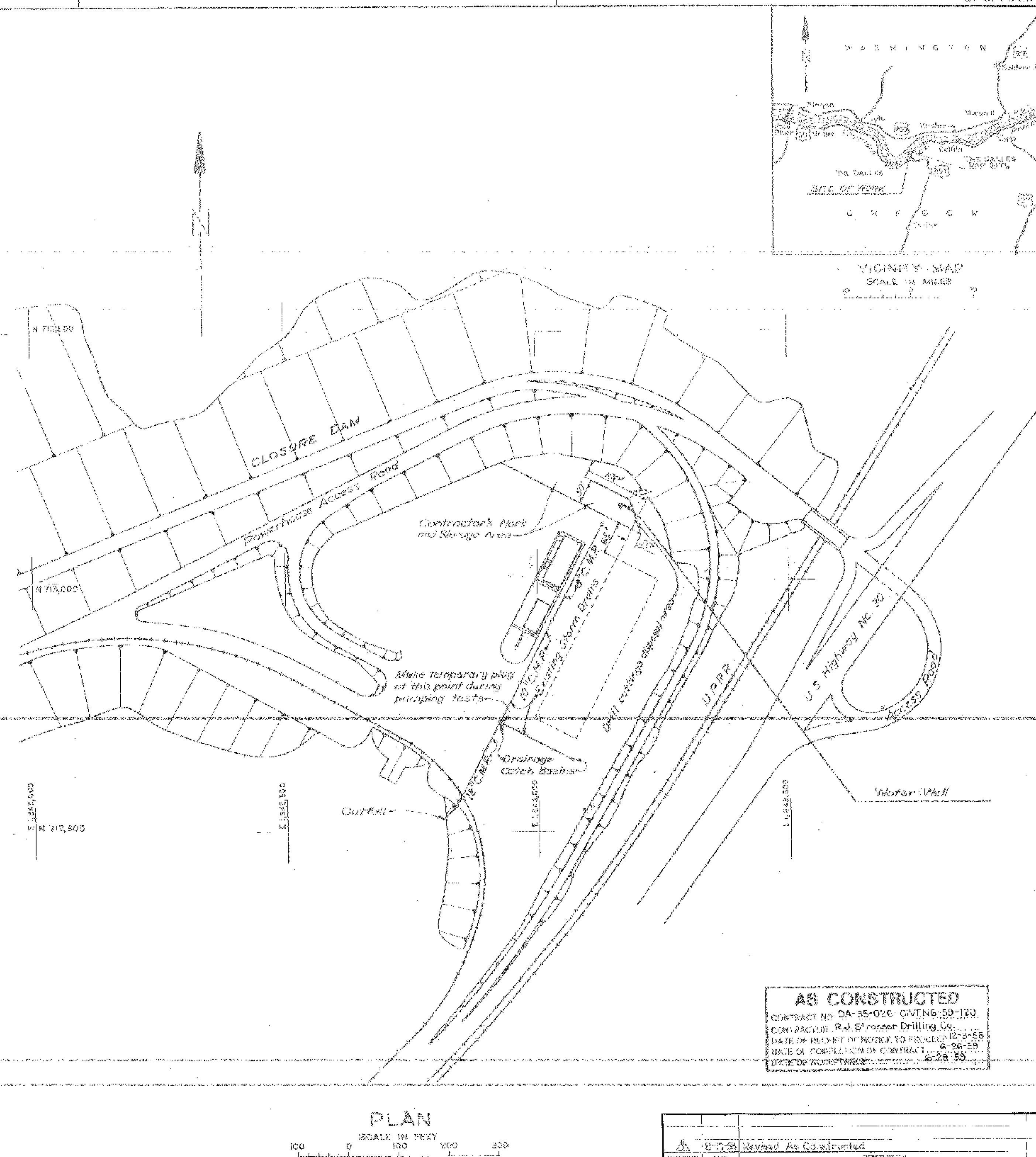


SCHEMATIC CROSS SECTION - DEEP WELL

ALL DIMENSIONS ARE APPROXIMATE

Notes:

1. Overburden shall be removed to a sufficient distance from 18 inch hole to prevent caving and raveling into hole.
2. 18 inch casing shall be set, aligned and sealed by grouting from the bottom in a continuous operation before extending well below elevation + 10.
3. ~~14 inch well casing shall be perforated and set after the well yield above elevation -100 has been determined. Perforated section range may vary from 30 to 50 feet in length.~~
4. Casing liners shall be used in areas of caving rock only where required. Liners will be fixed by a 3 feet, or less, cement plug and shall have perforated sections of 5 feet to 15 feet in length.



PLAN

SCALE IN FEET

100 0 100 200 300

AS CONSTRUCTED

CONTRACT NO. DA-35-026-CIVENG-56-120
CONTRACTOR R.J. Strasser Drilling Co.
DATE OF RECEIPT OF NOTICE TO PROCEED 12-3-55
DATE OF COMPLETION OF CONTRACT 5-26-56
DATE OF ACCEPTANCE 5-28-56

MARK	DATE	DESCRIPTION	BY
1	8-7-56	Revised As Constructed	

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

THE DALLES DAM

COLUMBIA RIVER — WASHINGTON - OREGON

OREGON SHORE WATER WELL

SCALE AS SHOWN

DDG-1-7-8/4

FOR INFORMATION ONLY

US Army Corps of Engineers

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

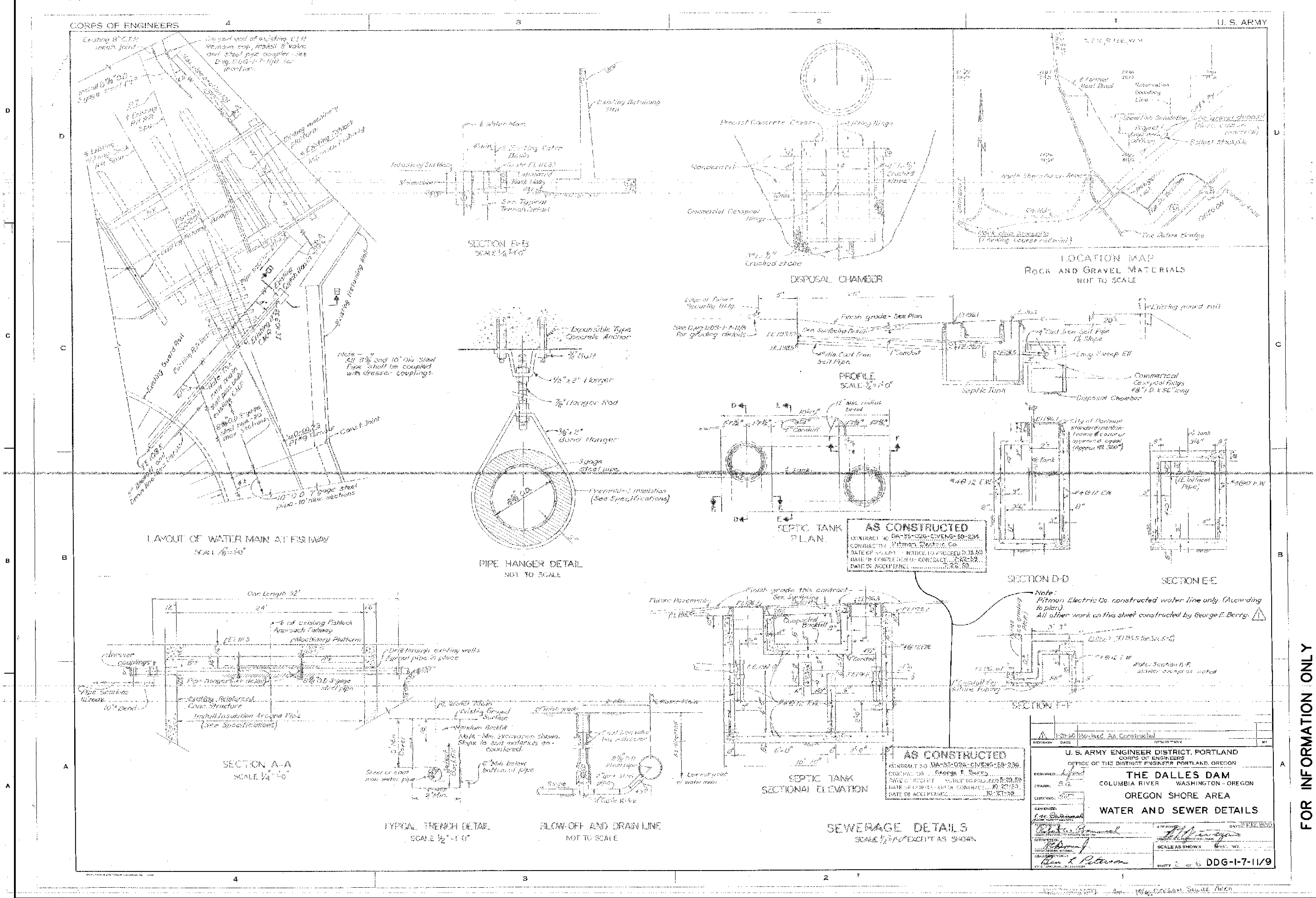
DESIGNED BY: | DWN BY: | CKD BY: | SUBMITTED BY: | PLOT SCALE: | PLOT DATE: 08-JAN-2014 13:... | FILE NAME: DDG-1-7-8/4 | SIZE: | DATE: | SOLICITATION NO.: | CONTRACT NO.: | DRAWING NUMBER:

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

OREGON SHORE WATER WELL

SHEET IDENTIFICATION
FIO-505

DESIGN FILE: $PWDIR$



US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: | DWN BY: | CKD BY: | SUBMITTED BY: | PLOT SCALE: | PLOT DATE: 08-JAN-2014 | SIZE: | FILE NAME: DDG-1-7-11/9 | DATE: | SOLICITATION NO.: | CONTRACT NO.: | DRAWING NUMBER:

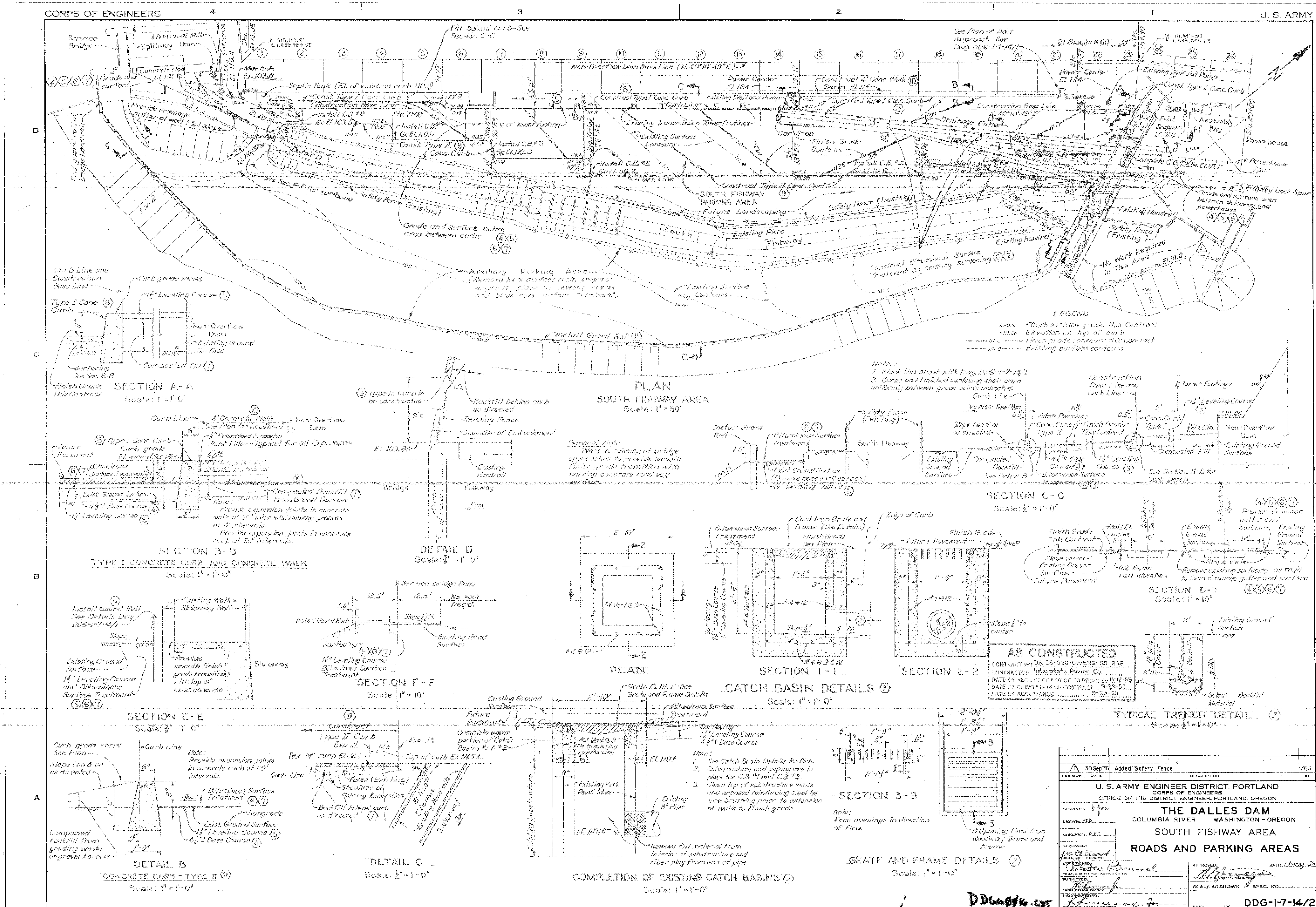
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

OREGON SHORE AREA
WATER AND SEWER DETAILS

SHEET IDENTIFICATION
FIO-506

DESIGN FILE: $PWDIR$

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:00 | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$



FOR INFORMATION ONLY

US Army Corps of Engineers

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

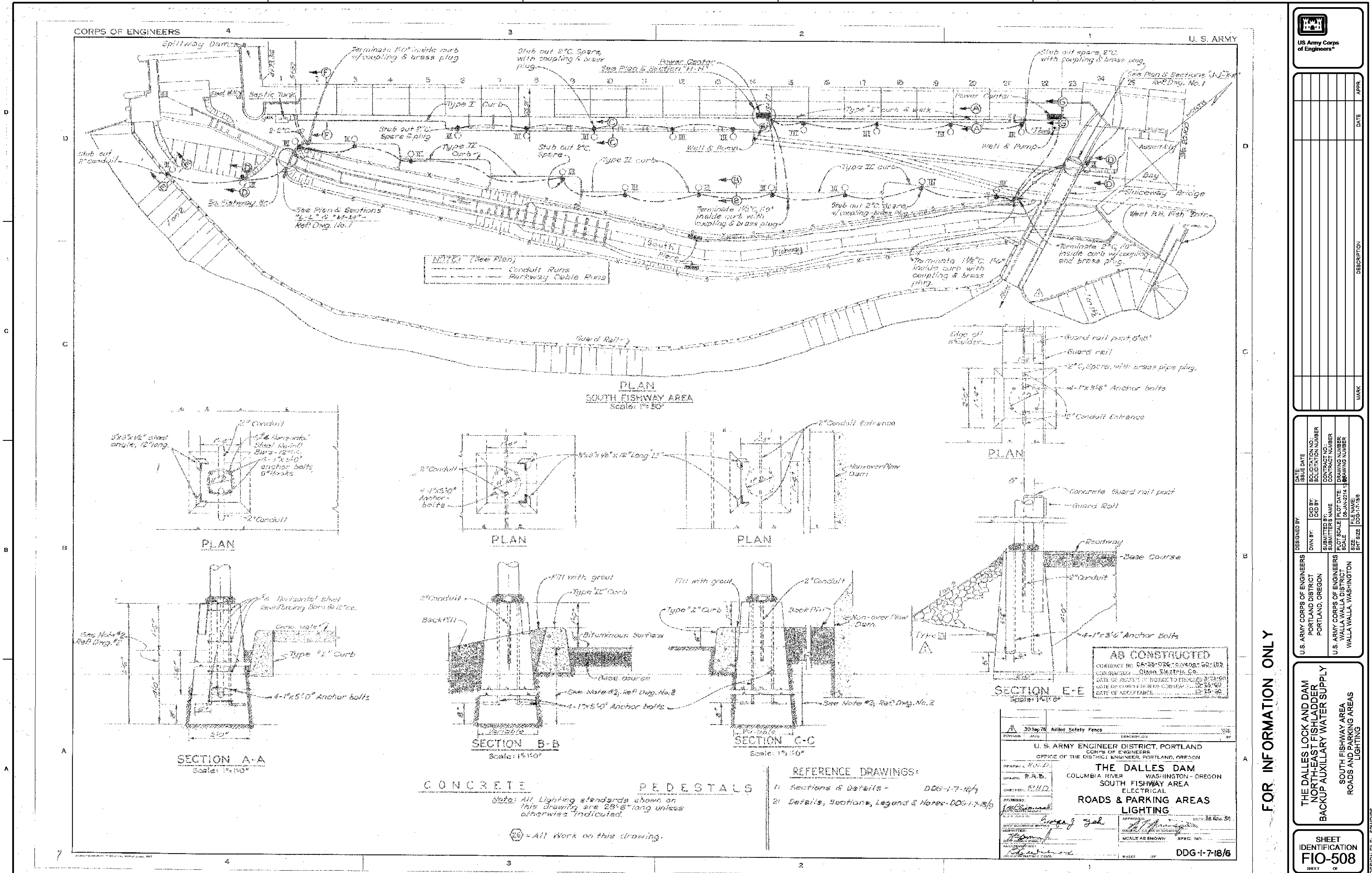
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

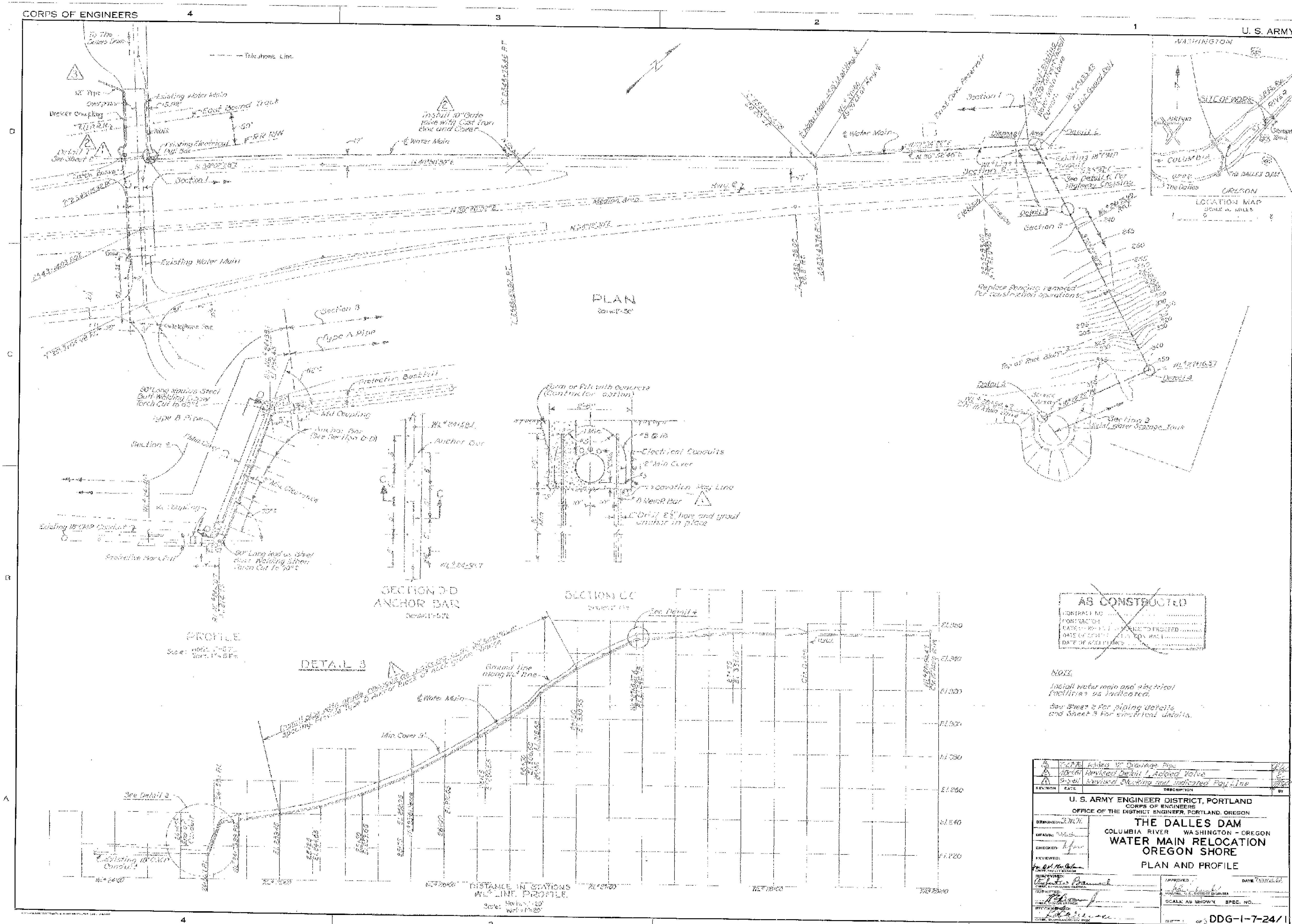
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

SOUTH FISHWAY AREA
ROADS AND PARKING AREAS

SHEET IDENTIFICATION
FIO-507

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:00 | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$


CORPS OF ENGINEERS
U. S. ARMY
PLAN
SOUTH FISHWAY AREA
Scale: 1"=50'
NOTE: (See Plan)
Conduit Runs
Parkway Cable Runs
Spillway Dam
Septic Tank
Power Center
Well & Pump
Type I Curb
Type II Curb
So. Fishway Br.
South Fishway
Sluiceway Bridge
Assembly Bay
Guard Rail
PLAN
SECTION A-A
Scale: 1"=1'-0"
SECTION B-B
Scale: 1"=1'-0"
SECTION C-C
Scale: 1"=1'-0"
SECTION E-E
Scale: 1"=1'-0"
CONCRETE PEDESTALS
Note: All Lighting standards shown on this drawing are 28'-6" long unless otherwise indicated.
(26) = All Work on this drawing.
REFERENCE DRAWINGS:
1: Sections & Details - DDG-1-7-18/7
2: Details, Sections, Legend & Notes - DDG-1-7-18/8
AS CONSTRUCTED
30 Sep 76 Added Safety Fence
U. S. ARMY ENGINEER DISTRICT, PORTLAND
CORPS OF ENGINEERS
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON
THE DALLES DAM
COLUMBIA RIVER WASHINGTON - OREGON
SOUTH FISHWAY AREA
ELECTRICAL
ROADS & PARKING AREAS
LIGHTING
SCALE AS SHOWN
DDG-1-7-18/6
FOR INFORMATION ONLY
US Army Corps of Engineers
U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY
SOUTH FISHWAY AREA
ROADS AND PARKING AREAS
LIGHTING
SHEET IDENTIFICATION
FIO-508
DRAWING PLOT SIZE: $BORDER$
DATE AND TIME PLOTTED: 08-JAN-2014
BY USERNAME: $USER$
SHEET NAME: $SHEETN$



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US Army Corps of Engineers

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

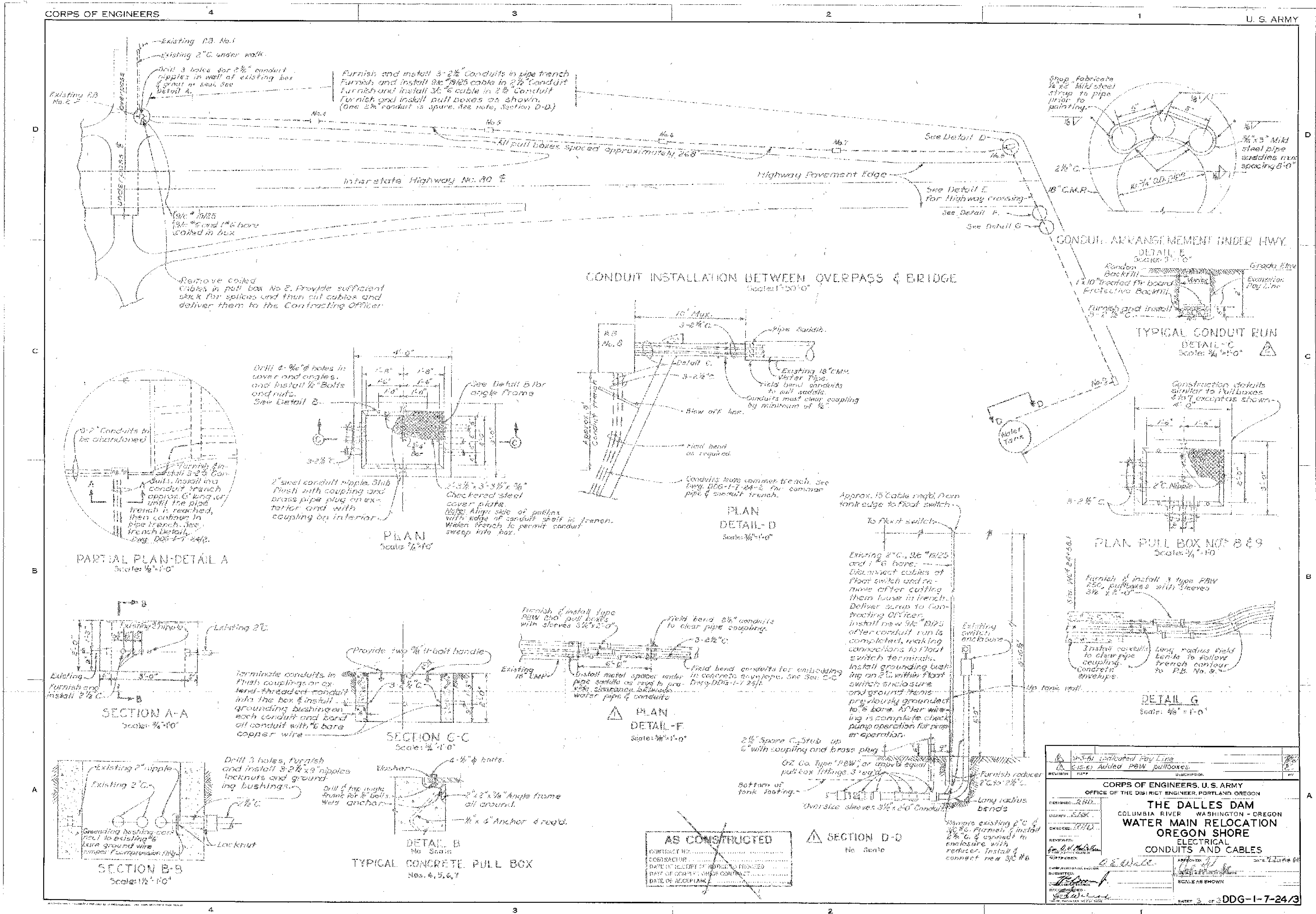
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

WATER MAIN RELOCATION
OREGON SHORE
PLAN AND PROFILE

SHEET IDENTIFICATION
FIO-509

DRAWING PLOT SIZE: $BORDERS$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:30 | BY USERNAME: $USERS$ | SHEET NAME: $SHEETN$

DESIGN FILE: $PWDIR$



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US Army Corps of Engineers

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

WATER MAIN RELOCATION
OREGON SHORE
CONDUITS AND CABLES

SHEET IDENTIFICATION
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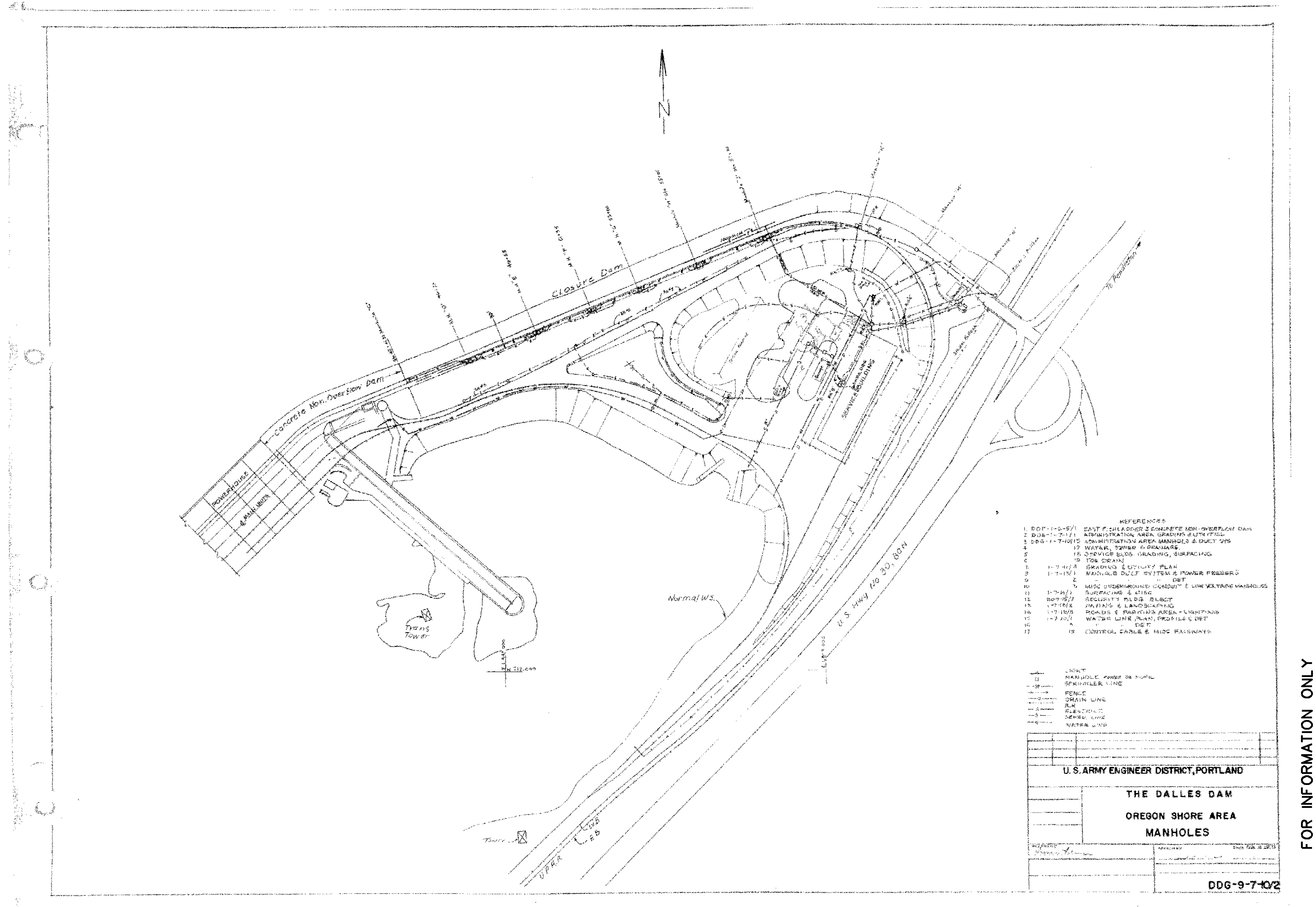

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US Army Corps of Engineers

MARK	DESCRIPTION	DATE	APPR

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: | DWN BY: | CKD BY: | SUBMITTED BY: | PLOT SCALE: | PLOT DATE: 08-JAN-2014 13:30 | SIZE: | FILE NAME: DDG-9-7-10/2 | DATE: | SOLICITATION NO.: | CONTRACT NO.: | DRAWING NUMBER:

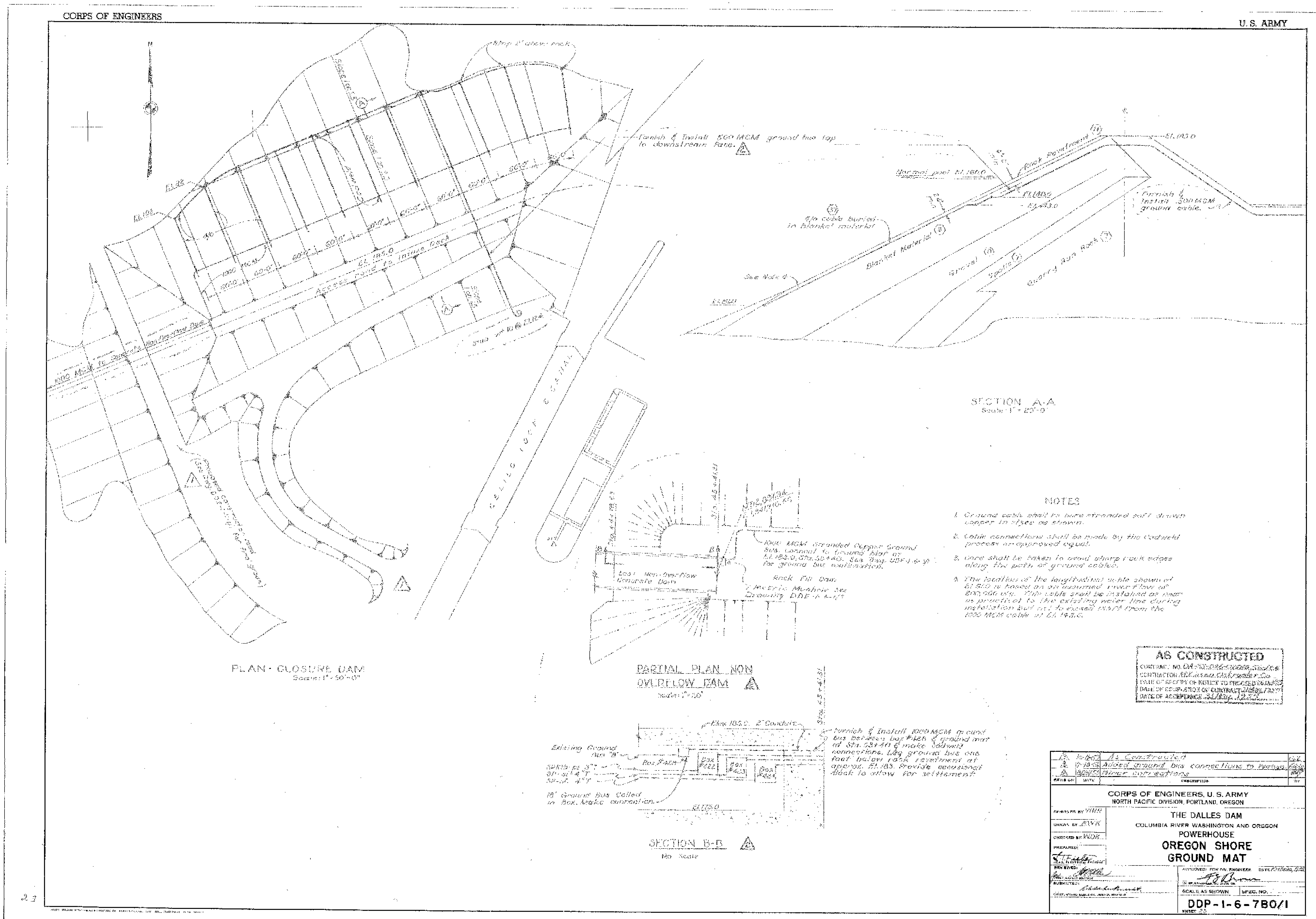
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILARY WATER SUPPLY

OREGON SHORE AREA
MANHOLES

SHEET IDENTIFICATION
FIO-511

DESIGN FILE: $PWDIR$

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 08-JAN-2014 13:30 | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$



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US Army Corps of Engineers

MARK	DESCRIPTION	DATE	APPR

DESIGNED BY: | DWN BY: | CKD BY: | SUBMITTED BY: | PLOT SCALE: | PLOT DATE: 08-JAN-2014 | SIZE: | FILE NAME:

DATE: ISSUE DATE | SOLICITATION NO.: | CONTRACT NO.: | DRAWING NUMBER:

U.S. ARMY CORPS OF ENGINEERS, PORTLAND DISTRICT, PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS, WALLA WALLA DISTRICT, WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILARY WATER SUPPLY

POWERHOUSE
OREGON SHORE
GROUND MAT

SHEET IDENTIFICATION
FIO-512

DESIGN FILE: $PWDIR$

The Dalles East Fish Ladder Auxiliary Water Backup System

90 Percent Design Documentation Report

APPENDIX G

Cost Estimates

Table of Contents

****** TOTAL PROJECT COST SUMMARY ******

PROJECT: Dalles AWC Option 1 - Cofferdam
PROJECT NO: P2 14630
LOCATION: The Dalles Lock and Dam

DISTRICT: NWD Portland District PREPARED: 2/1/2014
POC: CHIEF, COST ENGINEERING, xxx

This Estimate reflects the scope and schedule in report; The Dalles East Fish Ladder Auxiliary Water Backup System

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**				**TOTAL PROJECT COST (FULLY FUNDED)**				
						Program Year (Budget EC): 2014 Effective Price Level Date: 1 OCT 13								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	**TOTAL ($K)**	Spent Thru: 1-Oct-13 ($K)		COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*	*N*	*O*
03	RESERVOIRS	$0	$0	-	$0	-	$0	$0	$0	$0		$0	$0	$0
04	DAMS	$0	$0	-	$0	-	$0	$0	$0	$0		$0	$0	$0
05	LOCKS	$0	$0	-	$0	-	$0	$0	$0	$0		$0	$0	$0
06	FISH & WILDLIFE FACILITIES	$8,286	$2,237	27%	$10,523	0.0%	$8,286	$2,237	$10,523	$0		$8,690	$2,346	$11,037
07	POWER PLANT	$0	$0	-	$0	-	$0	$0	$0	$0		$0	$0	$0
	CONSTRUCTION ESTIMATE TOTALS:	$8,286	$2,237		$10,523	0.0%	$8,286	$2,237	$10,523	$0		$8,690	$2,346	$11,037
01	LANDS AND DAMAGES	$0	$0	-	$0	-	$0	$0	$0	$0		$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN	$1,368	$369	27%	$1,737	0.0%	$1,368	$369	$1,737	$0		$1,425	$385	$1,810
31	CONSTRUCTION MANAGEMENT	$1,202	$325	27%	$1,527	0.0%	$1,202	$325	$1,527	$0		$1,326	$358	$1,684
	PROJECT COST TOTALS:	$10,856	$2,931	27%	$13,787		$10,856	$2,931	**$13,787**	$0		$11,441	$3,089	$14,531

______________ CHIEF, COST ENGINEERING, xxx

______________ PROJECT MANAGER, xxx

______________ CHIEF, REAL ESTATE, xxx

______________ CHIEF, PLANNING,xxx

______________ CHIEF, ENGINEERING, xxx

______________ CHIEF, OPERATIONS, xxx

______________ CHIEF, CONSTRUCTION, xxx

______________ CHIEF, CONTRACTING,xxx

______________ CHIEF, PM-PB, xxxx

______________ CHIEF, DPM, xxx

ESTIMATED FEDERAL COST:	**100%**	**$14,531**
ESTIMATED NON-FEDERAL COST:	**0%**	**$0**
ESTIMATED TOTAL PROJECT COST:		**$14,531**

Filename: option 1DALLES AWC TPCS Jan 2014.xlsx
TPCS

****** TOTAL PROJECT COST SUMMARY ******

****** CONTRACT COST SUMMARY ******

PROJECT: Dalles AWC Option 1 - Cofferdam
LOCATION: The Dalles Lock and Dam
This Estimate reflects the scope and schedule in report; The Dalles East Fish Ladder Auxiliary Water Backup System

DISTRICT: NWD Portland District
POC: CHIEF, COST ENGINEERING, xxx
PREPARED: 2/1/2014

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: 1/2/2014 Effective Price Level: 41548				Program Year (Budget EC): 2014 Effective Price Level Date: 1 OCT 13								
				RISK BASED										
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Dalles East Fish Ladder AWS													
03	RESERVOIRS	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
04	DAMS	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
05	LOCKS	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
06	FISH & WILDLIFE FACILITIES	$8,286	$2,237	27%	$10,523	0.0%	$8,286	$2,237	$10,523	2016Q3	4.9%	$8,690	$2,346	$11,037
07	POWER PLANT	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
							$0							
	CONSTRUCTION ESTIMATE TOTALS:	$8,286	$2,237	27%	**$10,523**		$8,286	$2,237	$10,523			$8,690	$2,346	$11,037
01	LANDS AND DAMAGES	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
1.3%	Project Management	$104	$28	27%	$132	0.0%	$104	$28	$132	2014Q3	1.5%	$106	$29	$134
1.0%	Planning & Environmental Compliance	$83	$22	27%	$105	0.0%	$83	$22	$105	2014Q3	1.5%	$84	$23	$107
4.3%	Engineering & Design	$352	$95	27%	$447	0.0%	$352	$95	$447	2014Q3	1.5%	$357	$97	$454
0.5%	Reviews, ATRs, IEPRs, VE	$41	$11	27%	$52	0.0%	$41	$11	$52	2014Q3	1.5%	$42	$11	$53
0.5%	Life Cycle Updates (cost, schedule, risks)	$41	$11	27%	$52	0.0%	$41	$11	$52	2014Q3	1.5%	$42	$11	$53
2.0%	Contracting & Reprographics	$166	$45	27%	$211	0.0%	$166	$45	$211	2014Q3	1.5%	$169	$46	$214
3.0%	Engineering During Construction	$249	$67	27%	$316	0.0%	$249	$67	$316	2016Q3	10.3%	$275	$74	$349
2.0%	Planning During Construction	$166	$45	27%	$211	0.0%	$166	$45	$211	2016Q3	10.3%	$183	$49	$233
2.0%	Project Operations	$166	$45	27%	$211	0.0%	$166	$45	$211	2014Q3	1.5%	$169	$46	$214
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$829	$224	27%	$1,053	0.0%	$829	$224	$1,053	2016Q3	10.3%	$914	$247	$1,161
2.0%	Project Operation:	$166	$45	27%	$211	0.0%	$166	$45	$211	2016Q3	10.3%	$183	$49	$233
2.5%	Project Management	$207	$56	27%	$263	0.0%	$207	$56	$263	2016Q3	10.3%	$228	$62	$290
	CONTRACT COST TOTALS:	$10,856	$2,931		**$13,787**		$10,856	$2,931	$13,787			$11,441	$3,089	**$14,531**

Filename: option 1DALLES AWC TPCS Jan 2014.xlsx
TPCS

Abbreviated Risk Analysis

The Dalles AWS 90% DDR, Cofferdam Option 1
Feasibility (Alternatives)

Meeting Date: 20-Dec-13

PDT Members
Note: PDT involvement is commensurate with project size and involvement.

Technical Lead:	Ryan Laughery, NWW
Geotech:	Mike Schaffer, NWW
Hydraulics	Logan Negherbon, NWW
Structural:	Eric Walton, NWW
Mechanical:	Phil Auth, NWW
Electrical:	Dan Pullen, NWW
Cost Engineering:	Kevin Kuhar, NWW
Biologist:	Brad Trumbo, NWW

Abbreviated Risk Analysis

Project (less than $40M): **The Dalles AWS 90% DDR, Cofferdam Option 1**
Project Development Stage: **Feasibility (Alternatives)**
Risk Category: **High Risk: Complex Project or Life Safety**

Total Construction Contract Cost = **$ 8,285,593**

	CWWBS	Feature of Work	Contract Cost		% Contingency	$ Contingency	Total
	01 LANDS AND DAMAGES	Real Estate			0.00%	$ -	$ -
1	06 01 FISH FACILITIES AT DAMS	Mobilization/Demobilization	$ 298,999		13.30%	$ 39,773	$ 338,772.60
2	06 01 FISH FACILITIES AT DAMS	Concrete Mining	$ 933,766		26.67%	$ 248,999	$ 1,182,764.71
3	06 01 FISH FACILITIES AT DAMS	Steel Pipe - Through Dam	$ 525,895		18.01%	$ 94,732	$ 620,626.75
4	06 01 FISH FACILITIES AT DAMS	Steel Pipe - Dam to AWS Chamber	$ 1,579,095		28.27%	$ 446,396	$ 2,025,491.19
5	06 01 FISH FACILITIES AT DAMS	Steel Pipe - Discharge in AWS Chamber	$ 455,355		44.29%	$ 201,691	$ 657,046.20
6	06 01 FISH FACILITIES AT DAMS	Valve	$ 351,343		20.54%	$ 72,154	$ 423,496.96
7	06 01 FISH FACILITIES AT DAMS	Emergency Closure Gate & Guides	$ 639,670		16.19%	$ 103,547	$ 743,217.23
8	06 01 FISH FACILITIES AT DAMS	Trash Rack/Trash Rake & Guides	$ 1,047,362		23.72%	$ 248,424	$ 1,295,785.93
9	06 01 FISH FACILITIES AT DAMS	Electrical, Site Work, Utility Repairs	$ 211,590		23.81%	$ 50,389	$ 261,979.01
10	06 01 FISH FACILITIES AT DAMS	Cofferdam	$ 2,242,518		30.74%	$ 689,415	$ 2,931,933.25
12		**Remaining Construction Items**	**$ (0)**	*0.0%*	0.00%	$ (0)	$ (0.14)
13	30 PLANNING, ENGINEERING, AND DESIGN	**Planning, Engineering, & Design**			0.00%	$ -	$ -
14	31 CONSTRUCTION MANAGEMENT	**Construction Management**			0.00%	$ -	$ -

Totals				
Real Estate	$ -	0.00%	$ -	$ -
Total Construction Estimate	$ 8,285,593	26.50%	$ 2,195,521	$ 10,481,114
Total Planning, Engineering & Design	$ -	0.00%	$ -	$ -
Total Construction Management	$ -	0.00%	$ -	$ -
Total	$ 8,285,593		$ 2,195,521	$ 10,481,114
			Escalation @ 4.88%	$ 511,478
			Total	**$ 10,992,592**

The Dalles AWS 90% DDR, Cofferdam Option 1
Feasibility (Alternatives)
Abbreviated Risk Analysis

Meeting Date: 20-Dec-13

Risk Level

	Negligible	Marginal	Significant	Critical	Crisis
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Possible	0	1	2	3	4
Unlikely	0	0	1	2	3

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
Project Scope Growth							
						Max Potential Cost Growth	200%
PS-1	Mobilization/Demobilization	• Potential for scope growth, added features and quantities?			Unlikely	Negligible	0
PS-2	Concrete Mining	• Investigations sufficient to support design assumptions?	Quality of concrete • Water care and diversion fully understood, planned?	Does NWP have info of any known leaks? Information required from NWP to meet risk assessment in Construction Elements Current design assumes no leaks	Likely	Marginal	2
PS-3	Steel Pipe - Through Dam	• Water care and diversion fully understood, planned?		None anticipated; design generally is known for the most part	Unlikely	Negligible	0
PS-4	Steel Pipe - Dam to AWS Chamber	• Potential for scope growth, added features and quantities?	Depth of pipe; appears that the excavation is through soil and some rock; Trust concerns.		Very LIKELY	Negligible	2
PS-5	Steel Pipe - Discharge in AWS Chamber	• Potential for scope growth, added features and quantities?	Design will be developed further.		Very LIKELY	Marginal	3
PS-6	Valve	• Potential for scope growth, added features and quantities?		None anticipated; design is known	Unlikely	Negligible	0
PS-7	Emergency Closure Gate & Guides	• Potential for scope growth, added features and quantities?	design of guides may change	embedded plate not change	Possible	Marginal	1
PS-8	Trash Rack/Trash Rake & Guides	• Potential for scope growth, added features and quantities?	design may improve for rake; guide slots not designed; trash rack good design	alignment of rake to rack a potential issue	Likely	Marginal	2
PS-9	Electrical, Site Work, Utility Repairs	• Potential for scope growth, added features and quantities?	Some utilities will likely need to be repaired or relocated.		Likely	Marginal	2

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
PS-10	Cofferdam	• Investigations sufficient to support design assumptions?	• Investigations sufficient to support design assumptions? • Project accomplish intent? Contractor design/install., Investigations sufficient to support design assumptions? Potential need survey of existing conditions	Flatness of concrete face. Existing condition of anchor surface. Issues encountered should be able to be overcome with reasonable measures	Possible	Marginal	1
Acquisition Strategy							
						Max Potential Cost Growth	30%
AS-1	Mobilization/Demobilization	• Contracting plan firmly established?	Not a significant concern	bidding climate unknown	Possible	Marginal	1
AS-2	Concrete Mining	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
AS-3	Steel Pipe - Through Dam	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
AS-4	Steel Pipe - Dam to AWS Chamber	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
AS-5	Steel Pipe - Discharge in AWS Chamber	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
AS-6	Valve	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
AS-7	Emergency Closure Gate & Guides	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
AS-8	Trash Rack/Trash Rake & Guides	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1

AS-9	Electrical, Site Work, Utility Repairs	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
AS-10	Cofferdam	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
Risk Element	**Feature of Work**	**Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)**	**Concerns**	**PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)**	**Likelihood**	**Impact**	**Risk Level**
Construction Elements							
						Max Potential Cost Growth	**50%**
CE-1	Mobilization/Demobilization	• Special equipment or subcontractors needed?	Schedule for in water work windows could drive multiple mob/demob		Possible	Marginal	1
CE-2	Concrete Mining	• Accelerated schedule or harsh weather schedule?	Potential obstructions in proposed route Encounter substantial nuisance water Poor quality of concrete	Very signficant item Does NWP have info of any known leaks, history from previous contracts?	Unlikely	Critical	2
CE-3	Steel Pipe - Through Dam	• Accelerated schedule or harsh weather schedule?		No major issues envisioned Work platform size limited due to other activites at project	Unlikely	Significant	1
CE-4	Steel Pipe - Dam to AWS Chamber	• Accelerated schedule or harsh weather schedule?	elevated groundwater creating buoyancy issues Concrete work at diffuser outlet has extremely short work window; 6' dia pipe during in water work window		Unlikely	Significant	1
CE-5	Steel Pipe - Discharge in AWS Chamber	• Accelerated schedule or harsh weather schedule?	Difficult constructibility issues with limited access.		Likely	Marginal	2
CE-6	Valve	• Accelerated schedule or harsh weather schedule?	Lead time.	Lead time is unknown but could be an issue.	Likely	Marginal	2
CE-7	Emergency Closure Gate & Guides	• Accelerated schedule or harsh weather schedule?	tight work conditions for guide/gate installation maintaining dam access	potentially during winter.	Possible	Marginal	1

CE-8	Trash Rack/Trash Rake & Guides	• Accelerated schedule or harsh weather schedule?	tight tolerances on guide installation	potentially during winter	Possible	Marginal	1
CE-9	Electrical, Site Work, Utility Repairs	• Accelerated schedule or harsh weather schedule?			Possible	Negligible	0
CE-10	Cofferdam	• Accelerated schedule or harsh weather schedule?	Schedule/lead time concerns • Special mobilization - floating plant In water work window (Nov-Feb)? Potential leaking after install	Internal time/schedule issues to award to meet schedule	Possible	Significant	2
Risk Element	**Feature of Work**	**Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)**	**Concerns**	**PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)**	**Likelihood**	**Impact**	**Risk Level**
Quantities for Current Scope							
						Max Potential Cost Growth	**40%**
Q-1	Mobilization/Demobilization	• Level of confidence based on design and assumptions?	Not an issue		Unlikely	Negligible	0
Q-2	Concrete Mining	• Level of confidence based on design and assumptions?		Known quantities	Unlikely	Negligible	0
Q-3	Steel Pipe - Through Dam	• Level of confidence based on design and assumptions?		Quantities are generally known.	Unlikely	Negligible	0
Q-4	Steel Pipe - Dam to AWS Chamber	• Level of confidence based on design and assumptions?	steel known; concrete unknown	concrete requirements not known - pipe protection, thrust blocks, Rock excavation unknown.	Likely	Marginal	2
Q-5	Steel Pipe - Discharge in AWS Chamber	• Level of confidence based on design and assumptions?	Details of discharge nozzel not known.		Likely	Marginal	2
Q-6	Valve	• Level of confidence based on design and assumptions?			Unlikely	Negligible	0
Q-7	Emergency Closure Gate & Guides	• Sufficient investigations to develop quantities?	gate quantities known; guide & concrete work unknown; predation measures	angle shape covering corners	Unlikely	Negligible	0
Q-8	Trash Rack/Trash Rake & Guides	• Level of confidence based on design and assumptions?	gate quantities known; guide & concrete work unknown; predation measures	angle shape covering corners	Possible	Marginal	1

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
Q-9	Electrical, Site Work, Utility Repairs	• Level of confidence based on design and assumptions?	Impact on utilities not quantified.		Likely	Marginal	2
Q-10	Cofferdam	• Level of confidence based on design and assumptions?	Will be contractor designed/installed. Required envelope will be defined.	Variability in designs	Likely	Marginal	2
Risk Element	**Feature of Work**	**Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)**	**Concerns**	**PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)**	**Likelihood**	**Impact**	**Risk Level**
Specialty Fabrication or Equipment							
						Max Potential Cost Growth	**75%**
FE-1	Mobilization/Demobilization	• Unusual parts, material or equipment manufactured or installed?	Minimal issue Could affect crane & mining equipment		Unlikely	Negligible	0
FE-2	Concrete Mining	• Unusual parts, material or equipment manufactured or installed?	Standard steel work	Nothing out of the ordinary	Possible	Negligible	0
FE-3	Steel Pipe - Through Dam	• Unusual parts, material or equipment manufactured or installed?		Standard mining equipment & methods	Unlikely	Negligible	0
FE-4	Steel Pipe - Dam to AWS Chamber	• Unusual parts, material or equipment manufactured or installed?		Size of pipe; weldding of joints; coating of interior (vinyl)	Unlikely	Negligible	0
FE-5	Steel Pipe - Discharge in AWS Chamber	• Unusual parts, material or equipment manufactured or installed?	no special concerns	None	Unlikely	Negligible	0
FE-6	Valve	• Unusual parts, material or equipment manufactured or installed?	Custom fabricated part; limited suppliers	RH recommend SS due to submergence	Possible	Marginal	1
FE-7	Emergency Closure Gate & Guides	• Unusual parts, material or equipment manufactured or installed?	not a feature of the 90% DDR		Unlikely	Negligible	0
FE-8	Trash Rack/Trash Rake & Guides	• Unusual parts, material or equipment manufactured or installed?		none	Unlikely	Negligible	0
FE-9	Electrical, Site Work, Utility Repairs	• Unusual parts, material or equipment manufactured or installed?		none	Unlikely	Negligible	0
FE-10	Cofferdam	• Unusual parts, material or equipment manufactured or installed?	Standard steel work	Nothing out of the ordinary	Possible	Negligible	0
Risk Element	**Feature of Work**	**Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)**	**Concerns**	**PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)**	**Likelihood**	**Impact**	**Risk Level**

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
Cost Estimate Assumptions							
					Max Potential Cost Growth		45%
CT-1	Mobilization/Demobilization	• Assumptions related to prime and subcontractor markups/assignments?	• Assumptions related to prime and subcontractor markups/assignments?	based on % of direct cost at this stage	Likely	Negligible	1
CT-2	Concrete Mining	• Reliability and number of key quotes?	• Reliability and number of key quotes? One quote - obtain current.	Based on crew/equipment/productivity from Dorena project	Possible	Significant	2
CT-3	Steel Pipe - Through Dam	• Reliability and number of key quotes?	• Reliability and number of key quotes? One quote - obtain current.	need to obtain current quote; difficulty in finding quote for coated pipe.	Possible	Significant	2
CT-4	Steel Pipe - Dam to AWS Chamber	• Reliability and number of key quotes?	• Reliability and number of key quotes? One quote - obtain current.	need to obtain current quote; current estimate based on 1/2" thick walls	Possible	Marginal	1
CT-5	Steel Pipe - Discharge in AWS Chamber	• Reliability and number of key quotes?	• Reliability and number of key quotes? One quote - obtain current.	need to obtain current quote; current estimate based on 1/2" thick walls.	Possible	Marginal	1
CT-6	Valve	• Reliability and number of key quotes?	• Reliability and number of key quotes?	One quote procured	Possible	Marginal	1
CT-7	Emergency Closure Gate & Guides	• Reliability and number of key quotes?	gate quantites are good; guide & concrete less known		Possible	Marginal	1
CT-8	Trash Rack/Trash Rake & Guides	• Reliability and number of key quotes?	rack/rake quantites are good; guide & concrete less known		Possible	Marginal	1
CT-9	Electrical, Site Work, Utility Repairs	• Reliability and number of key quotes?	estimate based on assumptions. Impacts to utilities not fully known.		Likely	Negligible	1
CT-10	Cofferdam	• Reliability and number of key quotes?	Based on assumed conceptual design - contractor's design may vary		Possible	Significant	2
External Project Risks							
					Max Potential Cost Growth		60%
EX-1	Mobilization/Demobilization	• Potential for severe adverse weather?	Floating plant		Possible	Negligible	0

EX-2	Concrete Mining	• Potential for severe adverse weather?			Unlikely	Negligible	**0**
EX-3	Steel Pipe - Through Dam	• Potential for severe adverse weather?		Work platform interfering with other activites at project; contract delay due to other activities	Possible	Marginal	**1**
EX-4	Steel Pipe - Dam to AWS Chamber	• Potential for severe adverse weather?		Work interferance with project access.	Possible	Marginal	**1**
EX-5	Steel Pipe - Discharge in AWS Chamber	• Potential for severe adverse weather?			Possible	Negligible	**0**
EX-6	Valve	• Unanticipated inflations in fuel, key materials?	• Unanticipated inflations in fuel, key materials?	No concerns.	Unlikely	Significant	**1**
EX-7	Emergency Closure Gate & Guides	• Potential for severe adverse weather?	weather; temperature for guide grout		Unlikely	Negligible	**0**
EX-8	Trash Rack/Trash Rake & Guides	• Potential for severe adverse weather?	weather		Unlikely	Negligible	**0**
EX-9	Electrical, Site Work, Utility Repairs	• Potential for severe adverse weather?	weather		Possible	Negligible	**0**
EX-10	Cofferdam	• Potential for severe adverse weather?	• Potential for severe adverse weather? Forebay environment impacting installation	Debris, flow velocities for installation Mitigation includes data collection Q1FY14 for flow velocties	Unlikely	Critical	**2**

Estimated by NWW-EC-X
Designed by 90% DDR by Walla Walla District
Prepared by Dave Scott
Preparation Date 12/4/2013
Effective Date of Pricing 12/4/2013
Estimated Construction Time 600 Days

Date	Author	Note
12/26/2013 2:51:24 PM	Dave Scott	

PROJECT DESCRIPTION

Estimate is based on the construction of an Emergency backup water supply for the Dalles AWS which consists of a 10' diameter pipe through Monolith 5 to discharge into the AWS chamber with 2ea 7.5 diameter discharge nozzles. The estimate is based on the 90% Design Documentation Report. Two options were estimated.

Option 1 entails the construction of a temporary cofferdam at the face of the dam prior to tunneling through the dam.

Option 2 entails the installation of pre-cast piers at the face of the dam with integral guides for installation of bulkheads to enable the upstream portion of the tunnel to be dewatered. Option 2 includes a significant amount of dive time to install the pre-cast piers.

BASIS OF DESIGN

This estimate is based on the 90 percent Design Documentation Report Titled "The Dalles East Fish Ladder Auxiliary Water Backup System".

ACQUISITION PLAN

It is unknown how the project will be acquired. This estimate assumes it will be competitively bid.

It is also assumed this work will not be a small buisness set-aside.

SUB-CONTRACTING PLAN

The following are subcontractor on this project:

- Electrical Subcontractor
- Paving Subcontractor
- Concrete Sawcutting Subcontractor
- Industrial Coating Subcontractor
- Concrete Mining Subcontractor

It is assumed that the Prime Contractor will do the rest of the work.

PROJECT CONSTRUCTION

Date **Author** **Note**

SITE ACCESS

The project site is located at The Dalles Lock and Dam. There is road access to the project site. There is also barge access through the Columbia River Lock System.

BORROW AREAS

The borrow sources for materials will be commercially purchased. Assumed sources are located locally.

CONSTRUCTION METHODOLOGY

The construction methodology is standard

UNUSUAL CONDITION (Soil, Water, Weather)
Some excavation through bedrock is expected.

UNIQUE TECHNIQUES OF CONSTRUCTION
Underwater construction by divers is required for construction of the intake structure

Assumes that there will be an onsite disposal site for excess excavation and trench spoils.

CONSTRUCTION WINDOWS

In-water work windows from December 1 to February 28/29. The project schedule assumes that the contractor will utilize the In-water work windows during two seasons.

SCHEDULE

Assumed onsite work from Nov 2015 to Feb 2017.

OVERTIME

This estimate contains no overtime to complete the project.

Date **Author** **Note**

EQUIPMENT AND LABOR AVAILABILITY & DISTANCE TRAVELED

General Decision Number: OR130079 11/01/2013 OR79

Superseded General Decision Number: OR20120079

State: Oregon

Construction Type: Heavy

County: Wasco County in Oregon.

Equipment rates used are from EP 1110-1-8, Volume EP11R08, Region 8, 2011.

ENVIRONMENTAL CONCERNS

In water work restrictions.

COST AND PRICING

For the Prime Contractor, Job Office Overhead is 15% Home Office Overhead is 15%, and Bond is based on the bond table

CONTINGENCIES

A contingency was calculated with the Abbreviated Risk Analysis Spreadsheet.

Option 1 26.49%
Option 2 30.74%

PROFIT

Date	**Author**	**Note**
		Profit of 10% is assumed.

ESCALATION

Escalation was calculated at 4.88% from CWCCIS, and the index for 3Q16.

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Description	Quantity	UOM	Contractor	DirectCost	SubCMU	CostToPrime	PrimeCMU	ContractCost	C/O
Contract Cost Summary Report				**5,191,353**	**366,394**	**5,557,747**	**2,727,846**	**8,285,593**	
2 The Dalles EFL AWS - 90% DDR Estimate	**1.00**	**LS**	**2 Prime**	**5,191,353**	**366,394**	**5,557,747**	**2,727,846**	**8,285,593**	
				5,191,352.85		*5,557,746.74*		*8,285,592.75*	
2.1 Fish & Wildlife Facilities	**1.00**	**EA**	**2 Prime**	**5,191,353**	**366,394**	**5,557,747**	**2,727,846**	**8,285,593**	
				200,500.44		*200,500.44*		*298,999.13*	
2.1.1 Mob/Demob	**1.00**	**EA**	**2 Prime**	**200,500**	**0**	**200,500**	**98,499**	**298,999**	
2.1.2 Cofferdam	**1.00**	**LS**	**2 Prime**	**1,503,964**	**0**	**1,503,964**	**738,553**	**2,242,517**	
				37,200.00		*37,200.00*		*55,475.03*	
2.1.2.1 Design Cofferdam	**1.00**	**EA**	**2 Prime**	**37,200**	**0**	**37,200**	**18,275**	**55,475**	
				1,466,764.48		*1,466,764.48*		*2,187,042.32*	
2.1.2.2 Fabricate & Install Cofferdam	**1.00**	**EA**	**1 Prime - LS&H**	**1,466,764**	**0**	**1,466,764**	**720,278**	**2,187,042**	
2.1.3 Concrete Mining	**1.00**	**LS**	**2 Prime**	**425,144**	**201,014**	**626,158**	**307,609**	**933,766**	
				12,348.70		*18,415.18*		*27,461.90*	
2.1.3.1 Work Platform	**1.00**	**EA**	**2.1 Sub**	**12,349**	**6,066**	**18,415**	**9,047**	**27,462**	
				388,328.21		*579,099.96*		*863,591.06*	
2.1.3.2 Concrete Mining	**1.00**	**EA**	**2.1 Sub**	**388,328**	**190,772**	**579,100**	**284,491**	**863,591**	
				75.67		*75.67*		*112.85*	
2.1.3.3 Haul & Dispose	**211.00**	**CY**	**2 Prime**	**15,967**	**0**	**15,967**	**7,844**	**23,811**	
				8,500.00		*12,675.75*		*18,902.89*	
2.1.3.4 Work Platform Steel	**1.00**	**EA**	**2.1 Sub**	**8,500**	**4,176**	**12,676**	**6,227**	**18,903**	
				5,184.17		*5,879.83*		*8,764.92*	
2.1.4 Steel Pipe Through Dam	**60.00**	**LF**	**2 Prime**	**311,050**	**41,740**	**352,790**	**173,106**	**525,895**	
				166,268.71		*166,268.71*		*247,950.58*	
2.1.4.1 Furnish & Install Steel Pipe	**1.00**	**EA**	**2 Prime**	**166,269**	**0**	**166,269**	**81,682**	**247,951**	
				65,769.46		*98,079.64*		*146,262.65*	
2.1.4.2 Pressure Grouting	**1.00**	**EA**	**2.1 Sub**	**65,769**	**32,310**	**98,080**	**48,183**	**146,263**	
				7,464.21		*7,848.11*		*11,703.61*	
2.1.4.3 VP 6" vent pipe	**1.00**	**EA**	**2 Prime**	**7,464**	**384**	**7,848**	**3,855**	**11,704**	
				4.88		*7.28*		*10.86*	
2.1.4.3.1 E-11.3.6 Surface Prep & Paint outside of pipe.	**160.00**	**SF**	**2.1 Sub**	**781**	**384**	**1,165**	**572**	**1,738**	
				25,175.03		*25,175.03*		*37,542.62*	
2.1.4.4 Pipe Rail System	**1.00**	**EA**	**2 Prime**	**25,175**	**0**	**25,175**	**12,368**	**37,543**	
				27,959.82		*27,959.82*		*41,488.04*	
2.1.4.5 Intake Concrete	**1.00**	**EA**	**2.1 Sub**	**27,960**	**0**	**27,960**	**13,528**	**41,488**	
				0.83		*1.24*		*1.84*	

Description	Quantity	UOM	Contractor		DirectCost	SubCMU	CostToPrime	PrimeCMU	ContractCost	C/O
2.1.4.6 E-11.3.6 Surface Prep & Paint Inside Area of Conduit Pipe	**22,200.00**	**SF**	**2.1**	**Sub**	**18,413**	**9,046**	**27,458**	**13,489**	**40,948**	
2.1.5 Steel Pipe from Dam to AWS Chamber	**1.00**	**LS**	**2**	**Prime**	**1,011,785**	**47,112**	**1,058,897**	**520,198**	**1,579,095**	
					692,189.55		*692,189.55*		*1,032,237.52*	
2.1.5.1 Furnish & Install Steel Pipe	**1.00**	**EA**	**2**	**Prime**	**692,190**	**0**	**692,190**	**340,048**	**1,032,238**	
					106,079.51		*106,079.51*		*158,192.58*	
2.1.5.1.1 Fittings bends and orfice plate	**1.00**	**EA**	**2**	**Prime**	**106,080**	**0**	**106,080**	**52,113**	**158,193**	
					40,704.05		*40,704.05*		*60,700.50*	
2.1.5.1.1.1 WYE Fitting	**1.00**	**EA**	**2**	**Prime**	**40,704**	**0**	**40,704**	**19,996**	**60,700**	
					65,375.46		*65,375.46*		*97,492.08*	
2.1.5.1.1.2 10' Dia Bends	**1.00**	**EA**	**2**	**Prime**	**65,375**	**0**	**65,375**	**32,117**	**97,492**	
					18,963.17		*18,963.17*		*28,279.10*	
2.1.5.1.2 Access Hatch to 10' dia pipe	**1.00**	**EA**	**2**	**Prime**	**18,963**	**0**	**18,963**	**9,316**	**28,279**	
					16,600.77		*16,600.77*		*24,756.13*	
2.1.5.2 Common Excavation - 10' Dia. Pipe	**1.00**	**EA**	**2**	**Prime**	**16,601**	**0**	**16,601**	**8,155**	**24,756**	
					109,436.42		*109,436.42*		*163,198.61*	
2.1.5.3 Rock Excavation - 10' dia. Pipe	**1.00**	**EA**	**2**	**Prime**	**109,436**	**0**	**109,436**	**53,762**	**163,199**	
					567.55		*567.55*		*846.36*	
2.1.5.4 Common Excavation - 7.5' Dia. Pipe	**30.00**	**LF**	**2**	**Prime**	**17,026**	**0**	**17,026**	**8,364**	**25,391**	
					8,628.23		*8,628.23*		*12,866.97*	
2.1.5.5 Pipe Bedding	**1.00**	**EA**	**2**	**Prime**	**8,628**	**0**	**8,628**	**4,239**	**12,867**	
					60,483.91		*60,483.91*		*90,197.50*	
2.1.5.6 Pipe Backfill	**1.00**	**EA**	**2**	**Prime**	**60,484**	**0**	**60,484**	**29,714**	**90,197**	
					4.15		*6.19*		*9.23*	
2.1.5.7 E-11.3.6 Surface Prep & Paint All Conduit Pipe	**23,100.00**	**SF**	**2.1**	**Sub**	**95,899**	**47,112**	**143,011**	**70,256**	**213,267**	
					11,520.96		*11,520.96*		*17,180.79*	
2.1.5.8 Thrust Block	**1.00**	**EA**	**2**	**Prime**	**11,521**	**0**	**11,521**	**5,660**	**17,181**	
					277,754.52		*305,348.50*		*455,355.30*	
2.1.6 Steel Pipe in AWS Chamber	**1.00**	**EA**	**2**	**Prime**	**277,755**	**27,594**	**305,349**	**150,007**	**455,355**	
					12,161.00		*12,161.00*		*18,135.27*	
2.1.6.1 Set up platform and rigging in AWS chamber	**1.00**	**EA**	**2**	**Prime**	**12,161**	**0**	**12,161**	**5,974**	**18,135**	
					4,774.00		*4,774.00*		*7,119.30*	
2.1.6.2 Remove rigging and platforms from AWS Chamber	**1.00**	**EA**	**2**	**Prime**	**4,774**	**0**	**4,774**	**2,345**	**7,119**	
					44,974.63		*44,974.63*		*67,069.05*	
2.1.6.3 Crane and Above grade support crew.	**1.00**	**EA**	**2**	**Prime**	**44,975**	**0**	**44,975**	**22,094**	**67,069**	
					35,860.73		*35,860.73*		*53,477.82*	

Description	Quantity	UOM	Contractor	DirectCost	SubCMU	CostToPrime	PrimeCMU	ContractCost	C/O
2.1.6.4 Install Pipe	**1.00**	**EA**	**2 Prime**	**35,861**	**0**	**35,861**	**17,617**	**53,478**	
				1.00		*1.49*		*2.22*	
2.1.6.5 E-11.3.6 Surface Prep & Paint all Conduit Pipe	**23,100.00**	**SF**	**2.1 Sub**	**23,015**	**11,306**	**34,321**	**16,861**	**51,182**	
				33,154.52		*49,442.14*		*73,731.30*	
2.1.6.6 Concrete Sawcutting Fishladder and AWS Chamber	**1.00**	**EA**	**2 Prime**	**33,155**	**16,288**	**49,442**	**24,289**	**73,731**	
				33,154.52		*49,442.14*		*73,731.30*	
2.1.6.6.1 Concrete Cutting	**1.00**	**EA**	**2.1 Sub**	**33,155**	**16,288**	**49,442**	**24,289**	**73,731**	
				112,460.86		*112,460.86*		*167,708.86*	
2.1.6.7 90 degree bend and fabrication of orifice manifold.	**1.00**	**EA**	**2 Prime**	**112,461**	**0**	**112,461**	**55,248**	**167,709**	
				41,691.95		*41,691.95*		*62,173.71*	
2.1.6.7.1 7.5' Dia Bends	**1.00**	**EA**	**2 Prime**	**41,692**	**0**	**41,692**	**20,482**	**62,174**	
				70,768.92		*70,768.92*		*105,535.16*	
2.1.6.7.2 7.5' dia Orfice Manifold.	**1.00**	**EA**	**2 Prime**	**70,769**	**0**	**70,769**	**34,766**	**105,535**	
				11,353.96		*11,353.96*		*16,931.75*	
2.1.6.8 Scaffold and hoist	**1.00**	**EA**	**2 Prime**	**11,354**	**0**	**11,354**	**5,578**	**16,932**	
				235,600.77		*235,600.77*		*351,343.00*	
2.1.7 120" Butterfly Valve w/Acutator	**1.00**	**EA**	**2 Prime**	**235,601**	**0**	**235,601**	**115,742**	**351,343**	
				232,157.26		*232,157.26*		*346,207.82*	
2.1.7.1 Valve	**1.00**	**EA**	**2 Prime**	**232,157**	**0**	**232,157**	**114,051**	**346,208**	
				3,443.50		*3,443.50*		*5,135.17*	
2.1.7.2 Shipping	**1.00**	**EA**	**2 Prime**	**3,444**	**0**	**3,444**	**1,692**	**5,135**	
				429,002.86		*429,276.65*		*639,670.07*	
2.1.8 Emergency Closure Gate	**1.00**	**EA**	**2 Prime**	**429,003**	**274**	**429,277**	**210,393**	**639,670**	
				199,497.50		*199,497.50*		*297,503.48*	
2.1.8.1 Furnish Emergency Closure Gate	**1.00**	**EA**	**2 Prime**	**199,498**	**0**	**199,498**	**98,006**	**297,503**	
				162,250.00		*162,250.00*		*241,957.62*	
2.1.8.2 Furnish Emergency Closure Gate Guides	**1.00**	**EA**	**2 Prime**	**162,250**	**0**	**162,250**	**79,708**	**241,958**	
				557.32		*831.11*		*1,239.41*	
2.1.8.3 Shipping	**1.00**	**EA**	**2.1 Sub**	**557**	**274**	**831**	**408**	**1,239**	
				61,124.76		*61,124.76*		*90,699.67*	
2.1.8.4 Install Emergency Gate Closure Guides	**1.00**	**EA**	**1 Prime - LS&H**	**61,125**	**0**	**61,125**	**29,575**	**90,700**	
				5,573.28		*5,573.28*		*8,269.88*	
2.1.8.5 Install Emergency Closure Gate	**1.00**	**EA**	**2.1 Sub**	**5,573**	**0**	**5,573**	**2,697**	**8,270**	
2.1.9 Trash Rack & Trash Rake	**1.00**	**LS**	**2 Prime**	**701,406**	**1,920**	**703,326**	**344,036**	**1,047,361**	
				290,000.00		*290,000.00*		*432,466.63*	

Description	Quantity	UOM	Contractor	DirectCost	SubCMU	CostToPrime	PrimeCMU	ContractCost	C/O
2.1.9.1 Furnish Trash Rack Panels	**1.00**	**EA**	**2 Prime**	**290,000**	**0**	**290,000**	**142,467**	**432,467**	
				35,782.27		*37,701.77*		*56,223.30*	
2.1.9.2 Furnish Track Rake	**1.00**	**EA**	**2 Prime**	**35,782**	**1,920**	**37,702**	**18,522**	**56,223**	
				190,375.08		*190,375.08*		*283,765.63*	
2.1.9.3 Furnish Trash Rack/Rake Guides	**1.00**	**EA**	**2 Prime**	**190,375**	**0**	**190,375**	**93,391**	**283,766**	
				3,443.50		*3,443.50*		*5,135.17*	
2.1.9.4 Shipping	**1.00**	**EA**	**2 Prime**	**3,444**	**0**	**3,444**	**1,692**	**5,135**	
				181,805.22		*181,805.22*		*269,770.76*	
2.1.9.5 Install Trash Rack/Trash Rake Guides	**1.00**	**EA**	**1 Prime - LS&H**	**181,805**	**0**	**181,805**	**87,966**	**269,771**	
				95,144.89		*141,886.17*		*211,589.77*	
2.1.10 Electrical, Site Work, Utility repairs	**1.00**	**EA**	**2 Prime**	**95,145**	**46,741**	**141,886**	**69,704**	**211,590**	
				38,535.29		*57,466.30*		*85,697.44*	
2.1.10.1 Electrical	**1.00**	**EA**	**2.1 Sub**	**38,535**	**18,931**	**57,466**	**28,231**	**85,697**	
				10,000.00		*14,912.64*		*22,238.69*	
2.1.10.1.1 Low Voltage Wiring and Instrumentation and sensors	**1.00**	**EA**	**2.1 Sub**	**10,000**	**4,913**	**14,913**	**7,326**	**22,239**	
				16,696.17		*24,898.40*		*37,130.09*	
2.1.10.1.2 Power to Valve Actuator	**1.00**	**EA**	**2.1 Sub**	**16,696**	**8,202**	**24,898**	**12,232**	**37,130**	
				2,532.73		*3,776.97*		*5,632.46*	
2.1.10.1.2.1 Conduit and Cable for Actuator	**1.00**	**EA**	**2.1 Sub**	**2,533**	**1,244**	**3,777**	**1,855**	**5,632**	
				1,120.83		*1,671.46*		*2,492.59*	
2.1.10.1.2.2 Lighting circuit, Light and Receptical at valve.	**1.00**	**EA**	**2.1 Sub**	**1,121**	**551**	**1,671**	**821**	**2,493**	
				5.67		*8.46*		*12.62*	
2.1.10.1.2.3 Conduit Feed Trench	**624.00**	**BCY**	**2.1 Sub**	**3,541**	**1,740**	**5,281**	**2,594**	**7,875**	
				4,414.74		*6,583.54*		*9,817.80*	
2.1.10.1.2.4 Upgrade " FCQ7-q" Bucket	**1.00**	**EA**	**2.1 Sub**	**4,415**	**2,169**	**6,584**	**3,234**	**9,818**	
				5,086.74		*7,585.67*		*11,312.24*	
2.1.10.1.2.5 Disconnect at Valve Actuator	**1.00**	**EA**	**2.1 Sub**	**5,087**	**2,499**	**7,586**	**3,727**	**11,312**	
				8,225.13		*12,265.85*		*18,291.62*	
2.1.10.1.3 Relocate Existing Electrical underground	**1.00**	**EA**	**2.1 Sub**	**8,225**	**4,041**	**12,266**	**6,026**	**18,292**	
				3,613.99		*5,389.42*		*8,037.04*	
2.1.10.1.4 Relocate conduit on the face of the Dam	**1.00**	**EA**	**2.1 Sub**	**3,614**	**1,775**	**5,389**	**2,648**	**8,037**	
				51,609.59		*76,963.54*		*114,772.98*	
2.1.10.2 Paving	**1.00**	**EA**	**2.1 Sub**	**51,610**	**25,354**	**76,964**	**37,809**	**114,773**	
				87.48		*130.45*		*194.54*	
2.1.10.2.1 8" Base Aggregate	**175.00**	**CY**	**2.1 Sub**	**15,308**	**7,520**	**22,829**	**11,215**	**34,044**	

Description	Quantity	UOM	Contractor	DirectCost	SubCMU	CostToPrime	PrimeCMU	ContractCost	C/O
				12.17		*18.15*		*27.06*	
2.1.10.2.2 Asphalt Concrete	**2,800.00**	**SF**	**2.1 Sub**	**34,073**	**16,739**	**50,811**	**24,962**	**75,773**	
				31.84		*47.48*		*70.80*	
2.1.10.2.3 Asphalt Pavment Hauling	**70.00**	**TON**	**2.1 Sub**	**2,229**	**1,095**	**3,324**	**1,633**	**4,956**	
				5,000.00		*7,456.32*		*11,119.34*	
2.1.10.3 Misc Utility repair or relocate	**1.00**	**EA**	**2 Prime**	**5,000**	**2,456**	**7,456**	**3,663**	**11,119**	

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
Project Direct Costs Report				**1,168,912**	**476,344**	**1,850,949**	**1,484,648**	**210,500**	**5,191,353**	**5,191,353**	
The Dalles EFL AWS - 90% DDR Estimate	**1.00**	**LS**	**Prime**	**1,168,912**	**476,344**	**1,850,949**	**1,484,648**	**210,500**	**5,191,353**	**5,191,353**	
				1,168,912.05	*476,343.76*	*1,850,949.09*	*1,484,647.50*		*5,191,352.85*	*5,191,352.85*	
Fish & Wildlife Facilities	**1.00**	**EA**	**Prime**	**1,168,912**	**476,344**	**1,850,949**	**1,484,648**	**210,500**	**5,191,353**	**5,191,353**	
				0.00	*0.00*	*0.00*	*0.00*		*200,500.44*	*200,500.44*	
Mob/Demob	**1.00**	**EA**	**Prime**	**0**	**0**	**0**	**0**	**200,500**	**200,500**	**200,500**	
				0.00	*0.00*	*0.00*	*0.00*		*5,012,511.00*	*5,012,511.00*	
USR Mob/Demob	0.04	EA	Prime	0	0	0	0	200,500	200,500	200,500	N
Cofferdam	**1.00**	**LS**	**Prime**	**136,083**	**18,182**	**270,000**	**1,079,700**	**0**	**1,503,964**	**1,503,964**	
				0.00	*0.00*	*0.00*	*37,200.00*		*37,200.00*	*37,200.00*	
Design Cofferdam	**1.00**	**EA**	**Prime**	**0**	**0**	**0**	**37,200**	**0**	**37,200**	**37,200**	
				0.00	*0.00*	*0.00*	*6,200.00*		*6,200.00*	*6,200.00*	
USR DES01 Sheet	6.00	EA	Prime	0	0	0	37,200	0	37,200	37,200	Sb
				136,082.67	*18,181.82*	*270,000.00*	*1,042,500.00*		*1,466,764.48*	*1,466,764.48*	
Fabricate & Install Cofferdam	**1.00**	**EA**	**Prime - LS&H**	**136,083**	**18,182**	**270,000**	**1,042,500**	**0**	**1,466,764**	**1,466,764**	
				0.00	*0.00*	*1.00*	*2.75*		*3.75*	*3.75*	
USR Fabrication of Dewatering Buttress	270,000.00	LB	Prime	0	0	270,000	742,500	0	1,012,500	1,012,500	MSb
				0.00	*0.00*	*0.00*	*150,000.00*		*150,000.00*	*150,000.00*	
USR Barge transport of buttress to The Dalles	1.00	EA	Prime	0	0	0	150,000	0	150,000	150,000	Sb
				1,233.66	*44.47*	*0.00*	*0.00*		*1,278.13*	*1,278.13*	
USR DIVE01 Mob Dive Crew	10.00	HR	Prime	12,337	445	0	0	0	12,781	12,781	N
				1,233.66	*44.47*	*0.00*	*0.00*		*1,278.13*	*1,278.13*	
USR DIVE01 Installation of Buttress, Dive Crew	40.00	HR	Prime	49,346	1,779	0	0	0	51,125	51,125	N
				256.74	*194.51*	*0.00*	*0.00*		*451.24*	*451.24*	
USR Buttress Placement, Ground Crew	40.00	HR	Prime - LS&H	10,269	7,780	0	0	0	18,050	18,050	O
				1,233.66	*44.47*	*0.00*	*0.00*		*1,278.13*	*1,278.13*	
USR DIVE01 Removal of Buttress, Dive Crew	30.00	HR	Prime	37,010	1,334	0	0	0	38,344	38,344	N
				256.74	*194.51*	*0.00*	*0.00*		*451.24*	*451.24*	
USR Buttress Removal, Ground Crew	30.00	HR	Prime - LS&H	7,702	5,835	0	0	0	13,537	13,537	O
				0.00	*0.00*	*0.00*	*150,000.00*		*150,000.00*	*150,000.00*	
USR Barge transport of buttress to Shop	1.00	EA	Prime	0	0	0	150,000	0	150,000	150,000	Sb
				1,233.66	*44.47*	*0.00*	*0.00*		*1,278.13*	*1,278.13*	
USR DIVE01 Demob Dive Crew	10.00	HR	Prime	12,337	445	0	0	0	12,781	12,781	N
				177.04	*14.09*	*0.00*	*0.00*		*191.14*	*191.14*	
USR Dewater Crew	40.00	HR	Prime - LS&H	7,082	564	0	0	0	7,645	7,645	N
Concrete Mining	**1.00**	**LS**	**Prime**	**174,477**	**221,117**	**9,550**	**20,000**	**0**	**425,144**	**425,144**	
				4,586.31	*212.39*	*7,550.00*	*0.00*		*12,348.70*	*12,348.70*	
Work Platform	**1.00**	**EA**	**Sub**	**4,586**	**212**	**7,550**	**0**	**0**	**12,349**	**12,349**	

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				994.38	*546.25*	*0.00*	*0.00*		*1,540.63*	*1,540.63*	
HNC 311110100156 Clear and grub, medium stumps, to 10" diameter, includes loading on site	0.01	ACR	Sub	11	6	0	0	0	18	18	N
				3,940.12	*1,177.12*	*0.00*	*0.00*		*5,117.24*	*5,117.24*	
HNC 311110100152 Clear and grub, cut and chip, medium trees, to 10" diameter	0.01	ACR	Sub	45	14	0	0	0	59	59	N
				7.87	*3.72*	*0.00*	*0.00*		*11.59*	*11.59*	
RSM 312316166040 Structural excavation for minor structures, bank measure, for spread and mat footings, elevator pits, and small building foundations, common earth, 1 C.Y. bucket, machine excavation, hydraulic backhoe	28.00	BCY	Sub	220	104	0	0	0	325	325	N
				0.39	*0.07*	*1.49*	*0.00*		*1.95*	*1.95*	
RSM 312323170800 Fill, gravel fill, compacted, under floor slabs, 12" deep	1,000.00	SF	Sub	392	65	1,490	0	0	1,948	1,948	N
				130.56	*0.76*	*202.00*	*0.00*		*333.32*	*333.32*	
RSM 033053404000 Structural concrete, in place, foundation mat (3000 psi), under 10 C.Y., includes forms(4 uses), reinforcing steel, concrete, placing and finishing	30.00	CY	Sub	3,917	23	6,060	0	0	10,000	10,000	N
				168,817.40	*219,510.80*	*0.00*	*0.00*		*388,328.21*	*388,328.21*	
Concrete Mining	**1.00**	**EA**	**Sub**	**168,817**	**219,511**	**0**	**0**	**0**	**388,328**	**388,328**	
				609.40	*70.23*	*0.00*	*0.00*		*679.63*	*679.63*	
USR BORE02 Boring Crew Labor - Mob/Demob	50.00	HR	Sub	30,470	3,512	0	0	0	33,982	33,982	N
				411.69	*692.21*	*0.00*	*0.00*		*1,103.90*	*1,103.90*	
USR BORE03 Boring Crew Equipment - Mob/Demob	40.00	HR	Sub	16,468	27,688	0	0	0	44,156	44,156	N
				2,031.33	*3,138.51*	*0.00*	*0.00*		*5,169.85*	*5,169.85*	
USR BORE01 Concrete Drill/Bore	60.00	LF	Sub	121,880	188,311	0	0	0	310,191	310,191	N
				5.08	*6.61*	*0.00*	*63.98*		*75.67*	*75.67*	
Haul & Dispose	**211.00**	**CY**	**Prime**	**1,073**	**1,394**	**0**	**13,500**	**0**	**15,967**	**15,967**	
				1.55	*2.07*	*0.00*	*0.00*		*3.62*	*3.62*	
HNC 312316440170 Excavate and load, bank measure, blasted rock, 3-1/2 C.Y. bucket, hydraulic excavator	211.00	BCY	Prime	327	437	0	0	0	764	764	N
				2.49	*3.19*	*0.00*	*0.00*		*5.68*	*5.68*	
RSM 312323201056 Cycle hauling(wait, load,travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 15 min load/wait/unload, 12 C.Y. truck, cycle 10 miles, 30 MPH, excludes loading equipment	300.00	LCY	Prime	746	956	0	0	0	1,703	1,703	N
				0.00	*0.00*	*0.00*	*30.00*		*30.00*	*30.00*	
USR Disposal Fee	450.00	TON	Prime	0	0	0	13,500	0	13,500	13,500	Sb
				0.00	*0.00*	*2,000.00*	*6,500.00*		*8,500.00*	*8,500.00*	
Work Platform Steel	**1.00**	**EA**	**Sub**	**0**	**0**	**2,000**	**6,500**	**0**	**8,500**	**8,500**	
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	
USR FAB01 Work Platform Steel - Shop Fabrication	2,000.00	LB	Sub	0	0	2,000	6,500	0	8,500	8,500	MSb

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				1,824.14	*382.18*	*2,419.92*	*557.92*		*5,184.17*	*5,184.17*	
Steel Pipe Through Dam	**60.00**	**LF**	**Prime**	**109,449**	**22,931**	**145,195**	**33,475**	**0**	**311,050**	**311,050**	
				49,328.42	*17,700.30*	*78,765.00*	*20,475.00*		*166,268.71*	*166,268.71*	
Furnish & Install Steel Pipe	**1.00**	**EA**	**Prime**	**49,328**	**17,700**	**78,765**	**20,475**	**0**	**166,269**	**166,269**	
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	
USR FAB01 Steel Flange Plate - Shop Fabrication	6,300.00	LB	Prime	0	0	6,300	20,475	0	26,775	26,775	MSb
				30.22	*3.15*	*15.50*	*0.00*		*48.88*	*48.88*	
RSM 050523151435 Chemical anchor, 1" dia x 11-3/4" L, in concrete, brick or stone, incl layout, drilling, threaded rod & epoxy cartridge	30.00	EA	Prime	907	95	465	0	0	1,466	1,466	N
				423.14	*160.25*	*0.00*	*0.00*		*583.39*	*583.39*	
USR TUN01 Tunnel Pipe Installation Crew	60.00	HR	Prime	25,388	9,615	0	0	0	35,004	35,004	N
				383.89	*133.17*	*1,200.00*	*0.00*		*1,717.06*	*1,717.06*	
NLU 331113401240 Pipe, black steel, plain end, welded, 3/4" wall thickness, 120" diameter, excludes excavation or backfill	60.00	LF	Prime	23,033	7,990	72,000	0	0	103,024	103,024	M
				21,061.75	*2,055.64*	*42,652.07*	*0.00*		*65,769.46*	*65,769.46*	
Pressure Grouting	**1.00**	**EA**	**Sub**	**21,062**	**2,056**	**42,652**	**0**	**0**	**65,769**	**65,769**	
				19.76	*2.08*	*42.50*	*0.00*		*64.34*	*64.34*	
RSM 314313130300 Concrete pressure grouting, cement and sand, 1:1 mix, per C.F., maximum	989.60	CF	Sub	19,556	2,056	42,058	0	0	63,670	63,670	N
				2.51	*0.00*	*0.99*	*0.00*		*3.50*	*3.50*	
RSM 238316100120 Radiant floor heating, tubing, PEX (cross-linked polyethylene), oxygen barrier type for systems with ferrous metals, 1/2"	600.00	LF	Sub	1,506	0	594	0	0	2,100	2,100	O
				4,452.75	*68.06*	*2,943.40*	*0.00*		*7,464.21*	*7,464.21*	
VP 6" vent pipe	**1.00**	**EA**	**Prime**	**4,453**	**68**	**2,943**	**0**	**0**	**7,464**	**7,464**	
				45.25	*0.35*	*36.50*	*0.00*		*82.10*	*82.10*	
RSM 221113442350 Pipe, steel, black, welded, 6" diameter, schedule 40, A-53 gr. A/B, includes hanger assemblies	60.00	LF	Prime	2,715	21	2,190	0	0	4,926	4,926	N
				334.88	*2.56*	*106.00*	*0.00*		*443.44*	*443.44*	
RSM 221113473140 Elbow, 90 Deg., steel, carbon steel, black, long radius, butt weld, standard weight, 6" pipe size, includes 1 weld per joint and weld machine	2.00	EA	Prime	670	5	212	0	0	887	887	N
				334.88	*2.56*	*97.50*	*0.00*		*434.94*	*434.94*	
RSM 221113473300 Elbow, 45 Deg., steel, carbon steel, black, long radius, butt weld, standard weight, 6" pipe size, includes 1 weld per joint and weld machine	2.00	EA	Prime	670	5	195	0	0	870	870	N
				2.49	*0.23*	*2.17*	*0.00*		*4.88*	*4.88*	
E-11.3.6 Surface Prep & Paint outside of pipe.	**160.00**	**SF**	**Sub**	**398**	**37**	**346**	**0**	**0**	**781**	**781**	
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100110 Paints & Coatings, material only, vinyl paint, V-766E, gray, 1 mil average thickness	720.00	SF	Sub	0	0	137	0	0	137	137	N

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100130 Paints & Coatings, material only, vinyl paint, V-766E, white, 1 mil average thickness	480.00	SF	Sub	0	0	91	0	0	91	91	N
				0.22	*0.00*	*0.00*	*0.00*		*0.22*	*0.22*	
HNC 099713330080 Coatings for Steel, structural steel, application only, paint, machinery & equip., spray, 1 coat	800.00	SF	Sub	174	0	0	0	0	174	174	N
				1.40	*0.23*	*0.74*	*0.00*		*2.37*	*2.37*	
RSM 050110516240 Metal cleaning, steel surface treatment, 3.0 lb sand per S.F., commercial blast, tight mill scale, little/no rust (SSPC-SP6)	160.00	SF	Sub	224	37	118	0	0	379	379	N
				5,536.44	*378.59*	*6,260.00*	*13,000.00*		*25,175.03*	*25,175.03*	
Pipe Rail System	**1.00**	**EA**	**Prime**	**5,536**	**379**	**6,260**	**13,000**	**0**	**25,175**	**25,175**	
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	
USR FAB01 Rail System - Shop Fabrication	4,000.00	LB	Prime	0	0	4,000	13,000	0	17,000	17,000	MSb
				0.00	*0.00*	*200.00*	*0.00*		*200.00*	*200.00*	
USR UHMW Pads	2.00	EA	Prime	0	0	400	0	0	400	400	M
				30.22	*3.15*	*15.50*	*0.00*		*48.88*	*48.88*	
RSM 050523151435 Chemical anchor, 1" dia x 11-3/4" L, in concrete, brick or stone, incl layout, drilling, threaded rod & epoxy cartridge	120.00	EA	Prime	3,627	379	1,860	0	0	5,865	5,865	N
				238.70	*0.00*	*0.00*	*0.00*		*238.70*	*238.70*	
USR RAIL01 Rail Installation Crew	8.00	HR	Prime	1,910	0	0	0	0	1,910	1,910	N
				19,690.99	*1,855.83*	*6,413.00*	*0.00*		*27,959.82*	*27,959.82*	
Intake Concrete	**1.00**	**EA**	**Sub**	**19,691**	**1,856**	**6,413**	**0**	**0**	**27,960**	**27,960**	
				296.71	*23.46*	*0.00*	*0.00*		*320.17*	*320.17*	
RSM 030505100070 Selective concrete demolition, maximum reinforcing, break up into small pieces, excludes shoring, bracing, saw or torch cutting, loading, hauling, dumping	15.00	CY	Prime - LS&H	4,451	352	0	0	0	4,803	4,803	N
				714.74	*79.23*	*305.00*	*0.00*		*1,098.98*	*1,098.98*	
RSM 033053400300 Structural concrete, in place, beam (3500 psi), 5 kip per L.F., 10' span, includes forms(4 uses), reinforcing steel, concrete, placing and finishing	15.00	CY	Prime - LS&H	10,721	1,188	4,575	0	0	16,485	16,485	N
				36.03	*3.15*	*15.50*	*0.00*		*54.68*	*54.68*	
RSM 050523151435 Chemical anchor, 1" dia x 11-3/4" L, in concrete, brick or stone, incl layout, drilling, threaded rod & epoxy cartridge	100.00	EA	Prime - LS&H	3,603	315	1,550	0	0	5,468	5,468	N
				9.16	*0.00*	*2.88*	*0.00*		*12.04*	*12.04*	
HNC 032110602440 Reinforcing steel, in place, dowels, deformed, 2' long, #8, A615, grade 60	100.00	EA	Prime - LS&H	916	0	288	0	0	1,204	1,204	N
				0.42	*0.04*	*0.37*	*0.00*		*0.83*	*0.83*	
E-11.3.6 Surface Prep & Paint Inside Area of Conduit Pipe	**22,200.00**	**SF**	**Sub**	**9,378**	**873**	**8,162**	**0**	**0**	**18,413**	**18,413**	
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100110 Paints & Coatings, material only, vinyl paint, V-766E, gray, 1 mil average thickness	16,964.00	SF	Sub	0	0	3,223	0	0	3,223	3,223	N

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100130 Paints & Coatings, material only, vinyl paint, V-766E, white, 1 mil average thickness	11,310.00	SF	Sub	0	0	2,149	0	0	2,149	2,149	N
				0.22	*0.00*	*0.00*	*0.00*		*0.22*	*0.22*	
HNC 099713330080 Coatings for Steel, structural steel, application only, paint, machinery & equip., spray, 1 coat	18,850.00	SF	Sub	4,110	0	0	0	0	4,110	4,110	N
				1.40	*0.23*	*0.74*	*0.00*		*2.37*	*2.37*	
RSM 050110516240 Metal cleaning, steel surface treatment, 3.0 lb sand per S.F., commercial blast, tight mill scale, little/no rust (SSPC-SP6)	3,770.00	SF	Sub	5,269	873	2,790	0	0	8,931	8,931	N
Steel Pipe from Dam to AWS Chamber	**1.00**	**LS**	**Prime**	**357,184**	**110,391**	**544,210**	**0**	**0**	**1,011,785**	**1,011,785**	
				188,503.96	*45,750.59*	*457,935.00*	*0.00*		*692,189.55*	*692,189.55*	
Furnish & Install Steel Pipe	**1.00**	**EA**	**Prime**	**188,504**	**45,751**	**457,935**	**0**	**0**	**692,190**	**692,190**	
				312.11	*108.27*	*1,050.00*	*0.00*		*1,470.38*	*1,470.38*	
HNC 331113401180 Pipe, black steel, plain end, welded, 5/8" wall thickness, 96" diameter, excludes excavation or backfill	200.00	LF	Prime	62,421	21,654	210,000	0	0	294,075	294,075	N
				383.89	*133.17*	*1,000.00*	*0.00*		*1,517.06*	*1,517.06*	
USER 5/8" pipe Pipe, black steel, plain end, welded, 5/8" wall thickness, 120" diameter, excludes excavation or backfill	180.00	LF	Prime	69,100	23,971	180,000	0	0	273,071	273,071	M
				49,469.51	*0.00*	*56,610.00*	*0.00*		*106,079.51*	*106,079.51*	
Fittings bends and orfice plate	**1.00**	**EA**	**Prime**	**49,470**	**0**	**56,610**	**0**	**0**	**106,080**	**106,080**	
				12,184.05	*0.00*	*28,520.00*	*0.00*		*40,704.05*	*40,704.05*	
WYE Fitting	**1.00**	**EA**	**Prime**	**12,184**	**0**	**28,520**	**0**	**0**	**40,704**	**40,704**	
				56.41	*0.00*	*15.00*	*0.00*		*71.41*	*71.41*	
USR wl Welding per lb	168.00	LB	Prime	9,476	0	2,520	0	0	11,996	11,996	N
				169.22	*0.00*	*0.00*	*0.00*		*169.22*	*169.22*	
USR FC Fab Crew at shop.	16.00	HR	Prime	2,708	0	0	0	0	2,708	2,708	N
				0.00	*0.00*	*26,000.00*	*0.00*		*26,000.00*	*26,000.00*	
USR Total for Pipe Material for the Y.	1.00	EA	Prime	0	0	26,000	0	0	26,000	26,000	M
				37,285.46	*0.00*	*28,090.00*	*0.00*		*65,375.46*	*65,375.46*	
10' Dia Bends	**1.00**	**EA**	**Prime**	**37,285**	**0**	**28,090**	**0**	**0**	**65,375**	**65,375**	
				169.22	*0.00*	*0.00*	*0.00*		*169.22*	*169.22*	
USR FC Fab Crew at shop.	85.00	HR	Prime	14,384	0	0	0	0	14,384	14,384	N
				0.00	*0.00*	*22,000.00*	*0.00*		*22,000.00*	*22,000.00*	
USR 10' dia pipe for fittings.	1.00	FT	Prime	0	0	22,000	0	0	22,000	22,000	M
				56.41	*0.00*	*15.00*	*0.00*		*71.41*	*71.41*	
USR wl Welding per lb	406.00	LB	Prime	22,902	0	6,090	0	0	28,992	28,992	N
				7,513.12	*125.05*	*11,325.00*	*0.00*		*18,963.17*	*18,963.17*	
Access Hatch to 10' dia pipe	**1.00**	**EA**	**Prime**	**7,513**	**125**	**11,325**	**0**	**0**	**18,963**	**18,963**	
				0.00	*0.00*	*11,325.00*	*0.00*		*11,325.00*	*11,325.00*	

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
USR Acces Hatch Materials	1.00	EA	Prime	0	0	11,325	0	0	11,325	11,325	M
				169.22	*0.00*	*0.00*	*0.00*		*169.22*	*169.22*	
USR FC Fab Crew at shop.	30.00	HR	Prime	5,077	0	0	0	0	5,077	5,077	N
				243.64	*12.51*	*0.00*	*0.00*		*256.15*	*256.15*	
USR MSPFB35A Filed Installation Crew.	10.00	HR	Prime	2,436	125	0	0	0	2,561	2,561	N
				9,278.90	*7,321.87*	*0.00*	*0.00*		*16,600.77*	*16,600.77*	
Common Excavation - 10' Dia. Pipe	**1.00**	**EA**	**Prime**	**9,279**	**7,322**	**0**	**0**	**0**	**16,601**	**16,601**	
				1.65	*0.94*	*0.00*	*0.00*		*2.59*	*2.59*	
RSM 312316130130 Excavating, trench or continuous footing, common earth, 1-1/2 C.Y. excavator, 4' to 6' deep, excludes sheeting or dewatering	2,106.00	BCY	Prime	3,485	1,971	0	0	0	5,457	5,457	N
				1.07	*0.39*	*0.00*	*0.00*		*1.45*	*1.45*	
HNC 312316440225 Excavate and load, bank measure, medium material, 1-1/2 C.Y. bucket, wheeled loader	2,106.00	BCY	Prime	2,252	812	0	0	0	3,064	3,064	N
				1.29	*1.66*	*0.00*	*0.00*		*2.95*	*2.95*	
RSM 312323201016 Cycle hauling(wait, load,travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 15 min load/wait/unload, 12 C.Y. truck, cycle 1 mile, 15 MPH, excludes loading equipment	2,737.80	LCY	Prime	3,542	4,539	0	0	0	8,080	8,080	N
				61,519.99	*20,117.22*	*27,799.20*	*0.00*		*109,436.42*	*109,436.42*	
Rock Excavation - 10' dia. Pipe	**1.00**	**EA**	**Prime**	**61,520**	**20,117**	**27,799**	**0**	**0**	**109,436**	**109,436**	
				2.00	*1.15*	*0.00*	*0.00*		*3.15*	*3.15*	
RSM 312316264600 Rock removal, drilling only for rock quarry production, 2-1/2" to 3-1/2" diameter	9,720.00	LF	Prime	19,455	11,133	0	0	0	30,588	30,588	O
				3.93	*0.49*	*2.86*	*0.00*		*7.28*	*7.28*	
USR 025210105277 Concrete removal, expansive demolition grout, conventional demolition grout, vertical, 1-7/8" dia hole	9,720.00	LF	Prime	38,237	4,732	27,799	0	0	70,768	70,768	O
				4.64	*4.61*	*0.00*	*0.00*		*9.25*	*9.25*	
HNC 312316440150 Excavate and load, bank measure, blasted rock, 2 C.Y. bucket, hydraulic excavator	486.00	BCY	Prime	2,256	2,238	0	0	0	4,495	4,495	O
				2.49	*3.19*	*0.00*	*0.00*		*5.68*	*5.68*	
RSM 312323201056 Cycle hauling(wait, load,travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 15 min load/wait/unload, 12 C.Y. truck, cycle 10 miles, 30 MPH, excludes loading equipment	631.80	LCY	Prime	1,572	2,014	0	0	0	3,586	3,586	N
				317.23	*250.32*	*0.00*	*0.00*		*567.55*	*567.55*	
Common Excavation - 7.5' Dia. Pipe	**30.00**	**LF**	**Prime**	**9,517**	**7,510**	**0**	**0**	**0**	**17,026**	**17,026**	
				1.65	*0.94*	*0.00*	*0.00*		*2.59*	*2.59*	
RSM 312316130130 Excavating, trench or continuous footing, common earth, 1-1/2 C.Y. excavator, 4' to 6' deep, excludes sheeting or dewatering	2,160.00	BCY	Prime	3,575	2,022	0	0	0	5,597	5,597	N
				1.07	*0.39*	*0.00*	*0.00*		*1.45*	*1.45*	
HNC 312316440225 Excavate and load, bank measure, medium material,	2,160.00	BCY	Prime	2,310	833	0	0	0	3,143	3,143	N

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
1-1/2 C.Y. bucket, wheeled loader											
				1.29	*1.66*	*0.00*	*0.00*		*2.95*	*2.95*	
RSM 312323201016 Cycle hauling(wait, load,travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 15 min load/wait/unload, 12 C.Y. truck, cycle 1 mile, 15 MPH, excludes loading equipment	2,808.00	LCY	Prime	3,632	4,655	0	0	0	8,287	8,287	N
				2,350.92	*260.81*	*6,016.50*	*0.00*		*8,628.23*	*8,628.23*	
Pipe Bedding	**1.00**	**EA**	**Prime**	**2,351**	**261**	**6,017**	**0**	**0**	**8,628**	**8,628**	
				8.47	*1.13*	*31.50*	*0.00*		*41.10*	*41.10*	
RSM 312323160100 Fill by borrow and utility bedding, for pipe and conduit, crushed stone, 3/4" to 1/2", excludes compaction	151.00	LCY	Prime	1,279	171	4,757	0	0	6,207	6,207	N
				8.47	*1.13*	*31.50*	*0.00*		*41.10*	*41.10*	
RSM 312323160100 Fill by borrow and utility bedding, for pipe and conduit, crushed stone, 3/4" to 1/2", excludes compaction	40.00	LCY	Prime	339	45	1,260	0	0	1,644	1,644	N
				4.42	*0.27*	*0.00*	*0.00*		*4.68*	*4.68*	
RSM 312323160500 Fill by borrow and utility bedding, for pipe and conduit, compacting bedding in trench	166.00	ECY	Prime	733	44	0	0	0	777	777	N
				35,637.73	*24,846.18*	*0.00*	*0.00*		*60,483.91*	*60,483.91*	
Pipe Backfill	**1.00**	**EA**	**Prime**	**35,638**	**24,846**	**0**	**0**	**0**	**60,484**	**60,484**	
				2.97	*1.07*	*0.00*	*0.00*		*4.03*	*4.03*	
HNC 312316440225 Excavate and load, bank measure, medium material, 1-1/2 C.Y. bucket, wheeled loader	4,419.00	BCY	Prime	13,104	4,724	0	0	0	17,828	17,828	O
				1.29	*1.66*	*0.00*	*0.00*		*2.95*	*2.95*	
RSM 312323201016 Cycle hauling(wait, load,travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 15 min load/wait/unload, 12 C.Y. truck, cycle 1 mile, 15 MPH, excludes loading equipment	5,303.00	LCY	Prime	6,860	8,791	0	0	0	15,651	15,651	N
				1.29	*1.66*	*0.00*	*0.00*		*2.95*	*2.95*	
RSM 312323201016 Cycle hauling(wait, load,travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 15 min load/wait/unload, 12 C.Y. truck, cycle 1 mile, 15 MPH, excludes loading equipment	5,303.00	LCY	Prime	6,860	8,791	0	0	0	15,651	15,651	N
				0.95	*0.41*	*0.00*	*0.00*		*1.36*	*1.36*	
HNC 312323145510 Backfill, structural, 6" lifts, backfill around foundation, with hydraulic excavator	5,303.00	LCY	Prime	5,050	2,188	0	0	0	7,238	7,238	N
				0.71	*0.07*	*0.00*	*0.00*		*0.78*	*0.78*	
RSM 312323237200 Compaction, 2 passes, 18" wide,12" lifts, walk behind, vibrating plate	5,303.00	ECY	Prime	3,764	353	0	0	0	4,117	4,117	N
				2.11	*0.20*	*1.84*	*0.00*		*4.15*	*4.15*	
E-11.3.6 Surface Prep & Paint All Conduit Pipe	**23,100.00**	**SF**	**Sub**	**48,844**	**4,545**	**42,510**	**0**	**0**	**95,899**	**95,899**	
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
HNC 099730100110 Paints & Coatings, material only, vinyl paint, V-766E, gray, 1 mil average thickness	88,357.00	SF	Sub	0	0	16,788	0	0	16,788	16,788	N
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100130 Paints & Coatings, material only, vinyl paint, V-766E, white, 1 mil average thickness	58,905.00	SF	Sub	0	0	11,192	0	0	11,192	11,192	N
				0.22	*0.00*	*0.00*	*0.00*		*0.22*	*0.22*	
HNC 099713330080 Coatings for Steel, structural steel, application only, paint, machinery & equip., spray, 1 coat	98,175.00	SF	Sub	21,404	0	0	0	0	21,404	21,404	N
				1.40	*0.23*	*0.74*	*0.00*		*2.37*	*2.37*	
RSM 050110516240 Metal cleaning, steel surface treatment, 3.0 lb sand per S.F., commercial blast, tight mill scale, little/no rust (SSPC-SP6)	19,635.00	SF	Sub	27,440	4,545	14,530	0	0	46,515	46,515	N
				1,531.70	*39.25*	*9,950.00*	*0.00*		*11,520.96*	*11,520.96*	
Thrust Block	**1.00**	**EA**	**Prime**	**1,532**	**39**	**9,950**	**0**	**0**	**11,521**	**11,521**	
				15.32	*0.39*	*0.00*	*0.00*		*15.71*	*15.71*	
RSM 033105703200 Structural concrete, placing, grade beam, direct chute, includes strike off & consolidation, excludes material	100.00	CY	Prime	1,532	39	0	0	0	1,571	1,571	N
				0.00	*0.00*	*99.50*	*0.00*		*99.50*	*99.50*	
RSM 033105350200 Structural concrete, ready mix, normal weight, 3500 psi, includes local aggregate, sand, Portland cement and water, delivered, excludes all additives and treatments	100.00	CY	Prime	0	0	9,950	0	0	9,950	9,950	N
				128,320.59	*48,321.51*	*101,112.41*	*0.00*		*277,754.52*	*277,754.52*	
Steel Pipe in AWS Chamber	**1.00**	**EA**	**Prime**	**128,321**	**48,322**	**101,112**	**0**	**0**	**277,755**	**277,755**	
				7,161.00	*0.00*	*5,000.00*	*0.00*		*12,161.00*	*12,161.00*	
Set up platform and rigging in AWS chamber	**1.00**	**EA**	**Prime**	**7,161**	**0**	**5,000**	**0**	**0**	**12,161**	**12,161**	
				238.70	*0.00*	*0.00*	*0.00*		*238.70*	*238.70*	
USR AWS labor Set up platform and rigging in AWS Chamber	30.00	HR	Prime	7,161	0	0	0	0	7,161	7,161	N
				0.00	*0.00*	*5,000.00*	*0.00*		*5,000.00*	*5,000.00*	
USR Materials for temporary platform	1.00	EA	Prime	0	0	5,000	0	0	5,000	5,000	M
				4,774.00	*0.00*	*0.00*	*0.00*		*4,774.00*	*4,774.00*	
Remove rigging and platforms from AWS Chamber	**1.00**	**EA**	**Prime**	**4,774**	**0**	**0**	**0**	**0**	**4,774**	**4,774**	
				238.70	*0.00*	*0.00*	*0.00*		*238.70*	*238.70*	
USR AWS labor Set up platform and rigging in AWS Chamber	20.00	HR	Prime	4,774	0	0	0	0	4,774	4,774	N
				21,547.61	*23,427.02*	*0.00*	*0.00*		*44,974.63*	*44,974.63*	
Crane and Above grade support crew.	**1.00**	**EA**	**Prime**	**21,548**	**23,427**	**0**	**0**	**0**	**44,975**	**44,975**	
				165.75	*180.21*	*0.00*	*0.00*		*345.96*	*345.96*	
USR AWS Chamber surface support crew.	130.00	HR	Prime	21,548	23,427	0	0	0	44,975	44,975	N
				34,110.02	*1,750.70*	*0.00*	*0.00*		*35,860.73*	*35,860.73*	
Install Pipe	**1.00**	**EA**	**Prime**	**34,110**	**1,751**	**0**	**0**	**0**	**35,861**	**35,861**	
				304.55	*15.63*	*0.00*	*0.00*		*320.19*	*320.19*	

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
USR 331113401220 Pipe, black steel, plain end, welded, 5/8" wall thickness, 96" diameter, pipe fab in AWS Chamber	80.00	LF	Prime	24,364	1,251	0	0	0	25,615	25,615	OM
				243.64	*12.51*	*0.00*	*0.00*		*256.15*	*256.15*	
USR MSPFB35A Additional Field Welds.	40.00	HR	Prime	9,746	500	0	0	0	10,246	10,246	N
				0.51	*0.05*	*0.44*	*0.00*		*1.00*	*1.00*	
E-11.3.6 Surface Prep & Paint all Conduit Pipe	**23,100.00**	**SF**	**Sub**	**11,722**	**1,091**	**10,202**	**0**	**0**	**23,015**	**23,015**	
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100110 Paints & Coatings, material only, vinyl paint, V-766E, gray, 1 mil average thickness	21,206.00	SF	Sub	0	0	4,029	0	0	4,029	4,029	N
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100130 Paints & Coatings, material only, vinyl paint, V-766E, white, 1 mil average thickness	14,137.00	SF	Sub	0	0	2,686	0	0	2,686	2,686	N
				0.22	*0.00*	*0.00*	*0.00*		*0.22*	*0.22*	
HNC 099713330080 Coatings for Steel, structural steel, application only, paint, machinery & equip., spray, 1 coat	23,562.00	SF	Sub	5,137	0	0	0	0	5,137	5,137	N
				1.40	*0.23*	*0.74*	*0.00*		*2.37*	*2.37*	
RSM 050110516240 Metal cleaning, steel surface treatment, 3.0 lb sand per S.F., commercial blast, tight mill scale, little/no rust (SSPC-SP6)	4,712.00	SF	Sub	6,585	1,091	3,487	0	0	11,163	11,163	N
				17,539.21	*13,679.94*	*1,935.36*	*0.00*		*33,154.52*	*33,154.52*	
Concrete Sawcutting Fishladder and AWS Chamber	**1.00**	**EA**	**Prime**	**17,539**	**13,680**	**1,935**	**0**	**0**	**33,155**	**33,155**	
				17,539.21	*13,679.94*	*1,935.36*	*0.00*		*33,154.52*	*33,154.52*	
Concrete Cutting	**1.00**	**EA**	**Sub**	**17,539**	**13,680**	**1,935**	**0**	**0**	**33,155**	**33,155**	
				4.91	*4.36*	*0.63*	*0.00*		*9.90*	*9.90*	
RSM 038116500820 Concrete sawing, concrete walls, rod reinforcing, per inch of depth	3,072.00	LF	Sub	15,086	13,382	1,935	0	0	30,403	30,403	N
				237.84	*23.46*	*0.00*	*0.00*		*261.30*	*261.30*	
RSM 030505100070 Selective concrete demolition, maximum reinforcing, break up into small pieces, excludes shoring, bracing, saw or torch cutting, loading, hauling, dumping	10.00	CY	Sub	2,378	235	0	0	0	2,613	2,613	N
				4.41	*2.23*	*0.00*	*0.00*		*6.64*	*6.64*	
HNC 312316440110 Excavate and load, bank measure, blasted rock, 3/4 C.Y. bucket, hydraulic excavator	10.00	BCY	Sub	44	22	0	0	0	66	66	N
				2.35	*3.19*	*0.00*	*0.00*		*5.53*	*5.53*	
RSM 312323201056 Cycle hauling(wait, load,travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 15 min load/wait/unload, 12 C.Y. truck, cycle 10 miles, 30 MPH, excludes loading equipment	13.00	LCY	Sub	30	41	0	0	0	72	72	N
				28,485.86	*0.00*	*83,975.00*	*0.00*		*112,460.86*	*112,460.86*	
90 degree bend and fabrication of orifice manifold.	**1.00**	**EA**	**Prime**	**28,486**	**0**	**83,975**	**0**	**0**	**112,461**	**112,461**	
				21,716.95	*0.00*	*19,975.00*	*0.00*		*41,691.95*	*41,691.95*	

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
7.5' Dia Bends	**1.00**	**EA**	**Prime**	**21,717**	**0**	**19,975**	**0**	**0**	**41,692**	**41,692**	
				169.22	*0.00*	*0.00*	*0.00*		*169.22*	*169.22*	
USR FC Fab Crew at shop.	40.00	HR	Prime	6,769	0	0	0	0	6,769	6,769	N
				0.00	*0.00*	*16,000.00*	*0.00*		*16,000.00*	*16,000.00*	
USR 7.5' dia pipe for bend	1.00	FT	Prime	0	0	16,000	0	0	16,000	16,000	M
				56.41	*0.00*	*15.00*	*0.00*		*71.41*	*71.41*	
USR wl Welding per lb	265.00	LB	Prime	14,948	0	3,975	0	0	18,923	18,923	N
				6,768.92	*0.00*	*64,000.00*	*0.00*		*70,768.92*	*70,768.92*	
7.5' dia Orfice Manifold.	**1.00**	**EA**	**Prime**	**6,769**	**0**	**64,000**	**0**	**0**	**70,769**	**70,769**	
				0.00	*0.00*	*64,000.00*	*0.00*		*64,000.00*	*64,000.00*	
USR 7.5' dia pipe for orfice manifold	1.00	FT	Prime	0	0	64,000	0	0	64,000	64,000	M
				169.22	*0.00*	*0.00*	*0.00*		*169.22*	*169.22*	
USR FC Fab Crew at shop.	40.00	HR	Prime	6,769	0	0	0	0	6,769	6,769	N
				2,980.82	*8,373.14*	*0.00*	*0.00*		*11,353.96*	*11,353.96*	
Scaffold and hoist	**1.00**	**EA**	**Prime**	**2,981**	**8,373**	**0**	**0**	**0**	**11,354**	**11,354**	
				0.00	*2,088.00*	*0.00*	*0.00*		*2,088.00*	*2,088.00*	
USR Scafold and Hoist Equipment Rental	4.00	WK	Prime	0	8,352	0	0	0	8,352	8,352	E
				99.36	*0.70*	*0.00*	*0.00*		*100.07*	*100.07*	
USR Deliver, Setup, and Return Scafolding	30.00	HR	Prime	2,981	21	0	0	0	3,002	3,002	N
				9,838.31	*5,762.46*	*220,000.00*	*0.00*		*235,600.77*	*235,600.77*	
120" Butterfly Valve w/Acutator	**1.00**	**EA**	**Prime**	**9,838**	**5,762**	**220,000**	**0**	**0**	**235,601**	**235,601**	
				8,091.97	*4,065.30*	*220,000.00*	*0.00*		*232,157.26*	*232,157.26*	
Valve	**1.00**	**EA**	**Prime**	**8,092**	**4,065**	**220,000**	**0**	**0**	**232,157**	**232,157**	
				0.00	*0.00*	*220,000.00*	*0.00*		*220,000.00*	*220,000.00*	
USR VALV01 Valve, Butterfly, 10' dia.	1.00	EA	Prime	0	0	220,000	0	0	220,000	220,000	M
				269.73	*135.51*	*0.00*	*0.00*		*405.24*	*405.24*	
USR VALV02 Valve Installation Crew	30.00	HR	Prime	8,092	4,065	0	0	0	12,157	12,157	N
				1,746.34	*1,697.16*	*0.00*	*0.00*		*3,443.50*	*3,443.50*	
Shipping	**1.00**	**EA**	**Prime**	**1,746**	**1,697**	**0**	**0**	**0**	**3,444**	**3,444**	
				48.51	*47.14*	*0.00*	*0.00*		*95.65*	*95.65*	
USR SHIP01 Shipping Crew	36.00	HR	Prime	1,746	1,697	0	0	0	3,444	3,444	N
				48,179.35	*13,968.51*	*229,557.50*	*137,297.50*		*429,002.86*	*429,002.86*	
Emergency Closure Gate	**1.00**	**EA**	**Prime**	**48,179**	**13,969**	**229,558**	**137,298**	**0**	**429,003**	**429,003**	
				0.00	*0.00*	*106,450.00*	*93,047.50*		*199,497.50*	*199,497.50*	
Furnish Emergency Closure Gate	**1.00**	**EA**	**Prime**	**0**	**0**	**106,450**	**93,048**	**0**	**199,498**	**199,498**	
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	
USR FAB01 Emergency Closure Gate - Shop Fabrication	22,550.00	LB	Prime	0	0	22,550	73,288	0	95,838	95,838	MSb
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
USR FAB01 Lifting Beam - Shop Fabrication	3,000.00	LB	Prime	0	0	3,000	9,750	0	12,750	12,750	MSb
				0.00	*0.00*	*0.00*	*65.00*		*65.00*	*65.00*	
USR PAINT01 Emergency Closure Gate - Shop Blasting	8.00	HR	Prime	0	0	0	520	0	520	520	Sb
USR PAINT01 Emergency Closure Gate - Shop Painting	1.00	LS	Prime	0	0	1,000	1,040	0	2,040	2,040	MSb
				0.00	*0.00*	*6,000.00*	*650.00*		*6,650.00*	*6,650.00*	
USR PAINT01 Roller Wheel Assembly - Shop Fabrication	10.00	EA	Prime	0	0	60,000	6,500	0	66,500	66,500	MSb
				0.00	*0.00*	*1,500.00*	*0.00*		*1,500.00*	*1,500.00*	
USR Roller Wheel Assembly - 10" Spherical Bearing	10.00	EA	Prime	0	0	15,000	0	0	15,000	15,000	M
				0.00	*0.00*	*60.00*	*0.00*		*60.00*	*60.00*	
USR Gate Seals	60.00	LF	Prime	0	0	3,600	0	0	3,600	3,600	M
				0.00	*0.00*	*4.00*	*0.00*		*4.00*	*4.00*	
USR Seal Keeper Plates - Material Only	325.00	LB	Prime	0	0	1,300	0	0	1,300	1,300	M
				0.00	*0.00*	*0.00*	*65.00*		*65.00*	*65.00*	
USR Seal Keeper Plates - Shop Fabrication	10.00	HR	Prime	0	0	0	650	0	650	650	Sb
				0.00	*0.00*	*0.00*	*65.00*		*65.00*	*65.00*	
USR Emergency Closure Gate - Shop Assembly	20.00	HR	Prime	0	0	0	1,300	0	1,300	1,300	Sb
				0.00	*0.00*	*118,000.00*	*44,250.00*		*162,250.00*	*162,250.00*	
Furnish Emergency Closure Gate Guides	**1.00**	**EA**	**Prime**	**0**	**0**	**118,000**	**44,250**	**0**	**162,250**	**162,250**	
				0.00	*0.00*	*4.00*	*1.50*		*5.50*	*5.50*	
USR FAB01 Emergency Closure Gate Guides - Shop Fabrication	29,500.00	LB	Prime	0	0	118,000	44,250	0	162,250	162,250	MSb
				274.46	*282.86*	*0.00*	*0.00*		*557.32*	*557.32*	
Shipping	**1.00**	**EA**	**Sub**	**274**	**283**	**0**	**0**	**0**	**557**	**557**	
				45.74	*47.14*	*0.00*	*0.00*		*92.89*	*92.89*	
USR SHIP01 Shipping Crew	6.00	HR	Sub	274	283	0	0	0	557	557	N
				43,633.41	*12,383.85*	*5,107.50*	*0.00*		*61,124.76*	*61,124.76*	
Install Emergency Gate Closure Guides	**1.00**	**EA**	**Prime - LS&H**	**43,633**	**12,384**	**5,108**	**0**	**0**	**61,125**	**61,125**	
				32.03	*2.80*	*8.55*	*0.00*		*43.38*	*43.38*	
RSM 050523151430 Chemical anchor, 3/4" dia x 9-1/2" L, in concrete, brick or stone, incl layout, drilling, threaded rod & epoxy cartridge	400.00	EA	Prime - LS&H	12,810	1,122	3,420	0	0	17,352	17,352	N
				427.15	*130.18*	*0.00*	*0.00*		*557.33*	*557.33*	
USR INSTALL02 Guide Install Crew	30.00	HR	Prime - LS&H	12,814	3,905	0	0	0	16,720	16,720	N
				66.70	*27.25*	*6.25*	*0.00*		*100.20*	*100.20*	
RSM 036213500300 Grout, non-shrink, for column and machine bases, non-metallic, 1" deep	270.00	SF	Prime - LS&H	18,009	7,357	1,688	0	0	27,053	27,053	O
				4,271.48	*1,301.80*	*0.00*	*0.00*		*5,573.28*	*5,573.28*	
Install Emergency Closure Gate	**1.00**	**EA**	**Sub**	**4,271**	**1,302**	**0**	**0**	**0**	**5,573**	**5,573**	
				427.15	*130.18*	*0.00*	*0.00*		*557.33*	*557.33*	
USR INSTALL02 Guide Install Crew	10.00	HR	Prime - LS&H	4,271	1,302	0	0	0	5,573	5,573	N
Trash Rack & Trash Rake	**1.00**	**LS**	**Prime**	**184,152**	**31,730**	**276,349**	**209,175**	**0**	**701,406**	**701,406**	

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				0.00	*0.00*	*160,000.00*	*130,000.00*		*290,000.00*	*290,000.00*	
Furnish Trash Rack Panels	**1.00**	**EA**	**Prime**	**0**	**0**	**160,000**	**130,000**	**0**	**290,000**	**290,000**	
				0.00	*0.00*	*4.00*	*3.25*		*7.25*	*7.25*	
USR FAB01 Trash Rack - Shop Fabrication	40,000.00	LB	Prime	0	0	160,000	130,000	0	290,000	290,000	MSb
				1,990.09	*185.18*	*9,232.00*	*24,375.00*		*35,782.27*	*35,782.27*	
Furnish Track Rake	**1.00**	**EA**	**Prime**	**1,990**	**185**	**9,232**	**24,375**	**0**	**35,782**	**35,782**	
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	
USR FAB01 Trash Rack - Shop Fabrication	7,500.00	LB	Prime	0	0	7,500	24,375	0	31,875	31,875	MSb
				1.40	*0.23*	*0.74*	*0.00*		*2.37*	*2.37*	
RSM 050110516240 Metal cleaning, steel surface treatment, 3.0 lb sand per S.F., commercial blast, tight mill scale, little/no rust (SSPC-SP6)	800.00	SF	Sub	1,118	185	592	0	0	1,895	1,895	N
				0.22	*0.00*	*0.00*	*0.00*		*0.22*	*0.22*	
HNC 099713330080 Coatings for Steel, structural steel, application only, paint, machinery & equip., spray, 1 coat	4,000.00	SF	Sub	872	0	0	0	0	872	872	N
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100130 Paints & Coatings, material only, vinyl paint, V-766E, white, 1 mil average thickness	2,400.00	SF	Sub	0	0	456	0	0	456	456	N
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100110 Paints & Coatings, material only, vinyl paint, V-766E, gray, 1 mil average thickness	3,600.00	SF	Sub	0	0	684	0	0	684	684	N
				59,615.83	*9,559.25*	*66,400.00*	*54,800.00*		*190,375.08*	*190,375.08*	
Furnish Trash Rack/Rake Guides	**1.00**	**EA**	**Prime**	**59,616**	**9,559**	**66,400**	**54,800**	**0**	**190,375**	**190,375**	
				0.00	*0.00*	*4.00*	*1.50*		*5.50*	*5.50*	
USR FAB01 Trash Rack/Rake Guides - Shop Fabrication	14,000.00	LB	Prime	0	0	56,000	21,000	0	77,000	77,000	MSb
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	
USR FAB01 Steel Plate for preditor protection.	10,400.00	LB	Prime	0	0	10,400	33,800	0	44,200	44,200	MSb
				1,233.66	*44.47*	*0.00*	*0.00*		*1,278.13*	*1,278.13*	
USR DIVE01 Dive Crew for installing preditor deflector plate.	40.00	HR	Prime	49,346	1,779	0	0	0	51,125	51,125	N
				256.74	*194.51*	*0.00*	*0.00*		*451.24*	*451.24*	
USR Install Deflector Plate, Ground Crew	40.00	HR	Prime - LS&H	10,269	7,780	0	0	0	18,050	18,050	O
				1,746.34	*1,697.16*	*0.00*	*0.00*		*3,443.50*	*3,443.50*	
Shipping	**1.00**	**EA**	**Prime**	**1,746**	**1,697**	**0**	**0**	**0**	**3,444**	**3,444**	
				48.51	*47.14*	*0.00*	*0.00*		*95.65*	*95.65*	
USR SHIP01 Shipping Crew	36.00	HR	Prime	1,746	1,697	0	0	0	3,444	3,444	N
				120,799.51	*20,288.70*	*40,717.00*	*0.00*		*181,805.22*	*181,805.22*	
Install Trash Rack/Trash Rake Guides	**1.00**	**EA**	**Prime - LS&H**	**120,800**	**20,289**	**40,717**	**0**	**0**	**181,805**	**181,805**	
				36.03	*3.15*	*15.50*	*0.00*		*54.68*	*54.68*	
RSM 050523151435 Chemical anchor, 1" dia x 11-3/4" L, in concrete, brick or stone, incl layout, drilling, threaded rod & epoxy cartridge	350.00	EA	Prime - LS&H	12,610	1,104	5,425	0	0	19,139	19,139	N

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				9.16	*0.00*	*2.88*	*0.00*		*12.04*	*12.04*	
HNC 032110602440 Reinforcing steel, in place, dowels, deformed, 2' long, #8, A615, grade 60	350.00	EA	Prime - LS&H	3,207	0	1,008	0	0	4,215	4,215	N
				601.85	*66.72*	*320.00*	*0.00*		*988.57*	*988.57*	
RSM 033053400350 Structural concrete, in place, beam (3500 psi), 5 kip per L.F., 25' span, includes forms(4 uses), reinforcing steel, concrete, placing and finishing	105.00	CY	Prime - LS&H	63,194	7,005	33,600	0	0	103,800	103,800	N
				427.15	*130.18*	*0.00*	*0.00*		*557.33*	*557.33*	
USR INSTALL02 Guide Install Crew	80.00	HR	Prime - LS&H	34,172	10,414	0	0	0	44,586	44,586	N
				32.03	*2.80*	*8.55*	*0.00*		*43.38*	*43.38*	
RSM 050523151430 Chemical anchor, 3/4" dia x 9-1/2" L, in concrete, brick or stone, incl layout, drilling, threaded rod & epoxy cartridge	80.00	EA	Prime - LS&H	2,562	224	684	0	0	3,470	3,470	N
				17.80	*5.42*	*0.00*	*0.00*		*23.22*	*23.22*	
USR Rough-up surface of the Dam	284.00	SF	Prime - LS&H	5,055	1,540	0	0	0	6,595	6,595	N
				21,229.89	*3,940.53*	*54,974.47*	*5,000.00*		*95,144.89*	*95,144.89*	
Electrical, Site Work, Utility repairs	**1.00**	**EA**	**Prime**	**21,230**	**3,941**	**54,974**	**5,000**	**10,000**	**95,145**	**95,145**	
				16,169.18	*996.54*	*11,369.57*	*0.00*		*38,535.29*	*38,535.29*	
Electrical	**1.00**	**EA**	**Sub**	**16,169**	**997**	**11,370**	**0**	**10,000**	**38,535**	**38,535**	
				0.00	*0.00*	*0.00*	*0.00*		*10,000.00*	*10,000.00*	
Low Voltage Wiring and Instrumentation and sensors	**1.00**	**EA**	**Sub**	**0**	**0**	**0**	**0**	**10,000**	**10,000**	**10,000**	
				0.00	*0.00*	*0.00*	*0.00*		*10,000.00*	*10,000.00*	
USR Low voltage wiring and instrumentation	1.00	EA	Sub	0	0	0	0	10,000	10,000	10,000	N
				8,030.65	*845.71*	*7,819.81*	*0.00*		*16,696.17*	*16,696.17*	
Power to Valve Actuator	**1.00**	**EA**	**Sub**	**8,031**	**846**	**7,820**	**0**	**0**	**16,696**	**16,696**	
				1,660.77	*0.00*	*871.96*	*0.00*		*2,532.73*	*2,532.73*	
Conduit and Cable for Actuator	**1.00**	**EA**	**Sub**	**1,661**	**0**	**872**	**0**	**0**	**2,533**	**2,533**	
				2.07	*0.00*	*1.13*	*0.00*		*3.20*	*3.20*	
RSM 337119151030 Electrical Underground Ducts and Manholes, PVC, conduit with coupling, 1" diameter, schedule 40, installed by direct burial in slab or duct bank	200.00	LF	Sub	414	0	226	0	0	640	640	N
				53.76	*0.00*	*39.00*	*0.00*		*92.76*	*92.76*	
RSM 260519903040 Wire, copper, stranded, 600 volt, #10, type XHHW, in raceway	16.00	CLF	Sub	860	0	624	0	0	1,484	1,484	N
				10.75	*0.00*	*0.61*	*0.00*		*11.36*	*11.36*	
RSM 260519350050 Terminal lugs, solderless, #16 to #10	36.00	EA	Sub	387	0	22	0	0	409	409	N
				682.98	*0.00*	*437.85*	*0.00*		*1,120.83*	*1,120.83*	
Lighting circuit, Light and Receptical at valve.	**1.00**	**EA**	**Sub**	**683**	**0**	**438**	**0**	**0**	**1,121**	**1,121**	
				2.07	*0.00*	*1.13*	*0.00*		*3.20*	*3.20*	
RSM 337119151030 Electrical Underground Ducts and Manholes, PVC,	50.00	LF	Sub	103	0	57	0	0	160	160	N

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
conduit with coupling, 1" diameter, schedule 40, installed by direct burial in slab or duct bank											
				53.76	*0.00*	*22.50*	*0.00*		*76.26*	*76.26*	
RSM 260519900120 Wire, copper, stranded, 600 volt, #10, type THW, in raceway	2.00	CLF	Sub	108	0	45	0	0	153	153	N
				134.40	*0.00*	*237.00*	*0.00*		*371.40*	*371.40*	
RSM 265623101170 High pressure sodium fixture, exterior, wall pack, 150 Watt, incl lamps	1.00	EA	Sub	134	0	237	0	0	371	371	N
				53.76	*0.00*	*26.00*	*0.00*		*79.76*	*79.76*	
RSM 260533182150 Pull boxes, sheet metal, type SC, raintight & weatherproof, 6" L x 6" W x 6" D, NEMA 3R	3.00	EA	Sub	161	0	78	0	0	239	239	N
				8.40	*0.00*	*7.25*	*0.00*		*15.65*	*15.65*	
RSM 260533171480 Outlet boxes, PVC, weatherproof blank cover, FS, 1 gang	1.00	EA	Sub	8	0	7	0	0	16	16	N
				16.80	*0.00*	*1.41*	*0.00*		*18.21*	*18.21*	
RSM 260533252560 Conduit fittings for rigid galvanized steel, nipples chase, plain, 3/4" diameter	10.00	EA	Sub	168	0	14	0	0	182	182	N
				3.50	*1.36*	*0.82*	*0.00*		*5.67*	*5.67*	
Conduit Feed Trench	**624.00**	**BCY**	**Sub**	**2,185**	**846**	**510**	**0**	**0**	**3,541**	**3,541**	
				0.62	*0.15*	*0.00*	*0.00*		*0.78*	*0.78*	
RSM 312316142850 Excavating, chain trencher, utility trench, common earth, 40 H.P., 24" wide, 42" deep, chain trencher, operator riding, includes backfill	200.00	LF	Sub	125	31	0	0	0	155	155	N
				237.84	*0.00*	*0.00*	*0.00*		*237.84*	*237.84*	
RSM 312316161030 Structural excavation for minor structures, bank measure, around obstructions, hand trimming	2.00	BCY	Sub	476	0	0	0	0	476	476	N
				28.85	*4.05*	*17.00*	*0.00*		*49.90*	*49.90*	
RSM 312323160200 Fill by borrow and utility bedding, for pipe and conduit, sand, dead or bank, excludes compaction	30.00	LCY	Sub	865	122	510	0	0	1,497	1,497	O
				11.83	*0.75*	*0.00*	*0.00*		*12.58*	*12.58*	
RSM 312323160500 Fill by borrow and utility bedding, for pipe and conduit, compacting bedding in trench	24.00	ECY	Sub	284	18	0	0	0	302	302	O
				4.07	*5.69*	*0.00*	*0.00*		*9.75*	*9.75*	
HNC 312323145520 Backfill, structural, 6" lifts, backfill around foundation, with dozer	50.00	LCY	Sub	203	284	0	0	0	488	488	O
				5.81	*9.78*	*0.00*	*0.00*		*15.59*	*15.59*	
RSM 312323236200 Compaction, 2 passes, 6" lifts, towed vibrating roller	40.00	ECY	Sub	232	391	0	0	0	623	623	O
				1,414.74	*0.00*	*3,000.00*	*0.00*		*4,414.74*	*4,414.74*	
Upgrade " FCQ7-q" Bucket	**1.00**	**EA**	**Sub**	**1,415**	**0**	**3,000**	**0**	**0**	**4,415**	**4,415**	
				1,414.74	*0.00*	*3,000.00*	*0.00*		*4,414.74*	*4,414.74*	
USE Upgrade "FCQ7-q" Bucket	1.00	EA	Sub	1,415	0	3,000	0	0	4,415	4,415	M

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				2,086.74	*0.00*	*3,000.00*	*0.00*		*5,086.74*	*5,086.74*	
Disconnect at Valve Actuator	**1.00**	**EA**	**Sub**	**2,087**	**0**	**3,000**	**0**	**0**	**5,087**	**5,087**	
				672.00	*0.00*	*1,000.00*	*0.00*		*1,672.00*	*1,672.00*	
USR Disconnect Stand, Unistrut.	1.00	EA	Sub	672	0	1,000	0	0	1,672	1,672	O
				1,414.74	*0.00*	*2,000.00*	*0.00*		*3,414.74*	*3,414.74*	
HNC 262416304870 Panelboards, assembled, 3 ph, 3 wire, main lugs, 277/480 V, 225 A, 32 - 20 amp breakers	1.00	EA	Sub	1,415	0	2,000	0	0	3,415	3,415	N
				5,574.30	*150.83*	*2,500.00*	*0.00*		*8,225.13*	*8,225.13*	
Relocate Existing Electrical underground	**1.00**	**EA**	**Sub**	**5,574**	**151**	**2,500**	**0**	**0**	**8,225**	**8,225**	
				139.36	*3.77*	*0.00*	*0.00*		*143.13*	*143.13*	
USR Standard Electrical Crew	40.00	HR	Sub	5,574	151	0	0	0	5,725	5,725	N
				0.00	*0.00*	*2,500.00*	*0.00*		*2,500.00*	*2,500.00*	
USR REM Relocate Existing Electrical Materials	1.00	EA	Sub	0	0	2,500	0	0	2,500	2,500	M
				2,564.23	*0.00*	*1,049.76*	*0.00*		*3,613.99*	*3,613.99*	
Relocate conduit on the face of the Dam	**1.00**	**EA**	**Sub**	**2,564**	**0**	**1,050**	**0**	**0**	**3,614**	**3,614**	
				2.22	*0.00*	*0.00*	*0.00*		*2.22*	*2.22*	
RSM 260505100100 Conduit, rigid galvanized steel, 1/2" to 1" diameter, electrical demolition, remove conduit to 15' high, including fittings & hangers	200.00	LF	Sub	444	0	0	0	0	444	444	N
				8.27	*0.00*	*4.18*	*0.00*		*12.45*	*12.45*	
RSM 260533131800 Rigid galvanized steel conduit, 1" diameter, to 15' H, incl 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	200.00	LF	Sub	1,654	0	836	0	0	2,490	2,490	N
				48.87	*0.00*	*26.00*	*0.00*		*74.87*	*74.87*	
RSM 260519903020 Wire, copper, stranded, 600 volt, #12, type XHHW, in raceway	8.00	CLF	Sub	391	0	208	0	0	599	599	N
				2.34	*0.00*	*0.18*	*0.00*		*2.52*	*2.52*	
RSM 260519350035 Wire connector, screw type, insulated, #16 to #10	32.00	EA	Sub	75	0	6	0	0	81	81	N
				5,060.71	*2,943.99*	*43,604.90*	*0.00*		*51,609.59*	*51,609.59*	
Paving	**1.00**	**EA**	**Sub**	**5,061**	**2,944**	**43,605**	**0**	**0**	**51,610**	**51,610**	
				4.91	*2.54*	*80.03*	*0.00*		*87.48*	*87.48*	
8" Base Aggregate	**175.00**	**CY**	**Sub**	**859**	**445**	**14,005**	**0**	**0**	**15,308**	**15,308**	
				1.16	*0.60*	*18.90*	*0.00*		*20.66*	*20.66*	
RSM 321123232012 Base course drainage layers, aggregate base course for roadways and large paved areas, alternate method to figure base course, crushed stone, 3/4"maximum size, 9" deep	741.00	TON	Sub	859	445	14,005	0	0	15,308	15,308	N
				1.09	*0.51*	*10.57*	*0.00*		*12.17*	*12.17*	
Asphalt Concrete	**2,800.00**	**SF**	**Sub**	**3,059**	**1,414**	**29,600**	**0**	**0**	**34,073**	**34,073**	
				0.15	*0.07*	*1.48*	*0.00*		*1.70*	*1.70*	

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
RSM 321216140600 Asphaltic concrete, parking lots & driveways, binder course, 4" thick, no asphalt hauling included	20,000.00	SF	Sub	3,059	1,414	29,600	0	0	34,073	34,073	O
				16.34	*15.50*	*0.00*	*0.00*		*31.84*	*31.84*	
Asphalt Pavment Hauling	**70.00**	**TON**	**Sub**	**1,144**	**1,085**	**0**	**0**	**0**	**2,229**	**2,229**	
				45.74	*43.40*	*0.00*	*0.00*		*89.15*	*89.15*	
USR Haul Asphalt Pavement	25.00	HR	Sub	1,144	1,085	0	0	0	2,229	2,229	N
				0.00	*0.00*	*0.00*	*5,000.00*		*5,000.00*	*5,000.00*	
Misc Utility repair or relocate	**1.00**	**EA**	**Prime**	**0**	**0**	**0**	**5,000**	**0**	**5,000**	**5,000**	
				0.00	*0.00*	*0.00*	*5,000.00*		*5,000.00*	*5,000.00*	
USR Utility repair and relocate.	1.00	EA	Sub	0	0	0	5,000	0	5,000	5,000	Sb

****** TOTAL PROJECT COST SUMMARY ******

PROJECT: Dalles AWC Option 2 - Precast Pier
PROJECT NO: P2 14630
LOCATION: The Dalles Lock and Dam

DISTRICT: NWD Portland District
POC: CHIEF, COST ENGINEERING, xxx
PREPARED: 2/1/2014

This Estimate reflects the scope and schedule in report; The Dalles East Fish Ladder Auxiliary Water Backup System

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**				**TOTAL PROJECT COST (FULLY FUNDED)**				
						Program Year (Budget EC): 2014 Effective Price Level Date: 1 OCT 13				Spent Thru:				
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	**TOTAL ($K)**	1-Oct-13 ($K)		COST ($K)	CNTG ($K)	FULL ($K)
A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***	***K***	***L***	***M***	***N***	***O***
03	RESERVOIRS	$0	$0	-	$0	-	$0	$0	$0	$0		$0	$0	$0
04	DAMS	$0	$0	-	$0	-	$0	$0	$0	$0		$0	$0	$0
05	LOCKS	$0	$0	-	$0	-	$0	$0	$0	$0		$0	$0	$0
06	FISH & WILDLIFE FACILITIES	$9,088	$2,790	31%	$11,878	0.0%	$9,088	$2,790	$11,878	$0		$9,532	$2,926	$12,458
07	POWER PLANT	$0	$0	-	$0	-	$0	$0	$0	$0		$0	$0	$0
	CONSTRUCTION ESTIMATE TOTALS:	$9,088	$2,790		$11,878	0.0%	$9,088	$2,790	$11,878	$0		$9,532	$2,926	$12,458
01	LANDS AND DAMAGES	$0	$0	-	$0	-	$0	$0	$0	$0		$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN	$1,500	$461	31%	$1,961	0.0%	$1,500	$461	$1,961	$0		$1,563	$480	$2,043
31	CONSTRUCTION MANAGEMENT	$1,318	$405	31%	$1,723	0.0%	$1,318	$405	$1,723	$0		$1,454	$446	$1,900
	PROJECT COST TOTALS:	$11,906	$3,655	31%	$15,561		$11,906	$3,655	**$15,561**	$0		$12,548	$3,852	$16,400

________________ CHIEF, COST ENGINEERING, xxx

________________ PROJECT MANAGER, xxx

________________ CHIEF, REAL ESTATE, xxx

________________ CHIEF, PLANNING,xxx

________________ CHIEF, ENGINEERING, xxx

________________ CHIEF, OPERATIONS, xxx

________________ CHIEF, CONSTRUCTION, xxx

________________ CHIEF, CONTRACTING,xxx

________________ CHIEF, PM-PB, xxxx

________________ CHIEF, DPM, xxx

ESTIMATED FEDERAL COST:	**100%**	**$16,400**
ESTIMATED NON-FEDERAL COST:	**0%**	**$0**
ESTIMATED TOTAL PROJECT COST:		**$16,400**

Filename: option 2 DALLES AWC TPCS Jan 2014.xlsx
TPCS

****** TOTAL PROJECT COST SUMMARY ******

****** CONTRACT COST SUMMARY ******

PROJECT: Dalles AWC Option 2 - Precast Pier
LOCATION: The Dalles Lock and Dam
This Estimate reflects the scope and schedule in report; The Dalles East Fish Ladder Auxiliary Water Backup System

DISTRICT: NWD Portland District PREPARED: 2/1/2014
POC: CHIEF, COST ENGINEERING, xxx

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**				**TOTAL PROJECT COST (FULLY FUNDED)**				
		Estimate Prepared:			1/2/2014	Program Year (Budget EC):			2014					
		Effective Price Level:			41548	Effective Price Level Date:			1 OCT 13					
				RISK BASED										
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Dalles East Fish Ladder AWS													
03	RESERVOIRS	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
04	DAMS	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
05	LOCKS	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
06	FISH & WILDLIFE FACILITIES	$9,088	$2,790	31%	$11,878	0.0%	$9,088	$2,790	$11,878	2016Q3	4.9%	$9,532	$2,926	$12,458
07	POWER PLANT	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
							$0							
	CONSTRUCTION ESTIMATE TOTALS:	$9,088	$2,790	31%	**$11,878**		$9,088	$2,790	$11,878			$9,532	$2,926	$12,458
01	LANDS AND DAMAGES	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
1.3%	Project Management	$114	$35	31%	$149	0.0%	$114	$35	$149	2014Q3	1.5%	$116	$36	$151
1.0%	Planning & Environmental Compliance	$91	$28	31%	$119	0.0%	$91	$28	$119	2014Q3	1.5%	$92	$28	$121
4.3%	Engineering & Design	$386	$119	31%	$505	0.0%	$386	$119	$505	2014Q3	1.5%	$392	$120	$512
0.5%	Reviews, ATRs, IEPRs, VE	$45	$14	31%	$59	0.0%	$45	$14	$59	2014Q3	1.5%	$46	$14	$60
0.5%	Life Cycle Updates (cost, schedule, risks)	$45	$14	31%	$59	0.0%	$45	$14	$59	2014Q3	1.5%	$46	$14	$60
2.0%	Contracting & Reprographics	$182	$56	31%	$238	0.0%	$182	$56	$238	2014Q3	1.5%	$185	$57	$242
3.0%	Engineering During Construction	$273	$84	31%	$357	0.0%	$273	$84	$357	2016Q3	10.3%	$301	$92	$394
2.0%	Planning During Construction	$182	$56	31%	$238	0.0%	$182	$56	$238	2016Q3	10.3%	$201	$62	$262
2.0%	Project Operations	$182	$56	31%	$238	0.0%	$182	$56	$238	2014Q3	1.5%	$185	$57	$242
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$909	$279	31%	$1,188	0.0%	$909	$279	$1,188	2016Q3	10.3%	$1,002	$308	$1,310
2.0%	Project Operation:	$182	$56	31%	$238	0.0%	$182	$56	$238	2016Q3	10.3%	$201	$62	$262
2.5%	Project Management	$227	$70	31%	$297	0.0%	$227	$70	$297	2016Q3	10.3%	$250	$77	$327
	CONTRACT COST TOTALS:	$11,906	$3,655		**$15,561**		$11,906	$3,655	$15,561			$12,548	$3,852	**$16,400**

Filename: option 2 DALLES AWC TPCS Jan 2014.xlsx
TPCS

Abbreviated Risk Analysis

The Dalles AWS 90% DDR, precast pier option
Feasibility (Alternatives)

Meeting Date: 20-Dec-13

PDT Members
Note: PDT involvement is commensurate with project size and involvement.

Technical Lead:	Ryan Laughery, NWW
Geotech:	Mike Schafer, NWW
Hydraulics	Logan Negherbon, NWW
Structural:	Eric Walton, NWW
Mechanical:	Phil Auth, NWW
Electrical:	Dan Pullen, NWW
Cost Engineering:	Kevin Kuhar, NWW/Dave Scott, NWW
Biologist:	Brad Trumbo, NWW

Abbreviated Risk Analysis

Project (less than $40M): **The Dalles AWS 90% DDR, precast pier option**
Project Development Stage: **Feasibility (Alternatives)**
Risk Category: **High Risk: Complex Project or Life Safety**

Total Construction Contract Cost = **$ 9,088,100**

	CWWBS	Feature of Work	Contract Cost		% Contingency	$ Contingency	Total
	01 LANDS AND DAMAGES	Real Estate			**0.00%**	$ -	$ -
1	**06 01 FISH FACILITIES AT DAMS**	**Mobilization/Demobilization**	**$ 326,954**		13.30%	$ 43,492	$ 370,446.08
2	**06 01 FISH FACILITIES AT DAMS**	**Concrete Mining**	**$ 933,766**		26.67%	$ 248,999	$ 1,182,764.71
3	**06 01 FISH FACILITIES AT DAMS**	**Steel Pipe - Through Dam**	**$ 525,895**		18.01%	$ 94,732	$ 620,626.75
4	**06 01 FISH FACILITIES AT DAMS**	**Steel Pipe - Dam to AWS Chamber**	**$ 1,579,095**		28.27%	$ 446,396	$ 2,025,491.19
5	**06 01 FISH FACILITIES AT DAMS**	**Steel Pipe - Discharge to AWS Chamber**	**$ 455,355**		44.29%	$ 201,691	$ 657,046.20
6	**06 01 FISH FACILITIES AT DAMS**	**Valve**	**$ 351,343**		20.54%	$ 72,154	$ 423,496.96
7	**06 01 FISH FACILITIES AT DAMS**	**Emergency Closure Gate & Guides**	**$ 639,670**		16.19%	$ 103,547	$ 743,217.23
8	**06 01 FISH FACILITIES AT DAMS**	**Trash Rack/Trash Rake & Guides**	**$ 491,115**		23.72%	$ 116,488	$ 607,602.63
9	**06 01 FISH FACILITIES AT DAMS**	**Electrical, Site Work, Utility Repairs**	**$ 207,927**		23.81%	$ 49,517	$ 257,443.69
10	**06 01 FISH FACILITIES AT DAMS**	**Precast Pier, install with divers**	**$ 3,576,980**		39.58%	$ 1,415,608	$ 4,992,587.88
12		**Remaining Construction Items**	**$ -**	*0.0%*	0.00%	$ -	$ -
13	30 PLANNING, ENGINEERING, AND DESIGN	**Planning, Engineering, & Design**			0.00%	$ -	$ -
14	31 CONSTRUCTION MANAGEMENT	**Construction Management**			0.00%	$ -	$ -

Totals

	Contract Cost	% Contingency	$ Contingency	Total
Real Estate	$ -	0.00%	$ -	$ -
Total Construction Estimate	$ 9,088,100	30.73%	$ 2,792,623	$ 11,880,723
Total Planning, Engineering & Design	$ -	0.00%	$ -	$ -
Total Construction Management	$ -	0.00%	$ -	$ -
Total	$ 9,088,100		$ 2,792,623	$ 11,880,723
			Escalation @ 4.88%	$ 579,779
			Total	**$ 12,460,503**

The Dalles AWS 90% DDR, precast pier option
Feasibility (Alternatives)
Abbreviated Risk Analysis

Meeting Date: 20-Dec-13

Risk Level

	Negligible	Marginal	Significant	Critical	Crisis
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Possible	0	1	2	3	4
Unlikely	0	0	1	2	3

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
Project Scope Growth							
						Max Potential Cost Growth	200%
PS-1	Mobilization/Demobilization	• Potential for scope growth, added features and quantities?			Unlikely	Negligible	0
PS-2	Concrete Mining	• Investigations sufficient to support design assumptions?	Quality of concrete • Water care and diversion fully understood, planned?	Does NWP have info of any known leaks? Information required from NWP to meet risk assessment in Construction Elements Current design assumes no leaks	Likely	Marginal	2
PS-3	Steel Pipe - Through Dam	• Water care and diversion fully understood, planned?		None anticipated; design generally is known for the most part	Unlikely	Negligible	0
PS-4	Steel Pipe - Dam to AWS Chamber	• Potential for scope growth, added features and quantities?	Depth of pipe; appears that the excavation is through soil and some rock; Trust concerns.		Very LIKELY	Negligible	2
PS-5	Steel Pipe - Discharge to AWS Chamber	• Potential for scope growth, added features and quantities?	Design will be developed further.		Very LIKELY	Marginal	3
PS-6	Valve	• Potential for scope growth, added features and quantities?		None anticipated; design is known	Unlikely	Negligible	0
PS-7	Emergency Closure Gate & Guides	• Potential for scope growth, added features and quantities?	design of guides may change	embedded plate not change	Possible	Marginal	1
PS-8	Trash Rack/Trash Rake & Guides	• Potential for scope growth, added features and quantities?	design may improve for rake; guide slots not designed; trash rack good design	alignment of rake to rack a potential issue	Likely	Marginal	2
PS-9	Electrical, Site Work, Utility Repairs	• Potential for scope growth, added features and quantities?	Some utilities will likely need to be repaired or relocated.		Likely	Marginal	2

PS-10	Precast Pier, install with divers	• Investigations sufficient to support design assumptions?	• Investigations sufficient to support design assumptions? • Project accomplish intent? Investigations sufficient to support design assumptions? Potential need survey of existing conditions . Increased exposure to environmental condition due to increased dive time. Tolerances associated with grouting and alignment.	Flatness of concrete face. Existing condition of anchor surface. High river flows and operational constraints of the project will impact level of difficultly. Issues encountered should be able to be overcome with increased duration. Quality of grouting would require emphasis on monitoring.	Possible	Significant	2
Risk Element	**Feature of Work**	**Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)**	**Concerns**	**PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)**	**Likelihood**	**Impact**	**Risk Level**
Acquisition Strategy							
						Max Potential Cost Growth	**30%**
AS-1	Mobilization/Demobilization	• Contracting plan firmly established?	Not a significant concern	bidding climate unknown	Possible	Marginal	1
AS-2	Concrete Mining	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
AS-3	Steel Pipe - Through Dam	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
AS-4	Steel Pipe - Dam to AWS Chamber	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
AS-5	Steel Pipe - Discharge to AWS Chamber	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
AS-6	Valve	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
AS-7	Emergency Closure Gate & Guides	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
AS-8	Trash Rack/Trash Rake & Guides	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1

AS-9	Electrical, Site Work, Utility Repairs	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
AS-10	Precast Pier, install with divers	• Contracting plan firmly established?	Assume LPTA (possibly Best Value)	bidding climate unknown	Possible	Marginal	1
Risk Element	**Feature of Work**	**Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)**	**Concerns**	**PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)**	**Likelihood**	**Impact**	**Risk Level**
Construction Elements							
						Max Potential Cost Growth	**50%**
CE-1	Mobilization/Demobilization	• Special equipment or subcontractors needed?	Schedule for in water work windows could drive multiple mob/demob		Possible	Marginal	1
CE-2	Concrete Mining	• Accelerated schedule or harsh weather schedule?	Potential obstructions in proposed route Encounter substantial nuisance water Poor quality of concrete	Very signficant item Does NWP have info of any known leaks, history from previous contracts?	Unlikely	Critical	2
CE-3	Steel Pipe - Through Dam	• Accelerated schedule or harsh weather schedule?		No major issues envisioned Work platform size limited due to other activites at project	Unlikely	Significant	1
CE-4	Steel Pipe - Dam to AWS Chamber	• Accelerated schedule or harsh weather schedule?	elevated groundwater creating buoyancy issues Concrete work at diffuser outlet has extremely short work window; 6' dia pipe during in water work window		Unlikely	Significant	1
CE-5	Steel Pipe - Discharge to AWS Chamber	• Accelerated schedule or harsh weather schedule?	Difficult constructibility issues with limited access.		Likely	Marginal	2
CE-6	Valve	• Accelerated schedule or harsh weather schedule?	Lead time.	Lead time is unknown but could be an issue.	Likely	Marginal	2
CE-7	Emergency Closure Gate & Guides	• Accelerated schedule or harsh weather schedule?	tight work conditions for guide/gate installation maintaining dam access	potentially during winter.	Possible	Marginal	1

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
CE-8	Trash Rack/Trash Rake & Guides	• Accelerated schedule or harsh weather schedule?	tight tolerances on guide installation	potentially during winter	Possible	Marginal	1
CE-9	Electrical, Site Work, Utility Repairs	• Accelerated schedule or harsh weather schedule?			Possible	Negligible	0
CE-10	Precast Pier, install with divers	• High risk or complex construction elements, site access, in-water?	Schedule/lead time concerns • Special mobilization - floating plant In water work window (Nov-Feb)? Potential leaking after install • High risk or complex construction elements, site access, in-water?	Significant amount of work done with divers. Precast pier sections must line-up to tight tolerance for guide alignment.	Likely	Significant	3
Risk Element	**Feature of Work**	**Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)**	**Concerns**	**PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)**	**Likelihood**	**Impact**	**Risk Level**
Quantities for Current Scope							
						Max Potential Cost Growth	**40%**
Q-1	Mobilization/Demobilization	• Level of confidence based on design and assumptions?	Not an issue		Unlikely	Negligible	0
Q-2	Concrete Mining	• Level of confidence based on design and assumptions?		Known quantities	Unlikely	Negligible	0
Q-3	Steel Pipe - Through Dam	• Level of confidence based on design and assumptions?		Quantities are generally known.	Unlikely	Negligible	0
Q-4	Steel Pipe - Dam to AWS Chamber	• Level of confidence based on design and assumptions?	steel known; concrete unknown	concrete requirements not known - pipe protection, thrust blocks, Rock excavation unknown.	Likely	Marginal	2
Q-5	Steel Pipe - Discharge to AWS Chamber	• Level of confidence based on design and assumptions?	Details of discharge nozzel not known.		Likely	Marginal	2
Q-6	Valve	• Level of confidence based on design and assumptions?			Unlikely	Negligible	0
Q-7	Emergency Closure Gate & Guides	• Sufficient investigations to develop quantities?	gate quantities known; guide & concrete work unknown; predation measures	angle shape covering corners	Unlikely	Negligible	0
Q-8	Trash Rack/Trash Rake & Guides	• Level of confidence based on design and assumptions?	gate quantities known; guide & concrete work unknown; predation measures	angle shape covering corners	Possible	Marginal	1

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
Q-9	Electrical, Site Work, Utility Repairs	• Level of confidence based on design and assumptions?	Impact on utilities not quantified.		Likely	Marginal	2
Q-10	Precast Pier, install with divers	• Level of confidence based on design and assumptions?	• Level of confidence based on design and assumptions?		Possible	Marginal	1
Risk Element	**Feature of Work**	**Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)**	**Concerns**	**PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)**	**Likelihood**	**Impact**	**Risk Level**
Specialty Fabrication or Equipment							
						Max Potential Cost Growth	**75%**
FE-1	Mobilization/Demobilization	• Unusual parts, material or equipment manufactured or installed?	Minimal issue Could affect crane & mining equipment		Unlikely	Negligible	0
FE-2	Concrete Mining	• Unusual parts, material or equipment manufactured or installed?	Standard steel work	Nothing out of the ordinary	Possible	Negligible	0
FE-3	Steel Pipe - Through Dam	• Unusual parts, material or equipment manufactured or installed?		Standard mining equipment & methods	Unlikely	Negligible	0
FE-4	Steel Pipe - Dam to AWS Chamber	• Unusual parts, material or equipment manufactured or installed?		Size of pipe; weldding of joints; coating of interior (vinyl)	Unlikely	Negligible	0
FE-5	Steel Pipe - Discharge to AWS Chamber	• Unusual parts, material or equipment manufactured or installed?	no special concerns	None	Unlikely	Negligible	0
FE-6	Valve	• Unusual parts, material or equipment manufactured or installed?	Custom fabricated part; limited suppliers	RH recommend SS due to submergence	Possible	Marginal	1
FE-7	Emergency Closure Gate & Guides	• Unusual parts, material or equipment manufactured or installed?	not a feature of the 90% DDR		Unlikely	Negligible	0
FE-8	Trash Rack/Trash Rake & Guides	• Unusual parts, material or equipment manufactured or installed?		none	Unlikely	Negligible	0
FE-9	Electrical, Site Work, Utility Repairs	• Unusual parts, material or equipment manufactured or installed?		none	Unlikely	Negligible	0
FE-10	Precast Pier, install with divers	• Unusual parts, material or equipment manufactured or installed?	Standard steel work	Nothing out of the ordinary	Possible	Negligible	0
Risk Element	**Feature of Work**	**Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)**	**Concerns**	**PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)**	**Likelihood**	**Impact**	**Risk Level**

Cost Estimate Assumptions

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
					Max Potential Cost Growth		45%
CT-1	Mobilization/Demobilization	• Assumptions related to prime and subcontractor markups/assignments?	• Assumptions related to prime and subcontractor markups/assignments?	based on % of direct cost at this stage	Likely	Negligible	1
CT-2	Concrete Mining	• Reliability and number of key quotes?	• Reliability and number of key quotes? One quote - obtain current.	Based on crew/equipment/productivity from Dorena project	Possible	Significant	2
CT-3	Steel Pipe - Through Dam	• Reliability and number of key quotes?	• Reliability and number of key quotes? One quote - obtain current.	need to obtain current quote; difficulty in finding quote for coated pipe.	Possible	Significant	2
CT-4	Steel Pipe - Dam to AWS Chamber	• Reliability and number of key quotes?	• Reliability and number of key quotes? One quote - obtain current.	need to obtain current quote; current estimate based on 1/2" thick walls	Possible	Marginal	1
CT-5	Steel Pipe - Discharge to AWS Chamber	• Reliability and number of key quotes?	• Reliability and number of key quotes? One quote - obtain current.	need to obtain current quote; current estimate based on 1/2" thick walls.	Possible	Marginal	1
CT-6	Valve	• Reliability and number of key quotes?	• Reliability and number of key quotes?	One quote procured	Possible	Marginal	1
CT-7	Emergency Closure Gate & Guides	• Reliability and number of key quotes?	gate quantites are good; guide & concrete less known		Possible	Marginal	1
CT-8	Trash Rack/Trash Rake & Guides	• Reliability and number of key quotes?	rack/rake quantites are good; guide & concrete less known		Possible	Marginal	1
CT-9	Electrical, Site Work, Utility Repairs	• Reliability and number of key quotes?	estimate based on assumptions. Impacts to utilities not fully known.		Likely	Negligible	1
CT-10	Precast Pier, install with divers	• Reliability and number of key quotes?	Based on assumed conceptual design - contractor's design may vary	Production rate for underwater work assumed for low water velocities. Additional data is needed to determine water velocities.	Possible	Significant	2

External Project Risks

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
					Max Potential Cost Growth		60%
EX-1	Mobilization/Demobilization	• Potential for severe adverse weather?	Floating plant		Possible	Negligible	0

EX-2	Concrete Mining	• Potential for severe adverse weather?			Unlikely	Negligible	**0**
EX-3	Steel Pipe - Through Dam	• Potential for severe adverse weather?		Work platform interfering with other activites at project; contract delay due to other activities	Possible	Marginal	**1**
EX-4	Steel Pipe - Dam to AWS Chamber	• Potential for severe adverse weather?		Work interferance with project access.	Possible	Marginal	**1**
EX-5	Steel Pipe - Discharge to AWS Chamber	• Potential for severe adverse weather?			Possible	Negligible	**0**
EX-6	Valve	• Unanticipated inflations in fuel, key materials?	• Unanticipated inflations in fuel, key materials?	No concerns.	Unlikely	Significant	**1**
EX-7	Emergency Closure Gate & Guides	• Potential for severe adverse weather?	weather; temperature for guide grout		Unlikely	Negligible	**0**
EX-8	Trash Rack/Trash Rake & Guides	• Potential for severe adverse weather?	weather		Unlikely	Negligible	**0**
EX-9	Electrical, Site Work, Utility Repairs	• Potential for severe adverse weather?	weather		Possible	Negligible	**0**
EX-10	Precast Pier, install with divers	• Potential for severe adverse weather?	• Potential for severe adverse weather? Forebay environment impacting installation	Debris, flow velocities for installation Mitigation includes data collection Q1FY14 for flow velocties	Unlikely	Critical	**2**

Estimated by NWW-EC-X
Designed by 90% DDR by Walla Walla District
Prepared by Dave Scott
Preparation Date 12/4/2013
Effective Date of Pricing 12/4/2013
Estimated Construction Time 600 Days

Date **Author** **Note**

12/26/2013 2:51:24 PM Dave Scott

PROJECT DESCRIPTION

Estimate is based on the construction of an Emergency backup water supply for the Dalles AWS which consists of a 10' diameter pipe through Monolith 5 to discharge into the AWS chamber with 2ea 7.5 diameter discharge nozzles. The estimate is based on the 90% Design Documentation Report. Two options were estimated.

Option 1 entails the construction of a temporary cofferdam at the face of the dam prior to tunneling through the dam.

Option 2 entails the installation of pre-cast piers at the face of the dam with integral guides for installation of bulkheads to enable the upstream portion of the tunnel to be dewatered. Option 2 includes a significant amount of dive time to install the pre-cast piers.

BASIS OF DESIGN

This estimate is based on the 90 percent Design Documentation Report Titled "The Dalles East Fish Ladder Auxiliary Water Backup System".

ACQUISITION PLAN

It is unknown how the project will be acquired. This estimate assumes it will be competitively bid.

It is also assumed this work will not be a small buisness set-aside.

SUB-CONTRACTING PLAN

The following are subcontractor on this project:

- Electrical Subcontractor
- Paving Subcontractor
- Concrete Sawcutting Subcontractor
- Industrial Coating Subcontractor
- Concrete Mining Subcontractor

It is assumed that the Prime Contractor will do the rest of the work.

PROJECT CONSTRUCTION

Date **Author** **Note**

SITE ACCESS

The project site is located at The Dalles Lock and Dam. There is road access to the project site. There is also barge access through the Columbia River Lock System.

BORROW AREAS

The borrow sources for materials will be commercially purchased. Assumed sources are located locally.

CONSTRUCTION METHODOLOGY

The construction methodology is standard

UNUSUAL CONDITION (Soil, Water, Weather)
Some excavation through bedrock is expected.

UNIQUE TECHNIQUES OF CONSTRUCTION
Underwater construction by divers is required for construction of the intake structure

Assumes that there will be an onsite disposal site for excess excavation and trench spoils.

CONSTRUCTION WINDOWS

In-water work windows from December 1 to February 28/29. The project schedule assumes that the contractor will utilize the In-water work windows during two seasons.

SCHEDULE

Assumed onsite work from Nov 2015 to Feb 2017.

OVERTIME

This estimate contains no overtime to complete the project.

Date **Author** **Note**

EQUIPMENT AND LABOR AVAILABILITY & DISTANCE TRAVELED

General Decision Number: OR130079 11/01/2013 OR79

Superseded General Decision Number: OR20120079

State: Oregon

Construction Type: Heavy

County: Wasco County in Oregon.

Equipment rates used are from EP 1110-1-8, Volume EP11R08, Region 8, 2011.

ENVIRONMENTAL CONCERNS

In water work restrictions.

COST AND PRICING

For the Prime Contractor, Job Office Overhead is 15% Home Office Overhead is 15%, and Bond is based on the bond table

CONTINGENCIES

A contingency was calculated with the Abbreviated Risk Analysis Spreadsheet.

Option 1 26.49%
Option 2 30.74%

PROFIT

Date	**Author**	**Note**

Profit of 10% is assumed.

ESCALATION

Escalation was calculated at 4.88% from CWCCIS, and the index for 3Q16.

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Description	Quantity	UOM	Contractor	DirectCost	SubCMU	CostToPrime	PrimeCMU	ContractCost	C/O
Contract Cost Summary Report				**5,647,929**	**447,020**	**6,094,949**	**2,993,152**	**9,088,101**	
3 The Dalles EFL AWS - 90% DDR Estimate Precast Pier	**1.00**	**LS**	**2 Prime**	**5,647,929**	**447,020**	**6,094,949**	**2,993,152**	**9,088,101**	
				5,647,928.67		*6,094,949.07*		*9,088,100.79*	
3.1 Fish and Wildlife Facilities	**1.00**	**EA**	**2 Prime**	**5,647,929**	**447,020**	**6,094,949**	**2,993,152**	**9,088,101**	
3.1.1 Mob/Demob	**1.00**	**LS**	**2 Prime**	**219,246**	**0**	**219,246**	**107,708**	**326,953**	
				219,245.76		*219,245.76*		*326,953.36*	
3.1.1.1 Mob/Demob	**1.00**	**EA**	**2 Prime**	**219,246**	**0**	**219,246**	**107,708**	**326,953**	
				2,313,872.92		*2,398,875.26*		*3,576,980.44*	
3.1.2 Precast Pier	**1.00**	**EA**	**2 Prime**	**2,313,873**	**85,002**	**2,398,875**	**1,178,105**	**3,576,980**	
				171,422.60		*255,636.39*		*381,221.40*	
3.1.2.1 Precast Concrete	**1.00**	**EA**	**2.1 Sub**	**171,423**	**84,214**	**255,636**	**125,585**	**381,221**	
				763,046.01		*763,046.01*		*1,137,903.22*	
3.1.2.2 Dive Crew Labor	**1.00**	**EA**	**2 Prime**	**763,046**	**0**	**763,046**	**374,857**	**1,137,903**	
				14,635.88		*14,635.88*		*21,717.37*	
3.1.2.3 Place Grout Pad Materials & Surface Labor.	**1.00**	**EA**	**1 Prime - LS&H**	**14,636**	**0**	**14,636**	**7,081**	**21,717**	
				36,099.44		*36,099.44*		*53,565.98*	
3.1.2.4 Support Ground Crew	**1.00**	**EA**	**2 Prime**	**36,099**	**0**	**36,099**	**17,467**	**53,566**	
				766,605.13		*767,393.68*		*1,144,386.74*	
3.1.2.5 Bulkheads	**1.00**	**EA**	**2 Prime**	**766,605**	**789**	**767,394**	**376,993**	**1,144,387**	
				300,000.00		*300,000.00*		*447,379.27*	
3.1.2.6 Mobe Demobe Barge	**1.00**	**EA**	**2 Prime**	**300,000**	**0**	**300,000**	**147,379**	**447,379**	
				155,688.50		*155,688.50*		*232,172.69*	
3.1.2.7 SS nose for Precast Piers with Trash Rack Guide	**1.00**	**EA**	**2 Prime**	**155,689**	**0**	**155,689**	**76,484**	**232,173**	
				106,375.36		*106,375.36*		*158,633.77*	
3.1.2.8 Deflectors for preditor protection	**1.00**	**EA**	**2 Prime**	**106,375**	**0**	**106,375**	**52,258**	**158,634**	
3.1.3 Concrete Mining	**1.00**	**LS**	**2 Prime**	**425,144**	**201,014**	**626,158**	**307,609**	**933,766**	
				12,348.70		*18,415.18*		*27,461.90*	
3.1.3.1 Work Platform	**1.00**	**EA**	**2.1 Sub**	**12,349**	**6,066**	**18,415**	**9,047**	**27,462**	
				388,328.21		*579,099.96*		*863,591.06*	
3.1.3.2 Concrete Mining	**1.00**	**EA**	**2.1 Sub**	**388,328**	**190,772**	**579,100**	**284,491**	**863,591**	
				75.67		*75.67*		*112.85*	
3.1.3.3 Haul & Dispose	**211.00**	**CY**	**2 Prime**	**15,967**	**0**	**15,967**	**7,844**	**23,811**	
				8,500.00		*12,675.75*		*18,902.89*	
3.1.3.4 Work Platform Steel	**1.00**	**EA**	**2.1 Sub**	**8,500**	**4,176**	**12,676**	**6,227**	**18,903**	
				5,184.17		*5,879.83*		*8,764.92*	

Description	Quantity	UOM	Contractor		DirectCost	SubCMU	CostToPrime	PrimeCMU	ContractCost	C/O
3.1.4 Steel Pipe Through Dam	**60.00**	**LF**	**2**	**Prime**	**311,050**	**41,740**	**352,790**	**173,106**	**525,895**	
					166,268.71		*166,268.71*		*247,950.58*	
3.1.4.1 Furnish & Install Steel Pipe (3/4 wall)	**1.00**	**EA**	**2**	**Prime**	**166,269**	**0**	**166,269**	**81,682**	**247,951**	
					65,769.46		*98,079.64*		*146,262.65*	
3.1.4.2 Pressure Grouting	**1.00**	**EA**	**2.1**	**Sub**	**65,769**	**32,310**	**98,080**	**48,183**	**146,263**	
					7,464.21		*7,848.11*		*11,703.61*	
3.1.4.3 VP 6" vent pipe	**1.00**	**EA**	**2**	**Prime**	**7,464**	**384**	**7,848**	**3,855**	**11,704**	
					4.88		*7.28*		*10.86*	
3.1.4.3.1 E-11.3.6 Surface Prep & Paint outside of pipe.	**160.00**	**SF**	**2.1**	**Sub**	**781**	**384**	**1,165**	**572**	**1,738**	
					25,175.03		*25,175.03*		*37,542.62*	
3.1.4.4 Pipe Rail System	**1.00**	**EA**	**2**	**Prime**	**25,175**	**0**	**25,175**	**12,368**	**37,543**	
					27,959.82		*27,959.82*		*41,488.04*	
3.1.4.5 Intake Concrete	**1.00**	**EA**	**1**	**Prime - LS&H**	**27,960**	**0**	**27,960**	**13,528**	**41,488**	
					0.83		*1.24*		*1.84*	
3.1.4.6 E-11.3.6 Surface Prep & Paint Inside Area of Conduit Pipe	**22,200.00**	**SF**	**2.1**	**Sub**	**18,413**	**9,046**	**27,458**	**13,489**	**40,948**	
3.1.5 Steel Pipe from Dam to AWS Chamber	**1.00**	**LS**	**2**	**Prime**	**1,011,785**	**47,112**	**1,058,897**	**520,198**	**1,579,095**	
					692,189.55		*692,189.55*		*1,032,237.52*	
3.1.5.1 Furnish & Install Steel Pipe	**1.00**	**EA**	**2**	**Prime**	**692,190**	**0**	**692,190**	**340,048**	**1,032,238**	
					106,079.51		*106,079.51*		*158,192.58*	
3.1.5.1.1 Fittings bends and orfice plate	**1.00**	**EA**	**2**	**Prime**	**106,080**	**0**	**106,080**	**52,113**	**158,193**	
					40,704.05		*40,704.05*		*60,700.50*	
3.1.5.1.1.1 WYE Fitting	**1.00**	**EA**	**2**	**Prime**	**40,704**	**0**	**40,704**	**19,996**	**60,700**	
					65,375.46		*65,375.46*		*97,492.08*	
3.1.5.1.1.2 10' Dia Bends	**1.00**	**EA**	**2**	**Prime**	**65,375**	**0**	**65,375**	**32,117**	**97,492**	
					18,963.17		*18,963.17*		*28,279.10*	
3.1.5.1.2 Access Hatch to 10' dia pipe	**1.00**	**EA**	**2**	**Prime**	**18,963**	**0**	**18,963**	**9,316**	**28,279**	
					16,600.77		*16,600.77*		*24,756.13*	
3.1.5.2 Common Excavation - 10' Dia. Pipe	**1.00**	**EA**	**2**	**Prime**	**16,601**	**0**	**16,601**	**8,155**	**24,756**	
					109,436.42		*109,436.42*		*163,198.61*	
3.1.5.3 Rock Excavation - 10' dia. Pipe	**1.00**	**EA**	**2**	**Prime**	**109,436**	**0**	**109,436**	**53,762**	**163,199**	
					567.55		*567.55*		*846.36*	
3.1.5.4 Common Excavation - 7.5' Dia. Pipe	**30.00**	**LF**	**2**	**Prime**	**17,026**	**0**	**17,026**	**8,364**	**25,391**	
					8,628.23		*8,628.23*		*12,866.97*	
3.1.5.5 Pipe Bedding	**1.00**	**EA**	**2**	**Prime**	**8,628**	**0**	**8,628**	**4,239**	**12,867**	
					60,483.91		*60,483.91*		*90,197.50*	

Description	Quantity	UOM	Contractor	DirectCost	SubCMU	CostToPrime	PrimeCMU	ContractCost	C/O
3.1.5.6 Pipe Backfill	**1.00**	**EA**	**2 Prime**	**60,484**	**0**	**60,484**	**29,714**	**90,197**	
				4.15		*6.19*		*9.23*	
3.1.5.7 E-11.3.6 Surface Prep & Paint All Conduit Pipe	**23,100.00**	**SF**	**2.1 Sub**	**95,899**	**47,112**	**143,011**	**70,256**	**213,267**	
				11,520.96		*11,520.96*		*17,180.79*	
3.1.5.8 Thrust Block	**1.00**	**EA**	**2 Prime**	**11,521**	**0**	**11,521**	**5,660**	**17,181**	
				277,754.52		*305,348.50*		*455,355.30*	
3.1.6 Steel Pipe in AWS Chamber	**1.00**	**EA**	**2 Prime**	**277,755**	**27,594**	**305,349**	**150,007**	**455,355**	
				12,161.00		*12,161.00*		*18,135.27*	
3.1.6.1 Set up platform and rigging in AWS chamber	**1.00**	**EA**	**2 Prime**	**12,161**	**0**	**12,161**	**5,974**	**18,135**	
				4,774.00		*4,774.00*		*7,119.30*	
3.1.6.2 Remove rigging and platforms from AWS Chamber	**1.00**	**EA**	**2 Prime**	**4,774**	**0**	**4,774**	**2,345**	**7,119**	
				44,974.63		*44,974.63*		*67,069.05*	
3.1.6.3 Crane and Above grade support crew.	**1.00**	**EA**	**2 Prime**	**44,975**	**0**	**44,975**	**22,094**	**67,069**	
				35,860.73		*35,860.73*		*53,477.82*	
3.1.6.4 Install Pipe	**1.00**	**EA**	**2 Prime**	**35,861**	**0**	**35,861**	**17,617**	**53,478**	
				1.00		*1.49*		*2.22*	
3.1.6.5 E-11.3.6 Surface Prep & Paint all Conduit Pipe	**23,100.00**	**SF**	**2.1 Sub**	**23,015**	**11,306**	**34,321**	**16,861**	**51,182**	
				33,154.52		*49,442.14*		*73,731.30*	
3.1.6.6 Concrete Sawcutting Fishladder and AWS Chamber	**1.00**	**EA**	**2 Prime**	**33,155**	**16,288**	**49,442**	**24,289**	**73,731**	
				33,154.52		*49,442.14*		*73,731.30*	
3.1.6.6.1 Concrete Cutting	**1.00**	**EA**	**2.1 Sub**	**33,155**	**16,288**	**49,442**	**24,289**	**73,731**	
				112,460.86		*112,460.86*		*167,708.86*	
3.1.6.7 90 degree bend and fabrication of orifice manifold.	**1.00**	**EA**	**2 Prime**	**112,461**	**0**	**112,461**	**55,248**	**167,709**	
				41,691.95		*41,691.95*		*62,173.71*	
3.1.6.7.1 7.5' Dia Bends	**1.00**	**EA**	**2 Prime**	**41,692**	**0**	**41,692**	**20,482**	**62,174**	
				70,768.92		*70,768.92*		*105,535.16*	
3.1.6.7.2 7.5' dia Orfice Manifold.	**1.00**	**EA**	**2 Prime**	**70,769**	**0**	**70,769**	**34,766**	**105,535**	
				11,353.96		*11,353.96*		*16,931.75*	
3.1.6.8 Scafolding and hoist	**1.00**	**EA**	**2 Prime**	**11,354**	**0**	**11,354**	**5,578**	**16,932**	
				235,600.77		*235,600.77*		*351,343.00*	
3.1.7 120" Butterfly Valve w/Acutator	**1.00**	**EA**	**2 Prime**	**235,601**	**0**	**235,601**	**115,742**	**351,343**	
				3,443.50		*3,443.50*		*5,135.17*	
3.1.7.1 Shipping	**1.00**	**EA**	**2 Prime**	**3,444**	**0**	**3,444**	**1,692**	**5,135**	
				232,157.26		*232,157.26*		*346,207.82*	
3.1.7.2 Valve	**1.00**	**EA**	**2 Prime**	**232,157**	**0**	**232,157**	**114,051**	**346,208**	

Description	Quantity	UOM	Contractor	DirectCost	SubCMU	CostToPrime	PrimeCMU	ContractCost	C/O
				429,002.86		*429,276.65*		*639,670.07*	
3.1.8 Emergency Closure Gate	**1.00**	**EA**	**2 Prime**	**429,003**	**274**	**429,277**	**210,393**	**639,670**	
				199,497.50		*199,497.50*		*297,503.48*	
3.1.8.1 Furnish Emergency Closure Gate	**1.00**	**EA**	**2 Prime**	**199,498**	**0**	**199,498**	**98,006**	**297,503**	
				162,250.00		*162,250.00*		*241,957.62*	
3.1.8.2 Furnish Emergency Closure Gate Guides	**1.00**	**EA**	**2 Prime**	**162,250**	**0**	**162,250**	**79,708**	**241,958**	
				557.32		*831.11*		*1,239.41*	
3.1.8.3 Shipping	**1.00**	**EA**	**2.1 Sub**	**557**	**274**	**831**	**408**	**1,239**	
				61,124.76		*61,124.76*		*90,699.67*	
3.1.8.4 Install Emergency Gate Closure Guides	**1.00**	**EA**	**2.1 Sub**	**61,125**	**0**	**61,125**	**29,575**	**90,700**	
				5,573.28		*5,573.28*		*8,269.88*	
3.1.8.5 Install Emergency Closure Gate	**1.00**	**EA**	**2.1 Sub**	**5,573**	**0**	**5,573**	**2,697**	**8,270**	
3.1.9 Trash Rack & Trash Rake	**1.00**	**LS**	**2 Prime**	**329,328**	**0**	**329,328**	**161,787**	**491,115**	
				290,000.00		*290,000.00*		*432,466.63*	
3.1.9.1 Furnish Track Rack Panels	**1.00**	**EA**	**2 Prime**	**290,000**	**0**	**290,000**	**142,467**	**432,467**	
				35,884.62		*35,884.62*		*53,513.45*	
3.1.9.2 Furnish Track Rake	**1.00**	**EA**	**2 Prime**	**35,885**	**0**	**35,885**	**17,629**	**53,513**	
				3,443.50		*3,443.50*		*5,135.17*	
3.1.9.3 Shipping	**1.00**	**EA**	**2 Prime**	**3,444**	**0**	**3,444**	**1,692**	**5,135**	
				95,144.89		*139,429.85*		*207,926.74*	
3.1.10 Electrical, Site Work, Utility repairs	**1.00**	**EA**	**2 Prime**	**95,145**	**44,285**	**139,430**	**68,497**	**207,927**	
				38,535.29		*57,466.30*		*85,697.44*	
3.1.10.1 Electrical	**1.00**	**EA**	**2.1 Sub**	**38,535**	**18,931**	**57,466**	**28,231**	**85,697**	
				10,000.00		*14,912.64*		*22,238.69*	
3.1.10.1.1 Low Voltage Wiring and Instrumentation and sensors	**1.00**	**EA**	**2.1 Sub**	**10,000**	**4,913**	**14,913**	**7,326**	**22,239**	
				16,696.17		*24,898.40*		*37,130.09*	
3.1.10.1.2 Power to Valve Actuator	**1.00**	**EA**	**2.1 Sub**	**16,696**	**8,202**	**24,898**	**12,232**	**37,130**	
				2,532.73		*3,776.97*		*5,632.46*	
3.1.10.1.2.1 Conduit and Cable for Actuator	**1.00**	**EA**	**2.1 Sub**	**2,533**	**1,244**	**3,777**	**1,855**	**5,632**	
				1,120.83		*1,671.46*		*2,492.59*	
3.1.10.1.2.2 Lighting circuit, Light and Receptical at valve.	**1.00**	**EA**	**2.1 Sub**	**1,121**	**551**	**1,671**	**821**	**2,493**	
				5.67		*8.46*		*12.62*	
3.1.10.1.2.3 Conduit Feed Trench	**624.00**	**BCY**	**2.1 Sub**	**3,541**	**1,740**	**5,281**	**2,594**	**7,875**	
				4,414.74		*6,583.54*		*9,817.80*	
3.1.10.1.2.4 Upgrade " FCQ7-q" Bucket	**1.00**	**EA**	**2.1 Sub**	**4,415**	**2,169**	**6,584**	**3,234**	**9,818**	

Description	Quantity	UOM	Contractor	DirectCost	SubCMU	CostToPrime	PrimeCMU	ContractCost	C/O
				5,086.74		*7,585.67*		*11,312.24*	
3.1.10.1.2.5 Disconnect at Valve Actuator	**1.00**	**EA**	**2.1 Sub**	**5,087**	**2,499**	**7,586**	**3,727**	**11,312**	
				8,225.13		*12,265.85*		*18,291.62*	
3.1.10.1.3 Relocate Existing Electrical underground	**1.00**	**EA**	**2.1 Sub**	**8,225**	**4,041**	**12,266**	**6,026**	**18,292**	
				3,613.99		*5,389.42*		*8,037.04*	
3.1.10.1.4 Relocate conduit on the face of the Dam	**1.00**	**EA**	**2.1 Sub**	**3,614**	**1,775**	**5,389**	**2,648**	**8,037**	
				51,609.59		*76,963.54*		*114,772.98*	
3.1.10.2 Paving	**1.00**	**EA**	**2 Prime**	**51,610**	**25,354**	**76,964**	**37,809**	**114,773**	
				87.48		*130.45*		*194.54*	
3.1.10.2.1 8" Base Aggregate	**175.00**	**CY**	**2.1 Sub**	**15,308**	**7,520**	**22,829**	**11,215**	**34,044**	
				12.17		*18.15*		*27.06*	
3.1.10.2.2 Asphalt Concrete	**2,800.00**	**SF**	**2.1 Sub**	**34,073**	**16,739**	**50,811**	**24,962**	**75,773**	
				31.84		*47.48*		*70.80*	
3.1.10.2.3 Asphalt Pavment Hauling	**70.00**	**TON**	**2.1 Sub**	**2,229**	**1,095**	**3,324**	**1,633**	**4,956**	
				5,000.00		*5,000.00*		*7,456.32*	
3.1.10.3 Misc Utility repair or relocate	**1.00**	**EA**	**2 Prime**	**5,000**	**0**	**5,000**	**2,456**	**7,456**	

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
Project Direct Costs Report				**1,665,732**	**479,352**	**1,953,741**	**1,319,858**	**229,246**	**5,647,929**	**5,647,929**	
The Dalles EFL AWS - 90% DDR Estimate Precast Pier	**1.00**	**LS**	**Prime**	**1,665,732**	**479,352**	**1,953,741**	**1,319,858**	**229,246**	**5,647,929**	**5,647,929**	
				1,665,732.08	*479,351.99*	*1,953,740.84*	*1,319,858.00*		*5,647,928.67*	*5,647,928.67*	
Fish and Wildlife Facilities	**1.00**	**EA**	**Prime**	**1,665,732**	**479,352**	**1,953,741**	**1,319,858**	**229,246**	**5,647,929**	**5,647,929**	
Mob/Demob	**1.00**	**LS**	**Prime**	**0**	**0**	**0**	**0**	**219,246**	**219,246**	**219,246**	
				0.00	*0.00*	*0.00*	*0.00*		*219,245.76*	*219,245.76*	
Mob/Demob	**1.00**	**EA**	**Prime**	**0**	**0**	**0**	**0**	**219,246**	**219,246**	**219,246**	
				0.00	*0.00*	*0.00*	*0.00*		*5,481,144.00*	*5,481,144.00*	
USR Mob/Demob	0.04	EA	Prime	0	0	0	0	219,246	219,246	219,246	N
				813,215.69	*51,037.99*	*479,908.75*	*969,710.50*		*2,313,872.92*	*2,313,872.92*	
Precast Pier	**1.00**	**EA**	**Prime**	**813,216**	**51,038**	**479,909**	**969,711**	**0**	**2,313,873**	**2,313,873**	
				5,123.26	*6,112.67*	*160,186.67*	*0.00*		*171,422.60*	*171,422.60*	
Precast Concrete	**1.00**	**EA**	**Sub**	**5,123**	**6,113**	**160,187**	**0**	**0**	**171,423**	**171,423**	
				0.00	*0.00*	*800.93*	*0.00*		*800.93*	*800.93*	
NLU 034105151150 Precast column, reinforcing 525 #/C.Y., tied, 32" x 32", 3000 psi, includes material only	200.00	CY	Sub	0	0	160,187	0	0	160,187	160,187	N
				365.95	*436.62*	*0.00*	*0.00*		*802.57*	*802.57*	
USR HB Round Trip Haul Precast Sections	14.00	EA	Sub	5,123	6,113	0	0	0	11,236	11,236	N
				736,495.05	*26,550.96*	*0.00*	*0.00*		*763,046.01*	*763,046.01*	
Dive Crew Labor	**1.00**	**EA**	**Prime**	**736,495**	**26,551**	**0**	**0**	**0**	**763,046**	**763,046**	
				1,233.66	*44.47*	*0.00*	*0.00*		*1,278.13*	*1,278.13*	
USR DIVE01 Dive Crew for drilling anchors.	280.00	HR	Prime	345,425	12,453	0	0	0	357,878	357,878	N
				1,233.66	*44.47*	*0.00*	*0.00*		*1,278.13*	*1,278.13*	
USR DIVE01 Dive Crew for drilling anchors 7" dia.	140.00	HR	Prime	172,712	6,226	0	0	0	178,939	178,939	N
				1,233.66	*44.47*	*0.00*	*0.00*		*1,278.13*	*1,278.13*	
USR DIVE01 Dive Crew for drilling for angle guides.	80.00	HR	Prime	98,693	3,558	0	0	0	102,251	102,251	N
				1,233.66	*44.47*	*0.00*	*0.00*		*1,278.13*	*1,278.13*	
USR DIVE01 Dive Crew position and anchor precast assemblies	36.00	HR	Prime	44,412	1,601	0	0	0	46,013	46,013	N
				1,233.66	*44.47*	*0.00*	*0.00*		*1,278.13*	*1,278.13*	
USR DIVE01 Dive Crew pressure grouting.	21.00	HR	Prime	25,907	934	0	0	0	26,841	26,841	N
				1,233.66	*44.47*	*0.00*	*0.00*		*1,278.13*	*1,278.13*	
USR DIVE01 Dive Crew post tension anchors.	40.00	HR	Prime	49,346	1,779	0	0	0	51,125	51,125	N
				980.22	*161.58*	*13,494.08*	*0.00*		*14,635.88*	*14,635.88*	
Place Grout Pad Materials & Surface Labor.	**1.00**	**EA**	**Prime - LS&H**	**980**	**162**	**13,494**	**0**	**0**	**14,636**	**14,636**	
				20.42	*3.37*	*20.71*	*0.00*		*44.50*	*44.50*	
NLU 314313131170 Pressure grouting, in galleries, place grout	48.00	CF	Prime - LS&H	980	162	994	0	0	2,136	2,136	N
				0.00	*0.00*	*250.00*	*0.00*		*250.00*	*250.00*	
HNC 313313103220 Rock bolts, head assembly, mechanical anchors, long	50.00	EA	Prime - LS&H	0	0	12,500	0	0	12,500	12,500	M

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
cone and shell, 1 I/4" diam.rock bolt, 9-5/16" long											
				20,538.86	*15,560.58*	*0.00*	*0.00*		*36,099.44*	*36,099.44*	
Support Ground Crew	**1.00**	**EA**	**Prime**	**20,539**	**15,561**	**0**	**0**	**0**	**36,099**	**36,099**	
				256.74	*194.51*	*0.00*	*0.00*		*451.24*	*451.24*	
USR Ground Support Crew	80.00	HR	Prime - LS&H	20,539	15,561	0	0	0	36,099	36,099	O
				731.89	*873.24*	*180,000.00*	*585,000.00*		*766,605.13*	*766,605.13*	
Bulkheads	**1.00**	**EA**	**Prime**	**732**	**873**	**180,000**	**585,000**	**0**	**766,605**	**766,605**	
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	
USR Fabrication of Bulkheads	180,000.00	LB	Prime	0	0	180,000	585,000	0	765,000	765,000	MSb
				365.95	*436.62*	*0.00*	*0.00*		*802.57*	*802.57*	
USR HB Round Trip Haul Bulkheads	2.00	EA	Sub	732	873	0	0	0	1,605	1,605	N
				0.00	*0.00*	*0.00*	*300,000.00*		*300,000.00*	*300,000.00*	
Mobe Demobe Barge	**1.00**	**EA**	**Prime**	**0**	**0**	**0**	**300,000**	**0**	**300,000**	**300,000**	
				0.00	*0.00*	*0.00*	*150,000.00*		*150,000.00*	*150,000.00*	
USR Barge transport of buttress to Shop	2.00	EA	Prime	0	0	0	300,000	0	300,000	300,000	Sb
				0.00	*0.00*	*113,228.00*	*42,460.50*		*155,688.50*	*155,688.50*	
SS nose for Precast Piers with Trash Rack Guide	**1.00**	**EA**	**Prime**	**0**	**0**	**113,228**	**42,461**	**0**	**155,689**	**155,689**	
				0.00	*0.00*	*4.00*	*1.50*		*5.50*	*5.50*	
USR FAB01 SS nose on piers	28,307.00	LB	Prime	0	0	113,228	42,461	0	155,689	155,689	MSb
				49,346.40	*1,778.96*	*13,000.00*	*42,250.00*		*106,375.36*	*106,375.36*	
Deflectors for preditor protection	**1.00**	**EA**	**Prime**	**49,346**	**1,779**	**13,000**	**42,250**	**0**	**106,375**	**106,375**	
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	
USR FAB01 Steel Plate for Guide Corner - Shop Fabrication	13,000.00	LB	Prime	0	0	13,000	42,250	0	55,250	55,250	MSb
				1,233.66	*44.47*	*0.00*	*0.00*		*1,278.13*	*1,278.13*	
USR DIVE01 Dive Crew for installing preditor deflector plate.	40.00	HR	Prime	49,346	1,779	0	0	0	51,125	51,125	N
Concrete Mining	**1.00**	**LS**	**Prime**	**174,477**	**221,117**	**9,550**	**20,000**	**0**	**425,144**	**425,144**	
				4,586.31	*212.39*	*7,550.00*	*0.00*		*12,348.70*	*12,348.70*	
Work Platform	**1.00**	**EA**	**Sub**	**4,586**	**212**	**7,550**	**0**	**0**	**12,349**	**12,349**	
				994.38	*546.25*	*0.00*	*0.00*		*1,540.63*	*1,540.63*	
HNC 311110100156 Clear and grub, medium stumps, to 10" diameter, includes loading on site	0.01	ACR	Sub	11	6	0	0	0	18	18	N
				3,940.12	*1,177.12*	*0.00*	*0.00*		*5,117.24*	*5,117.24*	
HNC 311110100152 Clear and grub, cut and chip, medium trees, to 10" diameter	0.01	ACR	Sub	45	14	0	0	0	59	59	N
				7.87	*3.72*	*0.00*	*0.00*		*11.59*	*11.59*	
RSM 312316166040 Structural excavation for minor structures, bank measure, for spread and mat footings, elevator pits, and small building foundations, common earth, 1 C.Y. bucket, machine excavation, hydraulic backhoe	28.00	BCY	Sub	220	104	0	0	0	325	325	N

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				0.39	*0.07*	*1.49*	*0.00*		*1.95*	*1.95*	
RSM 312323170800 Fill, gravel fill, compacted, under floor slabs, 12" deep	1,000.00	SF	Sub	392	65	1,490	0	0	1,948	1,948	N
				130.56	*0.76*	*202.00*	*0.00*		*333.32*	*333.32*	
RSM 033053404000 Structural concrete, in place, foundation mat (3000 psi), under 10 C.Y., includes forms(4 uses), reinforcing steel, concrete, placing and finishing	30.00	CY	Sub	3,917	23	6,060	0	0	10,000	10,000	N
				168,817.40	*219,510.80*	*0.00*	*0.00*		*388,328.21*	*388,328.21*	
Concrete Mining	**1.00**	**EA**	**Sub**	**168,817**	**219,511**	**0**	**0**	**0**	**388,328**	**388,328**	
				609.40	*70.23*	*0.00*	*0.00*		*679.63*	*679.63*	
USR BORE02 Boring Crew Labor - Mob/Demob	50.00	HR	Sub	30,470	3,512	0	0	0	33,982	33,982	N
				411.69	*692.21*	*0.00*	*0.00*		*1,103.90*	*1,103.90*	
USR BORE03 Boring Crew Equipment - Mob/Demob	40.00	HR	Sub	16,468	27,688	0	0	0	44,156	44,156	N
				2,031.33	*3,138.51*	*0.00*	*0.00*		*5,169.85*	*5,169.85*	
USR BORE01 Concrete Drill/Bore	60.00	LF	Sub	121,880	188,311	0	0	0	310,191	310,191	N
				5.08	*6.61*	*0.00*	*63.98*		*75.67*	*75.67*	
Haul & Dispose	**211.00**	**CY**	**Prime**	**1,073**	**1,394**	**0**	**13,500**	**0**	**15,967**	**15,967**	
				1.55	*2.07*	*0.00*	*0.00*		*3.62*	*3.62*	
HNC 312316440170 Excavate and load, bank measure, blasted rock, 3-1/2 C.Y. bucket, hydraulic excavator	211.00	BCY	Prime	327	437	0	0	0	764	764	N
				2.49	*3.19*	*0.00*	*0.00*		*5.68*	*5.68*	
RSM 312323201056 Cycle hauling(wait, load,travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 15 min load/wait/unload, 12 C.Y. truck, cycle 10 miles, 30 MPH, excludes loading equipment	300.00	LCY	Prime	746	956	0	0	0	1,703	1,703	N
				0.00	*0.00*	*0.00*	*30.00*		*30.00*	*30.00*	
USR Disposal Fee	450.00	TON	Prime	0	0	0	13,500	0	13,500	13,500	Sb
				0.00	*0.00*	*2,000.00*	*6,500.00*		*8,500.00*	*8,500.00*	
Work Platform Steel	**1.00**	**EA**	**Sub**	**0**	**0**	**2,000**	**6,500**	**0**	**8,500**	**8,500**	
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	
USR FAB01 Work Platform Steel - Shop Fabrication	2,000.00	LB	Sub	0	0	2,000	6,500	0	8,500	8,500	MSb
				1,824.14	*382.18*	*2,419.92*	*557.92*		*5,184.17*	*5,184.17*	
Steel Pipe Through Dam	**60.00**	**LF**	**Prime**	**109,449**	**22,931**	**145,195**	**33,475**	**0**	**311,050**	**311,050**	
				49,328.42	*17,700.30*	*78,765.00*	*20,475.00*		*166,268.71*	*166,268.71*	
Furnish & Install Steel Pipe (3/4 wall)	**1.00**	**EA**	**Prime**	**49,328**	**17,700**	**78,765**	**20,475**	**0**	**166,269**	**166,269**	
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	
USR FAB01 Steel Flange Plate - Shop Fabrication	6,300.00	LB	Prime	0	0	6,300	20,475	0	26,775	26,775	MSb
				30.22	*3.15*	*15.50*	*0.00*		*48.88*	*48.88*	
RSM 050523151435 Chemical anchor, 1" dia x 11-3/4" L, in concrete, brick or stone, incl layout, drilling, threaded rod & epoxy cartridge	30.00	EA	Prime	907	95	465	0	0	1,466	1,466	N

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				423.14	*160.25*	*0.00*	*0.00*		*583.39*	*583.39*	
USR TUN01 Tunnel Pipe Installation Crew	60.00	HR	Prime	25,388	9,615	0	0	0	35,004	35,004	N
				383.89	*133.17*	*1,200.00*	*0.00*		*1,717.06*	*1,717.06*	
NLU 331113401240 Pipe, black steel, plain end, welded, 3/4" wall thickness, 120" diameter, excludes excavation or backfill	60.00	LF	Prime	23,033	7,990	72,000	0	0	103,024	103,024	M
				21,061.75	*2,055.64*	*42,652.07*	*0.00*		*65,769.46*	*65,769.46*	
Pressure Grouting	**1.00**	**EA**	**Sub**	**21,062**	**2,056**	**42,652**	**0**	**0**	**65,769**	**65,769**	
				19.76	*2.08*	*42.50*	*0.00*		*64.34*	*64.34*	
RSM 314313130300 Concrete pressure grouting, cement and sand, 1:1 mix, per C.F., maximum	989.60	CF	Sub	19,556	2,056	42,058	0	0	63,670	63,670	N
				2.51	*0.00*	*0.99*	*0.00*		*3.50*	*3.50*	
RSM 238316100120 Radiant floor heating, tubing, PEX (cross-linked polyethylene), oxygen barrier type for systems with ferrous metals, 1/2"	600.00	LF	Sub	1,506	0	594	0	0	2,100	2,100	O
				4,452.75	*68.06*	*2,943.40*	*0.00*		*7,464.21*	*7,464.21*	
VP 6" vent pipe	**1.00**	**EA**	**Prime**	**4,453**	**68**	**2,943**	**0**	**0**	**7,464**	**7,464**	
				45.25	*0.35*	*36.50*	*0.00*		*82.10*	*82.10*	
RSM 221113442350 Pipe, steel, black, welded, 6" diameter, schedule 40, A-53 gr. A/B, includes hanger assemblies	60.00	LF	Prime	2,715	21	2,190	0	0	4,926	4,926	N
				334.88	*2.56*	*106.00*	*0.00*		*443.44*	*443.44*	
RSM 221113473140 Elbow, 90 Deg., steel, carbon steel, black, long radius, butt weld, standard weight, 6" pipe size, includes 1 weld per joint and weld machine	2.00	EA	Prime	670	5	212	0	0	887	887	N
				334.88	*2.56*	*97.50*	*0.00*		*434.94*	*434.94*	
RSM 221113473300 Elbow, 45 Deg., steel, carbon steel, black, long radius, butt weld, standard weight, 6" pipe size, includes 1 weld per joint and weld machine	2.00	EA	Prime	670	5	195	0	0	870	870	N
				2.49	*0.23*	*2.17*	*0.00*		*4.88*	*4.88*	
E-11.3.6 Surface Prep & Paint outside of pipe.	**160.00**	**SF**	**Sub**	**398**	**37**	**346**	**0**	**0**	**781**	**781**	
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100110 Paints & Coatings, material only, vinyl paint, V-766E, gray, 1 mil average thickness	720.00	SF	Sub	0	0	137	0	0	137	137	N
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100130 Paints & Coatings, material only, vinyl paint, V-766E, white, 1 mil average thickness	480.00	SF	Sub	0	0	91	0	0	91	91	N
				0.22	*0.00*	*0.00*	*0.00*		*0.22*	*0.22*	
HNC 099713330080 Coatings for Steel, structural steel, application only, paint, machinery & equip., spray, 1 coat	800.00	SF	Sub	174	0	0	0	0	174	174	N
				1.40	*0.23*	*0.74*	*0.00*		*2.37*	*2.37*	
RSM 050110516240 Metal cleaning, steel surface treatment, 3.0 lb sand per S.F., commercial blast, tight mill scale, little/no rust (SSPC-SP6)	160.00	SF	Sub	224	37	118	0	0	379	379	N
				5,536.44	*378.59*	*6,260.00*	*13,000.00*		*25,175.03*	*25,175.03*	

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
Pipe Rail System	**1.00**	**EA**	**Prime**	**5,536**	**379**	**6,260**	**13,000**	**0**	**25,175**	**25,175**	
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	
USR FAB01 Rail System - Shop Fabrication	4,000.00	LB	Prime	0	0	4,000	13,000	0	17,000	17,000	MSb
				0.00	*0.00*	*200.00*	*0.00*		*200.00*	*200.00*	
USR UHMW Pads	2.00	EA	Prime	0	0	400	0	0	400	400	M
				30.22	*3.15*	*15.50*	*0.00*		*48.88*	*48.88*	
RSM 050523151435 Chemical anchor, 1" dia x 11-3/4" L, in concrete, brick or stone, incl layout, drilling, threaded rod & epoxy cartridge	120.00	EA	Prime	3,627	379	1,860	0	0	5,865	5,865	N
				238.70	*0.00*	*0.00*	*0.00*		*238.70*	*238.70*	
USR RAIL01 Rail Installation Crew	8.00	HR	Prime	1,910	0	0	0	0	1,910	1,910	N
				19,690.99	*1,855.83*	*6,413.00*	*0.00*		*27,959.82*	*27,959.82*	
Intake Concrete	**1.00**	**EA**	**Prime - LS&H**	**19,691**	**1,856**	**6,413**	**0**	**0**	**27,960**	**27,960**	
				296.71	*23.46*	*0.00*	*0.00*		*320.17*	*320.17*	
RSM 030505100070 Selective concrete demolition, maximum reinforcing, break up into small pieces, excludes shoring, bracing, saw or torch cutting, loading, hauling, dumping	15.00	CY	Prime - LS&H	4,451	352	0	0	0	4,803	4,803	N
				714.74	*79.23*	*305.00*	*0.00*		*1,098.98*	*1,098.98*	
RSM 033053400300 Structural concrete, in place, beam (3500 psi), 5 kip per L.F., 10' span, includes forms(4 uses), reinforcing steel, concrete, placing and finishing	15.00	CY	Prime - LS&H	10,721	1,188	4,575	0	0	16,485	16,485	N
				36.03	*3.15*	*15.50*	*0.00*		*54.68*	*54.68*	
RSM 050523151435 Chemical anchor, 1" dia x 11-3/4" L, in concrete, brick or stone, incl layout, drilling, threaded rod & epoxy cartridge	100.00	EA	Prime - LS&H	3,603	315	1,550	0	0	5,468	5,468	N
				9.16	*0.00*	*2.88*	*0.00*		*12.04*	*12.04*	
HNC 032110602440 Reinforcing steel, in place, dowels, deformed, 2' long, #8, A615, grade 60	100.00	EA	Prime - LS&H	916	0	288	0	0	1,204	1,204	N
				0.42	*0.04*	*0.37*	*0.00*		*0.83*	*0.83*	
E-11.3.6 Surface Prep & Paint Inside Area of Conduit Pipe	**22,200.00**	**SF**	**Sub**	**9,378**	**873**	**8,162**	**0**	**0**	**18,413**	**18,413**	
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100110 Paints & Coatings, material only, vinyl paint, V-766E, gray, 1 mil average thickness	16,964.00	SF	Sub	0	0	3,223	0	0	3,223	3,223	N
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100130 Paints & Coatings, material only, vinyl paint, V-766E, white, 1 mil average thickness	11,310.00	SF	Sub	0	0	2,149	0	0	2,149	2,149	N
				0.22	*0.00*	*0.00*	*0.00*		*0.22*	*0.22*	
HNC 099713330080 Coatings for Steel, structural steel, application only, paint, machinery & equip., spray, 1 coat	18,850.00	SF	Sub	4,110	0	0	0	0	4,110	4,110	N
				1.40	*0.23*	*0.74*	*0.00*		*2.37*	*2.37*	
RSM 050110516240 Metal cleaning, steel surface treatment, 3.0 lb sand per S.F., commercial blast, tight mill scale, little/no rust (SSPC-SP6)	3,770.00	SF	Sub	5,269	873	2,790	0	0	8,931	8,931	N
Steel Pipe from Dam to AWS Chamber	**1.00**	**LS**	**Prime**	**357,184**	**110,391**	**544,210**	**0**	**0**	**1,011,785**	**1,011,785**	

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				188,503.96	*45,750.59*	*457,935.00*	*0.00*		*692,189.55*	*692,189.55*	
Furnish & Install Steel Pipe	**1.00**	**EA**	**Prime**	**188,504**	**45,751**	**457,935**	**0**	**0**	**692,190**	**692,190**	
				312.11	*108.27*	*1,050.00*	*0.00*		*1,470.38*	*1,470.38*	
HNC 331113401180 Pipe, black steel, plain end, welded, 5/8" wall thickness, 96" diameter, excludes excavation or backfill	200.00	LF	Prime	62,421	21,654	210,000	0	0	294,075	294,075	N
				383.89	*133.17*	*1,000.00*	*0.00*		*1,517.06*	*1,517.06*	
USER 5/8" pipe Pipe, black steel, plain end, welded, 5/8" wall thickness, 120" diameter, excludes excavation or backfill	180.00	LF	Prime	69,100	23,971	180,000	0	0	273,071	273,071	M
				49,469.51	*0.00*	*56,610.00*	*0.00*		*106,079.51*	*106,079.51*	
Fittings bends and orfice plate	**1.00**	**EA**	**Prime**	**49,470**	**0**	**56,610**	**0**	**0**	**106,080**	**106,080**	
				12,184.05	*0.00*	*28,520.00*	*0.00*		*40,704.05*	*40,704.05*	
WYE Fitting	**1.00**	**EA**	**Prime**	**12,184**	**0**	**28,520**	**0**	**0**	**40,704**	**40,704**	
				56.41	*0.00*	*15.00*	*0.00*		*71.41*	*71.41*	
USR wl Welding per lb	168.00	LB	Prime	9,476	0	2,520	0	0	11,996	11,996	N
				169.22	*0.00*	*0.00*	*0.00*		*169.22*	*169.22*	
USR FC Fab Crew at shop.	16.00	HR	Prime	2,708	0	0	0	0	2,708	2,708	N
				0.00	*0.00*	*26,000.00*	*0.00*		*26,000.00*	*26,000.00*	
USR Total for Pipe Material for the Y.	1.00	EA	Prime	0	0	26,000	0	0	26,000	26,000	M
				37,285.46	*0.00*	*28,090.00*	*0.00*		*65,375.46*	*65,375.46*	
10' Dia Bends	**1.00**	**EA**	**Prime**	**37,285**	**0**	**28,090**	**0**	**0**	**65,375**	**65,375**	
				169.22	*0.00*	*0.00*	*0.00*		*169.22*	*169.22*	
USR FC Fab Crew at shop.	85.00	HR	Prime	14,384	0	0	0	0	14,384	14,384	N
				0.00	*0.00*	*22,000.00*	*0.00*		*22,000.00*	*22,000.00*	
USR 10' dia pipe for fittings.	1.00	FT	Prime	0	0	22,000	0	0	22,000	22,000	M
				56.41	*0.00*	*15.00*	*0.00*		*71.41*	*71.41*	
USR wl Welding per lb	406.00	LB	Prime	22,902	0	6,090	0	0	28,992	28,992	N
				7,513.12	*125.05*	*11,325.00*	*0.00*		*18,963.17*	*18,963.17*	
Access Hatch to 10' dia pipe	**1.00**	**EA**	**Prime**	**7,513**	**125**	**11,325**	**0**	**0**	**18,963**	**18,963**	
				0.00	*0.00*	*11,325.00*	*0.00*		*11,325.00*	*11,325.00*	
USR Acces Hatch Materials	1.00	EA	Prime	0	0	11,325	0	0	11,325	11,325	M
				169.22	*0.00*	*0.00*	*0.00*		*169.22*	*169.22*	
USR FC Fab Crew at shop.	30.00	HR	Prime	5,077	0	0	0	0	5,077	5,077	N
				243.64	*12.51*	*0.00*	*0.00*		*256.15*	*256.15*	
USR MSPFB35A Filed Installation Crew.	10.00	HR	Prime	2,436	125	0	0	0	2,561	2,561	N
				9,278.90	*7,321.87*	*0.00*	*0.00*		*16,600.77*	*16,600.77*	
Common Excavation - 10' Dia. Pipe	**1.00**	**EA**	**Prime**	**9,279**	**7,322**	**0**	**0**	**0**	**16,601**	**16,601**	
				1.65	*0.94*	*0.00*	*0.00*		*2.59*	*2.59*	
RSM 312316130130 Excavating, trench or continuous footing, common earth, 1-1/2 C.Y. excavator, 4' to 6' deep, excludes sheeting or dewatering	2,106.00	BCY	Prime	3,485	1,971	0	0	0	5,457	5,457	N

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				1.07	*0.39*	*0.00*	*0.00*		*1.45*	*1.45*	
HNC 312316440225 Excavate and load, bank measure, medium material, 1-1/2 C.Y. bucket, wheeled loader	2,106.00	BCY	Prime	2,252	812	0	0	0	3,064	3,064	N
				1.29	*1.66*	*0.00*	*0.00*		*2.95*	*2.95*	
RSM 312323201016 Cycle hauling(wait, load,travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 15 min load/wait/unload, 12 C.Y. truck, cycle 1 mile, 15 MPH, excludes loading equipment	2,737.80	LCY	Prime	3,542	4,539	0	0	0	8,080	8,080	N
				61,519.99	*20,117.22*	*27,799.20*	*0.00*		*109,436.42*	*109,436.42*	
Rock Excavation - 10' dia. Pipe	**1.00**	**EA**	**Prime**	**61,520**	**20,117**	**27,799**	**0**	**0**	**109,436**	**109,436**	
				2.00	*1.15*	*0.00*	*0.00*		*3.15*	*3.15*	
RSM 312316264600 Rock removal, drilling only for rock quarry production, 2-1/2" to 3-1/2" diameter	9,720.00	LF	Prime	19,455	11,133	0	0	0	30,588	30,588	O
				3.93	*0.49*	*2.86*	*0.00*		*7.28*	*7.28*	
USR 025210105277 Concrete removal, expansive demolition grout, conventional demolition grout, vertical, 1-7/8" dia hole	9,720.00	LF	Prime	38,237	4,732	27,799	0	0	70,768	70,768	O
				4.64	*4.61*	*0.00*	*0.00*		*9.25*	*9.25*	
HNC 312316440150 Excavate and load, bank measure, blasted rock, 2 C.Y. bucket, hydraulic excavator	486.00	BCY	Prime	2,256	2,238	0	0	0	4,495	4,495	O
				2.49	*3.19*	*0.00*	*0.00*		*5.68*	*5.68*	
RSM 312323201056 Cycle hauling(wait, load,travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 15 min load/wait/unload, 12 C.Y. truck, cycle 10 miles, 30 MPH, excludes loading equipment	631.80	LCY	Prime	1,572	2,014	0	0	0	3,586	3,586	N
				317.23	*250.32*	*0.00*	*0.00*		*567.55*	*567.55*	
Common Excavation - 7.5' Dia. Pipe	**30.00**	**LF**	**Prime**	**9,517**	**7,510**	**0**	**0**	**0**	**17,026**	**17,026**	
				1.65	*0.94*	*0.00*	*0.00*		*2.59*	*2.59*	
RSM 312316130130 Excavating, trench or continuous footing, common earth, 1-1/2 C.Y. excavator, 4' to 6' deep, excludes sheeting or dewatering	2,160.00	BCY	Prime	3,575	2,022	0	0	0	5,597	5,597	N
				1.07	*0.39*	*0.00*	*0.00*		*1.45*	*1.45*	
HNC 312316440225 Excavate and load, bank measure, medium material, 1-1/2 C.Y. bucket, wheeled loader	2,160.00	BCY	Prime	2,310	833	0	0	0	3,143	3,143	N
				1.29	*1.66*	*0.00*	*0.00*		*2.95*	*2.95*	
RSM 312323201016 Cycle hauling(wait, load,travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 15 min load/wait/unload, 12 C.Y. truck, cycle 1 mile, 15 MPH, excludes loading equipment	2,808.00	LCY	Prime	3,632	4,655	0	0	0	8,287	8,287	N
				2,350.92	*260.81*	*6,016.50*	*0.00*		*8,628.23*	*8,628.23*	
Pipe Bedding	**1.00**	**EA**	**Prime**	**2,351**	**261**	**6,017**	**0**	**0**	**8,628**	**8,628**	
				8.47	*1.13*	*31.50*	*0.00*		*41.10*	*41.10*	
RSM 312323160100 Fill by borrow and utility bedding, for pipe and	151.00	LCY	Prime	1,279	171	4,757	0	0	6,207	6,207	N

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
conduit, crushed stone, 3/4" to 1/2", excludes compaction											
				8.47	*1.13*	*31.50*	*0.00*		*41.10*	*41.10*	
RSM 312323160100 Fill by borrow and utility bedding, for pipe and conduit, crushed stone, 3/4" to 1/2", excludes compaction	40.00	LCY	Prime	339	45	1,260	0	0	1,644	1,644	N
				4.42	*0.27*	*0.00*	*0.00*		*4.68*	*4.68*	
RSM 312323160500 Fill by borrow and utility bedding, for pipe and conduit, compacting bedding in trench	166.00	ECY	Prime	733	44	0	0	0	777	777	N
				35,637.73	*24,846.18*	*0.00*	*0.00*		*60,483.91*	*60,483.91*	
Pipe Backfill	**1.00**	**EA**	**Prime**	**35,638**	**24,846**	**0**	**0**	**0**	**60,484**	**60,484**	
				2.97	*1.07*	*0.00*	*0.00*		*4.03*	*4.03*	
HNC 312316440225 Excavate and load, bank measure, medium material, 1-1/2 C.Y. bucket, wheeled loader	4,419.00	BCY	Prime	13,104	4,724	0	0	0	17,828	17,828	O
				1.29	*1.66*	*0.00*	*0.00*		*2.95*	*2.95*	
RSM 312323201016 Cycle hauling(wait, load,travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 15 min load/wait/unload, 12 C.Y. truck, cycle 1 mile, 15 MPH, excludes loading equipment	5,303.00	LCY	Prime	6,860	8,791	0	0	0	15,651	15,651	N
				1.29	*1.66*	*0.00*	*0.00*		*2.95*	*2.95*	
RSM 312323201016 Cycle hauling(wait, load,travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 15 min load/wait/unload, 12 C.Y. truck, cycle 1 mile, 15 MPH, excludes loading equipment	5,303.00	LCY	Prime	6,860	8,791	0	0	0	15,651	15,651	N
				0.95	*0.41*	*0.00*	*0.00*		*1.36*	*1.36*	
HNC 312323145510 Backfill, structural, 6" lifts, backfill around foundation, with hydraulic excavator	5,303.00	LCY	Prime	5,050	2,188	0	0	0	7,238	7,238	N
				0.71	*0.07*	*0.00*	*0.00*		*0.78*	*0.78*	
RSM 312323237200 Compaction, 2 passes, 18" wide,12" lifts, walk behind, vibrating plate	5,303.00	ECY	Prime	3,764	353	0	0	0	4,117	4,117	N
				2.11	*0.20*	*1.84*	*0.00*		*4.15*	*4.15*	
E-11.3.6 Surface Prep & Paint All Conduit Pipe	**23,100.00**	**SF**	**Sub**	**48,844**	**4,545**	**42,510**	**0**	**0**	**95,899**	**95,899**	
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100110 Paints & Coatings, material only, vinyl paint, V-766E, gray, 1 mil average thickness	88,357.00	SF	Sub	0	0	16,788	0	0	16,788	16,788	N
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100130 Paints & Coatings, material only, vinyl paint, V-766E, white, 1 mil average thickness	58,905.00	SF	Sub	0	0	11,192	0	0	11,192	11,192	N
				0.22	*0.00*	*0.00*	*0.00*		*0.22*	*0.22*	
HNC 099713330080 Coatings for Steel, structural steel, application only, paint, machinery & equip., spray, 1 coat	98,175.00	SF	Sub	21,404	0	0	0	0	21,404	21,404	N
				1.40	*0.23*	*0.74*	*0.00*		*2.37*	*2.37*	
RSM 050110516240 Metal cleaning, steel surface treatment, 3.0 lb sand per S.F., commercial blast, tight mill scale, little/no rust (SSPC-SP6)	19,635.00	SF	Sub	27,440	4,545	14,530	0	0	46,515	46,515	N

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				1,531.70	*39.25*	*9,950.00*	*0.00*		*11,520.96*	*11,520.96*	
Thrust Block	**1.00**	**EA**	**Prime**	**1,532**	**39**	**9,950**	**0**	**0**	**11,521**	**11,521**	
				15.32	*0.39*	*0.00*	*0.00*		*15.71*	*15.71*	
RSM 033105703200 Structural concrete, placing, grade beam, direct chute, includes strike off & consolidation, excludes material	100.00	CY	Prime	1,532	39	0	0	0	1,571	1,571	N
				0.00	*0.00*	*99.50*	*0.00*		*99.50*	*99.50*	
RSM 033105350200 Structural concrete, ready mix, normal weight, 3500 psi, includes local aggregate, sand, Portland cement and water, delivered, excludes all additives and treatments	100.00	CY	Prime	0	0	9,950	0	0	9,950	9,950	N
				128,320.59	*48,321.51*	*101,112.41*	*0.00*		*277,754.52*	*277,754.52*	
Steel Pipe in AWS Chamber	**1.00**	**EA**	**Prime**	**128,321**	**48,322**	**101,112**	**0**	**0**	**277,755**	**277,755**	
				7,161.00	*0.00*	*5,000.00*	*0.00*		*12,161.00*	*12,161.00*	
Set up platform and rigging in AWS chamber	**1.00**	**EA**	**Prime**	**7,161**	**0**	**5,000**	**0**	**0**	**12,161**	**12,161**	
				238.70	*0.00*	*0.00*	*0.00*		*238.70*	*238.70*	
USR AWS labor Set up platform and rigging in AWS Chamber	30.00	HR	Prime	7,161	0	0	0	0	7,161	7,161	N
				0.00	*0.00*	*5,000.00*	*0.00*		*5,000.00*	*5,000.00*	
USR Materials for temporary platform	1.00	EA	Prime	0	0	5,000	0	0	5,000	5,000	M
				4,774.00	*0.00*	*0.00*	*0.00*		*4,774.00*	*4,774.00*	
Remove rigging and platforms from AWS Chamber	**1.00**	**EA**	**Prime**	**4,774**	**0**	**0**	**0**	**0**	**4,774**	**4,774**	
				238.70	*0.00*	*0.00*	*0.00*		*238.70*	*238.70*	
USR AWS labor Set up platform and rigging in AWS Chamber	20.00	HR	Prime	4,774	0	0	0	0	4,774	4,774	N
				21,547.61	*23,427.02*	*0.00*	*0.00*		*44,974.63*	*44,974.63*	
Crane and Above grade support crew.	**1.00**	**EA**	**Prime**	**21,548**	**23,427**	**0**	**0**	**0**	**44,975**	**44,975**	
				165.75	*180.21*	*0.00*	*0.00*		*345.96*	*345.96*	
USR AWS Chamber surface support crew.	130.00	HR	Prime	21,548	23,427	0	0	0	44,975	44,975	N
				34,110.02	*1,750.70*	*0.00*	*0.00*		*35,860.73*	*35,860.73*	
Install Pipe	**1.00**	**EA**	**Prime**	**34,110**	**1,751**	**0**	**0**	**0**	**35,861**	**35,861**	
				304.55	*15.63*	*0.00*	*0.00*		*320.19*	*320.19*	
USR 331113401220 Pipe, black steel, plain end, welded, 5/8" wall thickness, 96" diameter, pipe fab in AWS Chamber	80.00	LF	Prime	24,364	1,251	0	0	0	25,615	25,615	OM
				243.64	*12.51*	*0.00*	*0.00*		*256.15*	*256.15*	
USR MSPFB35A Additional Field Welds.	40.00	HR	Prime	9,746	500	0	0	0	10,246	10,246	N
				0.51	*0.05*	*0.44*	*0.00*		*1.00*	*1.00*	
E-11.3.6 Surface Prep & Paint all Conduit Pipe	**23,100.00**	**SF**	**Sub**	**11,722**	**1,091**	**10,202**	**0**	**0**	**23,015**	**23,015**	
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100110 Paints & Coatings, material only, vinyl paint, V-766E, gray, 1 mil average thickness	21,206.00	SF	Sub	0	0	4,029	0	0	4,029	4,029	N
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100130 Paints & Coatings, material only, vinyl paint, V-766E,	14,137.00	SF	Sub	0	0	2,686	0	0	2,686	2,686	N

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
white, 1 mil average thickness											
				0.22	*0.00*	*0.00*	*0.00*		*0.22*	*0.22*	
HNC 099713330080 Coatings for Steel, structural steel, application only, paint, machinery & equip., spray, 1 coat	23,562.00	SF	Sub	5,137	0	0	0	0	5,137	5,137	N
				1.40	*0.23*	*0.74*	*0.00*		*2.37*	*2.37*	
RSM 050110516240 Metal cleaning, steel surface treatment, 3.0 lb sand per S.F., commercial blast, tight mill scale, little/no rust (SSPC-SP6)	4,712.00	SF	Sub	6,585	1,091	3,487	0	0	11,163	11,163	N
				17,539.21	*13,679.94*	*1,935.36*	*0.00*		*33,154.52*	*33,154.52*	
Concrete Sawcutting Fishladder and AWS Chamber	**1.00**	**EA**	**Prime**	**17,539**	**13,680**	**1,935**	**0**	**0**	**33,155**	**33,155**	
				17,539.21	*13,679.94*	*1,935.36*	*0.00*		*33,154.52*	*33,154.52*	
Concrete Cutting	**1.00**	**EA**	**Sub**	**17,539**	**13,680**	**1,935**	**0**	**0**	**33,155**	**33,155**	
				4.91	*4.36*	*0.63*	*0.00*		*9.90*	*9.90*	
RSM 038116500820 Concrete sawing, concrete walls, rod reinforcing, per inch of depth	3,072.00	LF	Sub	15,086	13,382	1,935	0	0	30,403	30,403	N
				237.84	*23.46*	*0.00*	*0.00*		*261.30*	*261.30*	
RSM 030505100070 Selective concrete demolition, maximum reinforcing, break up into small pieces, excludes shoring, bracing, saw or torch cutting, loading, hauling, dumping	10.00	CY	Sub	2,378	235	0	0	0	2,613	2,613	N
				4.41	*2.23*	*0.00*	*0.00*		*6.64*	*6.64*	
HNC 312316440110 Excavate and load, bank measure, blasted rock, 3/4 C.Y. bucket, hydraulic excavator	10.00	BCY	Sub	44	22	0	0	0	66	66	N
				2.35	*3.19*	*0.00*	*0.00*		*5.53*	*5.53*	
RSM 312323201056 Cycle hauling(wait, load,travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 15 min load/wait/unload, 12 C.Y. truck, cycle 10 miles, 30 MPH, excludes loading equipment	13.00	LCY	Sub	30	41	0	0	0	72	72	N
				28,485.86	*0.00*	*83,975.00*	*0.00*		*112,460.86*	*112,460.86*	
90 degree bend and fabrication of orifice manifold.	**1.00**	**EA**	**Prime**	**28,486**	**0**	**83,975**	**0**	**0**	**112,461**	**112,461**	
				21,716.95	*0.00*	*19,975.00*	*0.00*		*41,691.95*	*41,691.95*	
7.5' Dia Bends	**1.00**	**EA**	**Prime**	**21,717**	**0**	**19,975**	**0**	**0**	**41,692**	**41,692**	
				169.22	*0.00*	*0.00*	*0.00*		*169.22*	*169.22*	
USR FC Fab Crew at shop.	40.00	HR	Prime	6,769	0	0	0	0	6,769	6,769	N
				0.00	*0.00*	*16,000.00*	*0.00*		*16,000.00*	*16,000.00*	
USR 7.5' dia pipe for bend	1.00	FT	Prime	0	0	16,000	0	0	16,000	16,000	M
				56.41	*0.00*	*15.00*	*0.00*		*71.41*	*71.41*	
USR wl Welding per lb	265.00	LB	Prime	14,948	0	3,975	0	0	18,923	18,923	N
				6,768.92	*0.00*	*64,000.00*	*0.00*		*70,768.92*	*70,768.92*	
7.5' dia Orfice Manifold.	**1.00**	**EA**	**Prime**	**6,769**	**0**	**64,000**	**0**	**0**	**70,769**	**70,769**	
				0.00	*0.00*	*64,000.00*	*0.00*		*64,000.00*	*64,000.00*	
USR 7.5' dia pipe for bend	1.00	FT	Prime	0	0	64,000	0	0	64,000	64,000	M

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				169.22	*0.00*	*0.00*	*0.00*		*169.22*	*169.22*	
USR FC Fab Crew at shop.	40.00	HR	Prime	6,769	0	0	0	0	6,769	6,769	N
				2,980.82	*8,373.14*	*0.00*	*0.00*		*11,353.96*	*11,353.96*	
Scafolding and hoist	**1.00**	**EA**	**Prime**	**2,981**	**8,373**	**0**	**0**	**0**	**11,354**	**11,354**	
				0.00	*2,088.00*	*0.00*	*0.00*		*2,088.00*	*2,088.00*	
USR Scafold and Hoist Equipment Rental	4.00	WK	Prime	0	8,352	0	0	0	8,352	8,352	E
				99.36	*0.70*	*0.00*	*0.00*		*100.07*	*100.07*	
USR Deliver, Setup, and Return Scafolding	30.00	HR	Prime	2,981	21	0	0	0	3,002	3,002	N
				9,838.31	*5,762.46*	*220,000.00*	*0.00*		*235,600.77*	*235,600.77*	
120" Butterfly Valve w/Acutator	**1.00**	**EA**	**Prime**	**9,838**	**5,762**	**220,000**	**0**	**0**	**235,601**	**235,601**	
				1,746.34	*1,697.16*	*0.00*	*0.00*		*3,443.50*	*3,443.50*	
Shipping	**1.00**	**EA**	**Prime**	**1,746**	**1,697**	**0**	**0**	**0**	**3,444**	**3,444**	
				48.51	*47.14*	*0.00*	*0.00*		*95.65*	*95.65*	
USR SHIP01 Shipping Crew	36.00	HR	Prime	1,746	1,697	0	0	0	3,444	3,444	N
				8,091.97	*4,065.30*	*220,000.00*	*0.00*		*232,157.26*	*232,157.26*	
Valve	**1.00**	**EA**	**Prime**	**8,092**	**4,065**	**220,000**	**0**	**0**	**232,157**	**232,157**	
				0.00	*0.00*	*220,000.00*	*0.00*		*220,000.00*	*220,000.00*	
USR VALV01 Valve, Butterfly, 10' dia.	1.00	EA	Prime	0	0	220,000	0	0	220,000	220,000	M
				269.73	*135.51*	*0.00*	*0.00*		*405.24*	*405.24*	
USR VALV02 Valve Installation Crew	30.00	HR	Prime	8,092	4,065	0	0	0	12,157	12,157	N
				48,179.35	*13,968.51*	*229,557.50*	*137,297.50*		*429,002.86*	*429,002.86*	
Emergency Closure Gate	**1.00**	**EA**	**Prime**	**48,179**	**13,969**	**229,558**	**137,298**	**0**	**429,003**	**429,003**	
				0.00	*0.00*	*106,450.00*	*93,047.50*		*199,497.50*	*199,497.50*	
Furnish Emergency Closure Gate	**1.00**	**EA**	**Prime**	**0**	**0**	**106,450**	**93,048**	**0**	**199,498**	**199,498**	
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	
USR FAB01 Emergency Closure Gate - Shop Fabrication	22,550.00	LB	Prime	0	0	22,550	73,288	0	95,838	95,838	MSb
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	
USR FAB01 Lifting Beam - Shop Fabrication	3,000.00	LB	Prime	0	0	3,000	9,750	0	12,750	12,750	MSb
				0.00	*0.00*	*0.00*	*65.00*		*65.00*	*65.00*	
USR PAINT01 Emergency Closure Gate - Shop Blasting	8.00	HR	Prime	0	0	0	520	0	520	520	Sb
USR PAINT01 Emergency Closure Gate - Shop Painting	1.00	LS	Prime	0	0	1,000	1,040	0	2,040	2,040	MSb
				0.00	*0.00*	*6,000.00*	*650.00*		*6,650.00*	*6,650.00*	
USR PAINT01 Roller Wheel Assembly - Shop Fabrication	10.00	EA	Prime	0	0	60,000	6,500	0	66,500	66,500	MSb
				0.00	*0.00*	*1,500.00*	*0.00*		*1,500.00*	*1,500.00*	
USR Roller Wheel Assembly - 10" Spherical Bearing	10.00	EA	Prime	0	0	15,000	0	0	15,000	15,000	M
				0.00	*0.00*	*60.00*	*0.00*		*60.00*	*60.00*	
USR Gate Seals	60.00	LF	Prime	0	0	3,600	0	0	3,600	3,600	M
				0.00	*0.00*	*4.00*	*0.00*		*4.00*	*4.00*	

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
USR Seal Keeper Plates - Material Only	325.00	LB	Prime	0	0	1,300	0	0	1,300	1,300	M
				0.00	*0.00*	*0.00*	*65.00*		*65.00*	*65.00*	
USR Seal Keeper Plates - Shop Fabrication	10.00	HR	Prime	0	0	0	650	0	650	650	Sb
				0.00	*0.00*	*0.00*	*65.00*		*65.00*	*65.00*	
USR Emergency Closure Gate - Shop Assembly	20.00	HR	Prime	0	0	0	1,300	0	1,300	1,300	Sb
				0.00	*0.00*	*118,000.00*	*44,250.00*		*162,250.00*	*162,250.00*	
Furnish Emergency Closure Gate Guides	**1.00**	**EA**	**Prime**	**0**	**0**	**118,000**	**44,250**	**0**	**162,250**	**162,250**	
				0.00	*0.00*	*4.00*	*1.50*		*5.50*	*5.50*	
USR FAB01 Emergency Closure Gate Guides - Shop Fabrication	29,500.00	LB	Prime	0	0	118,000	44,250	0	162,250	162,250	MSb
				274.46	*282.86*	*0.00*	*0.00*		*557.32*	*557.32*	
Shipping	**1.00**	**EA**	**Sub**	**274**	**283**	**0**	**0**	**0**	**557**	**557**	
				45.74	*47.14*	*0.00*	*0.00*		*92.89*	*92.89*	
USR SHIP01 Shipping Crew	6.00	HR	Sub	274	283	0	0	0	557	557	N
				43,633.41	*12,383.85*	*5,107.50*	*0.00*		*61,124.76*	*61,124.76*	
Install Emergency Gate Closure Guides	**1.00**	**EA**	**Sub**	**43,633**	**12,384**	**5,108**	**0**	**0**	**61,125**	**61,125**	
				32.03	*2.80*	*8.55*	*0.00*		*43.38*	*43.38*	
RSM 050523151430 Chemical anchor, 3/4" dia x 9-1/2" L, in concrete, brick or stone, incl layout, drilling, threaded rod & epoxy cartridge	400.00	EA	Prime - LS&H	12,810	1,122	3,420	0	0	17,352	17,352	N
				427.15	*130.18*	*0.00*	*0.00*		*557.33*	*557.33*	
USR INSTALL02 Guide Install Crew	30.00	HR	Prime - LS&H	12,814	3,905	0	0	0	16,720	16,720	N
				66.70	*27.25*	*6.25*	*0.00*		*100.20*	*100.20*	
RSM 036213500300 Grout, non-shrink, for column and machine bases, non-metallic, 1" deep	270.00	SF	Prime - LS&H	18,009	7,357	1,688	0	0	27,053	27,053	O
				4,271.48	*1,301.80*	*0.00*	*0.00*		*5,573.28*	*5,573.28*	
Install Emergency Closure Gate	**1.00**	**EA**	**Sub**	**4,271**	**1,302**	**0**	**0**	**0**	**5,573**	**5,573**	
				427.15	*130.18*	*0.00*	*0.00*		*557.33*	*557.33*	
USR INSTALL02 Guide Install Crew	10.00	HR	Prime - LS&H	4,271	1,302	0	0	0	5,573	5,573	N
Trash Rack & Trash Rake	**1.00**	**LS**	**Prime**	**3,839**	**1,882**	**169,232**	**154,375**	**0**	**329,328**	**329,328**	
				0.00	*0.00*	*160,000.00*	*130,000.00*		*290,000.00*	*290,000.00*	
Furnish Track Rack Panels	**1.00**	**EA**	**Prime**	**0**	**0**	**160,000**	**130,000**	**0**	**290,000**	**290,000**	
				0.00	*0.00*	*4.00*	*3.25*		*7.25*	*7.25*	
USR FAB01 Trash Rack - Shop Fabrication	40,000.00	LB	Prime	0	0	160,000	130,000	0	290,000	290,000	MSb
				2,092.44	*185.18*	*9,232.00*	*24,375.00*		*35,884.62*	*35,884.62*	
Furnish Track Rake	**1.00**	**EA**	**Prime**	**2,092**	**185**	**9,232**	**24,375**	**0**	**35,885**	**35,885**	
				0.00	*0.00*	*1.00*	*3.25*		*4.25*	*4.25*	
USR FAB01 Trash Rack - Shop Fabrication	7,500.00	LB	Prime	0	0	7,500	24,375	0	31,875	31,875	MSb
				1.47	*0.23*	*0.74*	*0.00*		*2.44*	*2.44*	
RSM 050110516240 Metal cleaning, steel surface treatment, 3.0 lb sand per S.F., commercial blast, tight mill scale, little/no rust (SSPC-SP6)	800.00	SF	Prime	1,175	185	592	0	0	1,953	1,953	N

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				0.23	*0.00*	*0.00*	*0.00*		*0.23*	*0.23*	
HNC 099713330080 Coatings for Steel, structural steel, application only, paint, machinery & equip., spray, 1 coat	4,000.00	SF	Prime	917	0	0	0	0	917	917	N
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100130 Paints & Coatings, material only, vinyl paint, V-766E, white, 1 mil average thickness	2,400.00	SF	Prime	0	0	456	0	0	456	456	N
				0.00	*0.00*	*0.19*	*0.00*		*0.19*	*0.19*	
HNC 099730100110 Paints & Coatings, material only, vinyl paint, V-766E, gray, 1 mil average thickness	3,600.00	SF	Prime	0	0	684	0	0	684	684	N
				1,746.34	*1,697.16*	*0.00*	*0.00*		*3,443.50*	*3,443.50*	
Shipping	**1.00**	**EA**	**Prime**	**1,746**	**1,697**	**0**	**0**	**0**	**3,444**	**3,444**	
				48.51	*47.14*	*0.00*	*0.00*		*95.65*	*95.65*	
USR SHIP01 Shipping Crew	36.00	HR	Prime	1,746	1,697	0	0	0	3,444	3,444	N
				21,229.89	*3,940.53*	*54,974.47*	*5,000.00*		*95,144.89*	*95,144.89*	
Electrical, Site Work, Utility repairs	**1.00**	**EA**	**Prime**	**21,230**	**3,941**	**54,974**	**5,000**	**10,000**	**95,145**	**95,145**	
				16,169.18	*996.54*	*11,369.57*	*0.00*		*38,535.29*	*38,535.29*	
Electrical	**1.00**	**EA**	**Sub**	**16,169**	**997**	**11,370**	**0**	**10,000**	**38,535**	**38,535**	
				0.00	*0.00*	*0.00*	*0.00*		*10,000.00*	*10,000.00*	
Low Voltage Wiring and Instrumentation and sensors	**1.00**	**EA**	**Sub**	**0**	**0**	**0**	**0**	**10,000**	**10,000**	**10,000**	
				0.00	*0.00*	*0.00*	*0.00*		*10,000.00*	*10,000.00*	
USR Low voltage wiring and instrumentation	1.00	EA	Sub	0	0	0	0	10,000	10,000	10,000	N
				8,030.65	*845.71*	*7,819.81*	*0.00*		*16,696.17*	*16,696.17*	
Power to Valve Actuator	**1.00**	**EA**	**Sub**	**8,031**	**846**	**7,820**	**0**	**0**	**16,696**	**16,696**	
				1,660.77	*0.00*	*871.96*	*0.00*		*2,532.73*	*2,532.73*	
Conduit and Cable for Actuator	**1.00**	**EA**	**Sub**	**1,661**	**0**	**872**	**0**	**0**	**2,533**	**2,533**	
				2.07	*0.00*	*1.13*	*0.00*		*3.20*	*3.20*	
RSM 337119151030 Electrical Underground Ducts and Manholes, PVC, conduit with coupling, 1" diameter, schedule 40, installed by direct burial in slab or duct bank	200.00	LF	Sub	414	0	226	0	0	640	640	N
				53.76	*0.00*	*39.00*	*0.00*		*92.76*	*92.76*	
RSM 260519903040 Wire, copper, stranded, 600 volt, #10, type XHHW, in raceway	16.00	CLF	Sub	860	0	624	0	0	1,484	1,484	N
				10.75	*0.00*	*0.61*	*0.00*		*11.36*	*11.36*	
RSM 260519350050 Terminal lugs, solderless, #16 to #10	36.00	EA	Sub	387	0	22	0	0	409	409	N
				682.98	*0.00*	*437.85*	*0.00*		*1,120.83*	*1,120.83*	
Lighting circuit, Light and Receptical at valve.	**1.00**	**EA**	**Sub**	**683**	**0**	**438**	**0**	**0**	**1,121**	**1,121**	
				2.07	*0.00*	*1.13*	*0.00*		*3.20*	*3.20*	
RSM 337119151030 Electrical Underground Ducts and Manholes, PVC, conduit with coupling, 1" diameter, schedule 40, installed by direct burial	50.00	LF	Sub	103	0	57	0	0	160	160	N

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
in slab or duct bank											
				53.76	*0.00*	*22.50*	*0.00*		*76.26*	*76.26*	
RSM 260519900120 Wire, copper, stranded, 600 volt, #10, type THW, in raceway	2.00	CLF	Sub	108	0	45	0	0	153	153	N
				134.40	*0.00*	*237.00*	*0.00*		*371.40*	*371.40*	
RSM 265623101170 High pressure sodium fixture, exterior, wall pack, 150 Watt, incl lamps	1.00	EA	Sub	134	0	237	0	0	371	371	N
				53.76	*0.00*	*26.00*	*0.00*		*79.76*	*79.76*	
RSM 260533182150 Pull boxes, sheet metal, type SC, raintight & weatherproof, 6" L x 6" W x 6" D, NEMA 3R	3.00	EA	Sub	161	0	78	0	0	239	239	N
				8.40	*0.00*	*7.25*	*0.00*		*15.65*	*15.65*	
RSM 260533171480 Outlet boxes, PVC, weatherproof blank cover, FS, 1 gang	1.00	EA	Sub	8	0	7	0	0	16	16	N
				16.80	*0.00*	*1.41*	*0.00*		*18.21*	*18.21*	
RSM 260533252560 Conduit fittings for rigid galvanized steel, nipples chase, plain, 3/4" diameter	10.00	EA	Sub	168	0	14	0	0	182	182	N
				3.50	*1.36*	*0.82*	*0.00*		*5.67*	*5.67*	
Conduit Feed Trench	**624.00**	**BCY**	**Sub**	**2,185**	**846**	**510**	**0**	**0**	**3,541**	**3,541**	
				0.62	*0.15*	*0.00*	*0.00*		*0.78*	*0.78*	
RSM 312316142850 Excavating, chain trencher, utility trench, common earth, 40 H.P., 24" wide, 42" deep, chain trencher, operator riding, includes backfill	200.00	LF	Sub	125	31	0	0	0	155	155	N
				237.84	*0.00*	*0.00*	*0.00*		*237.84*	*237.84*	
RSM 312316161030 Structural excavation for minor structures, bank measure, around obstructions, hand trimming	2.00	BCY	Sub	476	0	0	0	0	476	476	N
				28.85	*4.05*	*17.00*	*0.00*		*49.90*	*49.90*	
RSM 312323160200 Fill by borrow and utility bedding, for pipe and conduit, sand, dead or bank, excludes compaction	30.00	LCY	Sub	865	122	510	0	0	1,497	1,497	O
				11.83	*0.75*	*0.00*	*0.00*		*12.58*	*12.58*	
RSM 312323160500 Fill by borrow and utility bedding, for pipe and conduit, compacting bedding in trench	24.00	ECY	Sub	284	18	0	0	0	302	302	O
				4.07	*5.69*	*0.00*	*0.00*		*9.75*	*9.75*	
HNC 312323145520 Backfill, structural, 6" lifts, backfill around foundation, with dozer	50.00	LCY	Sub	203	284	0	0	0	488	488	O
				5.81	*9.78*	*0.00*	*0.00*		*15.59*	*15.59*	
RSM 312323236200 Compaction, 2 passes, 6" lifts, towed vibrating roller	40.00	ECY	Sub	232	391	0	0	0	623	623	O
				1,414.74	*0.00*	*3,000.00*	*0.00*		*4,414.74*	*4,414.74*	
Upgrade " FCQ7-q" Bucket	**1.00**	**EA**	**Sub**	**1,415**	**0**	**3,000**	**0**	**0**	**4,415**	**4,415**	
				1,414.74	*0.00*	*3,000.00*	*0.00*		*4,414.74*	*4,414.74*	
USE Upgrade "FCQ7-q" Bucket	1.00	EA	Sub	1,415	0	3,000	0	0	4,415	4,415	M
				2,086.74	*0.00*	*3,000.00*	*0.00*		*5,086.74*	*5,086.74*	

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
Disconnect at Valve Actuator	**1.00**	**EA**	**Sub**	**2,087**	**0**	**3,000**	**0**	**0**	**5,087**	**5,087**	
				672.00	*0.00*	*1,000.00*	*0.00*		*1,672.00*	*1,672.00*	
USR Disconnect Stand, Unistrut.	1.00	EA	Sub	672	0	1,000	0	0	1,672	1,672	O
				1,414.74	*0.00*	*2,000.00*	*0.00*		*3,414.74*	*3,414.74*	
HNC 262416304870 Panelboards, assembled, 3 ph, 3 wire, main lugs, 277/480 V, 225 A, 32 - 20 amp breakers	1.00	EA	Sub	1,415	0	2,000	0	0	3,415	3,415	N
				5,574.30	*150.83*	*2,500.00*	*0.00*		*8,225.13*	*8,225.13*	
Relocate Existing Electrical underground	**1.00**	**EA**	**Sub**	**5,574**	**151**	**2,500**	**0**	**0**	**8,225**	**8,225**	
				139.36	*3.77*	*0.00*	*0.00*		*143.13*	*143.13*	
USR Standard Electrical Crew	40.00	HR	Sub	5,574	151	0	0	0	5,725	5,725	N
				0.00	*0.00*	*2,500.00*	*0.00*		*2,500.00*	*2,500.00*	
USR REM Relocate Existing Electrical Materials	1.00	EA	Sub	0	0	2,500	0	0	2,500	2,500	M
				2,564.23	*0.00*	*1,049.76*	*0.00*		*3,613.99*	*3,613.99*	
Relocate conduit on the face of the Dam	**1.00**	**EA**	**Sub**	**2,564**	**0**	**1,050**	**0**	**0**	**3,614**	**3,614**	
				2.22	*0.00*	*0.00*	*0.00*		*2.22*	*2.22*	
RSM 260505100100 Conduit, rigid galvanized steel, 1/2" to 1" diameter, electrical demolition, remove conduit to 15' high, including fittings & hangers	200.00	LF	Sub	444	0	0	0	0	444	444	N
				8.27	*0.00*	*4.18*	*0.00*		*12.45*	*12.45*	
RSM 260533131800 Rigid galvanized steel conduit, 1" diameter, to 15' H, incl 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	200.00	LF	Sub	1,654	0	836	0	0	2,490	2,490	N
				48.87	*0.00*	*26.00*	*0.00*		*74.87*	*74.87*	
RSM 260519903020 Wire, copper, stranded, 600 volt, #12, type XHHW, in raceway	8.00	CLF	Sub	391	0	208	0	0	599	599	N
				2.34	*0.00*	*0.18*	*0.00*		*2.52*	*2.52*	
RSM 260519350035 Wire connector, screw type, insulated, #16 to #10	32.00	EA	Sub	75	0	6	0	0	81	81	N
				5,060.71	*2,943.99*	*43,604.90*	*0.00*		*51,609.59*	*51,609.59*	
Paving	**1.00**	**EA**	**Prime**	**5,061**	**2,944**	**43,605**	**0**	**0**	**51,610**	**51,610**	
				4.91	*2.54*	*80.03*	*0.00*		*87.48*	*87.48*	
8" Base Aggregate	**175.00**	**CY**	**Sub**	**859**	**445**	**14,005**	**0**	**0**	**15,308**	**15,308**	
				1.16	*0.60*	*18.90*	*0.00*		*20.66*	*20.66*	
RSM 321123232012 Base course drainage layers, aggregate base course for roadways and large paved areas, alternate method to figure base course, crushed stone, 3/4"maximum size, 9" deep	741.00	TON	Sub	859	445	14,005	0	0	15,308	15,308	N
				1.09	*0.51*	*10.57*	*0.00*		*12.17*	*12.17*	
Asphalt Concrete	**2,800.00**	**SF**	**Sub**	**3,059**	**1,414**	**29,600**	**0**	**0**	**34,073**	**34,073**	
				0.15	*0.07*	*1.48*	*0.00*		*1.70*	*1.70*	
RSM 321216140600 Asphaltic concrete, parking lots & driveways, binder course, 4" thick, no asphalt hauling included	20,000.00	SF	Sub	3,059	1,414	29,600	0	0	34,073	34,073	O

Description	Quantity	UOM	Contractor	DirectLabor	DirectEQ	DirectMatl	DirectSubBid	DirectUserCost	DirectCost	DirectCost	CostOverride
				16.34	*15.50*	*0.00*	*0.00*		*31.84*	*31.84*	
Asphalt Pavment Hauling	**70.00**	**TON**	**Sub**	**1,144**	**1,085**	**0**	**0**	**0**	**2,229**	**2,229**	
				45.74	*43.40*	*0.00*	*0.00*		*89.15*	*89.15*	
USR Haul Asphalt Pavement	25.00	HR	Sub	1,144	1,085	0	0	0	2,229	2,229	N
				0.00	*0.00*	*0.00*	*5,000.00*		*5,000.00*	*5,000.00*	
Misc Utility repair or relocate	**1.00**	**EA**	**Prime**	**0**	**0**	**0**	**5,000**	**0**	**5,000**	**5,000**	
				0.00	*0.00*	*0.00*	*5,000.00*		*5,000.00*	*5,000.00*	
USR Utility repair and relocate.	1.00	EA	Prime	0	0	0	5,000	0	5,000	5,000	Sb

Construction Schedule
The Dalles East Fish Ladder, Auxiliary Water Backup System
90 Percent Design Documentation Report

ID	Task Name	Duration	Start	Finish	Predeces
1					
2	Construction Contract NTP	0 days	Mon 6/1/15	Mon 6/1/15	
3	Preconstruction Submittals	60 days	Mon 6/1/15	Fri 8/21/15	2
4	Cofferdam Engineering	30 days	Mon 6/1/15	Fri 7/10/15	2
5	Government Approval of Cofferdam Design	20 days	Mon 7/13/15	Fri 8/7/15	4
6	Offsite Fabrication of Cofferdam	60 days	Mon 8/10/15	Fri 10/30/15	5
7	Offsite Fabrication Pipe & Pipe Fittings	60 days	Mon 8/24/15	Fri 11/13/15	3
8	Offsite Fabrication, Trash Rack & Trash Rake	60 days	Mon 8/24/15	Fri 11/13/15	3
9	Procurement of Special Order Butterfly Valve.	90 days	Mon 8/24/15	Fri 12/25/15	3
10					
11	Mobilization	12 days	Mon 11/16/15	Tue 12/1/15	6
12	In Water Work Window 2015 to 2016	65 days	Tue 12/1/15	Mon 2/29/16	
13	Construct Cofferdam	20 days	Wed 12/2/15	Tue 12/29/15	12SS+
14	Pump Water, Seal Leaks Cofferdam	5 days	Wed 12/30/15	Tue 1/5/16	13
15					
16					
17	Dewater AWS Chamber	5 days	Tue 12/1/15	Mon 12/7/15	12SS
18	Set-up Scaffolding and Rigging	5 days	Tue 12/8/15	Mon 12/14/15	17
19	Sawcut Concrete	10 days	Tue 12/15/15	Mon 12/28/15	18
20	Construct Discharge Piping in AWS Chamber.	40 days	Tue 12/29/15	Mon 2/22/16	19
21	Demobe from AWS Chamber and Junction Pool	5 days	Tue 2/23/16	Mon 2/29/16	20
22					
23	Set-up for concrete tunnling	5 days	Wed 12/2/15	Tue 12/8/15	11
24	Concrete Tunneling	25 days	Wed 1/6/16	Tue 2/9/16	14,23
25	Install Rail System Through Tunnel	5 days	Wed 2/10/16	Tue 2/16/16	24
26	Install 10' dia pipe through dam	10 days	Wed 2/17/16	Tue 3/1/16	25
27	Pressure Grout Pipe Dam	10 days	Wed 3/2/16	Tue 3/15/16	26
28	Seal Grout Holes, coating repairs	5 days	Wed 3/16/16	Tue 3/22/16	27
29					
30	Install Butterfly Valve	5 days	Wed 3/23/16	Tue 3/29/16	28,9
31					
32	Construct Trashrack Guide	40 days	Wed 1/6/16	Tue 3/1/16	14
33	Install Emergency Closure Gate	8 days	Wed 3/2/16	Fri 3/11/16	32
34	Install 6" Vent Pipe	5 days	Mon 3/14/16	Fri 3/18/16	33,8
35	Install Trash Rack	5 days	Mon 3/21/16	Fri 3/25/16	34
36	Install Trash Rake	5 days	Mon 3/28/16	Fri 4/1/16	35
37					
38					
39	Utility Locates, Disconnect Affected site utilities	10 days	Wed 11/18/15	Tue 12/1/15	11SS+
40					
41	Drill and Inject Expansive Grout for Rock Removal	10 days	Wed 3/30/16	Tue 4/12/16	30,39
42	10' Dia Pipe Excavation STA 0+70 to STA 1+50	10 days	Wed 4/13/16	Tue 4/26/16	41
43	Place Bedding to BOP	1 day	Wed 4/27/16	Wed 4/27/16	42
44	10'dia Pipe Install	10 days	Thu 4/28/16	Wed 5/11/16	43
45	Backfill/Compact	3 days	Thu 5/12/16	Mon 5/16/16	44
46					
47	10' Dia Pipe Excavation STA 0+70 to 2+20	5 days	Tue 5/17/16	Mon 5/23/16	45
48	Place Bedding to BOP	1 day	Tue 5/24/16	Tue 5/24/16	47
49	10'dia and WYE Pipe Install	10 days	Wed 5/25/16	Tue 6/7/16	48
50	Backfill.compact STA 0+70 to 2+20	3 days	Wed 6/8/16	Fri 6/10/16	49
51					
52					
53					
54	7.5' Dia Pipe Excavation 2+20 to 2+50	8 days	Mon 6/13/16	Wed 6/22/16	50
55	Place Bedding	1 day	Thu 6/23/16	Thu 6/23/16	54
56	7.5'dia Pipe Install	10 days	Fri 6/24/16	Thu 7/7/16	55
57	Backfill/compact	3 days	Fri 7/8/16	Tue 7/12/16	56
58					
59	Site Restoration, Paving, Restore Utilities	30 days	Wed 7/13/16	Tue 8/23/16	57
60					
61	In Water Work Window 2016 to 2017	64 days	Thu 12/1/16	Tue 2/28/17	
62	Remove Cofferdam	10 days	Thu 12/1/16	Wed 12/14/16	61SS
63	Divers Install Preditor Deflector Panels	10 days	Thu 12/15/16	Wed 12/28/16	62

Page 1

The Dalles East Fish Ladder Auxiliary Water Backup System

90 Percent Design Documentation Report

APPENDIX H

Plates

US Army Corps
of Engineers
Portland District

THE DALLES LOCK AND DAM
NORTH-EAST FISH LADDER
BACKUP AUXILIARY WATER SUPPLY

THIS PROJECT WAS DESIGNED BY THE PORTLAND DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS OR SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER 1110-1-8152 AND INDICATE OFFICIAL RECOMMENDATION AND APPROVAL OF ALL THE DRAWINGS IN THIS SET.

BRIAN S. KAMISATO, P.E.
CHIEF, DESIGN BRANCH

LANCE A. HELWIG, P.E.
CHIEF, ENGINEERING & CONSTRUCTION DIVISION

JOHN W. EISENHAUER, P.E.
COLONEL, CORPS OF ENGINEERS
DISTRICT COMMANDER

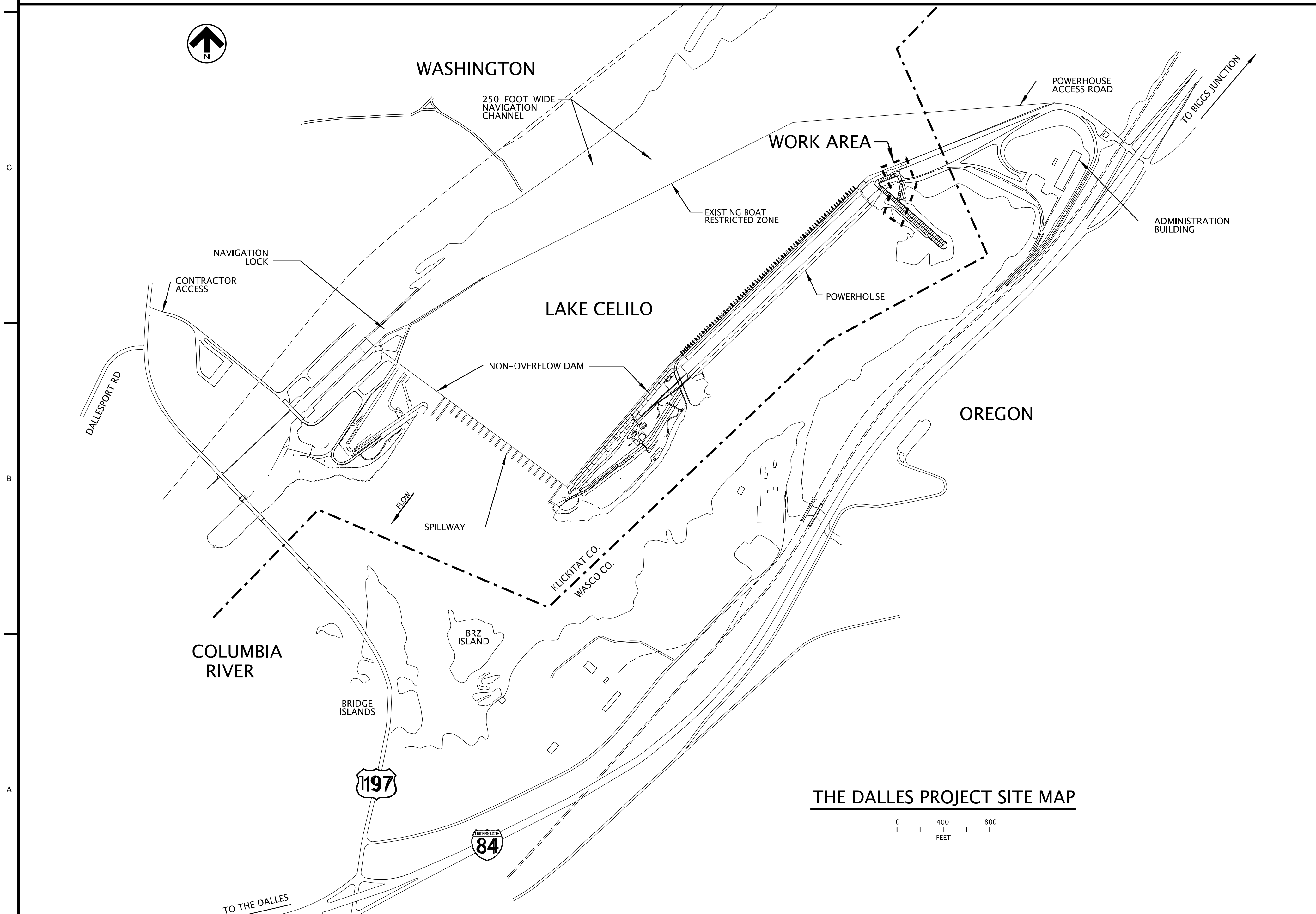
DATE: ____________________

SOLICITATION NUMBER:

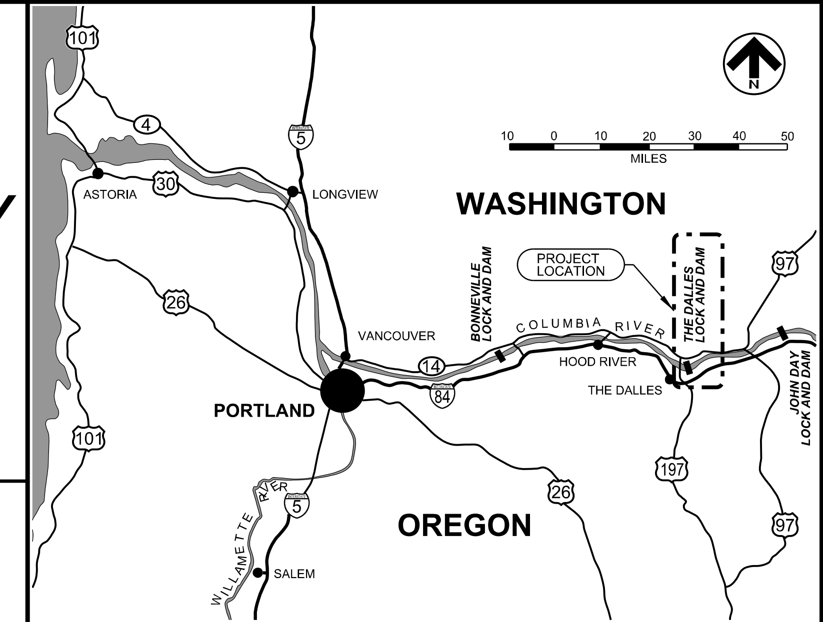
US ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
DDR - BACKUP AUXILLARY WATER SUPPLY

SOLICITATION NUMBER:
DATE:



PROJECT SITE MAP



LOCAL VICINITY MAP

PROJECT PHOTO

THIS PROJECT WAS DESIGNED BY THE PORTLAND DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS OR SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER 1110-1-8152 AND INDICATE OFFICIAL RECOMMENDATION AND APPROVAL OF ALL THE DRAWINGS IN THIS SET.

SUBMITTED

X
CHIEF, DESIGN BRANCH

SUBMITTED

X
CHIEF, ENGINEERING & CONSTRUCTION DIVISION

APPROVED

X
COLONEL, CORPS OF ENGINEERS
DISTRICT COMMANDER

US Army Corps of Engineers
PORTLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: | DATE: ISSUE DATE
DWN BY: | CKD BY: | SOLICITATION NO.: SOLICITATION NUMBER
SUBMITTED BY: | CONTRACT NO.: CONTRACT NUMBER
PLOT SCALE: | PLOT DATE: 1/7/2014 | DRAWING NUMBER:
SIZE: SHT SIZE | FILE NAME: DDF1.102_G-002XX.dgn

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GENERAL
VICINITY MAP
LOCATION MAP

SHEET IDENTIFICATION
G-002
SHEET 0 OF 0

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DDF1.102_G-002XXX.dgn	G-001	2	GENERAL - VICINITY MAP - LOCATION MAP		1/7/2014
DDF1.102_G-003XXX.dgn	G-002	3	GENERAL - INDEX TO DRAWINGS		1/7/2014
DFF1.XXX_G-101XXX.dgn	G-101	4	GENERAL - MAIN AUXILLARY WATER SUPPLY PIPE - PROJECT PLAN VIEW		1/7/2014
DFF1.XXX_G-102XXX.dgn	G-102	5	GENERAL - MAIN AUXILLARY WATER SUPPLY PIPE - INTAKE		1/7/2014
DFF1.XXX_G-103XXX.dgn	G-103	6	GENERAL - MAIN AUXILLARY WATER SUPPLY PIPE - SECTION - START OF CONDUIT		1/7/2014
DFF1.XXX_G-104XXX.dgn	G-104	7	GENERAL - MAIN AUXILLARY WATER SUPPLY PIPE - SECTION - PARKING LOT		1/7/2014
DFF1.XXX_G-105XXX.dgn	G-105		GENERAL - MAIN AUXILLARY WATER SUPPLY PIPE - SECTION - AWS DISCHARGE		1/7/2014
					1/7/2014
DFF1.XXX_S-201XXX.dgn	S-201	8	STRUCTURAL - GATE GUIDE - ELEVATION AND SECTIONS		1/7/2014
DFF1.XXX_S-202XXX.dgn	S-202	9	STRUCTURAL - CONCRETE PIERS - SECTIONS AND DETAILS		1/7/2014
DFF1.XXX_S-901XXX.dgn	S-901	10	STRUCTURAL - CLOSURE GATE - ISOMETRIC		1/7/2014
DFF1.XXX_S-902XXX.dgn	S-902	11	STRUCTURAL - TRASHRACK - ISOMETRIC		1/7/2014
					1/7/2014
DFF1.XXX_M-401XXX.dgn	M-401	12	MECHANICAL - INTAKE - TRASH RAKE		1/7/2014
DFF1.XXX_M-402XXX.dgn	M-402	13	MECHANICAL - INTAKE - GATE WHEEL		1/7/2014
					1/7/2014
DFF1.XXX_E-101XXX.dgn	E-101	14	ELECTRICAL VALVE MOTOR, RELOCATIONS, SENSORS SITE PLAN		1/7/2014

US Army Corps of Engineers
PORTLAND DISTRICT

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GENERAL
INDEX TO DRAWINGS

SHEET IDENTIFICATION
G-003

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US Army Corps of Engineers®
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: G4ECHLLN
DWN BY: G4ECHLLN
CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE
PLOT DATE: 1/7/2014
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GENERAL
MAIN AUXILIARY WATER SUPPLY PIPE
PROJECT PLAN VIEW

SHEET IDENTIFICATION
G-101
SHEET OF

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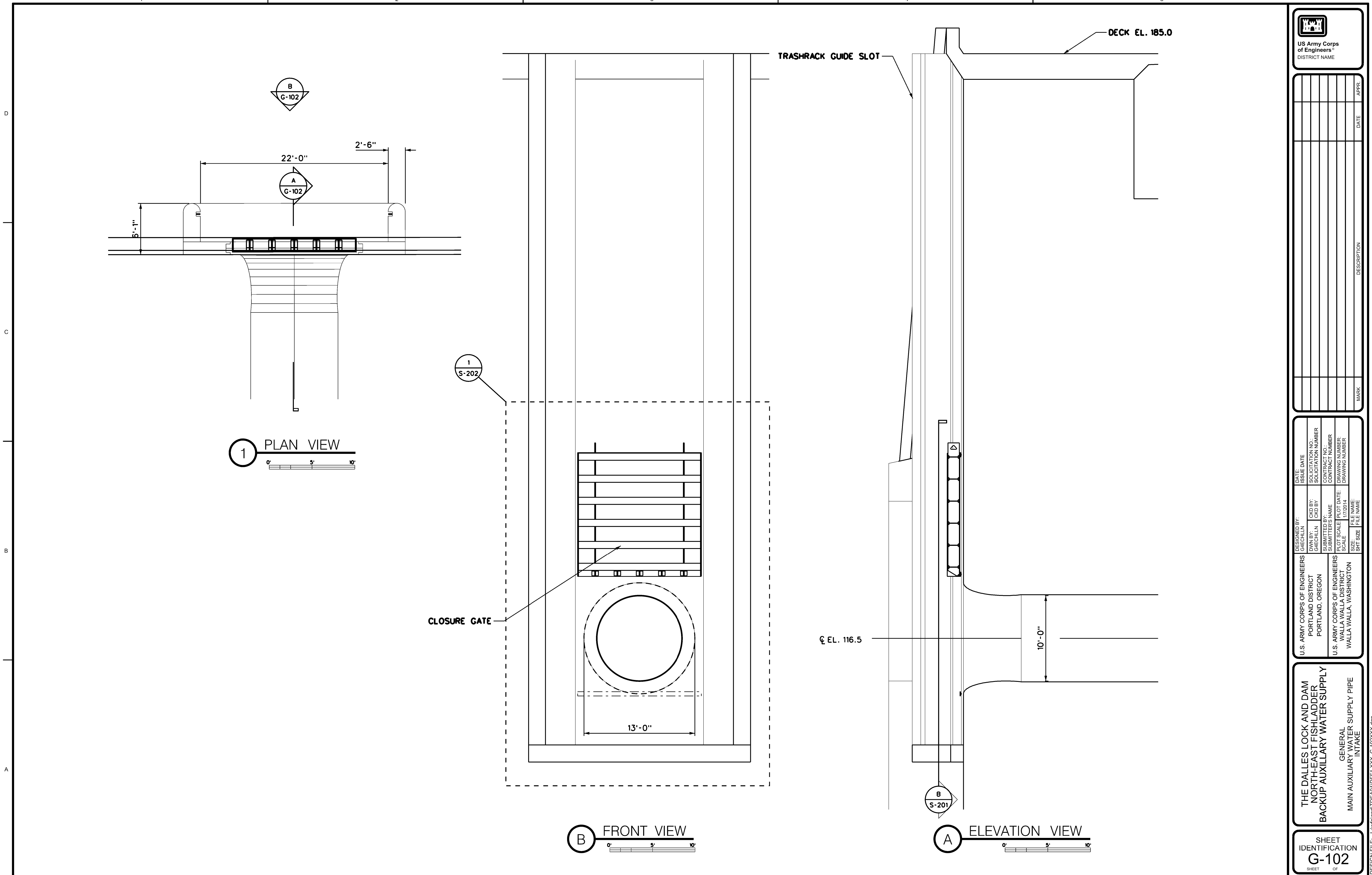
B
G-102
2'-6"
22'-0"
A
G-102
5'-1"
1 PLAN VIEW
0' 5' 10'
1
S-202
CLOSURE GATE
13'-0"
B FRONT VIEW
0' 5' 10'
TRASHRACK GUIDE SLOT
DECK EL. 185.0
℄ EL. 116.5
10'-0"
B
S-201
A ELEVATION VIEW
0' 5' 10'
US Army Corps of Engineers
DISTRICT NAME
MARK
DESCRIPTION
DATE
APPR
U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON
DESIGNED BY: G4ECHLLN
DWN BY: G4ECHLLN
CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE
PLOT DATE: 1/7/2014
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY
GENERAL
MAIN AUXILIARY WATER SUPPLY PIPE
INTAKE
SHEET IDENTIFICATION
G-102
DESIGN FILE: L:\wfo\cad\TDEA01DFF1.XXX_G-102XXX.dgn
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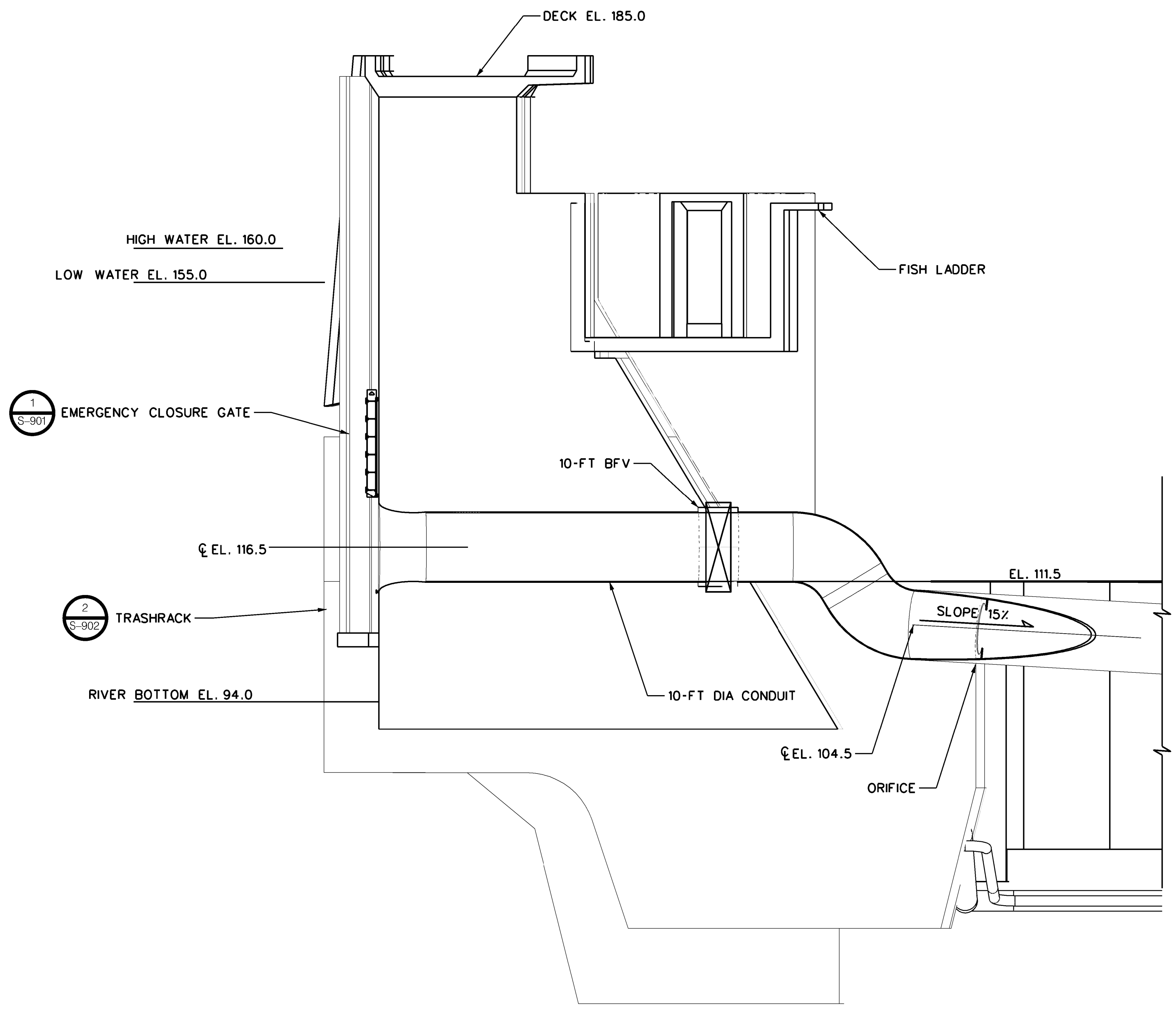
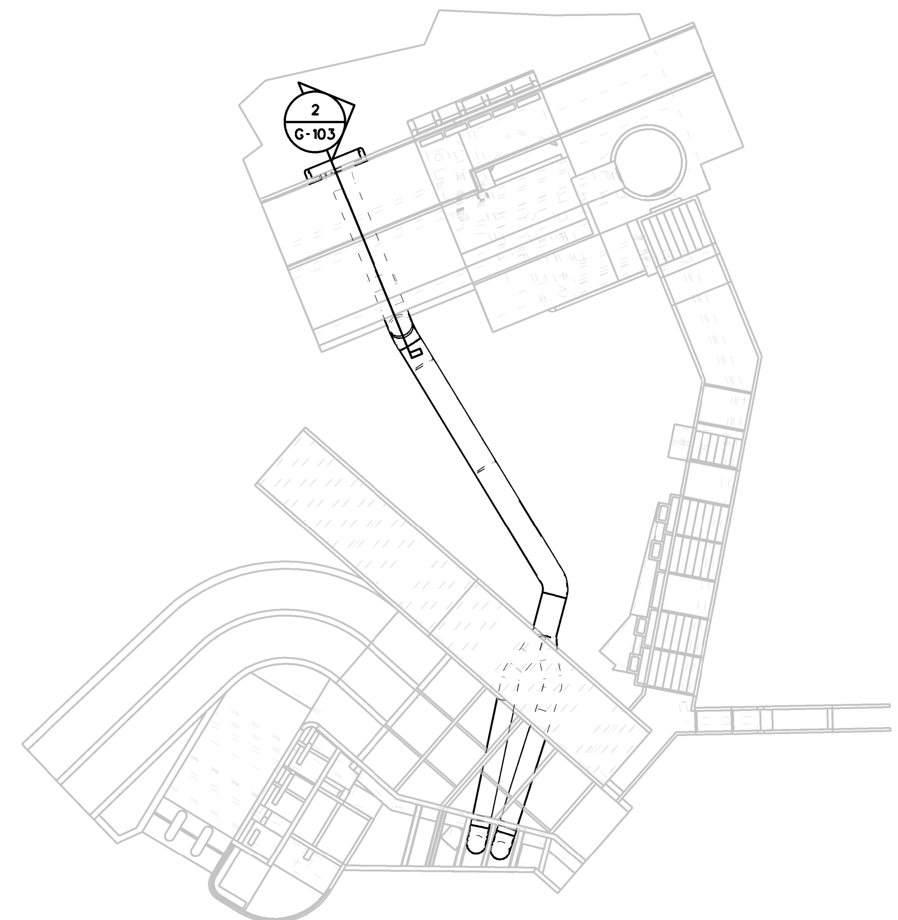
DATE AND TIME PLOTTED: 1/7/2014 12:58:21 PM
BY USERNAME: $USER$
SHEET NAME: $SHEETN$



2 SECTION: START OF CONDUIT



PLAN VIEW
NOT TO SCALE

US Army Corps of Engineers
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR

DESIGNED BY: G4ECHLLN
DWN BY: G4ECHLLN
CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE
PLOT DATE: 1/7/2014
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GENERAL
MAIN AUXILIARY WATER SUPPLY PIPE
SECTION - START OF CONDUIT

SHEET IDENTIFICATION
G-103
SHEET OF

DESIGN FILE: L:\wfo\cad\TDEA01\DFF1.XXX_G-103XXX.dgn

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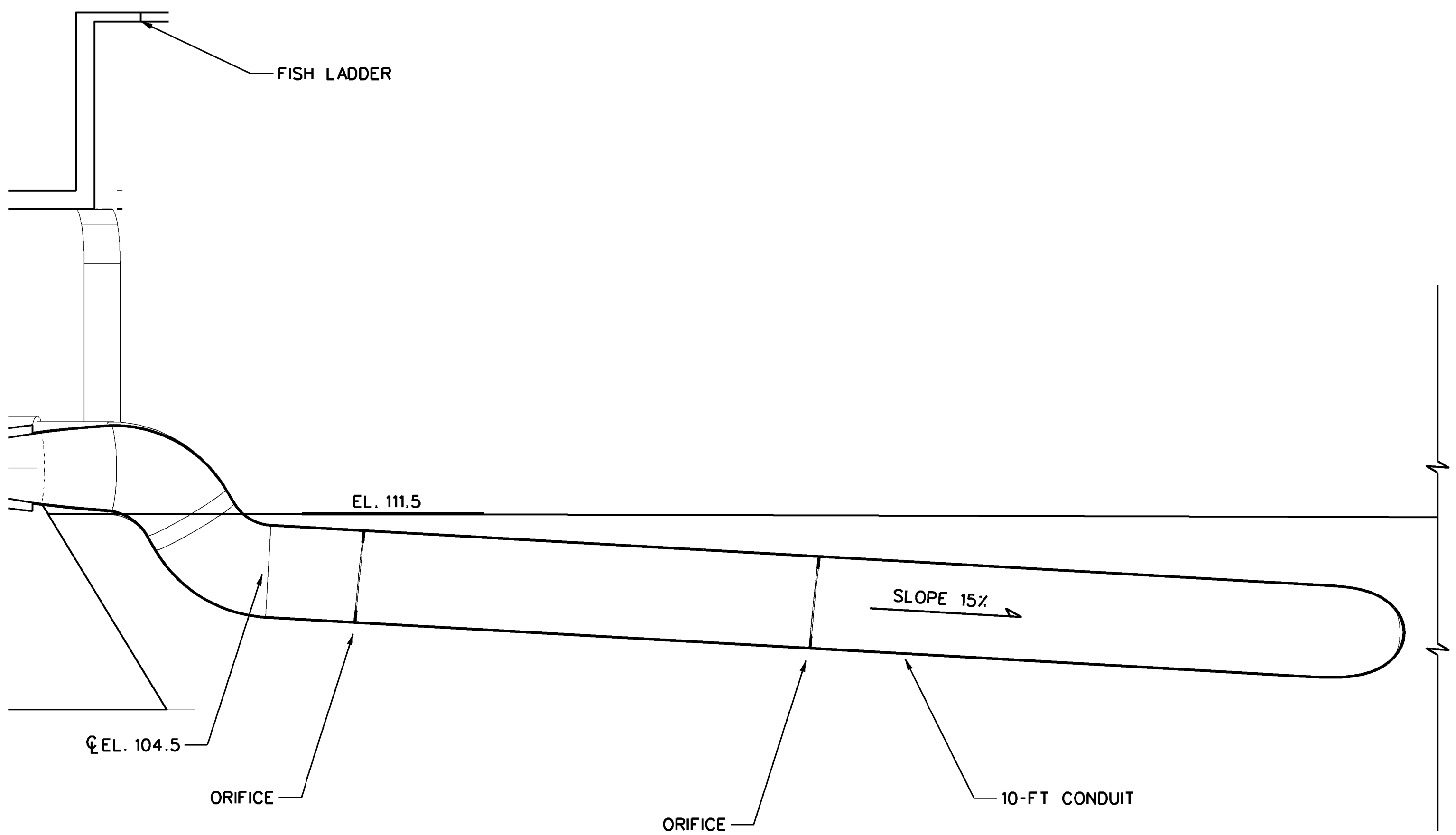
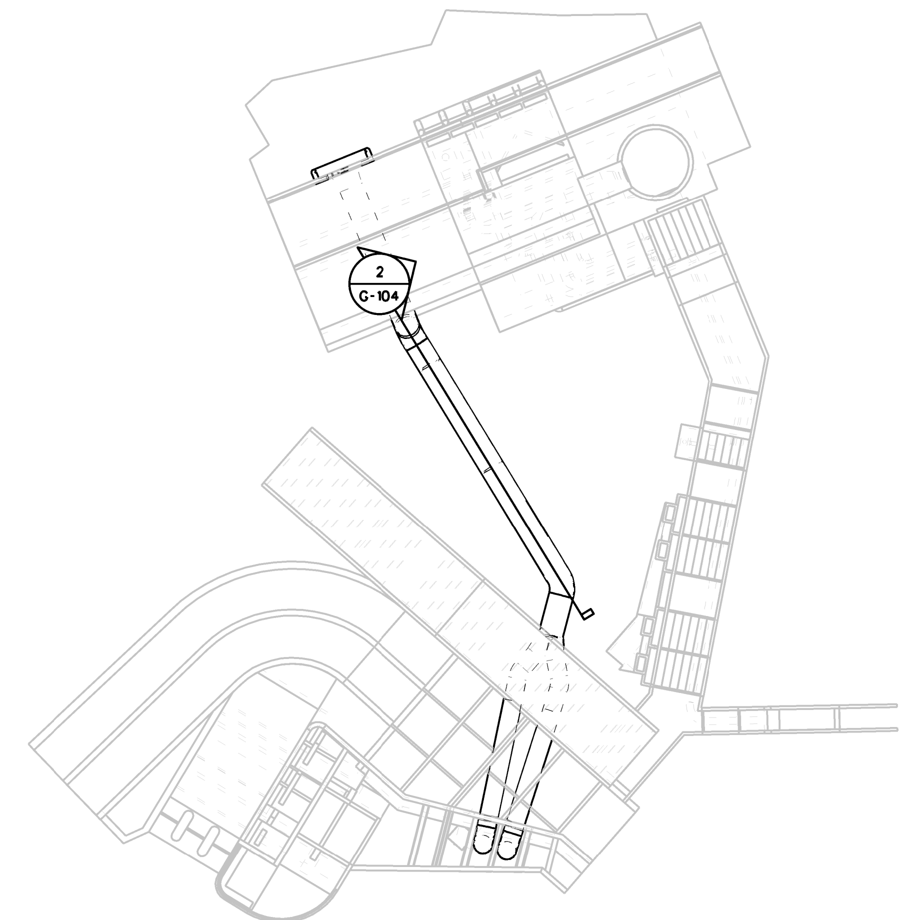


2 SECTION: 10.0' SECTION OF CONDUIT

0' 10' 20'



PLAN VIEW

US Army Corps of Engineers
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: G4ECHLLN | DATE: ISSUE DATE
DWN BY: G4ECHLLN | CKD BY: CKD BY | SOLICITATION NO.: SOLICITATION NUMBER
SUBMITTED BY: SUBMITTER'S NAME | CONTRACT NO.: CONTRACT NUMBER
PLOT SCALE: SCALE | PLOT DATE: 1/7/2014 | DRAWING NUMBER: DRAWING NUMBER
SIZE: SHT SIZE | FILE NAME: FILE NAME

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GENERAL
MAIN AUXILIARY WATER SUPPLY PIPE
SECTION - START OF CONDUIT

SHEET IDENTIFICATION
G-104
SHEET OF

DESIGN FILE: L:\wfo\cad\TDEA01\DFF1.XXX_G-104XXX.dgn

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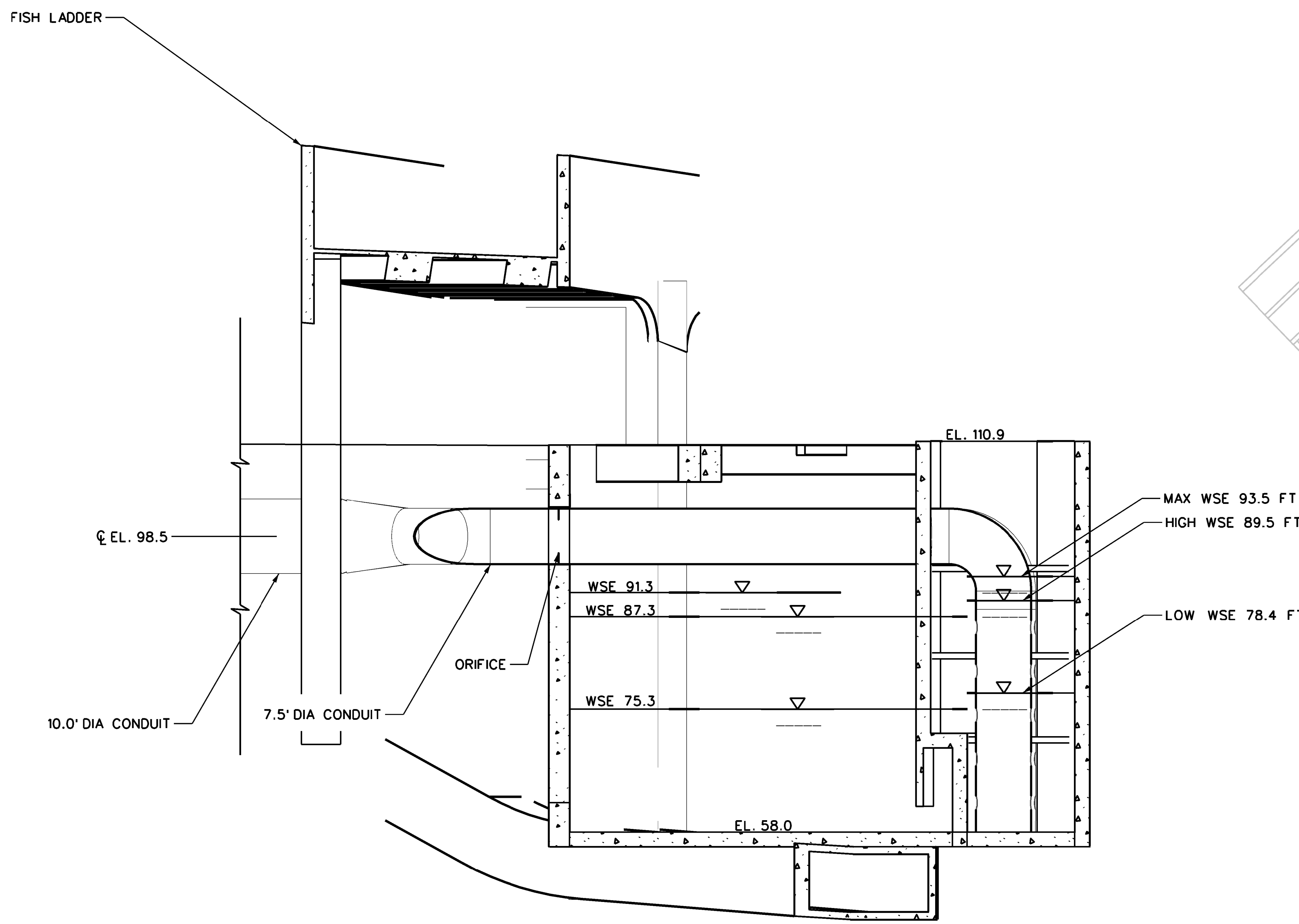
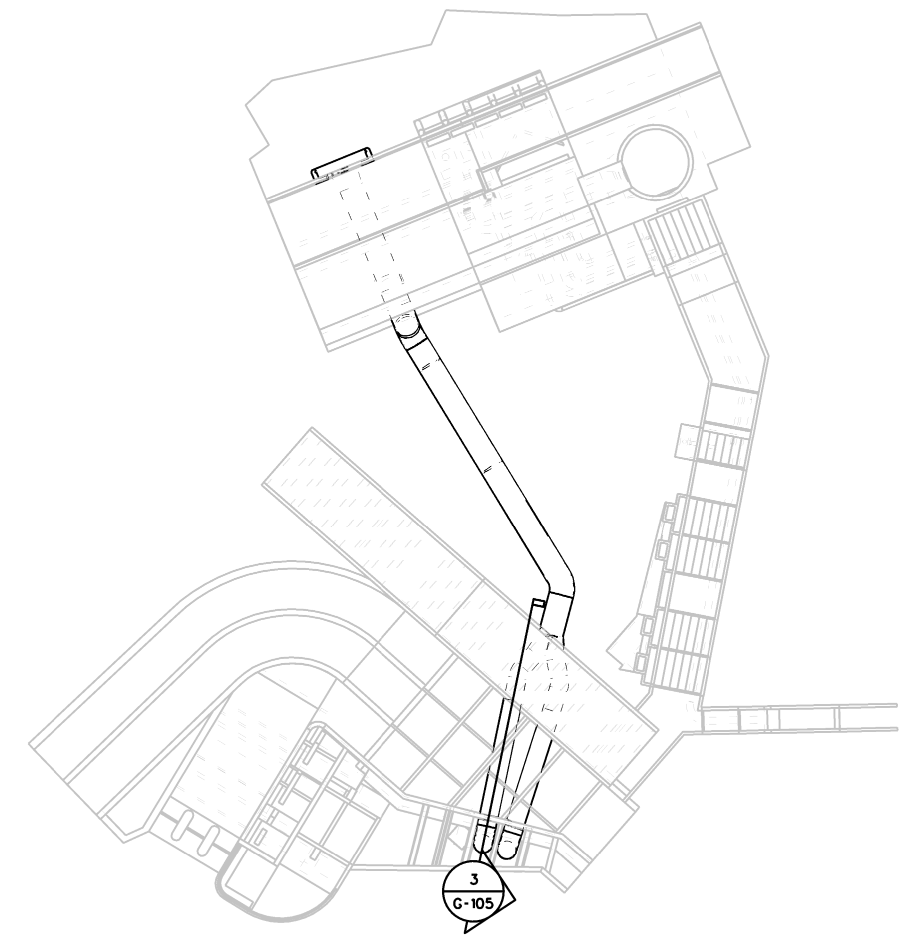


3 SECTION: 7.5-FT AND AWS CHAMBER DISCHARGE



PLAN VIEW

US Army Corps of Engineers®
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR

DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER
DESIGNED BY: G4ECHLLN
DWN BY: G4ECHLLN | CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE | PLOT DATE: 1/7/2014
SIZE: SHT SIZE | FILE NAME: FILE NAME

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

GENERAL
MAIN AUXILIARY WATER SUPPLY PIPE
SECTION - AWS CHAMBER DISCHARGE

SHEET IDENTIFICATION
G-105
SHEET OF

DESIGN FILE: L:\wfo\cad\TDEA01DFF1.XXX_G-105XXX.dgn

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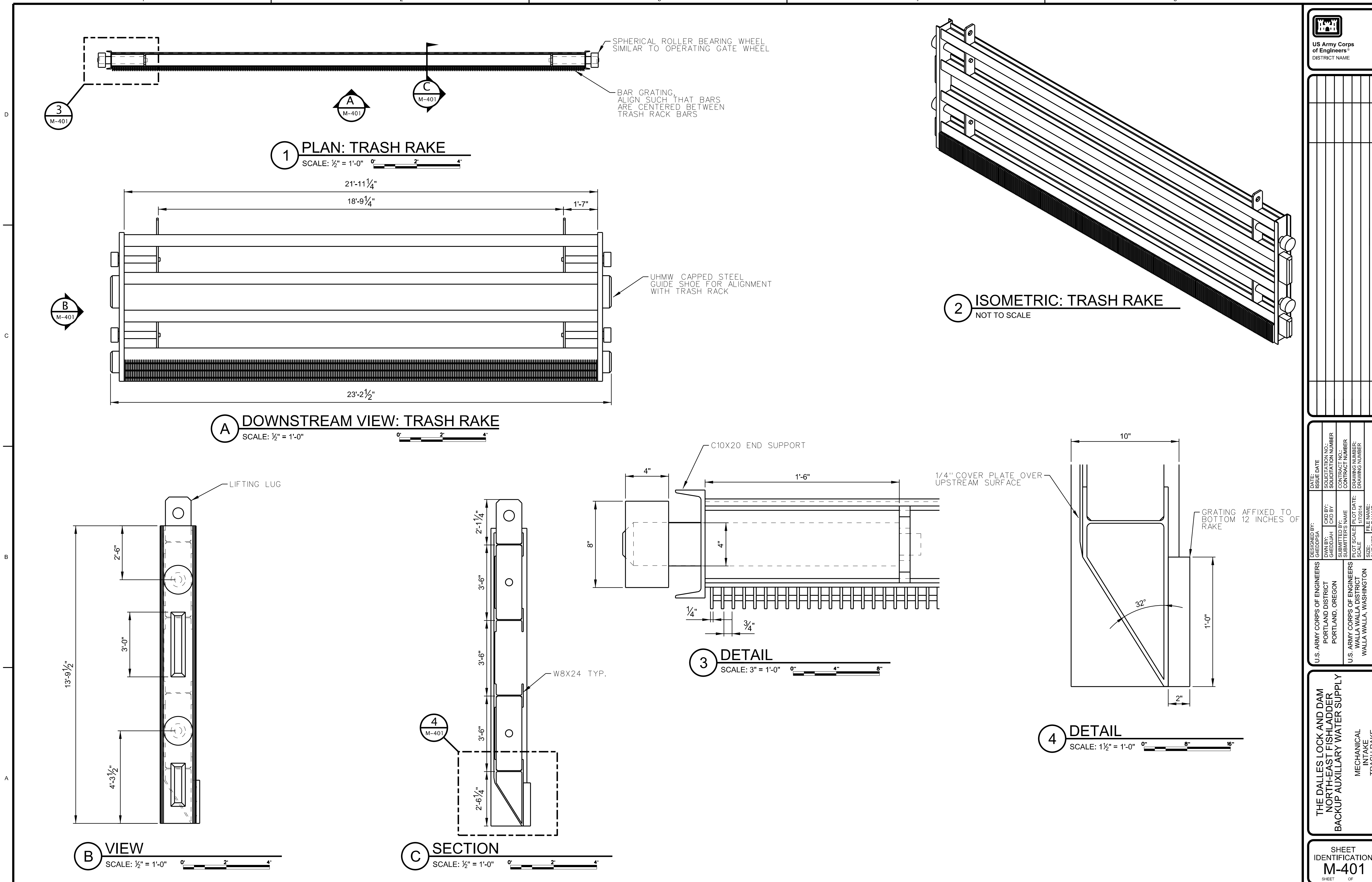

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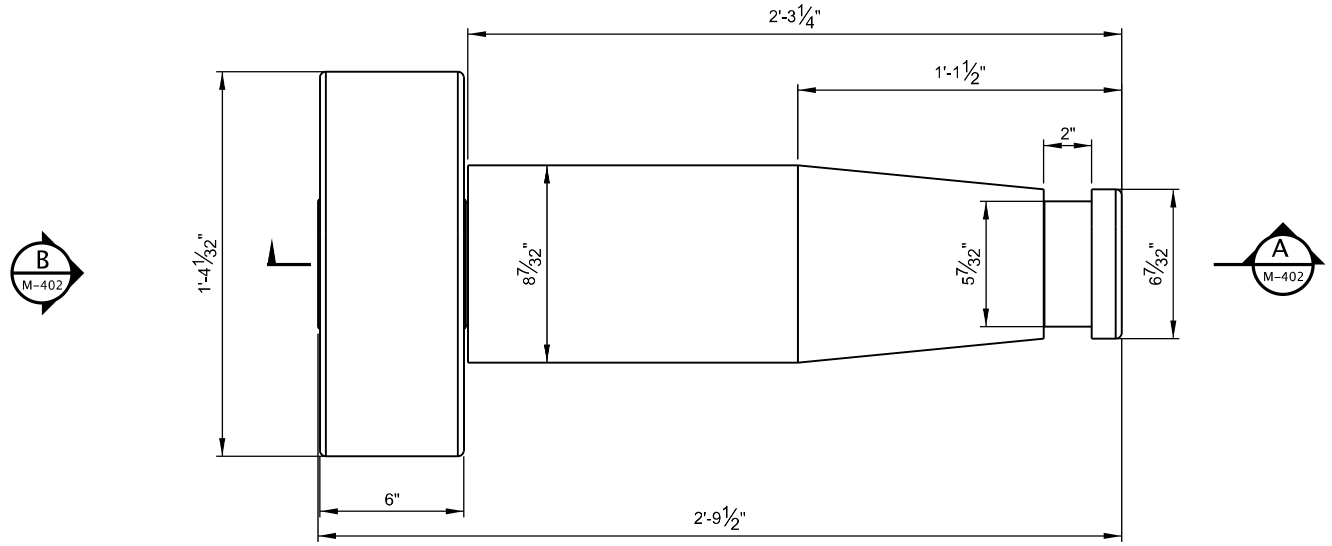
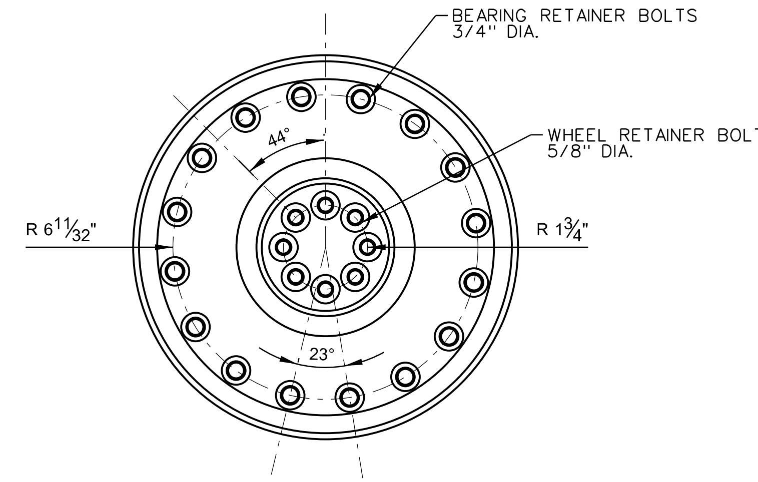
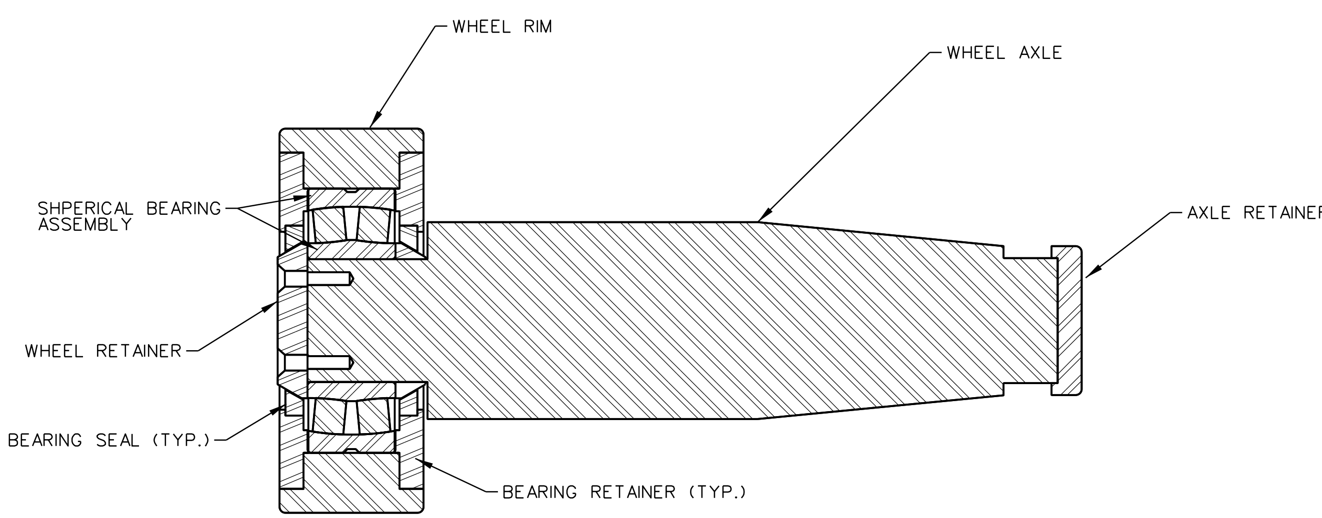


2 DETAIL: INTAKE GATE ROLLER WHEEL



B END VIEW:



A SECTION

US Army Corps of Engineers®
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: G4EDDPSA
DWN BY: G4EDDJAH
CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE
PLOT DATE: 1/7/2014
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

MECHANICAL
INTAKE
GATE WHEELS

SHEET IDENTIFICATION
M-402
SHEET OF

DESIGN FILE: L:\wfo\cad\TDEA01\DFF1.XXX_M-402XXX.dgn

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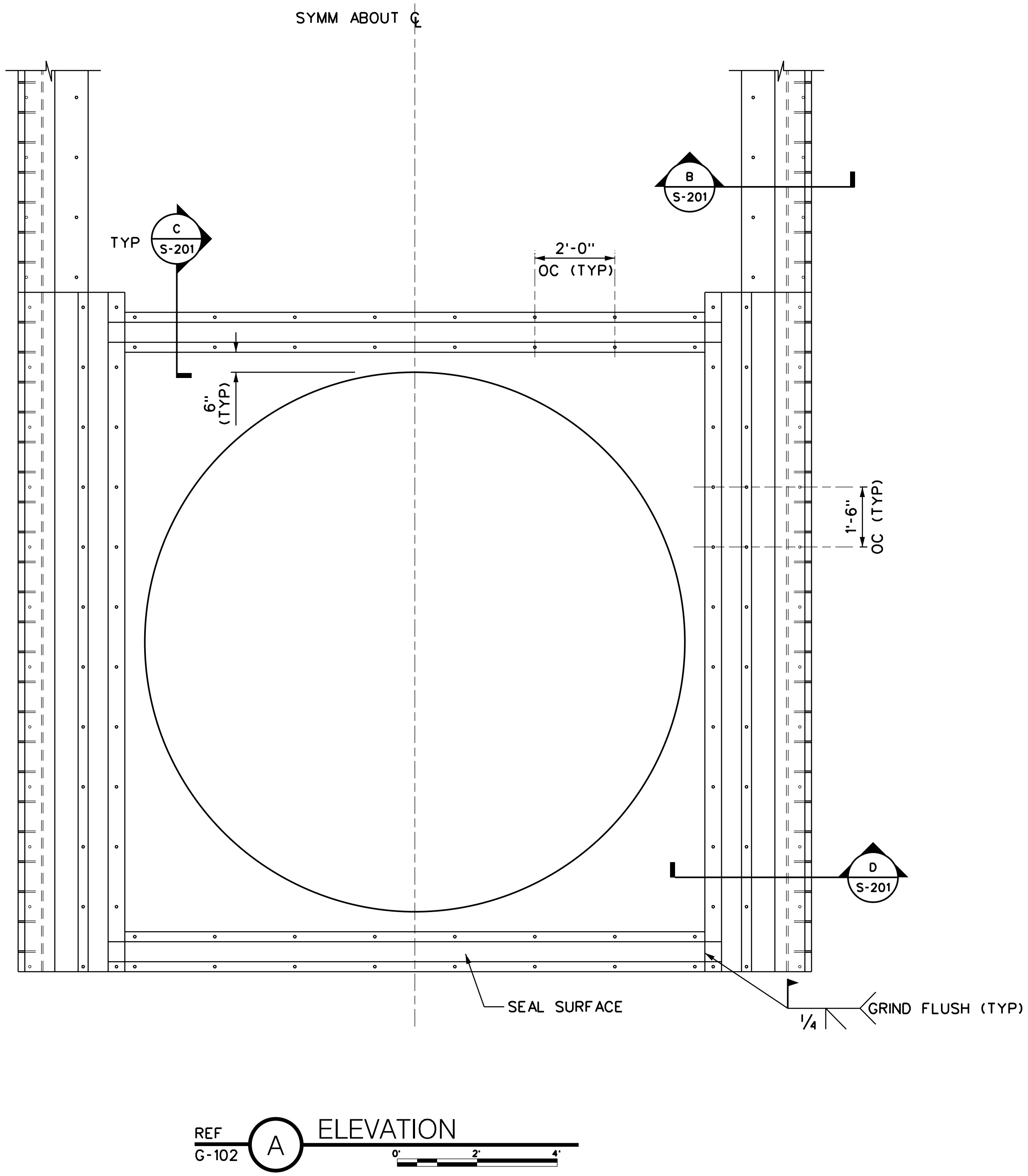

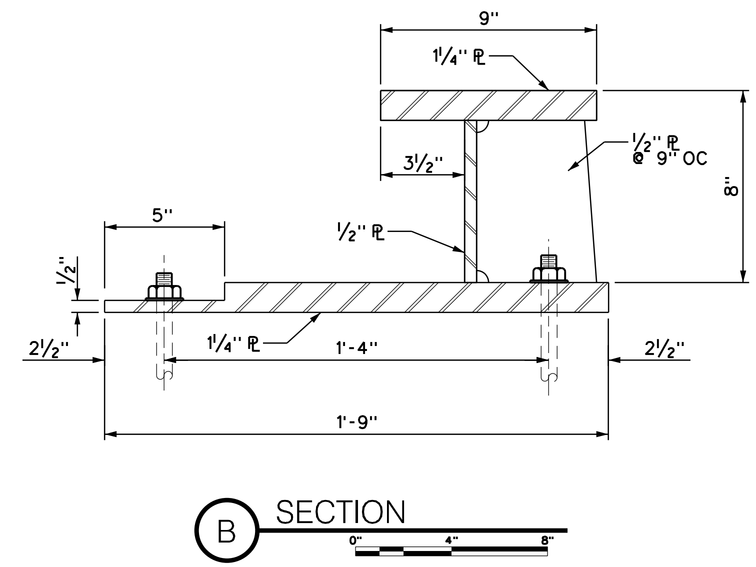

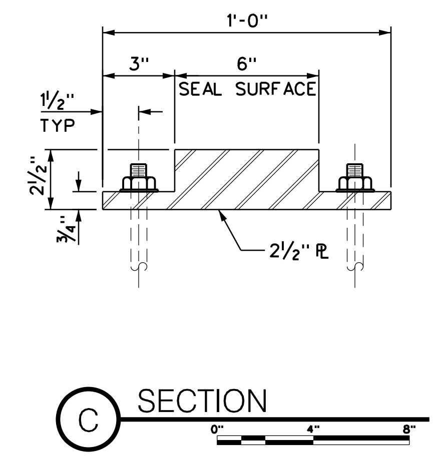

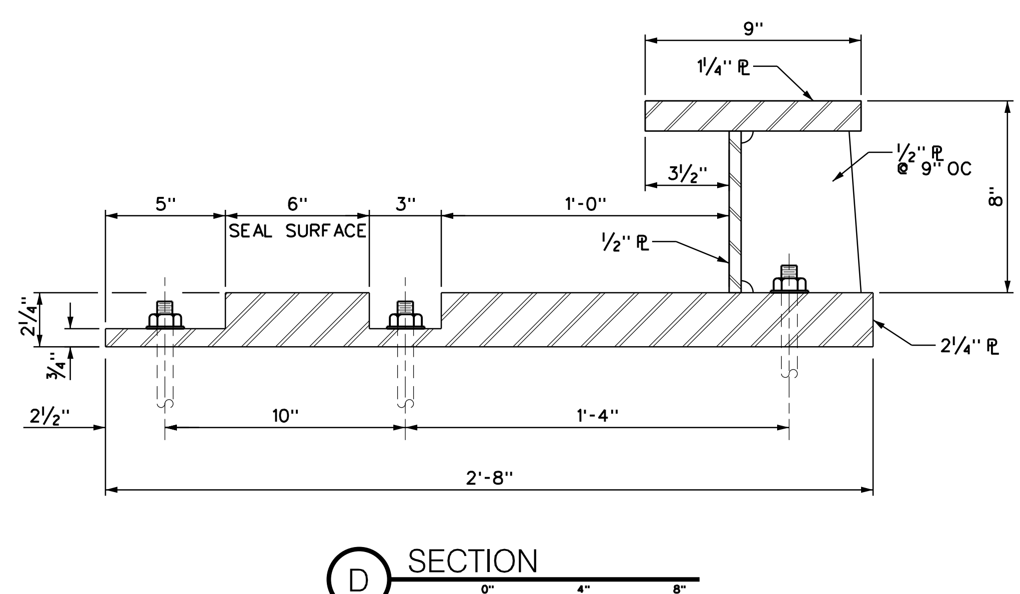

NOTES:

1. TWO TO THREE INCHES OF GROUT PLACED BEHIND GUIDES. GROUT TO BE CHOCKFAST RED OR APPROVED EQUAL.

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: G4EDDXXX | DATE: ISSUE DATE | SOLICITATION NO.: SOLICITATION NUMBER
DWN BY: SHENEFIELD | CKD BY: CKD BY | CONTRACT NO.: CONTRACT NUMBER
SUBMITTED BY: STEPHENS | DRAWING NUMBER: DRAWING NUMBER
PLOT SCALE: SCALE | PLOT DATE: 1/7/2014
SIZE: SHT SIZE | FILE NAME: FILE NAME

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

GATE GUIDE
ELEVATION AND SECTIONS

SHEET IDENTIFICATION
S-201
SHEET OF

DESIGN FILE: L:\wfo\cad\TDEA01\DFF1.XXX_S-201XXX.dgn

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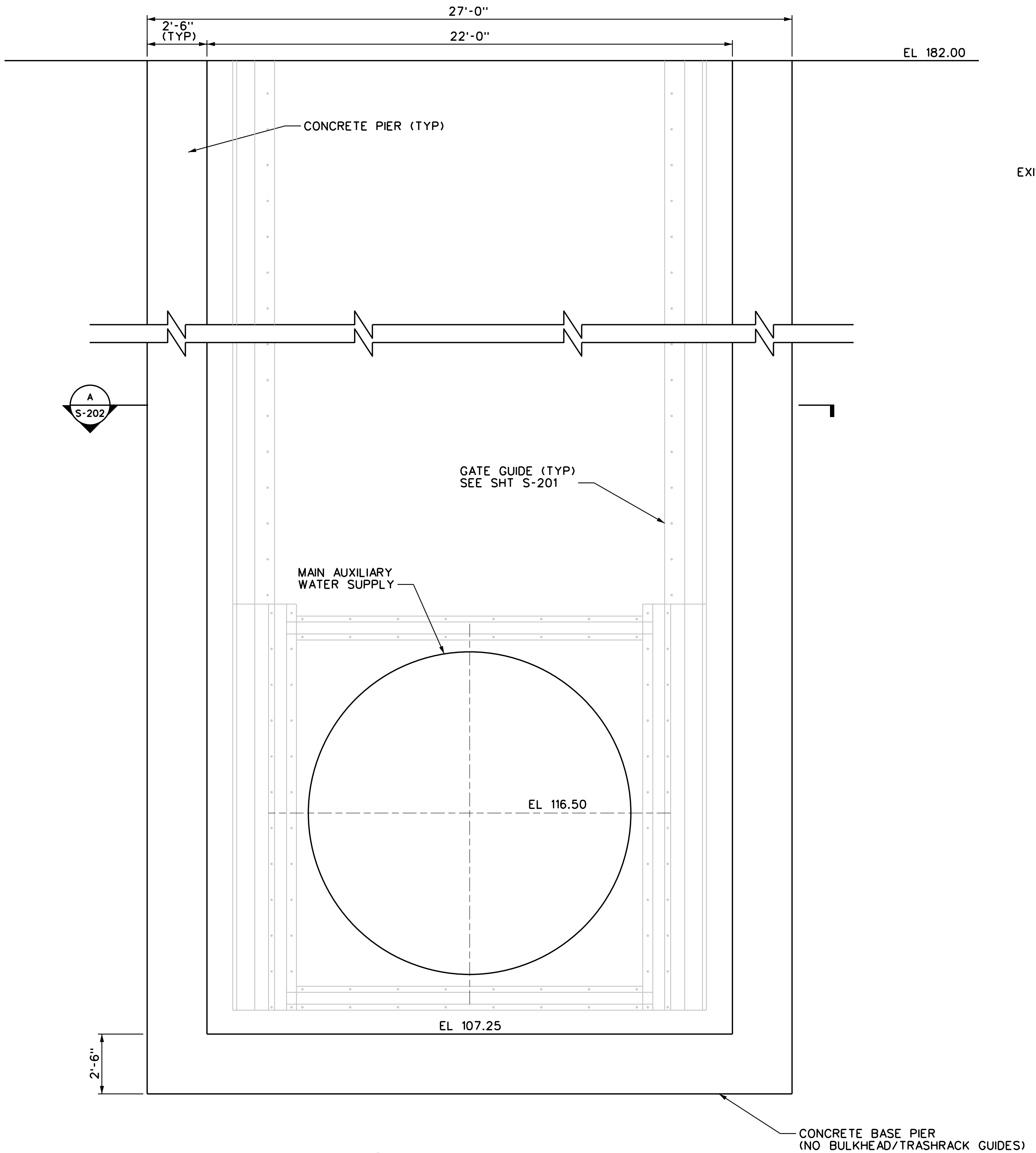
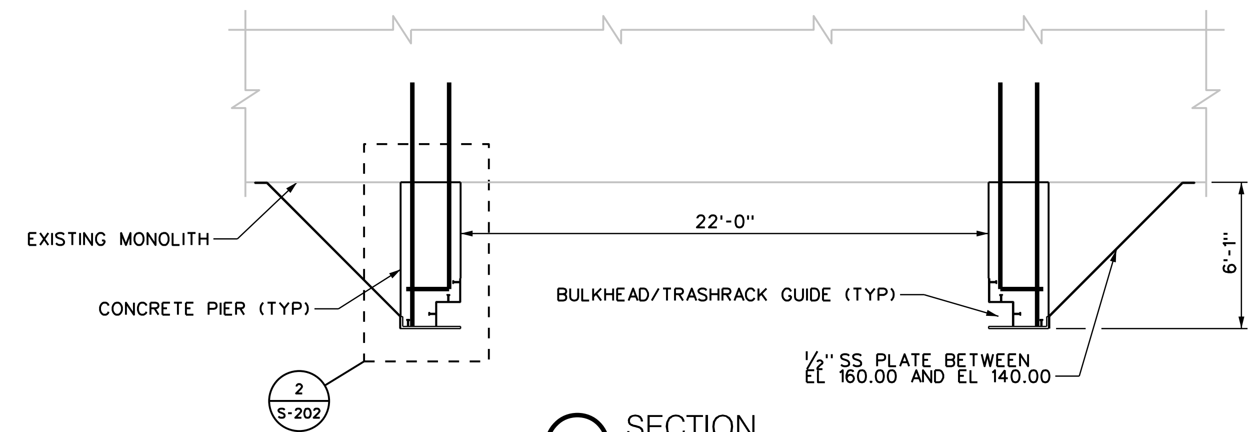


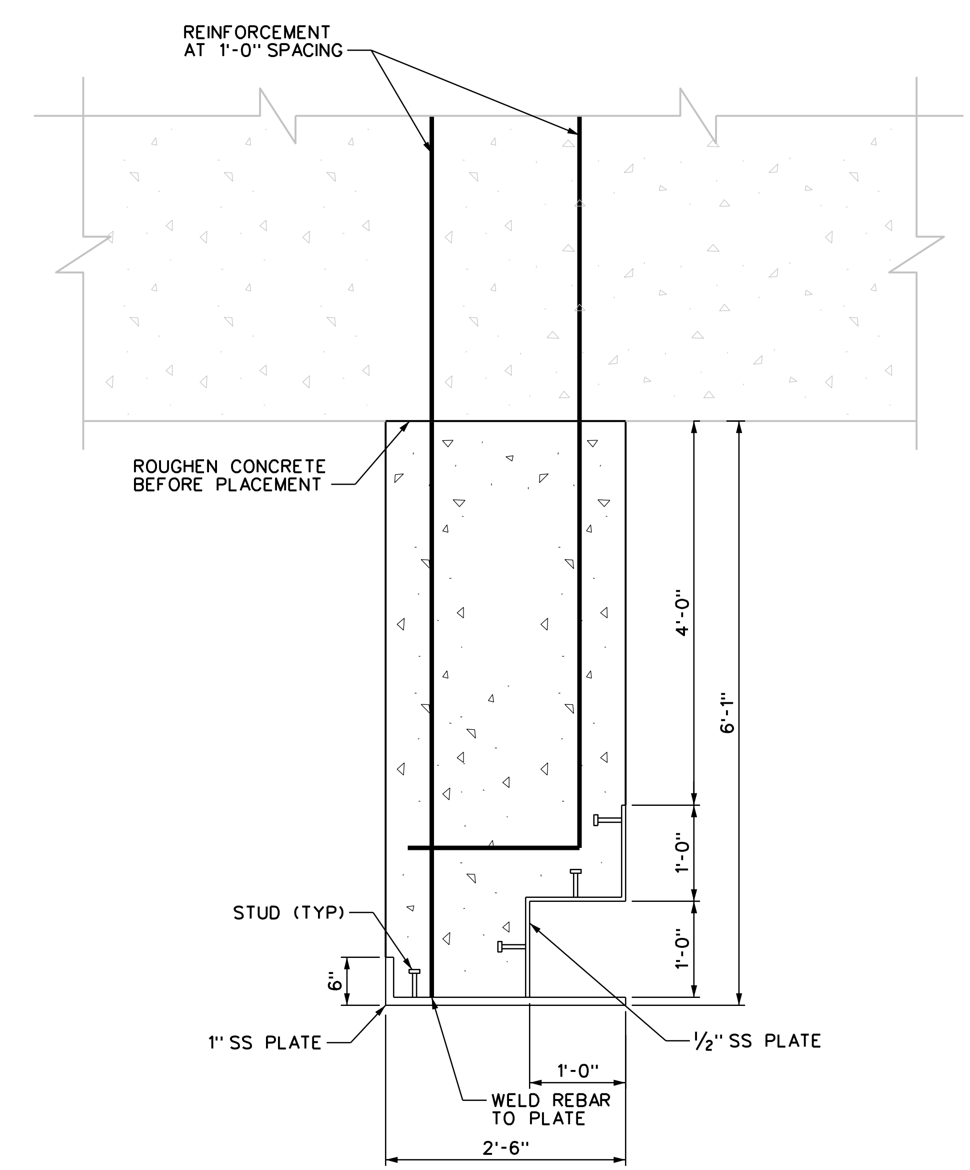
REF 1 DETAIL

CLOSURE GATE NOT SHOWN



A SECTION

CLOSURE GATE NOT SHOWN



2 DETAIL

US Army Corps of Engineers®
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: WALTON
DWN BY: SHENEFIELD
CKD BY: CKD BY
SUBMITTED BY: STEPHENS
PLOT SCALE: SCALE
PLOT DATE: 1/7/2014
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

CONCRETE PIERS
SECTIONS AND DETAILS

SHEET IDENTIFICATION
S-202
SHEET OF

DESIGN FILE: L:\wfo\cad\TDEA01DFF1.XXX_S-202XXX.dgn

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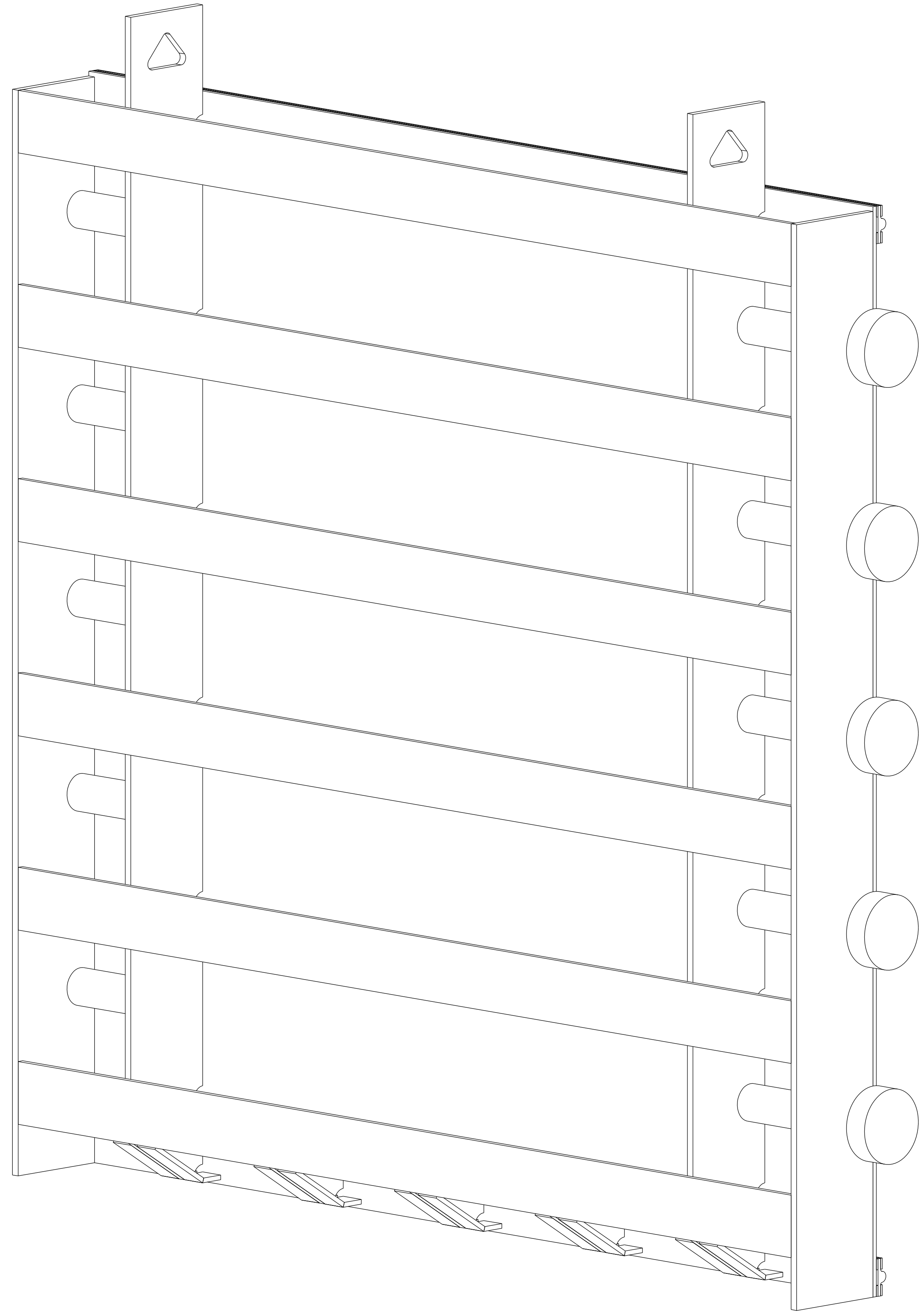

NOTES:

1. OVERALL STRUCTURAL GATE SIZE IS 14.5' x 14.5'.

2. APPROXIMATE TOTAL WEIGHT OF GATE IS 20,500 lbs.

US Army Corps of Engineers
DISTRICT NAME

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

STRUCTURAL
CLOSURE GATE
ISOMETRIC

SHEET IDENTIFICATION
S-901

PLOT DATE: 1/7/2014

DESIGN FILE: L:\wfo\cad\TDEA01\DFF1.XXX_S-901XXX.DGN

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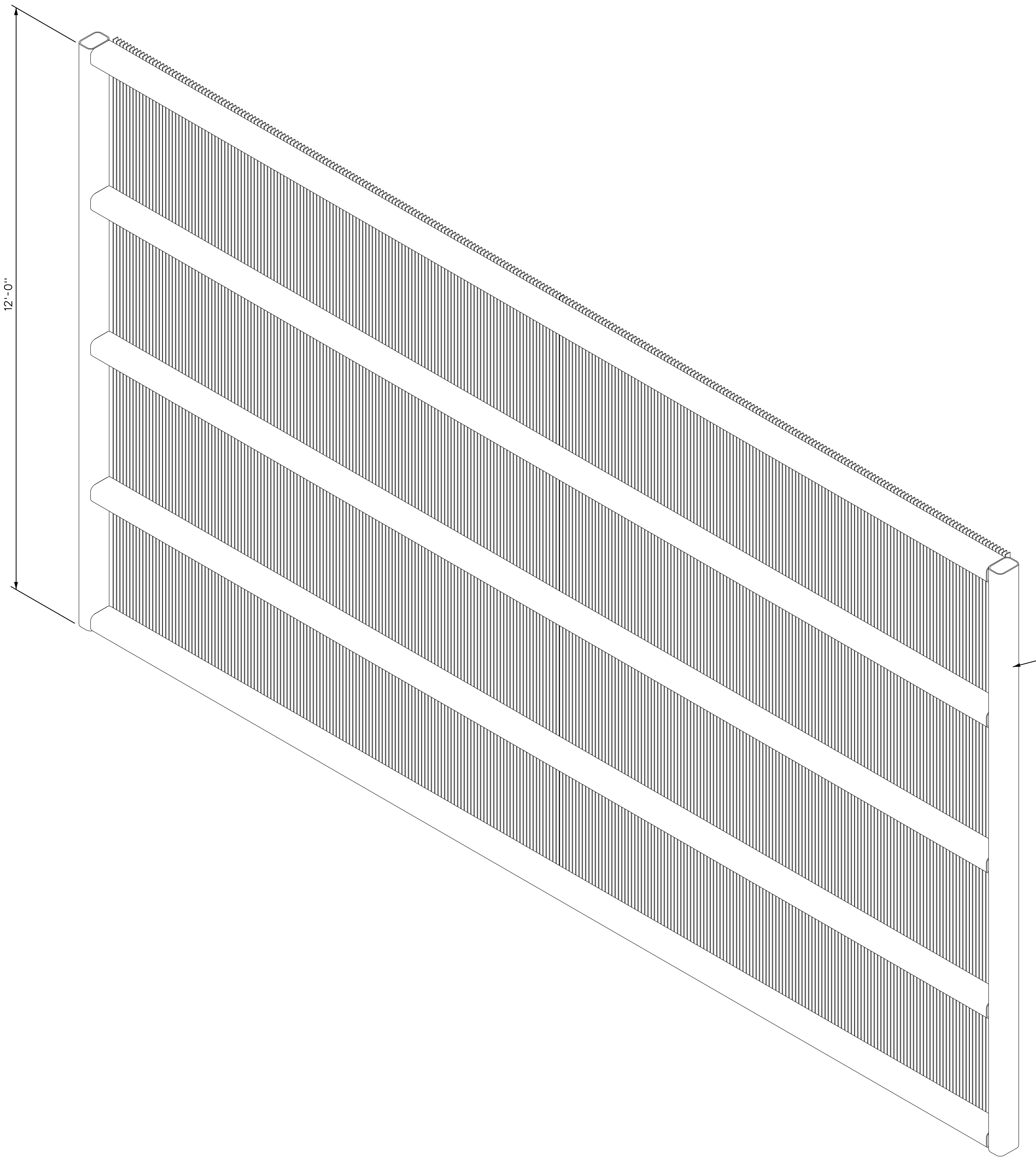

NOTES:

1. TRASHRACK DIMENSIONS ARE 12' x 23'.

US Army Corps of Engineers
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR.
07	ISSUE 07 DESCRIPTION	DATE 07	A-7
06	ISSUE 06 DESCRIPTION	DATE 06	A-6
05	ISSUE 05 DESCRIPTION	DATE 05	A-5
04	ISSUE 04 DESCRIPTION	DATE 04	A-4
03	ISSUE 03 DESCRIPTION	DATE 03	A-3
02	ISSUE 02 DESCRIPTION	DATE 02	A-2
01	ISSUE 01 DESCRIPTION	DATE 01	A-1

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: DESIGNER'S NAME
DWN BY: DWN BY
CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE
PLOT DATE: 1/7/2014
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

STRUCTURAL
TRASHRACK
ISOMETRIC

SHEET IDENTIFICATION
S-902
SHEET OF

DESIGN FILE: L:\wfo\cad\TDEA01\DFF1.XXX_S-902XXX.DGN

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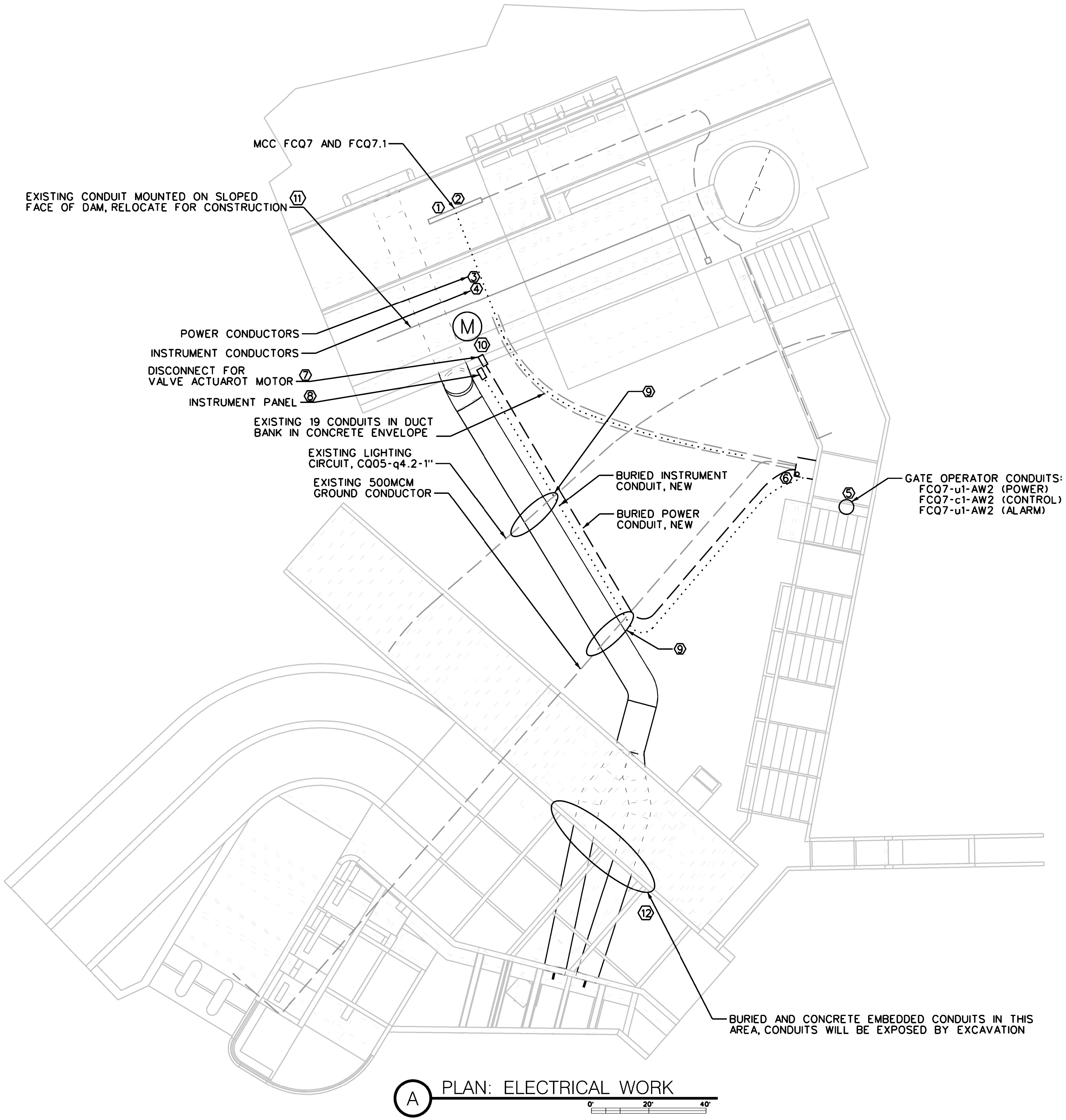

NUMBERED HEX NOTES:

1. REBUILD BUCKET FOR "FCQ7-q1-AW2" TO SUPPLY AND PROTECT THE ELECTRIC VALVE ACTUATOR.

2. UPGRADE BUCKET FOR "FCQ7-u1-AW2" TO MONITOR PIPE SENSORS. RECONFIGURE CIRCUIT TO CONTROL ROOM FOR AWS PIPE SENSORS.

3. REPLACE CONDUCTORS "FCQ7-q1-AW2" FROM "FCQ7" TO ELECTRIC VALVE ACTUATORWITH 4)#12 XHHW CONDUCTORS TO PROVIDE 480V/3PH POWER.

4. REPLACE CABLE "FCQ7-u1-AW2" FROM "FCQ7" TO AWS PIPE INSTRUMENT CABINET.

5. DISCONNECT AND REMOVE POWER, CONTROL, AND ALARM CONDUCTORS FROM GATE OPERATOR INDICATED TO "FQ07". USE POWER AND ALARM CONDUITS FOR NEW PIPE VALVE OPERATOR.

6. PROVIDE TWO 1-½" CONDUITS FROM MANHOLE TO INSTRUMENT PANEL AND DISCONNECT PANEL AT THE VALVE OPERATOR.

7. PROVIDE VALVE DISCONNECT FOR VALVE MOTOR MOUNTED ON UNISTRUT FRAME EMBEDDED IN CONCRETE PAD.

8. PROVIDE INSTRUMENT CABINTE MOUNTED ON UNISTRUT FRAME EMBEDDED IN CONCRETE PAD.

9. EXISTING CONDUIT AND GROUND CONDUCTOR SHALL BE DISCONNECTED AND REMOVED DURING CONSTRUCTION AND RECONNECTED AFTER CONSTRUCTION.

10. PROVIDE 120VAC GFCIRECEPTACLE AND AREA LIGHT AT VALVE ACTUATOR.

11. RELOCATE CONDUIT ON DOWNSTREAM SLOPED FACE OF DAM TO ABOVE THE CONSTRUCTION AREA.

12. BURIED AND CONCRETED EMBEDDED CONDUITS ARE IN THIS AREA. EXCAVATION FOR PIPE WILL EXPOSE BURIED CONDUIT. LOCATE AND PROTECT CONDUITS EXPOSED DURING EXCAVATION.

US Army Corps of Engineers®
DISTRICT NAME

MARK | DESCRIPTION | DATE | APPR

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: G4EDDDFP
DWN BY: G4EDDFP
CKD BY: CKD BY
SUBMITTED BY: SUBMITTERS NAME
PLOT SCALE: SCALE
PLOT DATE: 1/7/2014
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILIARY WATER SUPPLY

ELECTRICAL
VALVE MOTOR, RELOCATIONS, SENSORS
SITE PLANE

SHEET IDENTIFICATION
E-101
SHEET OF

DESIGN FILE: L:\wfo\cad\TDEA01\DFF1XXX_E-101XXX.dgn

DRAWING PLOT SIZE: $BORDER$ | DATE AND TIME PLOTTED: 1/7/2014 1:07:31 PM | BY USERNAME: $USER$ | SHEET NAME: $SHEETN$