EXH. JPH-19
DOCKETS UE-240004/UG-240005
2024 PSE GENERAL RATE CASE
WITNESS: JAMES P. HOGAN

BEFORE THE
WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION, **Complainant,** **v.** **PUGET SOUND ENERGY,** **Respondent.**	**Docket UE-240004** **Docket UG-240005**

EIGHTEENTH EXHIBIT (NONCONFIDENTIAL) TO THE PREFILED DIRECT TESTIMONY OF

JAMES P. HOGAN

ON BEHALF OF PUGET SOUND ENERGY

FEBRUARY XX, 2024

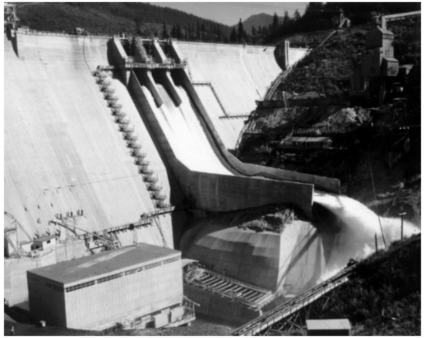
Upper Baker Dam Spillway Stabilization BOC Design In-brief
November 29, 2023

PSE PUGET SOUND ENERGY

UBK Spillway Stabilization – Design In-brief

Requesting BOC review and concurrence of the final design prior to construction.

Review Documents: DDR, Drawings, Specs, Foundation Failure Mode Report 2022, and 2023 PFMA Report. Sent to BOC on11/24



PSE PUGET SOUND ENERGY

- Introductions
  - Board of Consultants
    - Dr. Donald Bruce
    - Dr. Robin Charlwood
    - Dr. Brendan Fisher
  - PSE project team
    - Rex Whistler, Designer, Shannon & Wilson
    - Nabil Dbaibo, PSE Dam Safety Engineer
    - Mike Likavec, PSE Chief Dam Safety Engineer
    - Nate McGowan, Project Manager
  - FERC
    - Chris Humphrey, FERC
- Background and Progress since last meeting
- Overview of Final Design
  - Main features
  - Major changes since 60% design
- Construction Schedule
- BOC review request and schedule

Summary of Previous Meeting

BOC Meeting No. 10

- Question 1 – At the current design level, does the Board agree this is an adequate mitigation measure?
  - Board Response - …therefore judged acceptable.
- PFMs S-UB-3 and F-UB-3B
  - S-UB-3: Failure of the spillway and underlying rock block under seismic loading occurs and cannot be repaired before a flood occurs, leading to rock erosion and an undermining failure of Monoliths 16/17.
  - F-UB-3: Sliding failure of Spillway Monoliths 16/17 and adjacent monoliths to the south as a result of failure of the spillway chute block during a flood due to an increase in uplift, followed by rock erosion and undermining of the spillway
- Board Recommendations
  - S&W should document their basis for design criteria and consistency with FERC guidelines.
  - Groundwater pressures are clearly important… recommends that at least two piezometers be installed downslope of the spillway to measure pre/post construction phreatic surface.
  - Drains are recommended.
  - Attention to corrosion protection.
  - Existing sluiceway stability evaluation.
  - Long drain system should be capable of providing flow measurements/flushed/cleaned.

Summary of Previous Correspondence

S&W Design Basis – July 2nd, 2021

- FERC Guidelines for Stability
  - Factors of Safety for Usual, Unusual, and Post-Earthquake greater or equal to 1.5, 1.3, and 1.3, respectively.
- Groundwater, Existing Conditions, and Joint Roughness
  - Joint roughness following Barton-Bandis:

$$i = JRC \times \log\left(\frac{JCS}{\sigma'}\right)$$

BOC Comments on S&W Design Basis – November 9th, 2021

- BOC is in general agreement with S&W's design methodology
- BOC agrees with comments contained in FERC letter dated October 13th, 2021
  - FERC had the following statements that are relevant to current buttress design:
    1. Concur with S&W's conclusion that current static FS is not below 1.0
    2. Stability criteria presented (Table 2A from Chapter 3 of FERC Engineering Guidelines) may be used
    3. When modeling the static FS=1.0 condition, groundwater should not be set higher than assumed maximum historic levels.

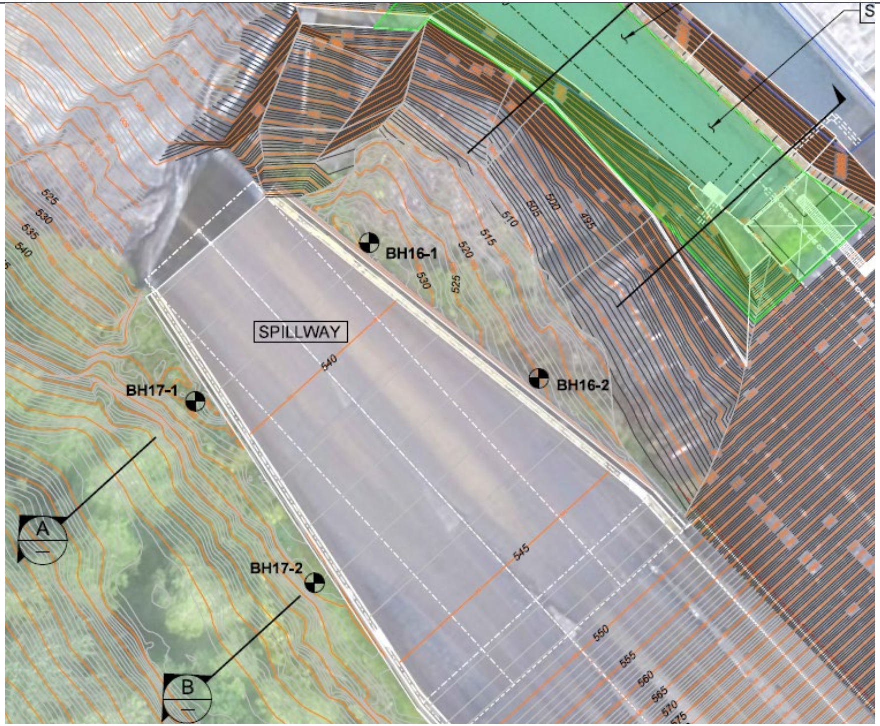
Design Memorandum

Criteria or Condition	Reference
The spillway slope shall have a global stability FS ≥ 1.5 for usual loading conditions (static) for dams having a high or significant hazard potential.	FERC, 2018, Engineering guidelines for the evaluation of hydropower projects, Chapter 3, Table 2A
The spillway slope shall have a global stability FS ≥ 1.3 for post-earthquake loading conditions for dams having a high or significant hazard potential. Based on our understanding of rock mass conditions, we do not believe that this criterion applies.	FERC, 2018, Engineering guidelines for the evaluation of hydropower projects, Chapter 3, Table 2A
The spillway slope shall have a global stability FS ≥ 1.1 for earthquake loading conditions for dams having a high or significant hazard potential.	**Based on engineering judgement**. The FERC, 2018, Engineering guidelines for the evaluation of hydropower projects does not provide a FS criterion.
The spillway slope shall have a global stability FS ≥ 1.3 for unusual loading conditions (probable maximum flood) for dams having a high or significant hazard potential.	FERC, 2018, Engineering guidelines for the evaluation of hydropower projects, Chapter 3, Table 2A
Seismic Design Criteria – 84th Percentile of the Maximum Credible Earthquake	Hatch (2018) and BOC Meeting No. 6
For global stability analyses for the design seismic event when not considering liquefaction or seismic-event-induced soil strength degradation, a horizontal pseudo-static coefficient, k_h, of 0.5 effective peak ground acceleration (A_s) and a vertical pseudo-static coefficient, k_v, equal to zero shall be used.	Kramer, S. L., 1996, Geotechnical earthquake engineering: Upper Saddle River, N. J., Prentice Hall, p. 436.
No piezometers are present in the spillway slope. Groundwater was observed to be at the ground surface on the upslope side of the spillway ranges from Elevation 553 to 548 feet at Station 12+11 and 13+10, respectively. Groundwater at the base of the slope will be assumed to be the equal to the mean minus one standard deviation tailrace water surface elevation (Elev. 431 feet).	Appendix D

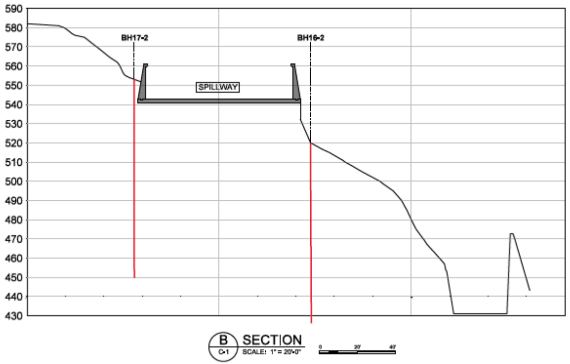
Criteria or Condition	Reference
The statistical distribution of discontinuity (foliation) persistence is approximated by a negative exponential distribution with values presented as the probability (in percent) a given discontinuity length is shorter. For analyses, we will use the 50th and 68th percentile.	Wyllie and Mah, 2004
The statistical distribution of discontinuity spacing is approximated by a negative exponential distribution with values presented as the probability (in percent) that a given discontinuity spacing is larger. For analyses, we will use the 50th and 68th percentile.	Wyllie and Mah, 2004
Concrete Facing Geometry	Stone & Webster (1958)
The statistical distribution of all other rock mass properties (i.e., dip and dip direction, joint friction angle, and foliation plane inclination) are approximated by a normal distribution.	Wyllie and Mah, 2004, and analysis of our data
Strength properties for major structure foliation will be based on Mohr-Coulomb strength criteria.	See Section 5.3 this memorandum

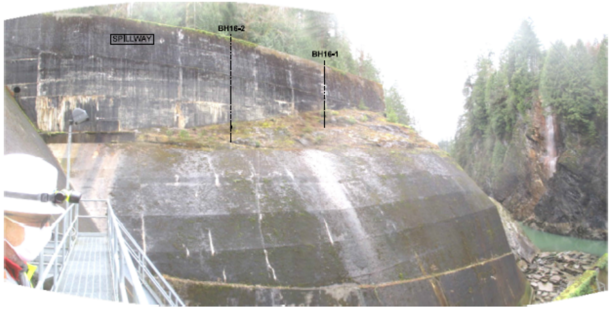
Design Progression – Geotechnical Exploration Program

- Four borings were completed in 2021
  - All to ~100ft bgs.
  - Optical/Acoustic Televiewer
  - VWP Installation
  - Lab Testing



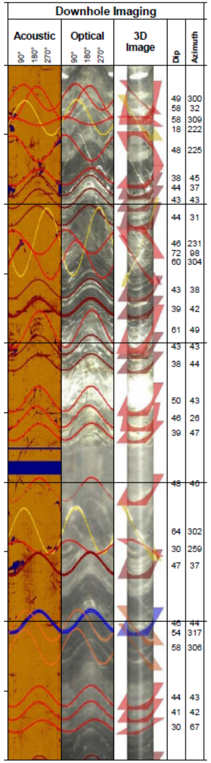
Design Progression – Geotechnical Exploration Program

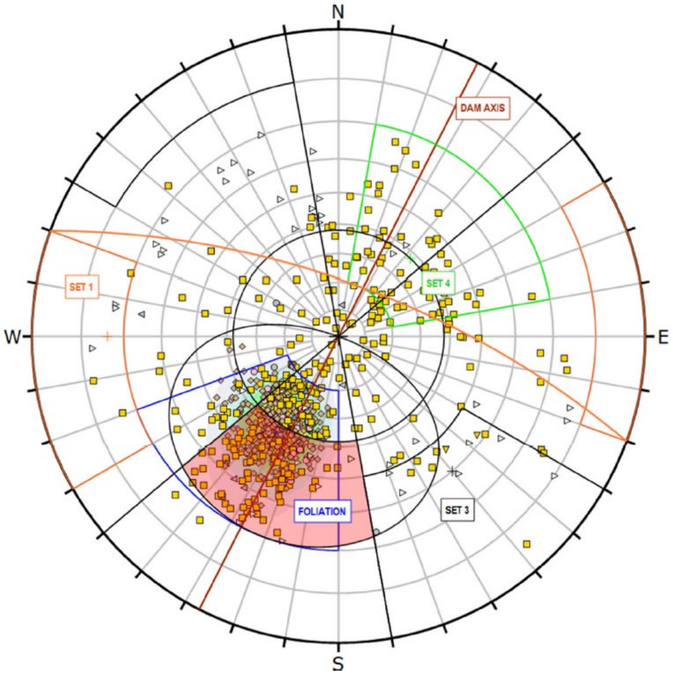




PUGET SOUND ENERGY

Design Progression – Geotechnical Analysis Revision





Symbol	WELLCAD CLASS	Quantity
○	Bedding or Foliation Plane (not fracture	30
◇	Fracture along bedding or foliation plan	268
□	Fracture observed in core and televiewe	328
△	Fracture observed on televiewer, not in	8
◇	Fracture with >1mm clay infilling observ	1
▷	Healed fracture, observed in core and te	45
▽	Partially healed fracture, observed in co	2
●	Rubble Zone	5
◁	Slickensided fracture observed in core	8

Kinematic Analysis	Planar Sliding
Slope Dip	70
Slope Dip Direction	20
Friction Angle	38°
Lateral Limits	30°

	Color	Dip	Dip Direction	Label
User Planes				
4		90	297	Dam Axis
Mean Set Planes				
6m		38	223	Joint Set 4
8m		41	33	Foliation
9m		74	90	Joint Set 1
10m		60	320	Joint Set 3

Plot Mode	Pole Vectors
Vector Count	695 (695 Entries)
Hemisphere	Lower
Projection	Equal Angle

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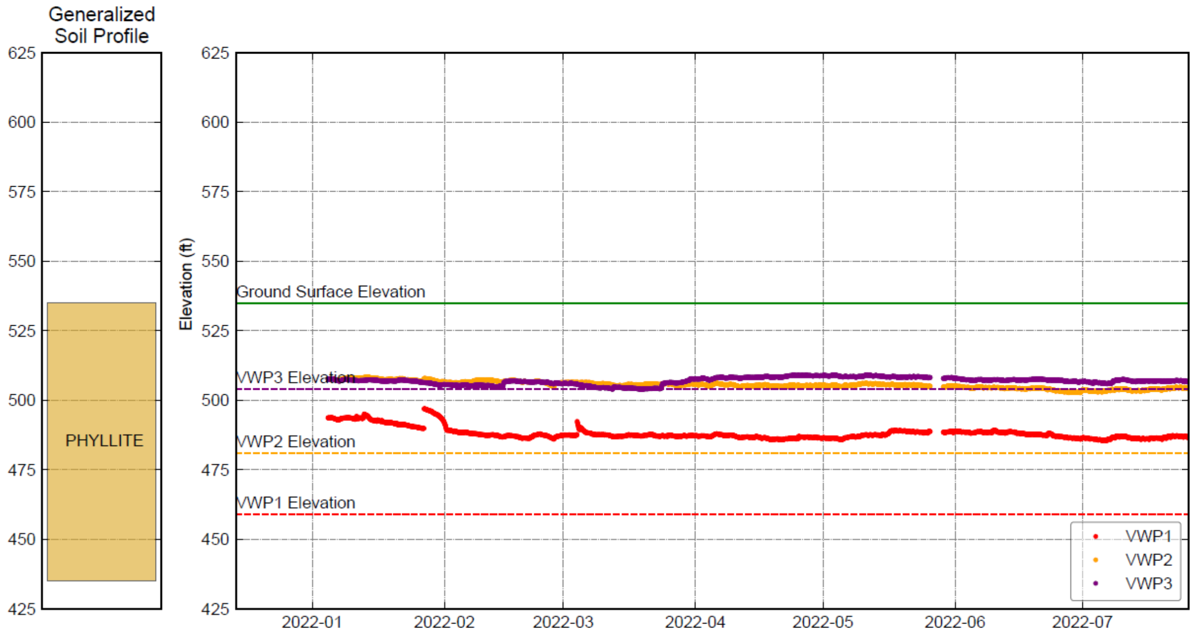
Design Progression – Geotechnical Analysis Revision

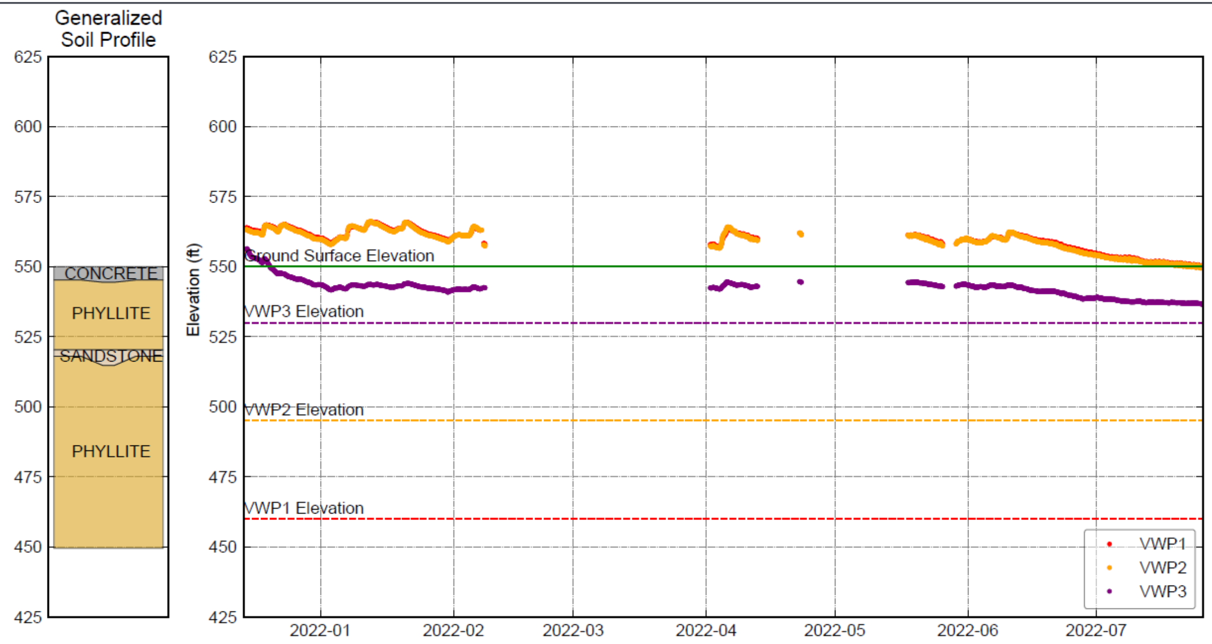


Note:
1. The maximum piezometric head measured in boring BH-16-1 is 509.1 feet.

Puget Sound Energy
Upper Baker Dam
Concrete, Washington

PUGET SOUND ENERGY

Design Progression – Geotechnical Analysis Revision

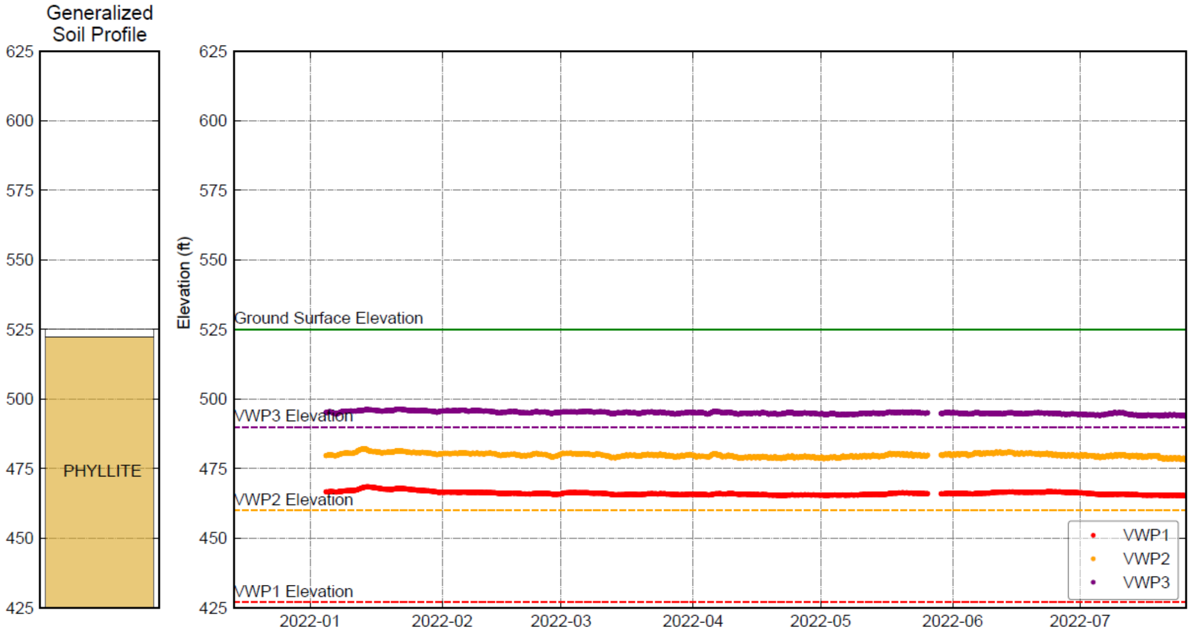


Note:
1. The maximum piezometric head measured in boring BH-17-1 is 566.2 feet.

Puget Sound Energy
Upper Baker Dam
Concrete, Washington

PSE PUGET SOUND ENERGY

Design Progression – Geotechnical Analysis Revision

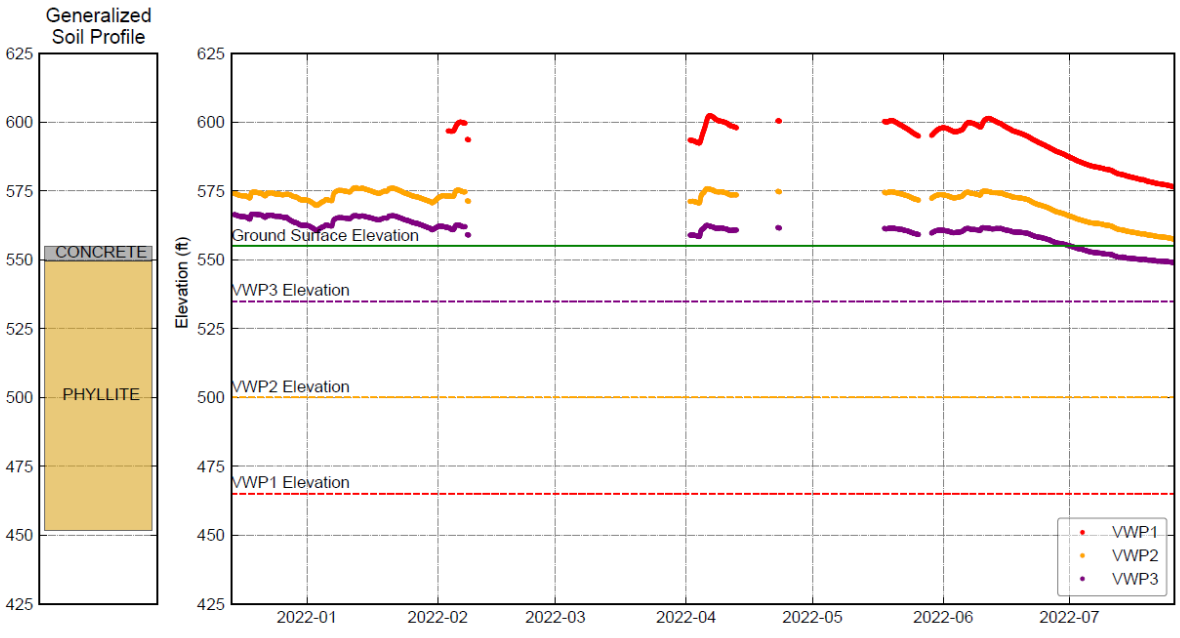


Note:
1. The maximum piezometric head measured in boring BH-16-2 is 496.4 feet.

Puget Sound Energy
Upper Baker Dam
Concrete, Washington

PUGET SOUND ENERGY

Design Progression – Geotechnical Analysis Revision



Note:
1. The maximum piezometric head measured in boring BH-17-2 is 602.3 feet.

Puget Sound Energy
Upper Baker Dam
Concrete, Washington

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Design Progression – Geotechnical Analysis Revision

# of Tests	Category	Mean ksi	Median ksi	Standard Deviation ksi	Min ksi	Max ksi
9	Failure Type C	6.4	3.2	6.8	1.4	24.4

- 11 Tests, 9 failed through combination of intact and along discontinuity. Design value is 3.2ksi.

	Peak Friction Angle (pcf)
Min	38
Max	74
Average	51
Median	44
Standard Deviation	12

- 8 saw cut direct shear tests performed. Used min value of 38 degrees for base friction angle in analyses.

	Unit Weight (pcf)
Min	163
Max	179
Average	170
Median	170
Standard Deviation	4

- Design used a value of 170 pcf.

Design Progression – Geotechnical Analysis Revision

	JRC
Min	1
Max	19
Average	6.8
Median	5
Standard Deviation	3.8

- Analyses used the median JRC of 5. This, coupled with a 10% reduction in UCS to obtain JCS used in Barton Bandis' i-value equation results in a friction angle of 48 degrees.

Spillway Borings	RMR89	GSI
Min	42	23
Max	68	77
Weighted Average	60	61
Median	61	62
Standard Deviation	5	10

- Analyses used the rounded median/weighted average GSI or 60.

	Post-Peak Friction Angle (pcf)
Min	33
Max	74
Average	48
Median	41
Standard Deviation	13

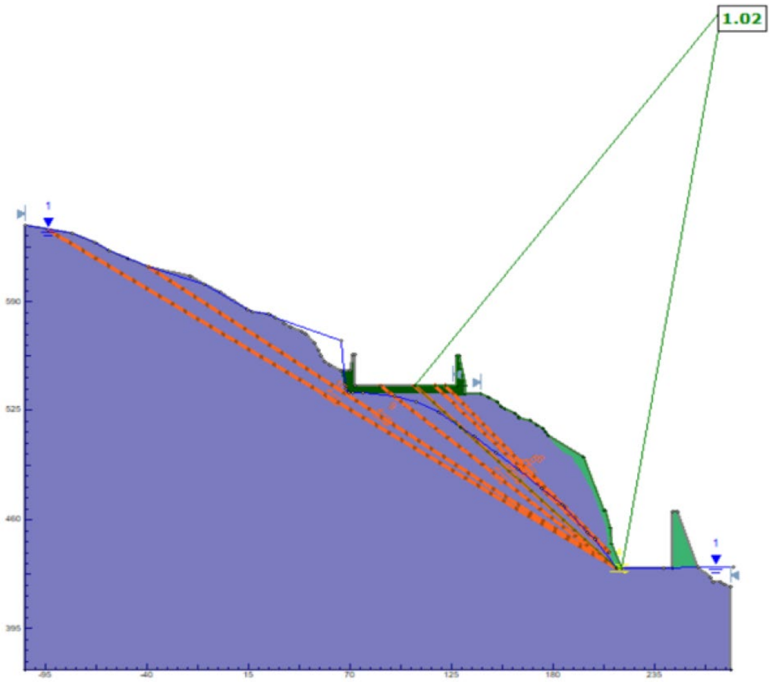
- Analyses used median post-peak saw cut friction of 41 degrees. This equates to a reduction of 15% in shear strength for the post-earthquake condition.

Design Progression – Geotechnical Analysis Revision

Exhibit 10-17: Summary of Limit Equilibrium Analyses from Previous Limit Equilibrium Analyses using Scaled Strength Properties

Loading Condition	FS Criteria	Existing Conditions	Grouted Rock Buttress		Anchor-Supported
			Below Buttress	Above Buttress	
Usual	1.5	0.97	1.52	1.82	1.75
Unusual	1.3	NA	1.49	1.75	1.66
Pseudo-static	1.1	NA	1.12	1.30	1.11
Post-Earthquake	1.3	NA	1.35	1.37	1.46

- Revised existing conditions used friction only discontinuity shear strength values, with phi = 48 degrees, resulting in FS=1.02 under measured groundwater levels.



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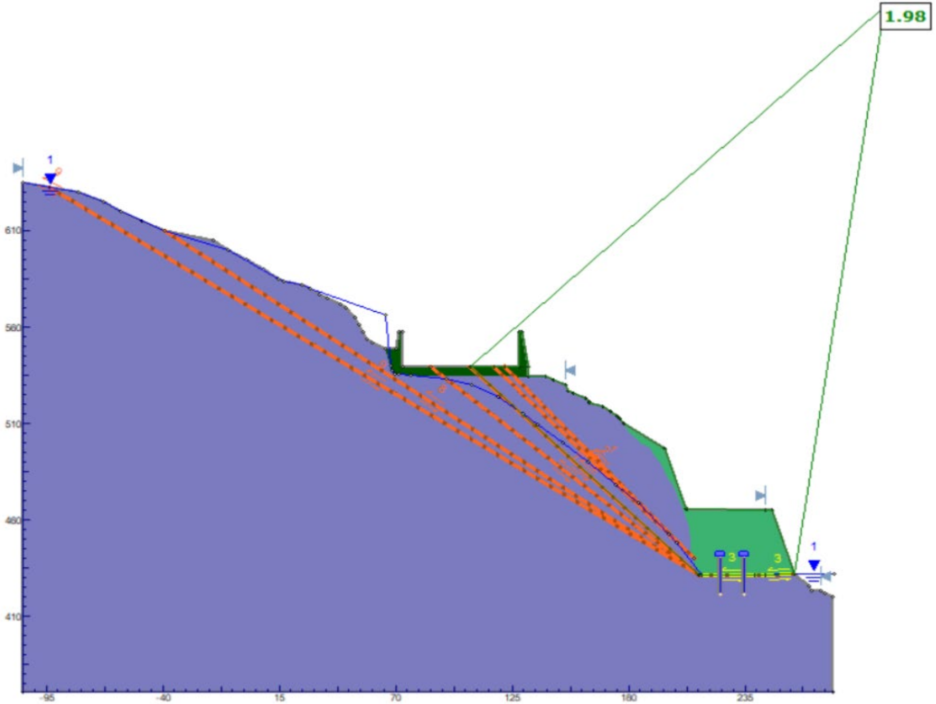
Design Progression – Geotechnical Analysis Revision

Exhibit 10-56: Summary of Resultant Factors of Safety of the Limit Equilibrium Analyses

Section	Loading Condition	FS Criteria	Grouted Rock Buttress		Anchor-Supported Slope	
			Above Buttress	Dowel Supported	1 ¾-inch, Grade 150	8 Strand
Section 1	Usual	1.5	1.6	2.0	2.2	2.4
	Unusual	1.3	1.6	2.0	2.2	2.4
	Pseudo-static	1.1	1.1	1.3	1.1	1.1
	Post-Earthquake	1.3	1.4	1.8	1.6	1.9
Section 2	Usual	1.5	2.8	2.3	2.3	2.7
	Unusual	1.3	2.8	2.3	2.3	2.6
	Pseudo-static	1.1	2.0	1.5	1.2	1.3
	Post-Earthquake	1.3	2.6	2.1	1.8	2.1



PSE PUGET SOUND ENERGY

Design Progression – Geotechnical Analysis Revision

- Newmark evaluation results with maximum estimated displacement of 0.1 inches. Low displacements due, in part, to the use of 2/3rd PGA for pseudo-static analyses.

Exhibit 10-53: Summary of Estimated Seismic Displacement for Section 1 using Newmark Analysis

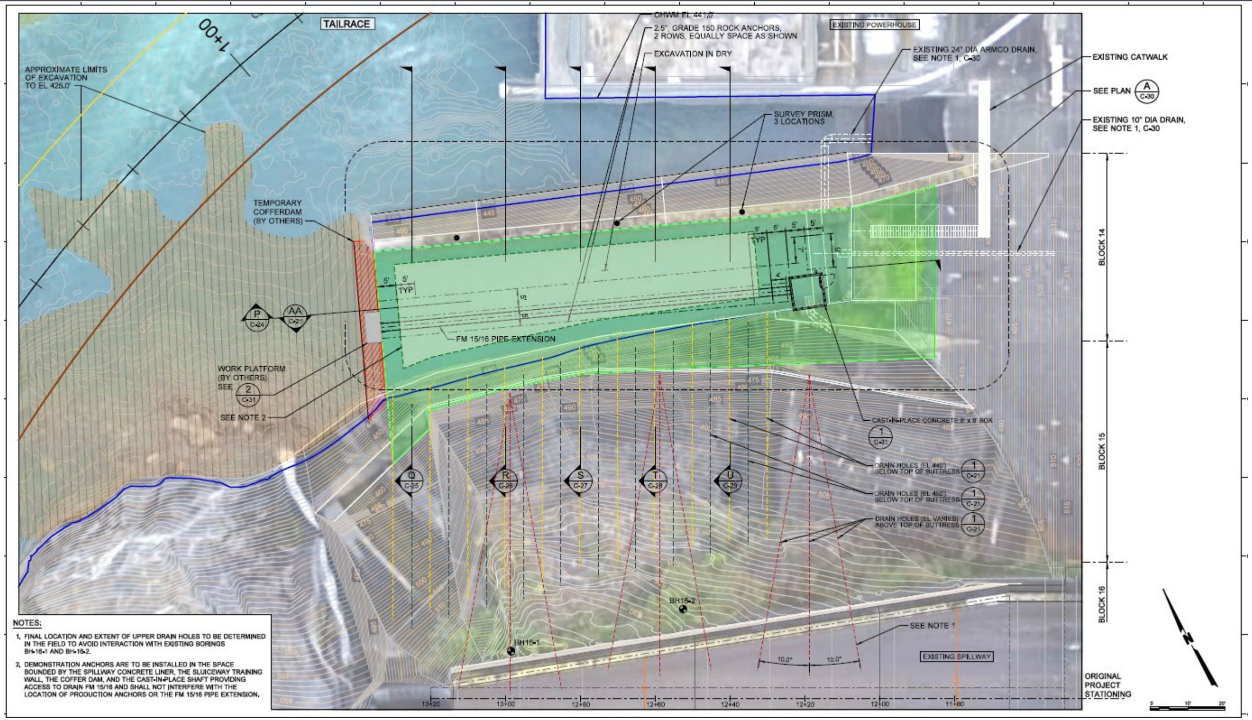
Section 1 – Estimate Seismic Displacement of Failure Mass (inches)					
		Anchor-supported		Buttress-supported	
Time History	Existing Spillway Condition	1 ¾-inch Anchors	8 Strand Anchors	Above	Dowel Supported
RSN72_SFERN_L04111	34.4	< 0.1	< 0.1	< 0.1	0.1
RSN72_SFERN_L04201	31.7	<0.1	< 0.1	< 0.1	< 0.1
RSN769_LOMAP_G06000	48.8	< 0.1	< 0.1	< 0.1	< 0.1
RSN769_LOMAP_G06090	48.1	< 0.1	< 0.1	< 0.1	< 0.1
RSN801_LOMAP_SJTE225	36.8	< 0.1	< 0.1	< 0.1	< 0.1
RSN801_LOMAP_SJTE315	47.0	< 0.1	< 0.1	< 0.1	< 0.1
RSN4845_CHUETSU_65008NS	27.4	< 0.1	< 0.1	< 0.1	< 0.1
RSN4845_CHUETSU_65008EW	26.0	< 0.1	< 0.1	< 0.1	< 0.1
RSN4869_CHUETSU_65042NS	50.6	< 0.1	< 0.1	< 0.1	0.1
RSN4869_CHUETSU_65042EW	56.4	< 0.1	< 0.1	< 0.1	< 0.1
RSN5618_IWATE_IWT010NS	66.5	< 0.1	< 0.1	< 0.1	< 0.1
RSN5618_IWATE_IWT010EW	51.7	< 0.1	< 0.1	< 0.1	< 0.1
RSN5815_IWATE_44BC1NS	50.5	< 0.1	< 0.1	< 0.1	< 0.1
RSN5815_IWATE_44BC1EW	45.2	< 0.1	< 0.1	< 0.1	< 0.1

NOTE:

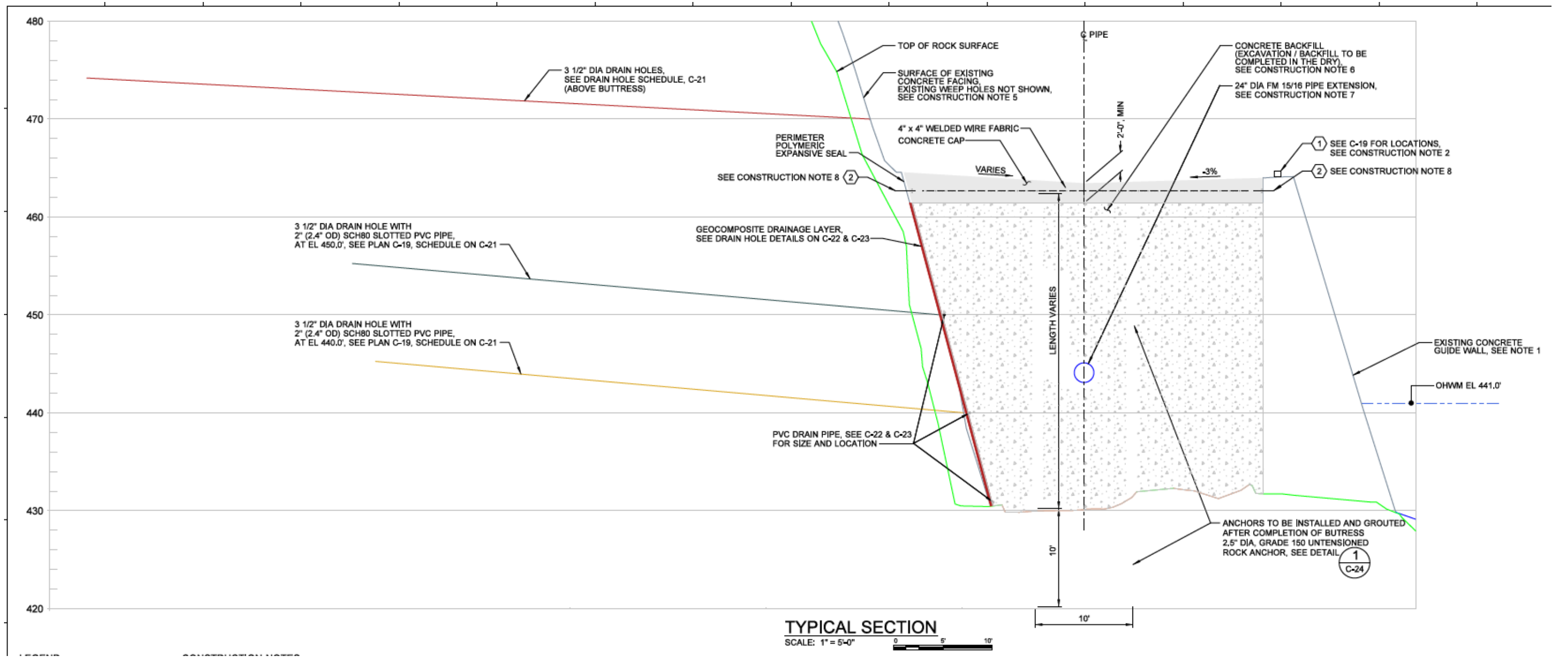
Reported values calculated in Slide v. 9.023 (Rocscience, 2022).

PSE PUGET SOUND ENERGY

Final Design

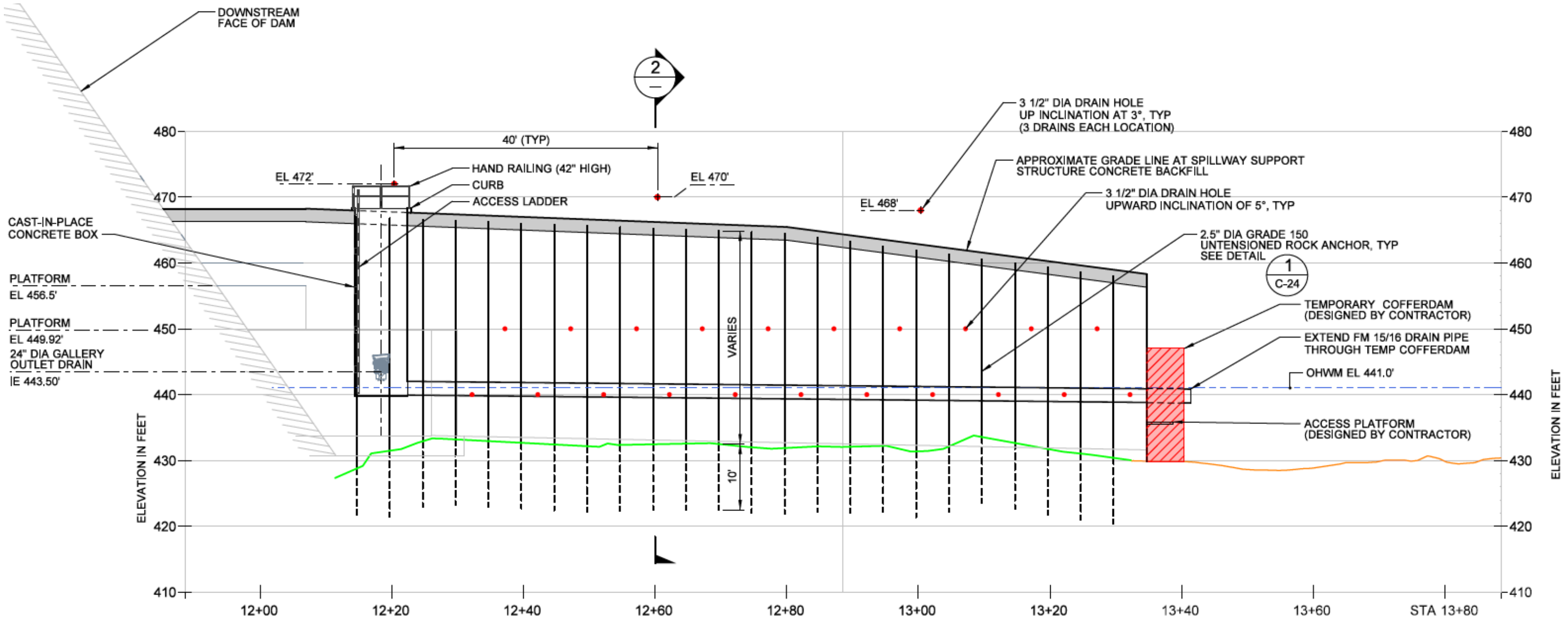


Final Design

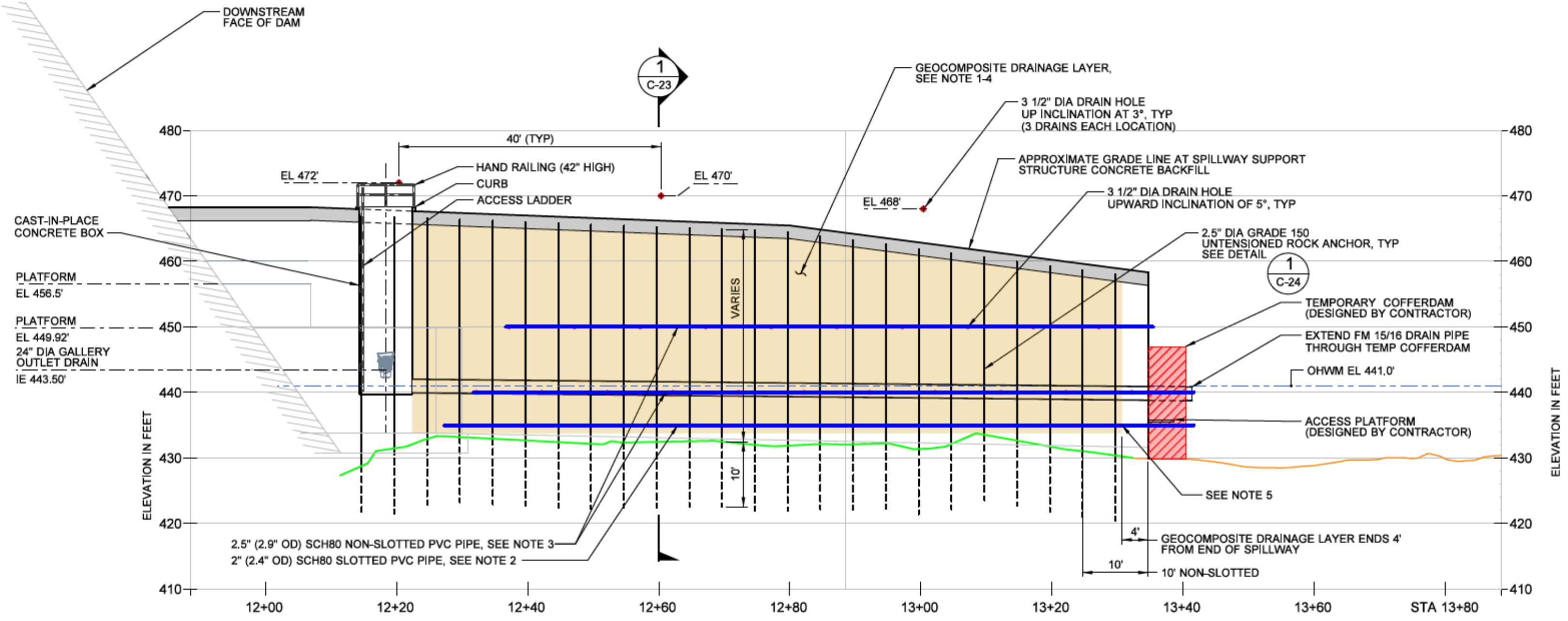


PUGET SOUND ENERGY

Final Design

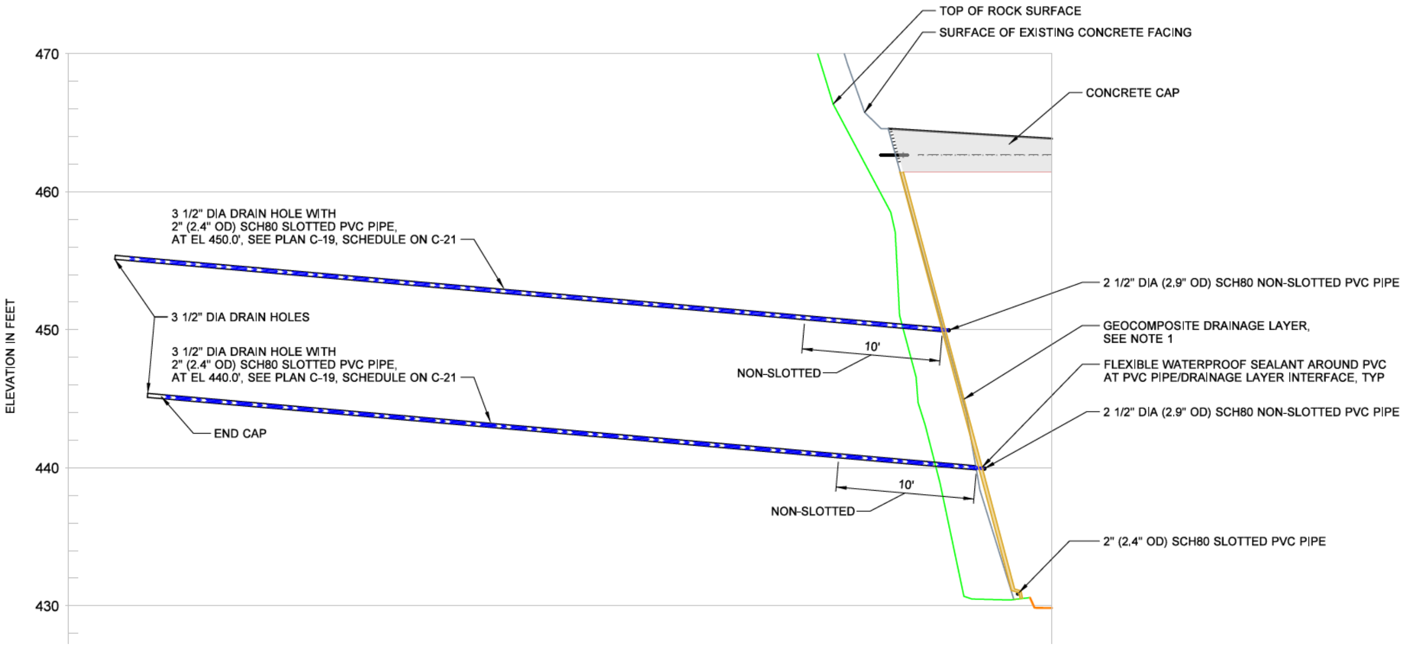


Final Design

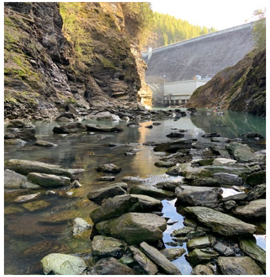


PUGET SOUND ENERGY

Final Design



Constructability Review & PFMA Workshop

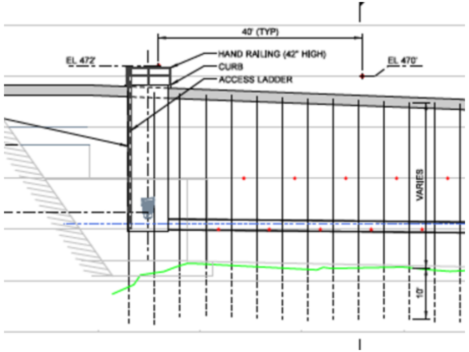


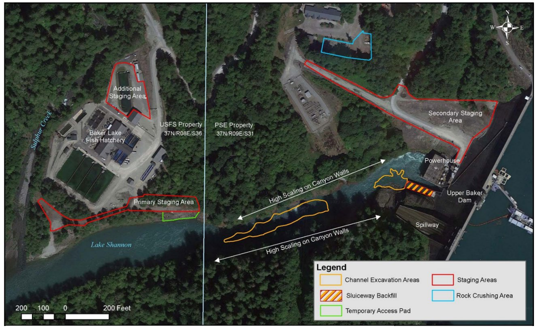
Knight Construction performed bidability and constructability review, produced construction schedules, cost estimates, and participated in PFMA

- Added safety high scaling, changed from grouted debris to concrete fill buttress, no longer precast access gallery, anchors drilled after buttress install

Design and Construction PFMA Workshop was on June 6, 2023

- Need to protect FM1516 drain during construction. Formwork will be designed and stamped by structural engineer





PUGET SOUND ENERGY

Design and Construction PFMA

4.1 PFM D1S – Seismic Loading (Clearly Negligible)

Rock bolt failure under severe seismic shaking.

4.1.1 PFM Description

1. A seismic event occurs at the site up to and including the MCE.
2. Rock anchors are overstressed at the rock-concrete interface due to the seismic event.
3. Buttress no longer has sufficient capacity to resist a sliding failure.
4. Rock foundation under the spillway chute slides, undermining support for the spillway chute.
5. Buttress or slope movement is observed but no intervention is possible.
6. Slope failure results in loss of the spillway chute, inability to operate the spillway as designed, and potential damage to the powerhouse.

4.1.3 Potential Risk Reduction Measures

Although not necessary, possible risk reduction measures that could be considered for this PFM include:

- Use Class 1 corrosion protection.
- Increase bar size to account to provide sacrificial steel.

Design and Construction PFMA

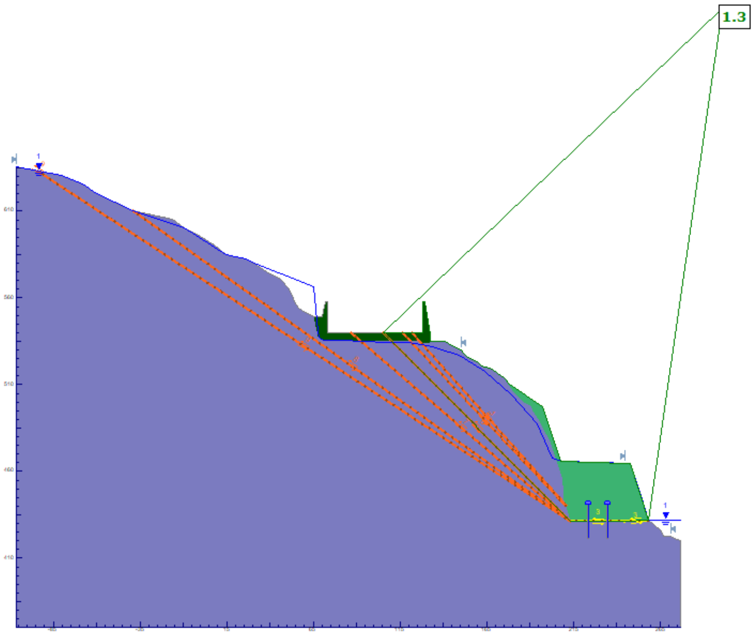
4.2 PFM C2N – Normal Loading (Ruled Out)

Damaged Cavidrain membrane leads to spillway slope buttress failure.

4.2.1 PFM Description

1. Cavidrain membrane is improperly installed or damaged during installation.
2. Membrane does not provide adequate drainage and pore pressures within the rock rise.
3. The rise in pore pressures goes unnoticed.
4. ~~The resulting pore pressure increase exceeds the stabilizing capacity of the buttress resulting in a slope failure and loss of spillway support.~~
5. ~~The damaged spillway is no longer capable of containing spillway flows.~~
6. ~~Due to high spillway flows spillway repairs are not possible.~~
7. ~~Spillway flows continue uncontrolled and erode the underlying foundation.~~
8. ~~Erosion continues upstream eventually connecting with the reservoir leading to an uncontrolled release.~~

Note: during PFM development it was determined that sliding safety factors meet FERC guidelines with the drains not functional. Therefore, PFM C2N is ruled out and steps 4 through 8 are not applicable.



Design and Construction PFMA

4.4 PFM C4N – Normal Loading (Credible)

Flowmeter (FM) 1516 drain plugs resulting in increased uplift pressures and failure of a monolith.

4.4.1 PFM Description

1. During construction, the FM_1516 drain pipe is blocked by concrete due to formwork failure.
2. The volume of concrete introduced into the drain pipe is too great to be removed before it sets up.
3. Hardened concrete does not allow water to flow through the drain.
4. Collector drain pipe in the drainage gallery fills up and surcharges the foundation.
5. Operators are unable to procure or set up sufficient pumping equipment to dewater the blocked drain.
6. Reservoir cannot be drawn down fast enough to reduce hydrostatic loads.
7. Uplift pressures increase under the dam monolith resulting in a sliding or rotational failure of a monolith.
8. Cascading failure of adjacent monoliths results in an uncontrolled release of the reservoir.

- Addressed within Specifications by requiring Structural Engineer to design, Sign and Stamp the formwork to be used.

Estimated Construction Schedule 2024 and 2025

- **Construction proposals received November 20, 2023**
- **Award late 2023 or early 2024**
- **Mobilize: March 2024**
- **High Scaling: March – April 2024**
- **Tailrace rock removal: April – May 2024**
- **Cofferdam installation for buttress (fish removal as needed): late May 2024**
- **Construct buttress: June – September 2024**
- **Demobe for 2024: October - November 2024**
- **Remobilize: March 2025**
- **Drill anchor holes and upper drain holes: March – May 2025**
- **Cleanup, punch-list, demobe: May – June 2025.**

PSE PUGET SOUND ENERGY

Request review and meeting from BOC

FERC statement: The Board of Consultants must review the 100% Design Documents and provide their comments and recommendations. The BOC will need to provide their concurrence with the construction documents prior to authorization of the remediation work for stabilizing the spillway.

- Does the BOC concur that the UBK Spillway Stabilization construction documents will improve the stability and mitigate PFMs S-UB-3 and F-UB-3B?

Review schedule and when to have the formal BOC meeting?