TO: Chase McLeod

CC: Dr. Jeffrey Heiderscheidt & Owen Allen

FROM: Smokerise Design Team

DATE: 05/05/2026

SUBJECT: Submission of Penstock Wash Redesign Project

Final Design Submittal

The Smokerise Design Team is pleased to submit the completed Penstock Wash Redesign Project for the Smokerise Neighborhood. This transmittal includes all final deliverables associated with the project, including the comprehensive report and design plans.

The submitted materials reflect the full scope of work outlined in the original proposal, including hydrologic and hydraulic analysis, evaluation of drainage alternatives, and development of a final redesign for the Penstock Wash system. The enclosed report documents the methodology, analysis, results, and recommendations, while the completed design provides the finalized plans and specifications.

All project components have been completed in accordance with the established schedule and project requirements. The final deliverables represent the culmination of the design process and incorporate feedback received during interim submissions.

Please review the attached materials at your convenience. We appreciate the opportunity to complete this project and to contribute to improving the Smokerise Neighborhood infrastructure.

As part of the final design submittal, the Smokerise Design Team has developed an Engineer's Opinion of Probable Cost (EOPC) for the Penstock Wash Redesign Project. This estimate reflects anticipated construction costs based on the completed design plans, current unit pricing, and standard construction practices.

The total estimated project cost is $422,935, which includes material costs, contract and hidden costs, and contingency allowances. Material costs are estimated at $271,460, covering major components such as site setup, earthwork, material installation, geomorphic restoration, and site restoration. Contract and hidden costs are estimated at $76,009, including mobilization adjustments, traffic control, erosion control measures, and contractor overhead and profit.

Contingency costs total $75,466, accounting for engineering design and a concept-level contingency to address uncertainties inherent in final design implementation.

This EOPC is intended to provide a reasonable cost projection for budgeting and planning purposes. Actual construction costs may vary depending on market conditions, contractor bids, and unforeseen site conditions.

If you have any questions or require additional information, please do not hesitate to contact us.

Sincerely,

Haile Nelson, Briana Pilling, Harth Beaty, & Qixuan Yang
Smokerise Design Team

Agua Jacks

Redesign of Penstock Wash for the Smokerise Neighborhood
Design Report

DRAFT #7

Revised 5/5/2026

Penstock Wash and Smokerise Neighborhood
Intersection of Snowflake Drive and East Trails End Drive
Flagstaff, AZ 86004
Coconino County, Arizona

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ABBREVIATIONS

Abbreviation	Definition
ADEQ	Arizona Department of Environmental Quality
ADOT	Arizona Department of Transportation
AZ	Arizona
Cfs	Cubic feet per second
CoF	City of Flagstaff
DEMs	Digital Elevation Models
EIT	Engineer in Training
EOPC	Engineer’s Opinion of Probabal Cost
EPA	Environmental Protection Agency
FE	Fundamentals of Engineering
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
GIS	Geographical Informational System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HRS	Hours
HW/D	Headwater to diameter
HWY	Highway
INT	Intern
I - ##	Interstate ##
LiDAR	Light Detection and Ranging
MAG	Maricopa Association of Governments
NAU	Northern Arizona University
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
PE	Principal Engineer
PrE	Project Engineer
QA	Quality Assurance
QC	Quality Control
SR - ##	State Route ##
TR-55	Technical Release - 55
USDA	United States Department of Agriculture
US - ##	United States Highway - ##
WSS	Web Soil Survey

ACKNOWLEDGEMENTS

The team would like to formally acknowledge the invaluable assistance and support provided by the staff at Northern Arizona University and the City of Flagstaff.

In particular, we extend our gratitude to Owen Allen and Dr. Jeffrey Heiderscheidt for their expert advice and guidance as the technical advisor and grading instructor for our team. Additionally, we would like to express our sincere appreciation to Chase McLeod for his insightful direction in establishing the project scope as the representative of the client.

Thank you to all who contributed to the success of this project.

1.0 Project Introduction

1.1. Project Overview

This report documents the evaluation and redesign of the Penstock Wash drainage system within the Smokerise Neighborhood of Flagstaff, Arizona. The report presents site investigation findings, summarizes hydrologic and hydraulic analyses of existing conditions, and documents the identification and screening of conceptual improvement alternatives. The work establishes a technical basis for addressing deficiencies in stormwater conveyance and supporting the development of a preliminary design intended to reduce flooding impacts on adjacent roadways and residential areas. The analyses and discussions presented herein support subsequent design refinement and decision-making in later project phases.

1.2. Project Objectives

The objective of the Penstock Wash Redesign Project is to evaluate and redesign a defined reach of the Penstock Wash to improve stormwater conveyance and reduce runoff impacts on adjacent neighborhoods streets within the Smokerise area. The project will identify hydraulic deficiencies in the existing channel and drainage infrastructure and develop a redesign that reduces roadway flooding during storm events, improves flow capacity, channel alignment, and overall conveyance. The project will be completed using design criteria consistent with the City of Flagstaff stormwater management standards and FEMA floodplain regulations.

1.3. Project Location and Existing Conditions

The project is located on the East side of Flagstaff, Arizona. The upstream limit of the study area begins where the flow discharges from the FEMA- designated floodplain, north of Living Christ Lutheran Church, where Penstock Wash enters the project corridor and flows beneath Highway 89 before continuing through East Trails End Drive. The downstream limit of the redesign area is defined as the intersection of East Trails End Drive and North Mountaineer Road. The flow downstream of the project area discharges into the Rio de Flag.

The project focuses on a defined reach of the wash. While the redesign is limited to this specific portion, the broader project boundaries remain relevant to evaluate how the proposed modifications influence upstream and downstream hydraulic conditions. The study area includes a natural wash segment that conveys runoff from State Route 89 and upstream water conveyed through the culvert system beneath the highway before it all enters the Smokerise neighborhood street network up to the culverts that run under Highway 89. This reach was selected due to its critical role in directing stormwater toward residential areas and its influence on downstream flooding conditions. Although our project redesign area is only around 500 feet, conveying the flow more effectively through the channel will result is the road being less likely to flood and hopefully cause trickle down effects in the overall Smokerise neighborhood.

Figure 1-1 illustrates the general location of the project within the state of Arizona. Figure 1-2 provides a map of the vicinity showing the project area in relation to the greater Flagstaff region. Figure 1-3 presents a detailed site map highlighting the Smokerise neighborhood and the alignment of Penstock Wash through the project area.

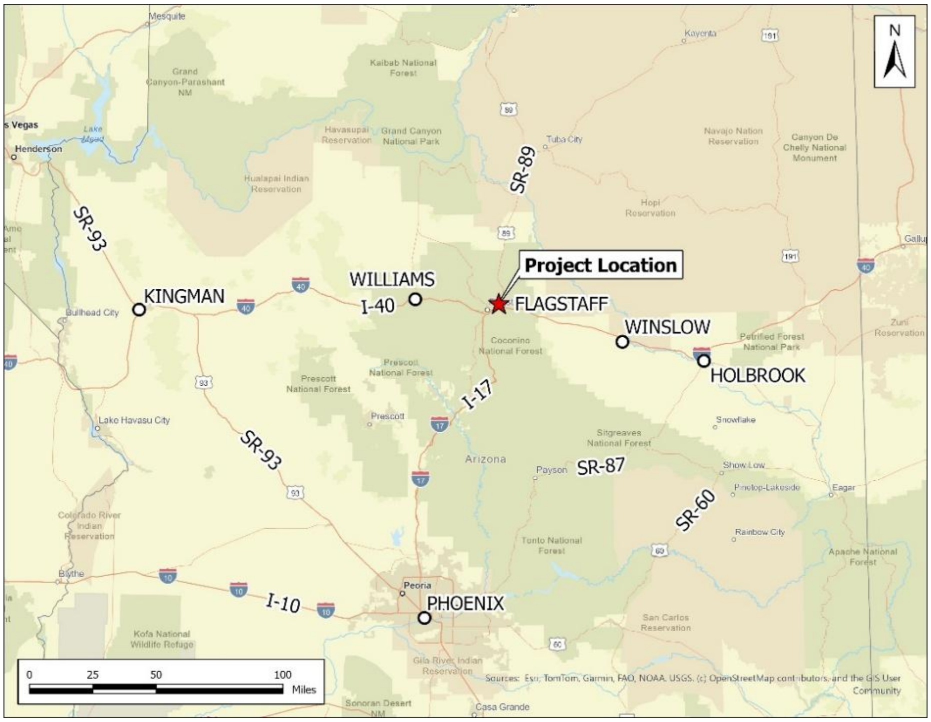

Figure 1-1: Project Location Map

Figure 1-2: Vicinity Map

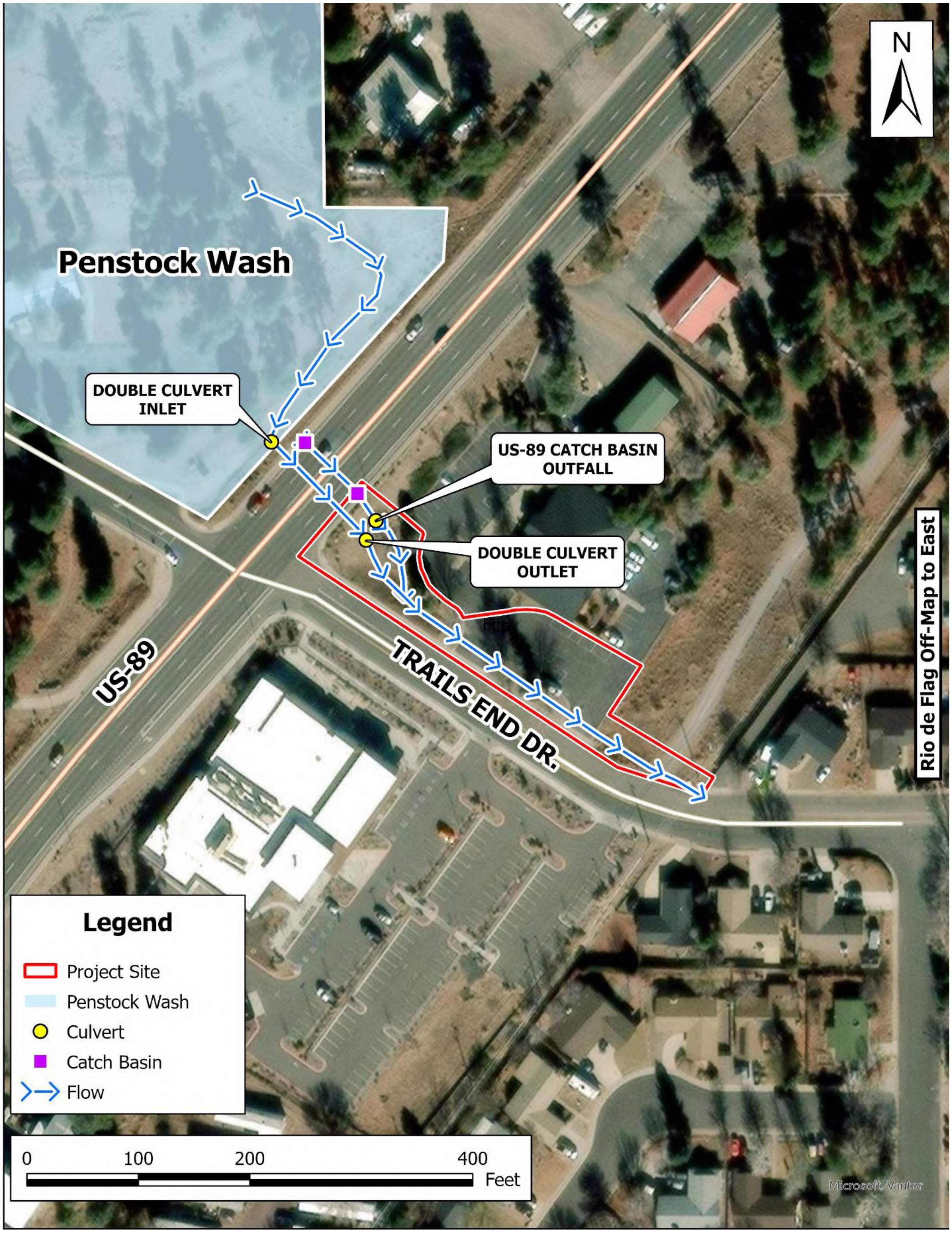

Figure 1-3: Site Map

1.4. Constraints and Design Considerations

The Penstock Wash redesign is shaped by multiple constraints that must be carefully balanced. Public health and safety require the stormwater system to convey runoff effectively, minimizing flood risks to residents, roadways, and streets, particularly in the Smokerise neighborhood. Environmental considerations mandate protection of downstream water quality, stable channels, and erosion control, while ensuring compliance with FEMA floodplain regulations and ADEQ requirements to support long-term site and ecosystem stability. Economic factors limit the feasibility of large-scale infrastructure replacement, so design alternatives must be cost-effective, durable, and maintainable, balancing construction costs, maintenance needs, and hydraulic performance. Technical requirements demand accurate topographic and site data for hydrologic and hydraulic analyses, which can be hindered by limited site access, dense vegetation, wet conditions, and physical obstacles.

Site access restrictions, including private property boundaries and obstructions, further influence data collection and construction feasibility. Finally, regulatory requirements from the City of Flagstaff, FEMA, and ADEQ limit design options, define minimum performance standards, and mandate compliance with floodplain, stormwater, and water quality regulations.

This project is limited to a feasibility-level evaluation and excludes work beyond the scope of this course due to resource, schedule, and professional licensure constraints. No geotechnical investigation, including subsurface drilling or laboratory soil testing, will be performed. Land or right-of-way acquisition, community outreach activities, and formal environmental permitting efforts, including NEPA and Section 404 documentation, are excluded. Construction-ready, Professional Engineer–stamped design documents will not be produced, and all deliverables remain at a preliminary design level. Construction-phase activities, including bidding, contractor coordination, and construction oversight, as well as preparation or submission of FEMA floodplain compliance documentation, are also excluded.

The drainage deficiencies associated with Penstock Wash primarily affect residential properties and local roadways within the Smokerise neighborhood, with limited direct impacts to major commercial, industrial, or regional transportation infrastructure. As a result, the observed flooding and conveyance limitations represent localized impacts. Infrastructure improvement prioritization is often influenced by the scale of risk, number of affected stakeholders, and potential consequences to economic activity, public safety, and essential services.

Socioeconomic characteristics of the neighborhood can also influence the rate and extent of infrastructure improvements. Areas with lower average household income levels and limited commercial presence may have reduced access to private resources, technical advocacy, and funding mechanisms needed to accelerate identification, documentation, and implementation of drainage improvements. Over time, prolonged exposure to recurring drainage limitations without implemented solutions or temporary resolutions can result in those affected by the issue adapting to existing conditions. This reduces the frequency of formal reporting or documented complaints. This can limit the availability of formal documentation used to support infrastructure prioritization and funding allocation.

2.0 Data Collection and Existing Conditions

2.1. Due Diligence

Due diligence research was performed to compile and evaluate all available background information relevant to the Penstock Wash system and the Smokerise Neighbourhood. This ensures that the analyses are grounded in verified data and consistent with existing regulatory and design frameworks.

2.1.1. Review of Available Reports and Criteria

Available reference materials were reviewed to confirm existing infrastructure characteristics, floodplain extents, and applicable design requirements. These materials include City of Flagstaff stormwater mapping, FEMA Flood Maps, and previously developed drainage documentation. Applicable design criteria from the City of Flagstaff Stormwater Management Design Manual and FEMA floodplain management regulations were reviewed as well. Table 2-1 shows an overall review of criteria found in the manual and regulations.

Table 2-1: Review of Criteria

Requirement Category	Design Criteria	Technical Specifications	Regulatory Standard	Maintenance Considerations
Open Channel Design	Conveyance of 25-year and 100-year storm events.	Min 0.5% slope; Max velocity 18 ft/s; Min 1 ft freeboard; Side slopes 3H:1V (natural) or 2H:1V (riprap).	City of Flagstaff 2025 Stormwater Management Design Manual Section 5.3.7	12-ft min maintenance access road; soil-cement linings prohibited for public channels.
Hydrologic Modeling	Selection of modeling method based on area and routing needs.	Rational Method or Unit Hydrograph for larger catchments.	City of Flagstaff 2025 Stormwater Management Design Manual Section 4.0 and SCS (NRCS) Standards	Accounting for land use changes and soil hydrologic groups.
Hydraulic Design Criteria - Streets	10-year and 100-year storm containment.	Local: 10-yr between curbs, 100-yr in ROW. Arterial/Collector: 10-yr one 12-ft lane open in each direction, 100-yr in ROW.	City of Flagstaff 2025 Stormwater Management Design Manual Section 5.3.3.1	Avoid concentrated flows over sidewalks; design to prevent silt/debris deposition on traveled way.
Post-Wildfire Flood Mitigation	Adjustment for altered hydrologic response in burn scars.	Use 2D flood routing; include bulking factor and 50% clogging for 10-yr post-burn.	City of Flagstaff 2025 Stormwater Management Design Manual Section 9.0	Frequent sediment removal; assess stabilization/recovery over 10-year period.

Hydraulic Design Criteria	Hydraulic efficiency and flow capacity for uniform flow and varied storm events.	Manning's n: concrete (0.013), asphalt (0.015), earth (0.022-0.035). 2 to 25-yr for pipes, 10 to 100-yr for detention.	Manning's Equation and City/Local Drainage Manual Standards	Provision of freeboard to prevent overflows due to waves or fluctuations.
Storm Drain Conduits	Material selection and structural integrity.	Min 18" diameter, Min velocity 3 ft/s full.	City of Flagstaff 2025 Stormwater Management Design Manual Section 5.3.4.4	Changes in size/grade; inspect for sediment/scour.
Erosion Hazard & Setbacks	Protection against soil piping, sloughing, and channel bank migration.	Min 10-ft setback from top edge of bank; installation of longitudinal drains or drainage blankets in earth embankments.	City of Flagstaff 2025 Stormwater Management Design Manual Section 7.0 and Casagrande phreatic surface analysis	Protection of downstream face; natural vegetation not acceptable for reducing setbacks.
Material Selection & Linings	Erosion control and channel stability.	Rigid liners (concrete, grouted riprap) vs. Flexible liners (gravel, riprap, gabions, grass).	Maximum Permissible Velocity Method	Self-healing properties of flexible liners; maintenance access on top width.
Reporting Contents	Submittal requirements for PDR, FDR, and hydrograph documentation.	8.5"x11" text; Maps max 36"x48"; include location, soils, hydraulic calcs.	City of Flagstaff 2025 Stormwater Management Design Manual Section 2.3 and HEC-RAS/EPA-SWMM standards	FDR must discuss maintenance access and documentation for future infrastructure evaluation.

2.1.2. Review of Existing Data

Existing topographic data was collected and reviewed to support watershed delineation. Figure 2-1 illustrates the existing stormwater infrastructure and inferred flow paths within the Smokerise Neighborhood. The map highlights roadway drainage patterns, culvert locations, and overland flow routes, demonstrating how runoff from upstream areas and Highway 89 is conveyed through the neighborhood street network toward Penstock Wash. Concentrations of mapped drainage features and flow paths indicate areas where stormwater is directed along roadways, contributing to localized ponding and flooding concerns observed during field reconnaissance. Data sources include City of Flagstaff GIS datasets, county and national LiDAR elevation data, and available aerial imagery. These datasets were evaluated for resolution, vertical accuracy, and applicability to the project area. The available LiDAR data was used to establish flows and elevation within the greater Penstock watershed. Upstream watershed data, including cross-sectional area, slopes, and soil type was mainly obtained through LiDAR data, Stream Stats, and Web Soil Survey.

Figure 2-1: Smokerise Neighborhood Current Stormwater Infrastructure

2.1.3. Identification of Known Issues

Known drainage deficiencies and flooding concerns within the Smokerise Neighbourhood were identified through a review of City of Flagstaff stormwater records, floodplain mapping, and prior documentation. Reported issues include frequent surface flooding during storm events, overtopping of existing conveyance features, sediment accumulation within channels, and reduced culvert capacity due to vegetation and debris. In addition to documented sources, recurring complaints from residents and staff at the nearby Forest Service located near the entrance to East Trails End Drive from Highway 89 further highlight the severity of the issue. These stakeholders have consistently reported roadway flooding within the neighborhood and significant ponding within the parking lot area, particularly during moderate to large storm events. Temporary mitigation measures, such as the placement of sandbags, have been implemented in an effort to redirect or contain flows; however, these measures have proven insufficient in preventing floodwaters from flowing into developed areas. Water damage has also been reported due to this flooding.

2.2. <u>Site Investigation</u>

A site investigation was conducted to verify existing conditions, document drainage features, and supplement desktop data with field observations. The field effort focused on both engineered and natural drainage elements within the project limits.

2.2.1. <u>Field Reconnaissance</u>

Field observations were used to identify areas of concern, such as foliage and debris buildup along the direct runoff of Highway 89, as well as dense native foliage obstructing the natural wash segment of the floodplain. It was also noted that the culvert running under HWY 89 conveys as much as it can but a majority of the Penstock Wash runoff stays on the west side of the highway. Highway 89 runoff is sent through a curb storm drain inlet, where it outlets into the natural channel area, as shown in Figure 1-3.

2.2.2. <u>Survey Data Collection</u>

Surveying efforts focused on channel geometry, culvert inlets and outlets, roadway crossings, and key grade breaks within the drainage path. Collected survey data provides critical elevation control for defining flow paths, channel slopes, and hydraulic structure geometry, and improves the accuracy of subsequent hydrologic and hydraulic modelling. Additional surveying photos can be found in Appendix A.

Figure 2-2 shows the upstream end of the project redesign area facing E Trails End Drive, including the double-barrel culvert system.

Figure 2-2: Upstream of Site Showing Double Barrel System Under Hwy 89

Figure 2-3 shows the culvert inlet that goes underneath the Forest Service building parking.

Figure 2-3: Culvert Inlet Under Forest Service Parking Lot

Figure 2-4 shows the channel and gravel area from the road looking upstream.

Figure 2-4: Culvert and Gravel Road

2.2.3. Data Processing and Base Mapping

Field and survey data were processed and integrated with existing GIS datasets using ArcGIS Pro. A preliminary topographic base map was developed to delineate watershed boundaries, identify drainage divides, locate existing infrastructure, and define channel alignments, which can be seen in Figure 2-5. This base mapping serves as the geometric foundation for hydrologic modelling, hydraulic evaluation of existing conditions, and development of conceptual design alternatives. Full size topographic map can be found in Appendix E.

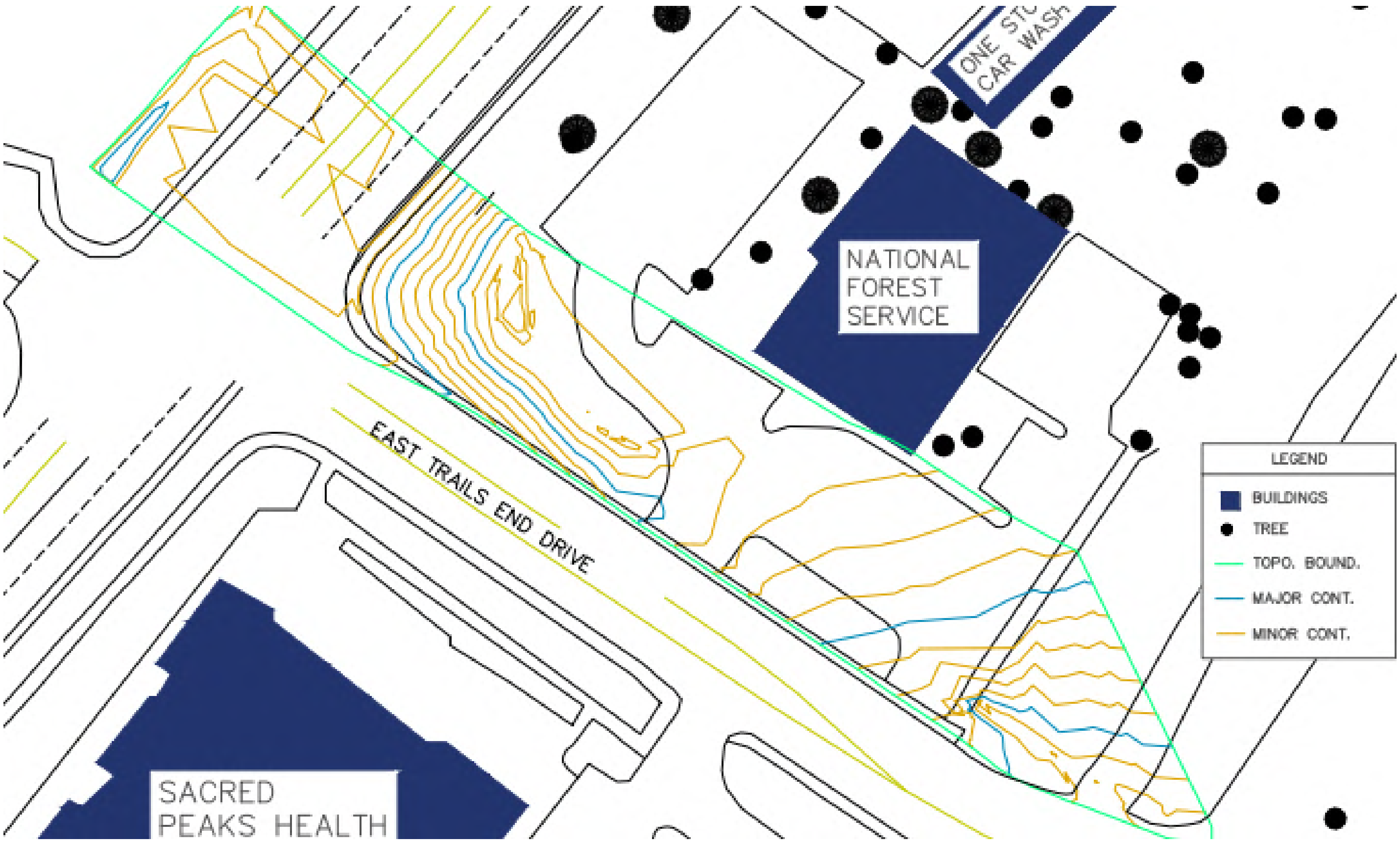

Figure 2-5: Topographic Map

3.0 <u>Hydrologic Analysis</u>

3.1. Watershed Delineation

Watershed delineation was conducted using Stream Stats, ArcGIS, and HEC-HMS in combination with LiDAR-derived elevation data and available City of Flagstaff GIS datasets. Digital elevation models were processed to identify drainage divides, flow paths, and contributing areas draining to the Penstock Wash corridor and associated culvert crossings. Sub-basins were defined based on topographic controls, roadway embankments, and existing channel geometry.

Field-verified elevation data collected during the site investigation were used to confirm critical drainage features and flow directions identified during desktop analysis. Watershed boundaries were refined to reflect observed site conditions, including localized drainage controls created by infrastructure and surface grading. This information allowed us to find the contributing drainage area, which directly influences runoff volume, peak discharge, and hydrograph shape used in design-level analyses. Figure 3-1 shows the delineated Penstock Watershed that was analyzed by HEC-HMS.

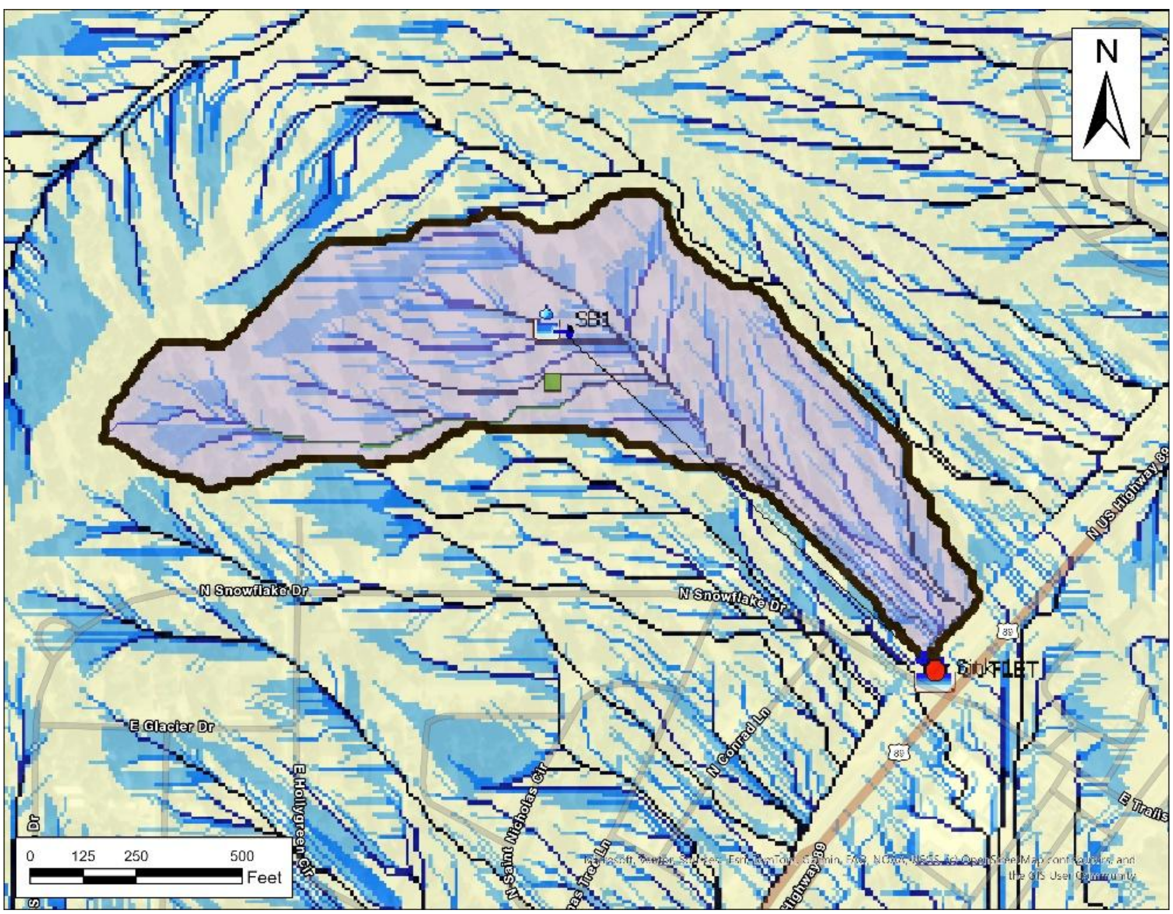

Figure 3-1: Delineated Penstock Watershed

3.2. Hydrologic Parameters and Assumptions

Hydrologic parameters were established based on a combination of field observations, GIS analysis, and published reference data. Land-use classifications within the watershed include a mixture of residential development, roadway surfaces, and undeveloped or vegetated areas. Impervious surface coverage was estimated using City of Flagstaff land-use GIS layers, aerial imagery, and Web Soil Survey. Figure 3-2 illustrates the soil map of the Penstock watershed and

Table 3-1 shows the soil types present. Hydrologic modeling was further performed using the Hydrologic Engineering Center's Hydrologic Modelling System (HEC-HMS) in conjunction with NRCS TR-55 runoff computation methods. Sub-basins delineated from the Rio de Flag were imported into the HEC-HMS modelling framework, and basin parameters, including area determined using LiDAR data and USGS DEMs, slope, Curve Number found using USDA, and time of concentration, were assigned to each sub-basin. Paths between sub-basins and outlets were simplified at this stage of design to focus on establishing key control points. More information is available in Appendix C.

Table 3-1: Soil Parameters

Soil Type / Description	% of Area	Slope	Drainage Class	Soil Group	Infiltration	Flooding Potential	Considerations
Paymaster fine sandy loam	0.30%	0–3%	Well drained	B	Moderate to high	Rare	Minimal influence due to small coverage
Mixed mountainous soils	21.90%	0–55%	Well drained	B&C/D	Very low to moderate	None to rare	Some areas promote runoff due to shallow soils and slope
Mountain slope soils	77.80%	8–75%	Well drained	C/D	Very low to moderate	None	Increase runoff potential

3.3. Time of Concentration and Analysis

The time of concentration (Tc), defined as the time required for runoff from the hydraulically most distant point in the watershed to reach the outlet was found using HEC-HMS and the Rational Method (Equation 3-3) to check the results. NRCS TR-55 methodologies were used within HEC-HMS in order to have flow paths divided based on observed site conditions and mapped drainage features. The time of concentration was computed by selecting appropriate Manning's roughness coefficients selected based on surface cover and slope. The HEC-HMS results were slightly higher than the Rational Method calculated results, but still within a comfortable area of error. Penstock Watershed was found to have a lag time of 30.63 minutes using Equation 3-2 and a time of concentration of 51 minutes using Equation 3-1.. Full reports are available in Appendix B.

Equation 3-1: HEC-HMS Time of Concentration Calculation

$$T_c = C_t * (\frac{L * L_c}{\sqrt{S}})^{0.3}$$

Where:

T_c = Time of Concentration
L = Length of Flow Path
L_c = Length of Centroidal Flow Path
S = 10-85 Flow path Slope
C_t = Empirical coefficient of 2.2

Equation 3-2: Lag Time Conversion

$$T_{lag} = 0.6 * T_c$$

Where:

T_L = Lag Time
T_c = Time of Concentration

Equation 3-3: Rational Method Equation

$$Q = C * I * A$$

Where:

Q = Maximum Rate of Runoff (ft^3/s)
C = Runoff Coefficient
I = Average Rainfall Intensity (in/hr)
A = Drainage Area (acres)

Rational Method parameters were gathered from StreamStats, NOAA, and Web Soil Survey for the corresponding 10-year and 100-year storms to check HEC-HMS outputs. Table 3-2 shows Rational Method inputs for runoff coefficient, average rainfall intensity, and drainage area to solve for volumetric flow rate as seen in Equation 3-3.

Table 3-2: Rational Method Inputs

Rational Method Inputs		
Variable	10 year	100 year
Q (ft^3/s)	179.37	268.93
C	0.46	0.46
I (in/hr)	2.91	4.35
A (acres)	134.4	134.4

3.4. Design Storm and Rainfall Data

Design storm precipitation depths and temporal distributions were obtained from Stream Stats and checked with NOAA Atlas 14 for Coconino County, Arizona and obtained the rainfall intensity value. Consistent with City of Flagstaff stormwater design requirements, the 10-year and 100-year storm events were selected for analysis. Rainfall depths were applied uniformly across the watershed, and storm durations were selected.

3.5. Preliminary Results

Preliminary hydrologic modeling results from Stream Stats include peak discharges for the 10-year and 100-year design storm events at key locations along Penstock Wash. The flows given were checked against Hydro CAD, and similar results were found.

Table 3-3 illustrates outputs from the HEC-HMS model, including flow path lengths and slopes, and relief and elongation ratios, and drainage density. More information on analysis done in HEC-HMS can be found in Appendix B.

Table 3-3: HEC-HMS Results

HEC-HMS Outputs	
Longest Flow path Length (mi)	1.63
Longest Flow path Slope (mi)	0.25
Centroidal Flow path Length (mi)	0.84
Centroidal Flow path Slope (ft/ft)	0.06
10-85 Flow path Length (mi)	1.2
10-85 Flow path Slope (ft/ft)	0.2
Basin Slope (ft/ft)	0.36
Basin Relief (ft/ft)	2117.06
Relief Ratio	0.25
Elongation Ratio	0.43
Drainage Density (mi/mi^2)	203.34

3.6. Additional Analysis

In order to get more accurate design storms, a separate analysis of the US-89 Basin was done to add to the existing flow rates. The Rational Method was used to estimate the additional flow from this culvert for both design storms. The US-89 basin, as outlined in Figure 3-3, contributes 4 and 6 cfs to the 10-year and 100-year storms. Hand calculations can be seen in Appendix B3.

Figure 3-2: Road Map of Site

The values used for the Rational Method to calculate the contributing flow are shown in Table 3-3, including runoff coefficent, rainfall intensity, and area of the Highway 89 basin.

Table 3-4: Flow Calculations

Additional Flow Calculations		
Variable	10 year	100 year
Q (ft^3/s)	4.00	6.00
C	0.95	0.95
I (in/hr)	3.00	4.50
A (acres)	1.38	1.38

Highway 89 runoff added 4 and 6 cfs to the 10 year and 100 year storms. The runoff in both the East and West parking lot basin was found to be negligible. Furthermore, the existing double barrel culvert under Highway 89 was put into Culvert Master in order to get a better idea of capacity since most of the flow continues south in the ditch along the highway. Table 3-5 shows inputs put into Culvert Master in order to calculate the maximum discharge.

Table 3-5: Culvert Master Inputs

Culvert Master Inputs	Value
Manning's	0.024
Ke	0.5
Invert Upstream (ft)	6905.31
Invert Downstream (ft)	6901.72
Length (ft)	122.07
Allowable HW (ft)	6911.19
Tailwater Elevation (ft)	6901.72

The outputs from Culvert Master can be seen in **Error! Reference source not found.**. It was found that the existing culverts are capable of moving around 53 cfs without overtopping Highway 89. Flooding of the road hasn't occurred at this specific road site even during recent 500-year storm events. Since detailed hydraulic analysis of the ditch that is along Highway 89 is outside of the scope of the project, the maximum flow that will reach the neighboorhood was assumed to be the culvert maximum capacity. The full report can be seen in Appendix B.

Table 3-6: Culvert Master Outputs

Culvert Master Outputs	Value
Slope	0.029
Discharge (cfs)	53.71
Velocity (ft/s)	9.00
Depth (ft)	1.81

The new design storrms for the 10 year and 100 year storm are 38 and 60 cubic feet per second after adding in the runoff from the curb inlets on Highway 89. The value of 53.71 was used as the design storm for the purposes of the HEC-RAS model to prevent overtopping of Highway 89 and downstream hydraulic structures of the culvert were designed for the new 10 year and 100 year storm values.

4.0 <u>Hydraulic Analysis</u>

4.1. <u>Existing Drainage Infrastructure Overview</u>

The existing Penstock Wash drainage system consists of a combination of engineered conveyance structures and natural drainage features. Key infrastructure elements include multiple roadway culverts conveying flow near East Trails End Drive and the National Park Service Parking lot and adjacent transportation corridors, followed by an open, unlined channel that transitions through vegetated and overgrown areas before entering a FEMA-designated floodplain channel. Downstream of the floodplain reach, flow is ultimately routed toward a detention basin that discharges to the Rio de Flag. Field reconnaissance confirmed that several drainage features exhibit signs of reduced hydraulic efficiency, including sediment accumulation, vegetation encroachment, and irregular channel geometry. The culvert system appears undersized relative to observed flood extents, and channel sections lack uniform cross-sectional shape and stabilization measures. The drainage infrastructure that will be focused on is only the doule barrel culverts and the one conveying flow under the parking lot.

Figure 4-1 shows river stationing (RS) of the project area with the first cross section being labelled 1488 as seen before the double barrel culvert and the last cross section as 1000 where the gravel road ends.

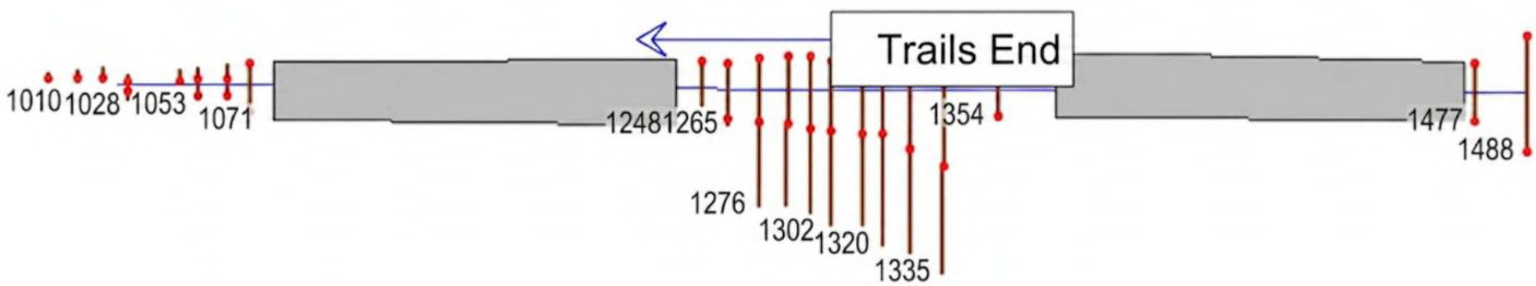

Figure 4-1: River Stationing of East Trails End Drive

Figure 4-2 shows the overall Penstock Wash system as a HEC-RAS profile, including 10- and 100-year storm events as well as all cross sections and culverts. The model illustrates the build-up of water flowing downstream to upstream and the flooding of the National Park Service parking lot. The model also shows the flooding across the gravel road below the culvert systems.

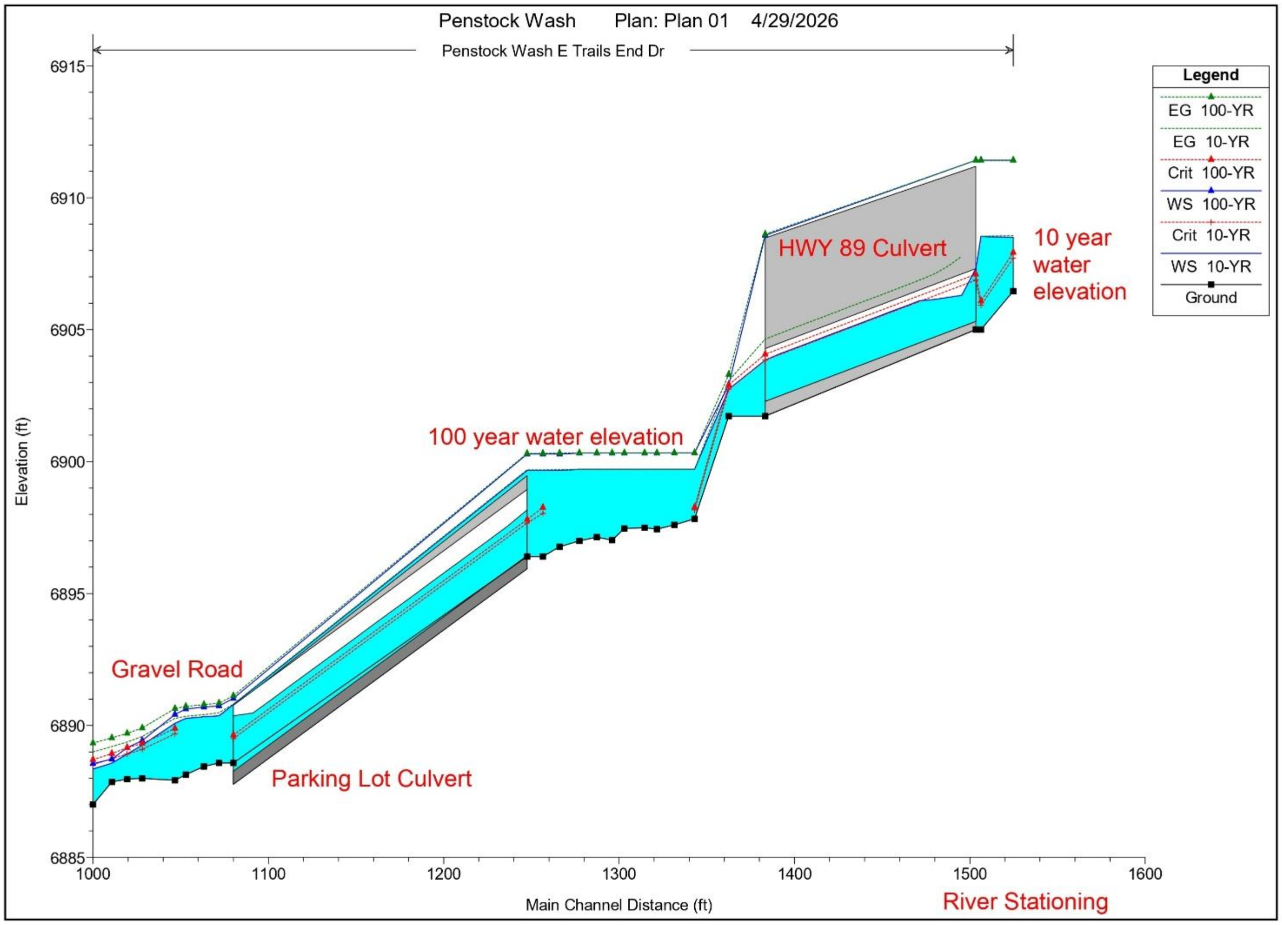

Figure 4-2: Penstock Wash Full Profile

4.2. Culvert Hydraulic Evaluation

Hydraulic evaluation of the existing culverts was performed to determine their capacity and performance under the 10-year and 100-year design storm discharges developed. The culverts were analysed to assess inlet and outlet control conditions, headwater depth, tailwater influence, and overall flow capacity. Calculations considered culvert geometry, material type, slope, and entrance conditions observed during field investigation. The culvert underneath HWY 89 is inlet control for 10 year and outlet control for the 100 year and the culvert underneath the National Park Service building is overtopping the parking lot, with outlet control in the 10 year storm.

Figure 4-3 shows the current conditions of the double barrel culvert flowing underneath Highway 89 located at River Station 1473. The culvert is full as mentioned previously with the Culvert Master analysis, but is not overtopping. The blue lines show the 10 year and 100 year storm water surface elevations. Both culvert inlet and outlets can be found in Appendix C.

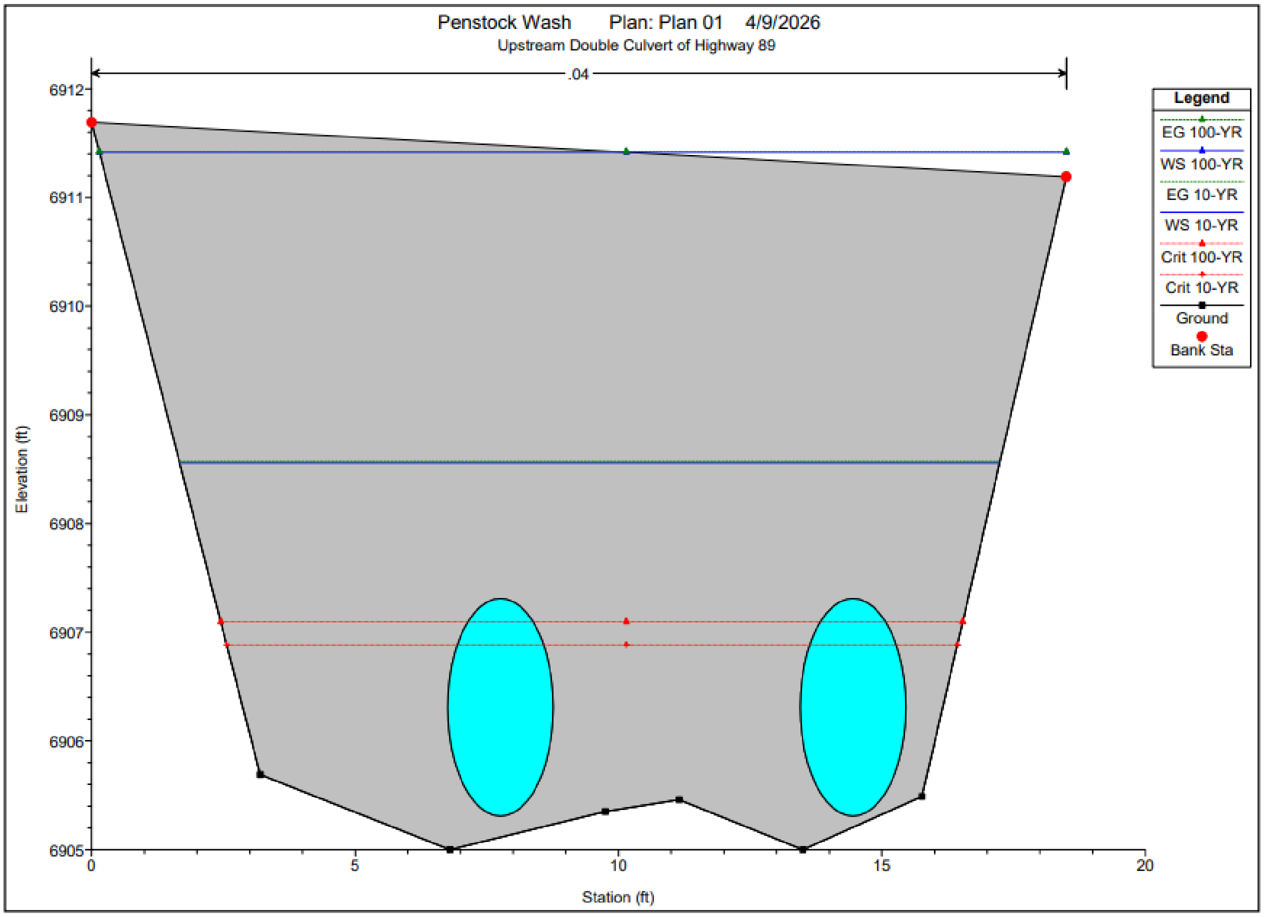

Figure 4-3: Double Barrel Culvert Inlet Condition

Figure 4-4 shows the current culvert conditions of the National Park Service parking lot culvert located at River Station 1248. Overtopping of the road is present in both the 10 and 100 year storms and it is conveying water inadequately. The blue lines represent the design storms, which cause significant flooding of the roadway – nearly a foot of water in the 100 year storm.

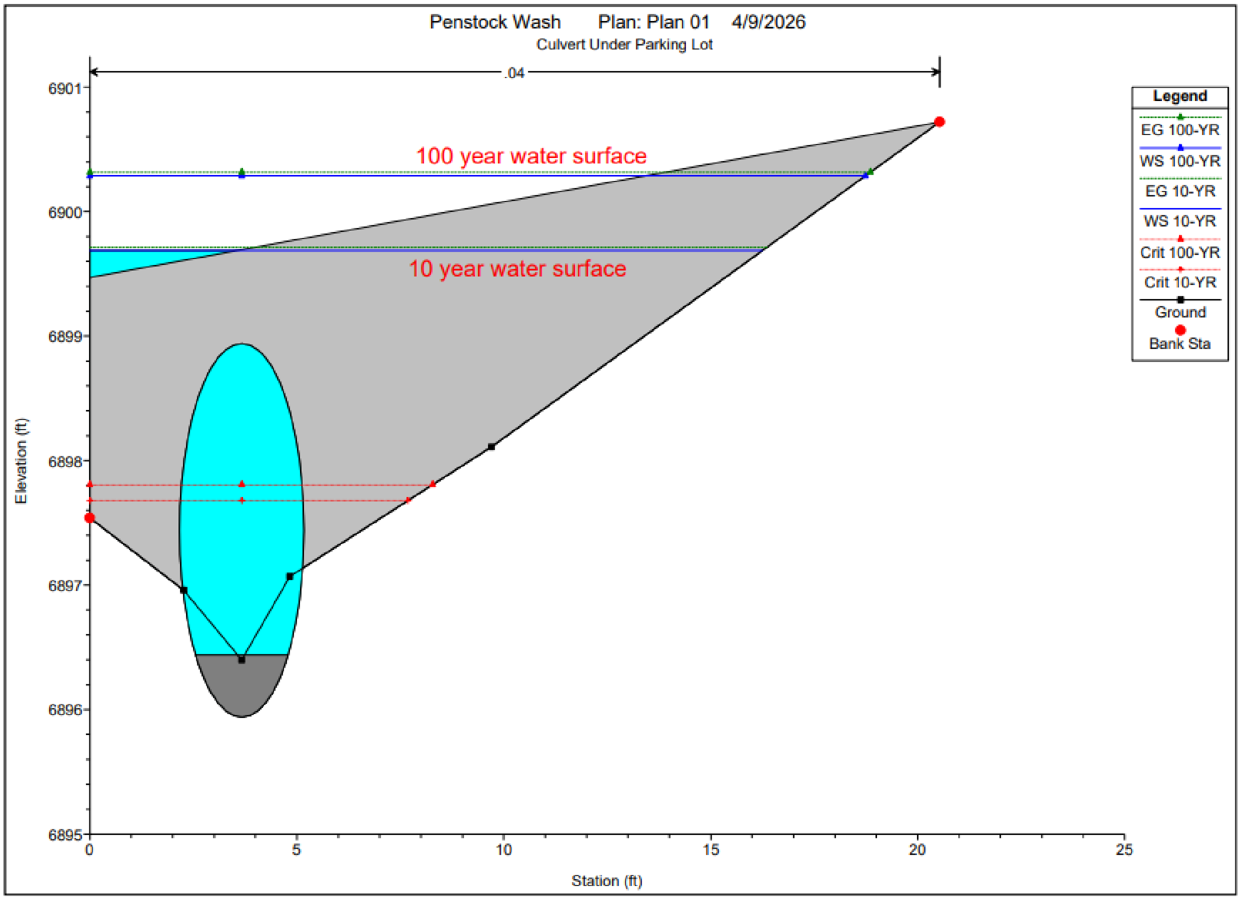

Figure 4-4: Parking Lot Culvert Inlet Condition

Headwater-to-diameter (HW/D) ratios were computed for each storm event to evaluate the potential for roadway overtopping and upstream backwater effects. Culvert capacities were estimated using HEC-RAS, inlet and outlet control, and energy balance as applicable. Modelled headwater elevations were compared against roadway profiles and City of Flagstaff design criteria to determine compliance with allowable freeboard and non-overtopping requirements. Table 4-1 shows outputs from culvert analysis for both culverts, including the energy grade inlet and outlet control (E.G.), water surface upstream and downstream (W.S), and culvert velocities and flows.

Table 4-1: Culvert Analysis Results

River Station	Profile	E.G. US.	W.S. US.	E.G. IC	E.G. OC	Min Weir Elevation	Flow Culvert	Flow Weir	Change WS	Culvert Velocity US	Culvert Velocity DS
		(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(ft)	(ft/s)	(ft/s)
1473	38	6908.57	6908.56	6908.57	6908.24	6911.20	38.35	0.00	5.81	6.10	7.22
1473	53	6911.42	6911.42	6910.14	6911.42	6911.20	52.07	0.93	8.51	8.29	8.79
1248	38	6899.71	6899.69	6899.71	6899.77	6899.48	37.89	0.46	9.30	7.76	6.58
1248	53	6900.32	6900.29	6900.32	6900.11	6899.48	43.06	9.94	9.55	6.84	6.85

At the Highway 89 culvert, the energy grade upstream is well below the minimum weir elevation and there is no flow going over the road for the 10 year storm. For the 100 year storm, the energy grade rises to 6911.42 feet which slightly exceeds the minimum weir elevation. These results depict the Highway 89 culvert as performing well under the 10 year storm, but starting to have backwater effects for the 100 year. The culvert underneath the National Park Service parking lot, has a energy grade elevation of 6899.71 ft that exceeds the mininum weir elevation. As a result, the parking lot experiences overtopping for both the 10 year and 100 year event, and almost 10 cfs of water flows over the roadway. Additionally, the water piles up on the upstream side of the parking lot due to the large amount of sediment present within the culvert which can be seen in the large water surface change. The velocities are shown exceeding 5 cubic feet per second in some areas with the highest velocity at 8.79 ft/s. This illustrates the need for erosion protection for the channel.

4.3. <u>Open Channel Hydraulic Evaluation</u>

The hydraulic performance of the existing open-channel segments of Penstock Wash was evaluated using the Hydrologic Engineering Center River Analysis System (HEC-RAS). Channel cross sections were developed using surveyed data supplemented with LiDAR-derived elevations where necessary. Manning's roughness coefficients were assigned based on observed channel conditions, including vegetation density, channel irregularity, and bed material.

Steady-flow simulations were conducted for the 10-year and 100-year design storm events to compute water-surface elevations, flow depths, velocities, and available freeboard along the channel. The analysis focuses on determining whether the existing channel geometry provides sufficient conveyance capacity while maintaining acceptable velocity ranges to limit erosion and sediment transport. Areas exhibiting excessive velocities, inadequate freeboard, or potential overtopping were identified as indicators of hydraulic and stability deficiencies. More information can be found in Appendix C.

Figure 4-5 shows River Station 1329, 30 feet downsteam from the culvert under Highway 89.

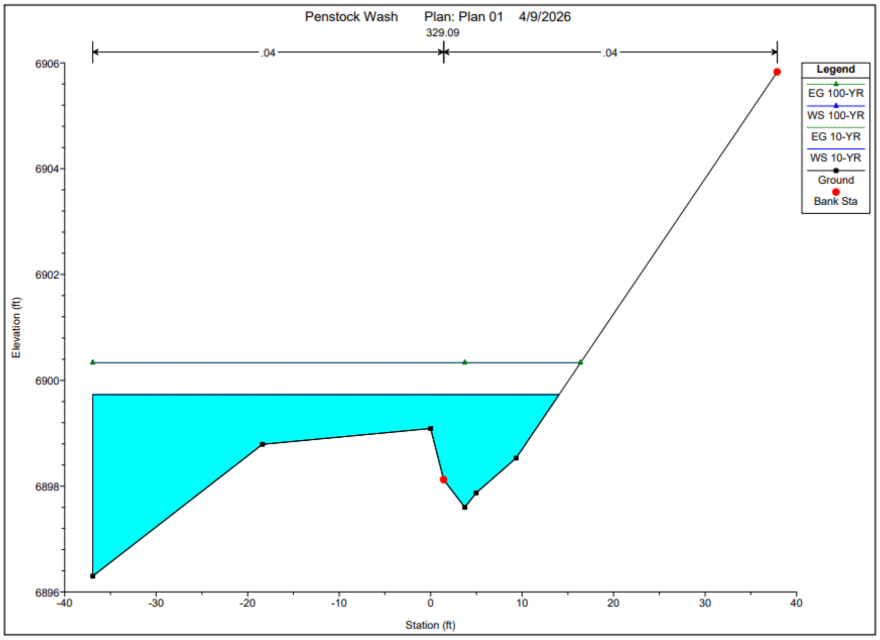

Figure 4-5: River Station 1329 Current Conditions

The cross section illustrates the flooding of the National Park Service parking lot under both the 10 year and 100 year storms. Existing conditions show the overtopping of the channel and the water spilling into the parking lot (Stations -37 to 0).

Figure 4-6 shows River Station 1256, the area right above the parking lot culvert.

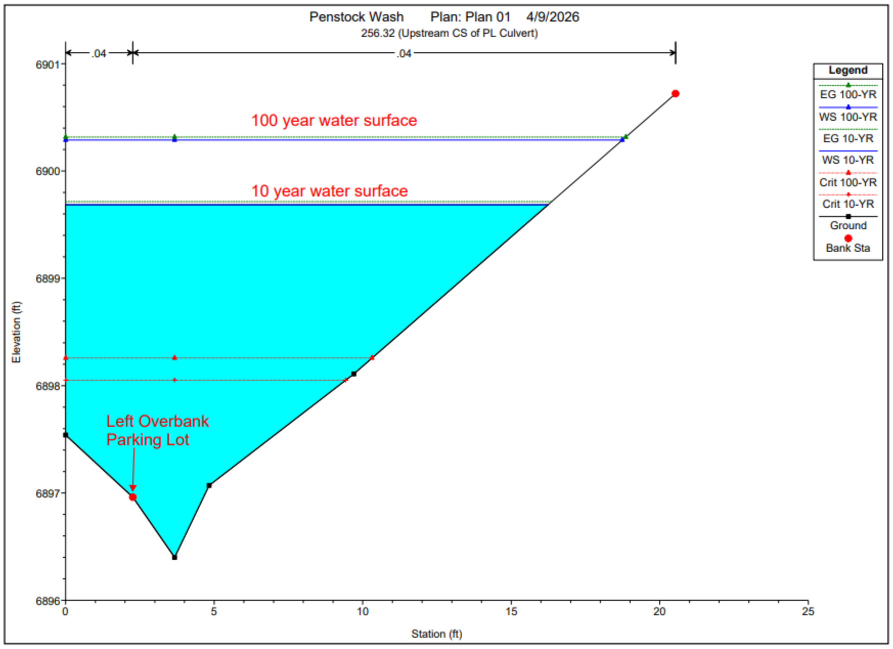

Figure 4-6: River Station 1256 Current Conditions

This cross section illustrates the extent of the flooding of the channel and parking lot, with a majority of the water over the left bank station. Figure 4-7 shows the gravel area at the end of the channel.

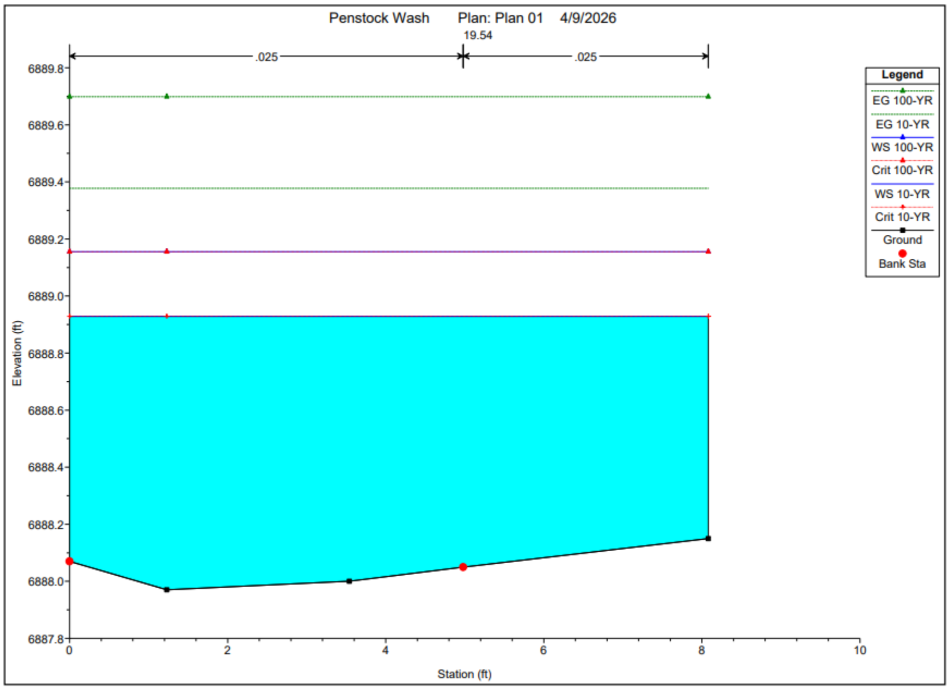

Figure 4-7: River Station 1019 Current Condition

The gravel area is flooding over due to the small slope change and it not being a channel like the rest of the area. During the 100 year storm, there could be up to 2 feet of water flowing over the road. Table 4-2 shows outputs for these three cross sections, River Stations 1329, 1256, and and 1019 and their corresponding elevations, energy grade (E.G.) slopes, velocities, and Froude numbers. All cross-section data is available in Appendix C.

Table 4-2: Cross Section Data

River Station	Profile	Flow Total	Min Channel Elevation	Water Surface Elevation	E.G. Elevation	E.G. Slope	Velocity Channel	Flow Area	Top Width	Froude Number
1329	10	38	6897.60	6899.70	6899.70	0.000139	0.51	72.83	50.95	0.08
1329	100	53	6897.60	6900.30	6900.30	0.000086	0.47	103.93	53.29	0.07
1256	10	38	6896.40	6899.70	6899.70	0.000756	1.39	28.52	16.24	0.19
1256	100	53	6896.40	6900.30	6900.30	0.000623	1.41	38.94	18.71	0.18
1019	10	38	6887.97	6888.90	6889.40	0.012074	5.57	7.17	8.08	1.02
1019	100	53	6887.97	6889.20	6889.70	0.011484	6.13	9.00	8.08	1.01

Across the entire channel there is a varied velocity that fluctuates between 1 cfs to 8 cfs. This velocity change can be attributed to both the culvert running under the parking lot's location and the increased slope of the channel. The velocity at River Station 1329 is only 0.47 cfs with a very large flow area of 103 square feet showing a clear representation of the varied channel conditions. Between River Stations 1477 and 1256, there is a lot of backwater, as shown by the extremely low velocities and the slope dropping to nearly zero. The water is pooling up and creating large flow areas, despite the small flow rate of 53 cfs, shown by the energy slope in River Station 1329 being nearly flat. Additionally, there's a large change in Froude numbers throughout the channel. At the upstream stations, the flow is subcritical as seen by the small values of 0.19 and 0.07, but the flow becomes supercritical at River Station 1019 (the start of the gravel road) where the Froude number exceeds 1 and is highly erosive. At this location, lower flow areas as small as 9 square feet become present. Ultimately, the drainage infrastructure in this area is not adequately able to convey water due to the large velocity and slope changes.

5.0 Alternatives Developments & Screening

After Existing Hydraulic Analysis was completed, improvement alternatives were developed to address the deficiencies described above. The goal of these alternatives was to improve flood control performance while minimizing cost and complying with regulations stated in the City of Flagstaff Stormwater Management Design Manual.

5.1. Design Criteria and Evaluation Framework

Design criteria include hydraulic performance, regulatory compliance, cost, constructability, durability, and environmental and social impact. Each criterion was assigned a weighting factor that reflects its relative importance in meeting project objectives and the total sums up to 100%. This was used to create a decision matrix in order to select the alternative that best balances performance, cost, and overall sustainability. In order to give each alternative as accurate a score as possible, each category was given a multiplier relative to its importance in the design process. Hydraulic performance was given 0.4 multiplier as it is most impactful for the design to reduce flooding in the Smokerise neighborhood, regulatory compliance was given 0.15 as it is important to follow the design standards outlined for City of Flagstaff, cost was given 0.1 as each alternative comes with differing long-term costs but is still important in the decision process, constructability was given a 0.1 multiplier which refers to how reasonable the design is to incorporate, durability was given 0.15 as the long-term maintenance is important, and environmental and social impact were given 0.1 as the design needs to provide community benefit, in addition to other factors.

5.2. Development of Alternative Design Considerations

Alternative 1 emphasizes maximizing flow conveyance through a combination of structural upgrades and grading modifications. This alternative includes culvert cleaning of both the Highway 89 and National Park Service parking lot culverts to remove sediment accumulation in order to increase hydraulic capacity at the primary control point. Downstream of the highway crossing, the channel adjacent to the National Park Service parking lot would be regraded through the construction of a retaining wall to better direct flow within the intended path as well as meet regulatory requirements. The entire channel will be reshaped into trapezoidal channel geometry to better convey water through the system. Additionally, the gravel road would be taken out in this case and becomes a defined flow path and reduces uncontrolled flow. Rip rap is put in areas with higher velocities within the channel to help with erosion. Collectively, these improvements are intended to reduce ponding in the parking lot, limit flow dispersion, and improve the efficiency of stormwater routing through the system. Figure 5-1 shows the plan view of Alternative 1 and Figure 5-2 shows the conceptual alternative as a full HEC-RAS profile. Full size plan views are available in Appendix E.

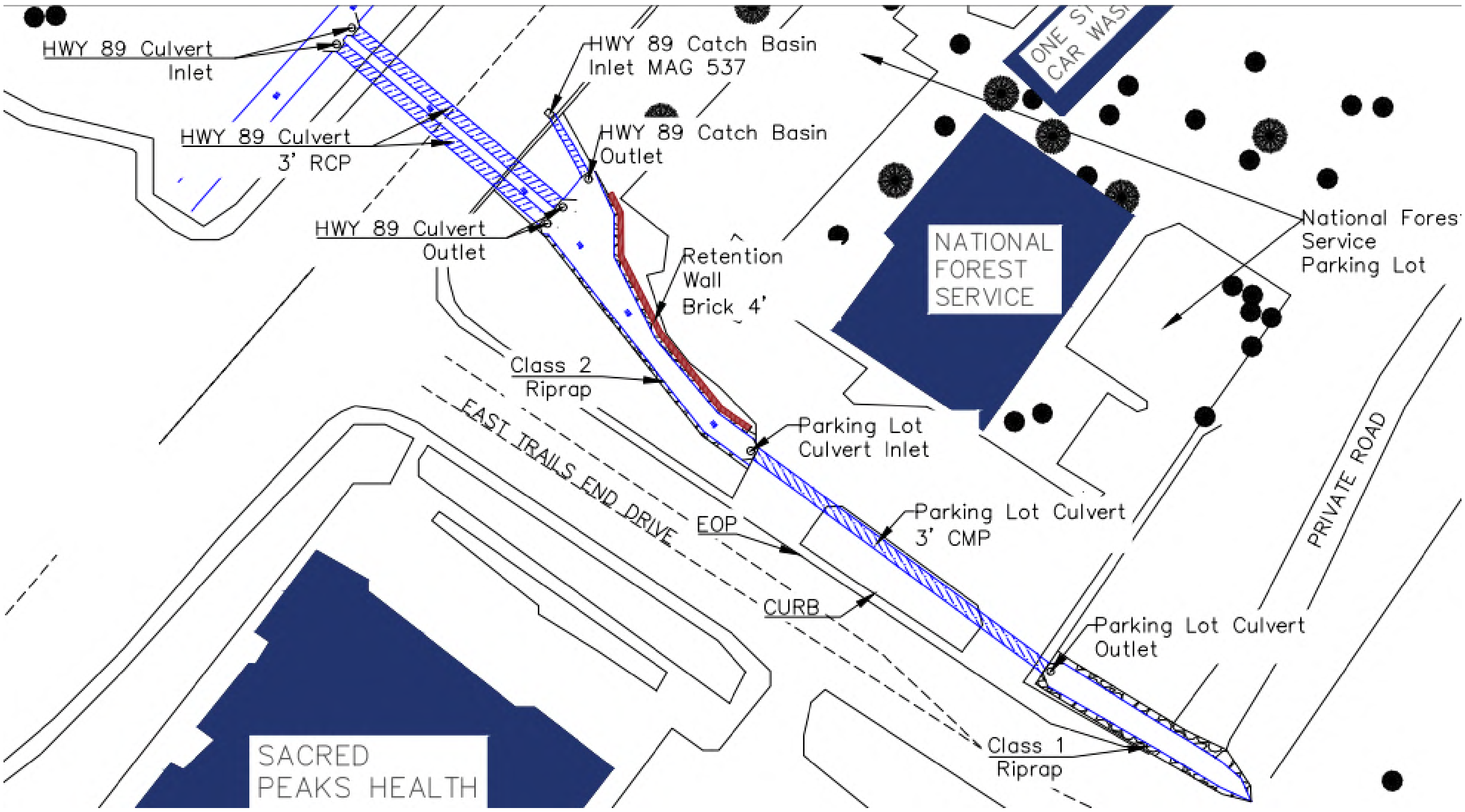

Figure 5-1: Plan View of Alternative 1

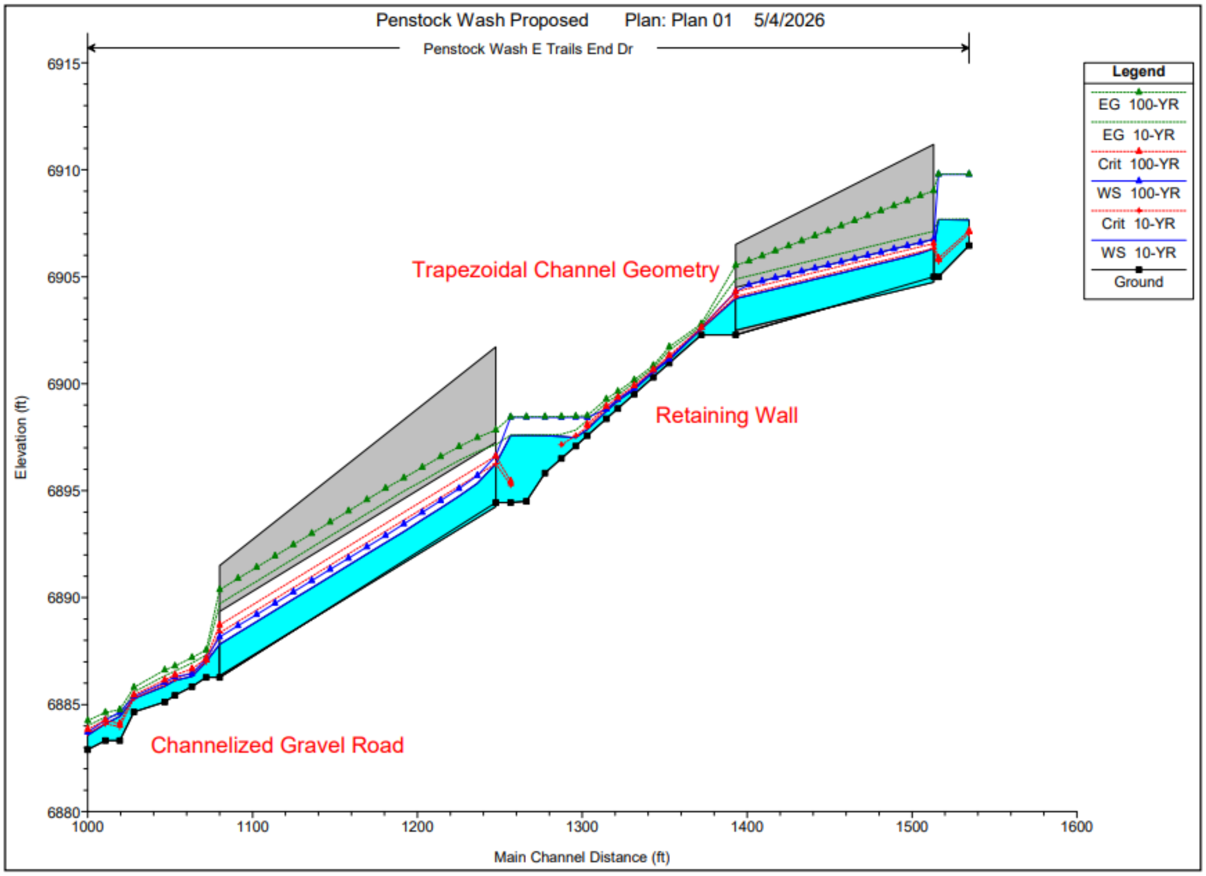

Figure 5-2: Alternative 1 Full Profile

Alternative 2 focuses on a more comprehensive reconfiguration of the existing drainage channel to improve hydraulic performance and long-term stability. This approach includes a full channel geomorphology redesign, incorporating revised channel geometry, alignment, and grading to better accommodate anticipated flow conditions while reducing erosion and sediment deposition with triangular channel shape. Culvert improvements under this alternative would only include cleaning. The gravel road would be taken out in this case and becomes a defined flow path and reduces uncontrolled flow. This alternative prioritizes a balanced approach between hydraulic capacity and geomorphic stability. Figure 5-3 shows the full plan view of Alternative 2. Figures 5-4 and 5-5 shows the full profile design in HEC-RAS and an example of the triangular channel geometry. Full size plan view available in Appendix E.

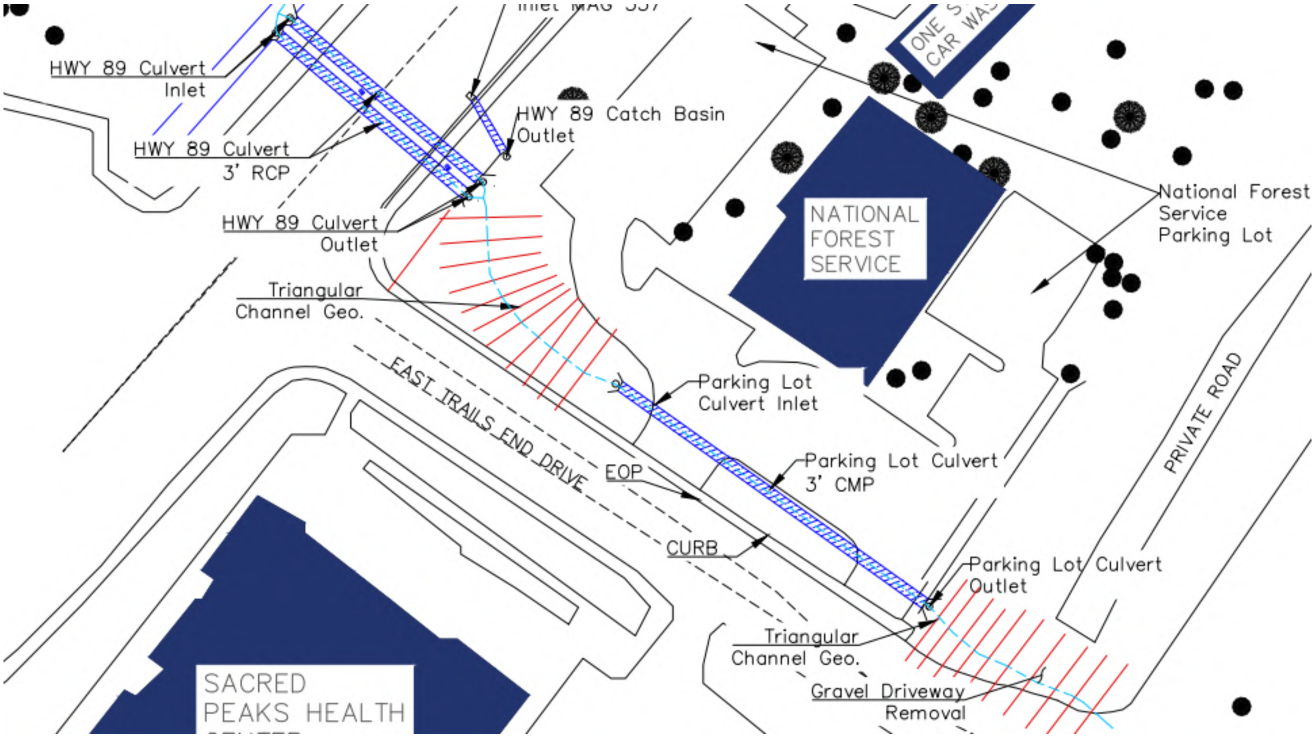

Figure 5-3: Plan View of Alternative 2

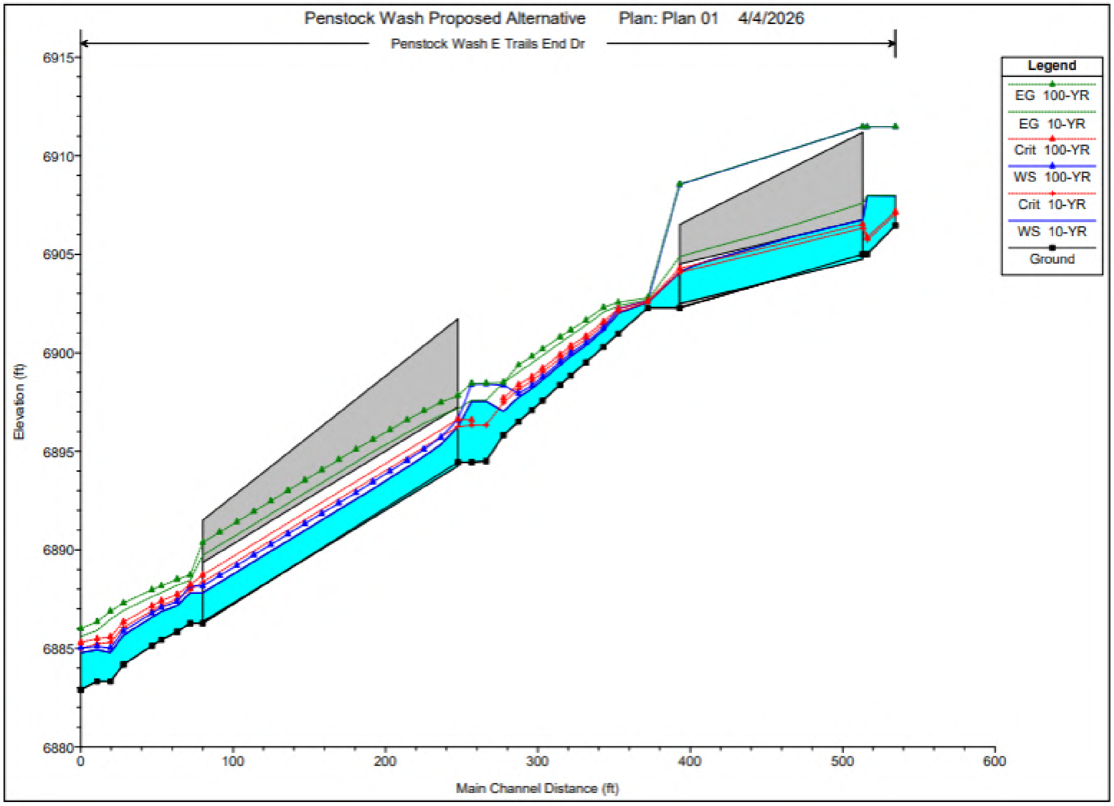

Figure 5-4: Alternative 2 Full Profile

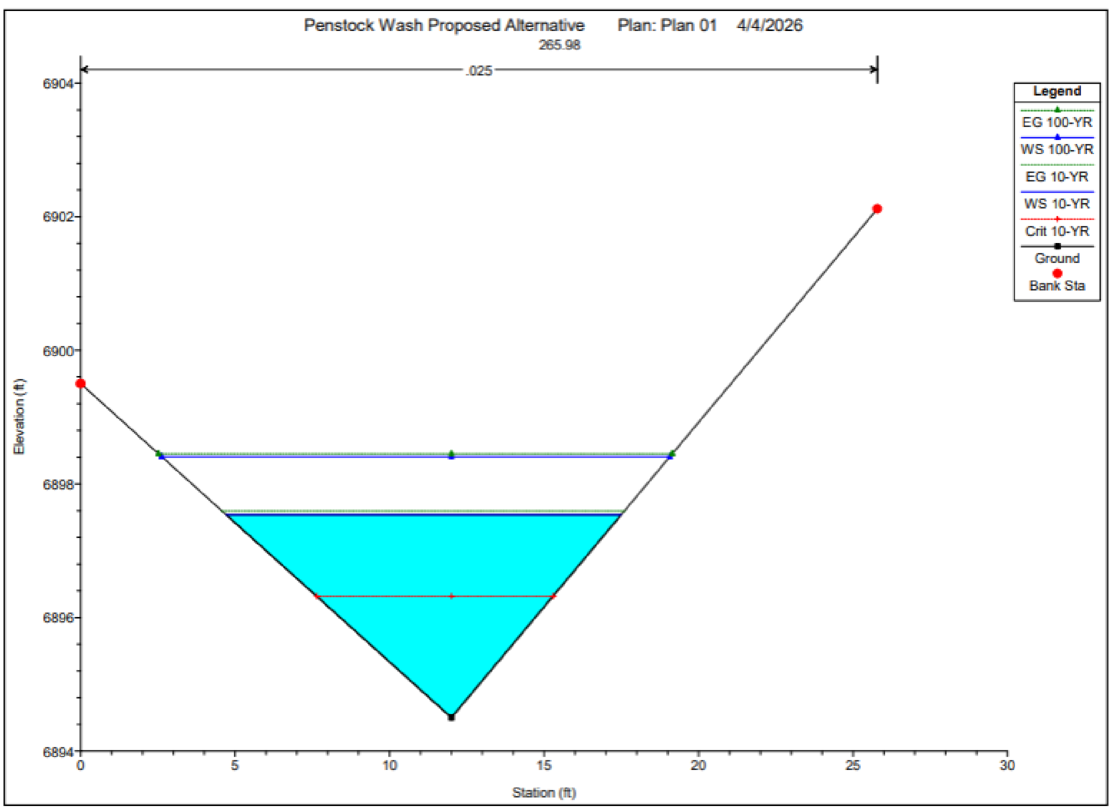

Figure 5-5: River Station 1265 Geometry

Alternative 3 emphasizes improving the hydraulic efficiency of the existing system through similar trapezoidal geometry as Alternative 1. Under this alternative, the existing channel would also be lined with a more hydraulically efficient and erosion-resistant material (e.g., concrete or cement) to reduce roughness, increase flow velocities, and minimize sediment accumulation. Culvert improvements would include cleaning existing culverts and adding into two 3x2 concrete box culverts with flared wingwalls under the gravel road. This alternative represents a more expensive approach that seeks to enhance use of the gravel road. Figure 5-6 shows the plan view for Alternative 3. Figures 5-7 and 5-8 show the full alternative profile as well as the design of the box culverts. Full size plan view of Alternative 3 is available in Appendix E.

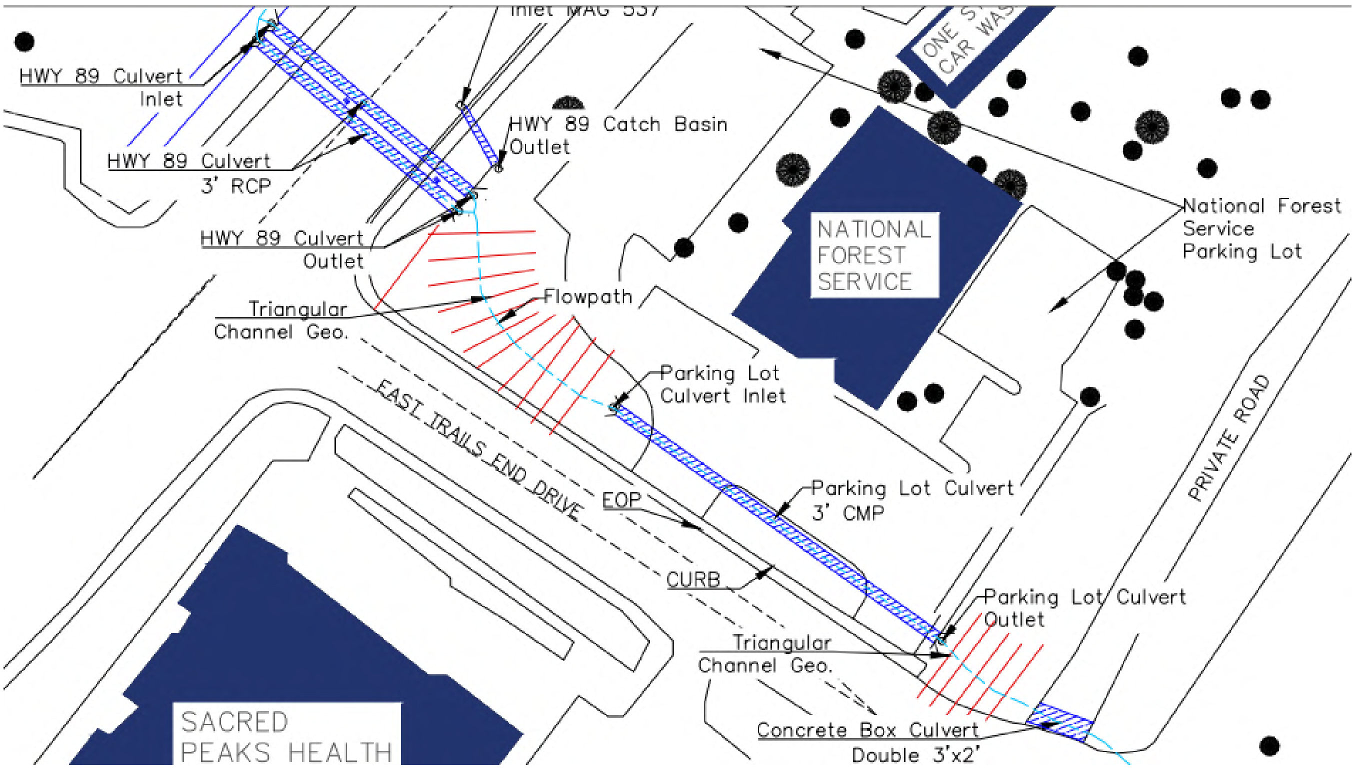

Figure 5-6: Plan View of Alternative 3

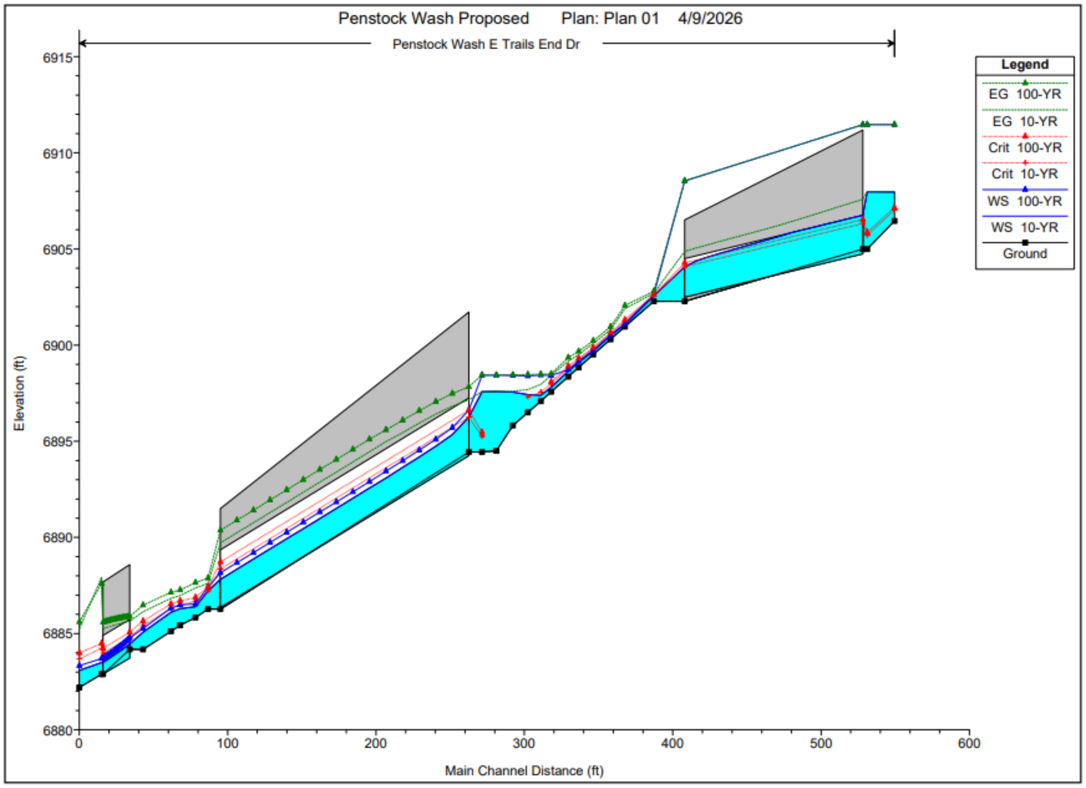

Figure 5-7: Alternative 3 Full Profile

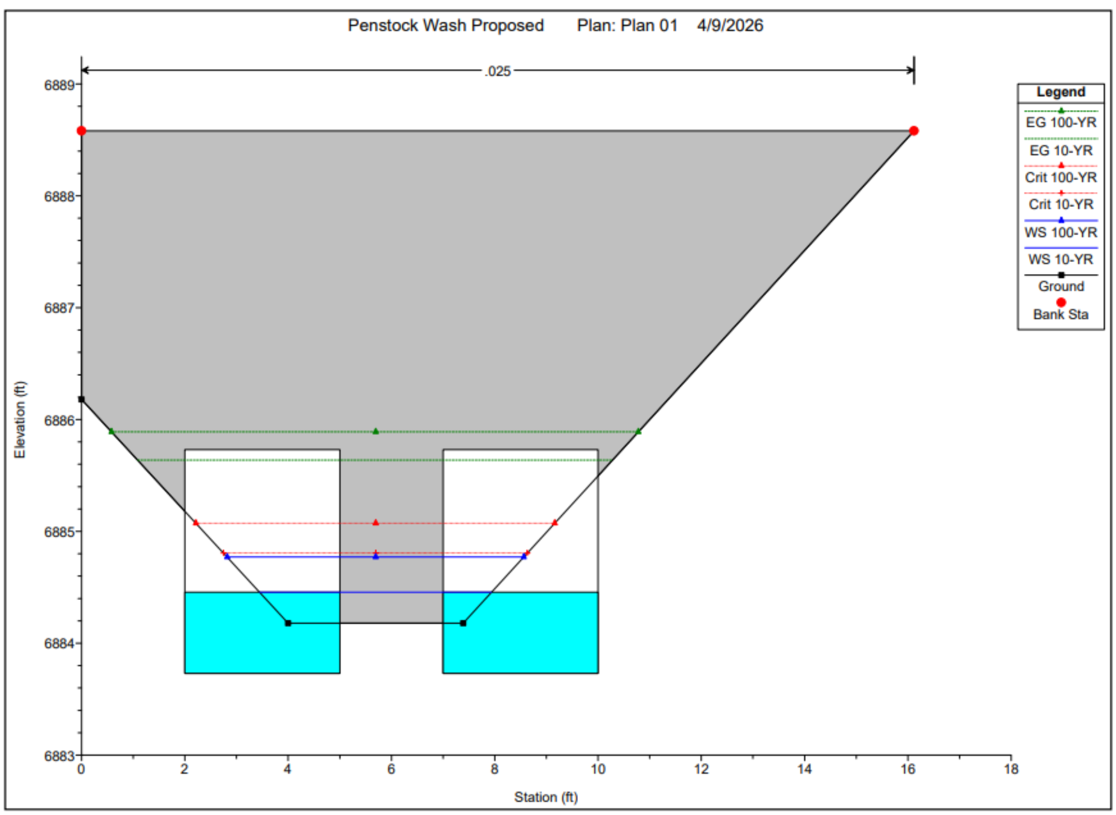

Figure 5-8: Box Culvert Design

5.3. Alternatives Evaluation Methodology

Each preliminary alternative was scored based on a scale of 1 to 10 for each category before being multiplied by the weight. The higher score that a design received the better it performed. Each catagory was evaluated by the team individually. Each member of the team explained their scoring and a final score was given once the teams individual opinions were weighed against eachother. Scores of four and below were inadequate preformance, five to seven are adequate performance, and scores eight and up exceed epectations.

5.4. Preliminary Alternatives Screening Results

The results of the preliminary alternatives screening are summarized in Table 5-1. Each alternative was evaluated using a weighted decision matrix that considered hydraulic performance, regulatory compliance, cost, constructability, durability, and environmental/social impacts. For hydraulic performance, Alternatives 2 and 3 scored lower due to them not being able to convey the design storms as well as Alternative 1. Constructability and durability were more of an issue for Alternative 2 because of the triangular channel geometry, as these channel shapes are harder to construct compared to trapezoidal channels. Similarly, Alternative 3 scored low in the cost and environmental categories because concrete box culverts are very expensive and concrete construction has a larger environmental and social impact than Alternatives 1 and 2.

Table 5-1: Decision Matrix

Penstock Wash Decision Matrix							
Alternatives	Hydraulic Performance (40%)	Regulatory Compliance: 15%	Cost (10%)	Constructability (10%)	Durability (15%)	Environmental/Social Impact (10%)	Weighted Score
1 (Trapezoidal & Retaining Wall)	3.2	1.2	0.5	0.6	1.2	0.5	**7.2**
2 (Triangular Channel Geometry)	2.4	0.45	0.4	0.5	0.6	0.7	**5.05**
3 (Trapezoidal, Lining, & Box Culvert)	1.6	0.9	0.2	0.4	0.75	0.3	**4.15**

Alternative 1 achieved the highest overall weighted score of 7.2, outperforming the other alternatives despite scoring lower in environmental and social impact. This result is primarily driven by its superior hydraulic performance and durability, which are the most critical factors for addressing the persistent flooding issues within the project area. Alternative 1 provides the greatest increase in conveyance capacity and the most effective control of stormwater flow paths, directly targeting the root causes of flooding observed in the Smokerise Neighborhood and adjacent facilities. While Alternatives 2 and 3 offer improvements to the existing system, their benefits are comparatively limited. In contrast, Alternative 1 provides a more comprehensive solution by significantly improving conveyance at key control points and reducing the likelihood of overtopping and ponding during storm events.

6.0 Final Design Recommendation

Alternative 1 was chosen for the final design recommendation. The proposed site plan for the Smokerise neighboorhood can be seen in Figure 6-1. Full size is available in Appendix E.

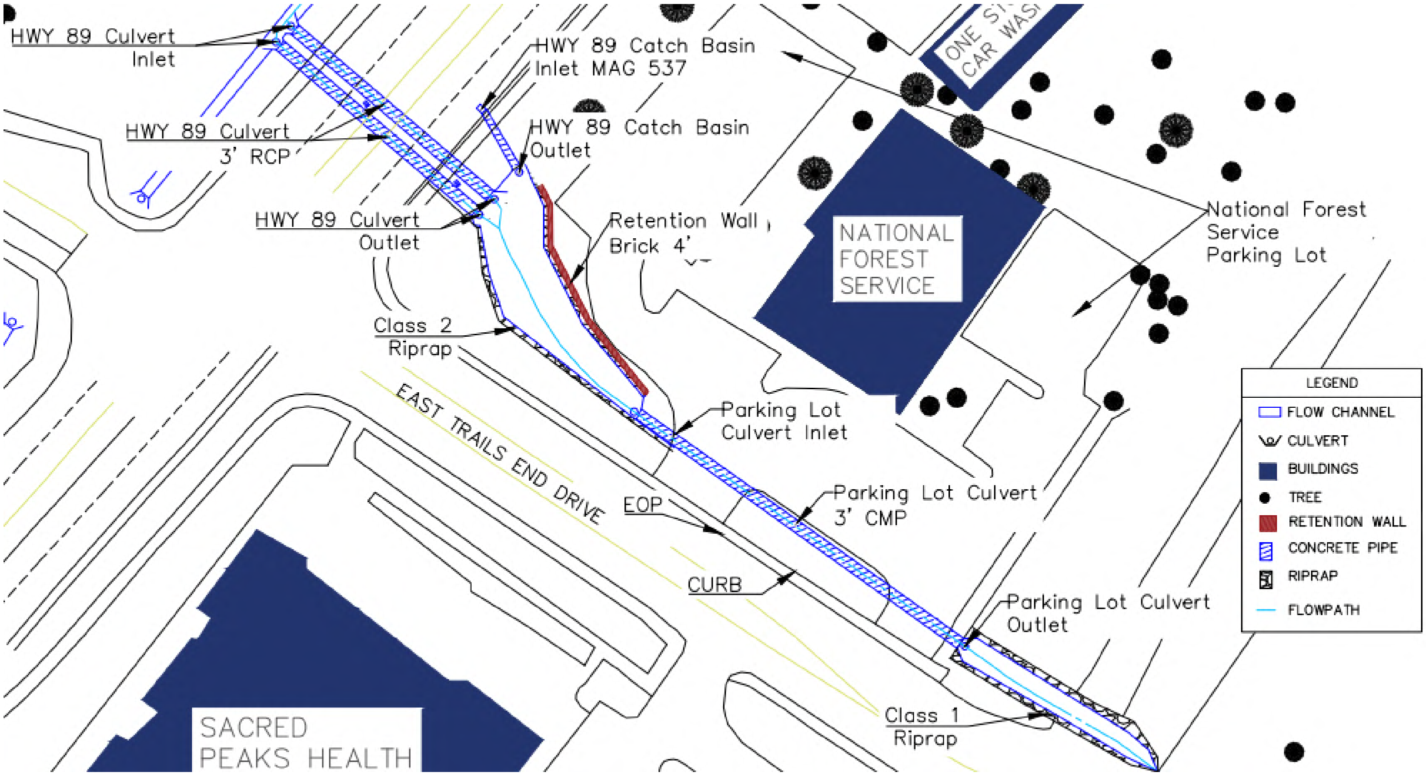

Figure 6-1: Proposed Site Plan

In this site plan, there's an addition of a 4 foot brick retaining wall to meet 2:1 slope regulations, as outlined in the City of Flagstaff standards. Figure 6-2 shows the final culvert design for both culverts. Figure 6-3 shows the retaining wall and class one and two rip rap specifications. The culverts will be cleaned out but otherwise not changed. The full plan set is available in Appendix E.

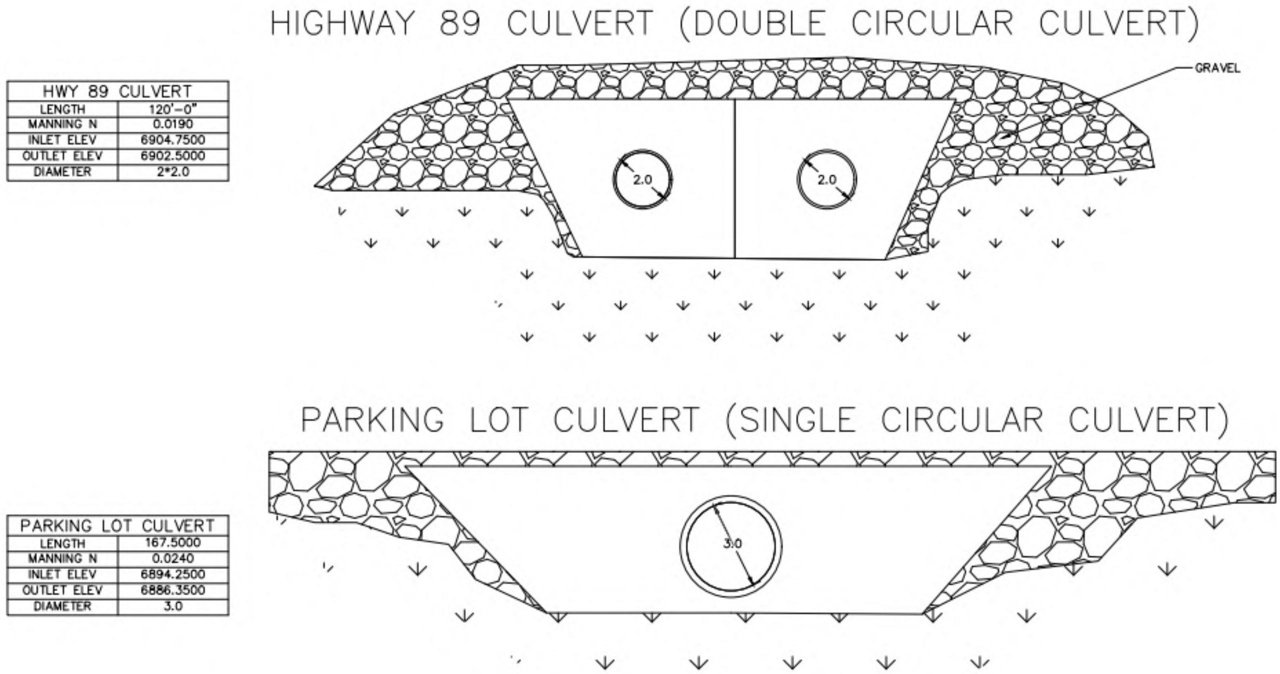

Figure 6-2: Final Culvert Design

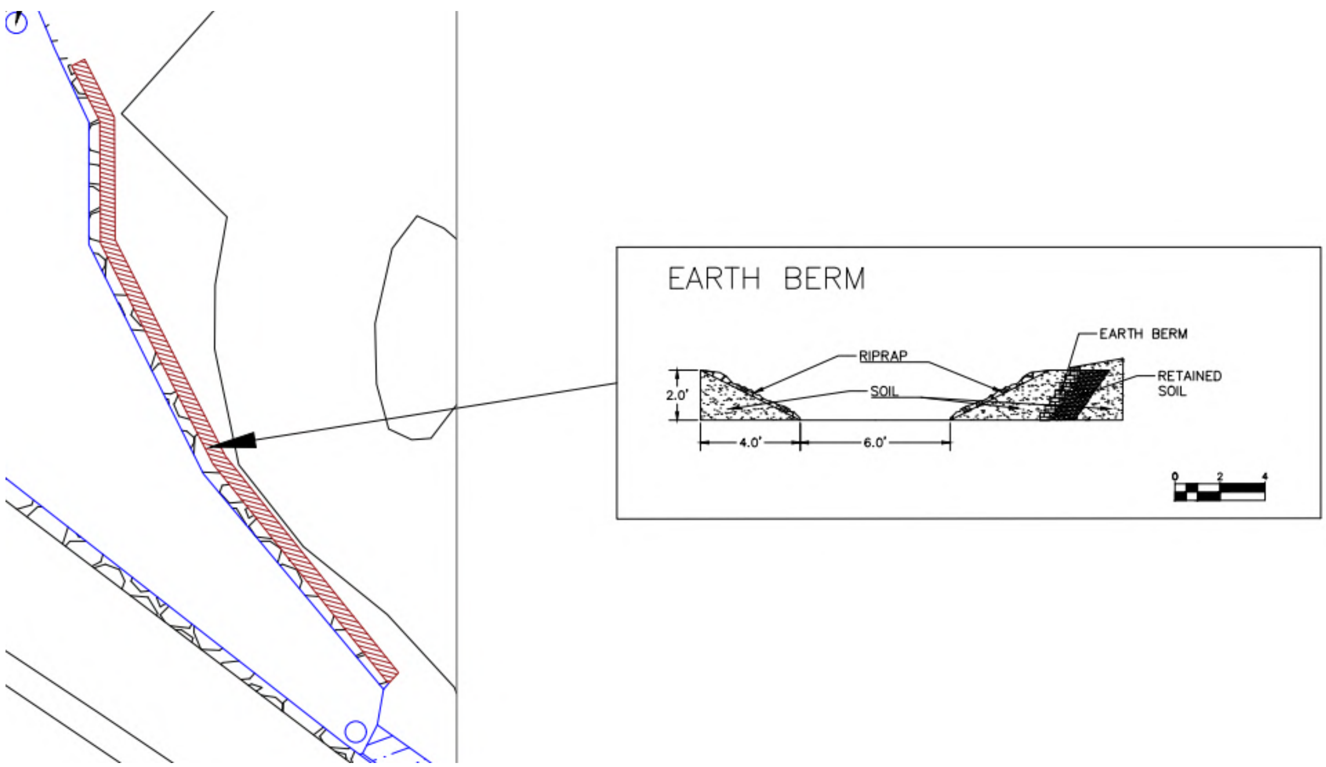

Figure 6-3: Retaining Wall and Rip Rap Specifications

Table 6-1 shows the proposed culvert analysis including grade, water surface, and velocities. The proposed design drops the water surface so that it no longer flows over the road of the parking lot. The water moves through faster so erosion protection at inlets and outlets is crucial.

Table 6-1: Proposed Culvert Results

River Station	Profile	E.G. US.	W.S. US.	E.G. IC	E.G. OC	Min Weir Elevation	Flow Culvert Group	Flow Weir	Change WS	Culvert Velocity US	Culvert Velocity DS
		(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(ft)	(ft/s)	(ft/s)
1473	10	6907.68	6907.67	6907.28	6907.68	6911.20	38	0	5.11	7.19	7.64
1473	100	6909.80	6909.79	6908.29	6909.80	6911.20	53	0	7.16	8.44	8.91
1248	10	6897.59	6897.57	6897.30	6897.59	6901.73	38	0	10.58	7.56	11.03
1248	100	6898.45	6898.43	6898.38	6898.45	6901.73	53	0	11.27	8.86	11.93

Figure 6-3 through 6-6 shows River Station 1329, 1256, and 1019 with their proposed designs. All cross sections are available in Appendix D.

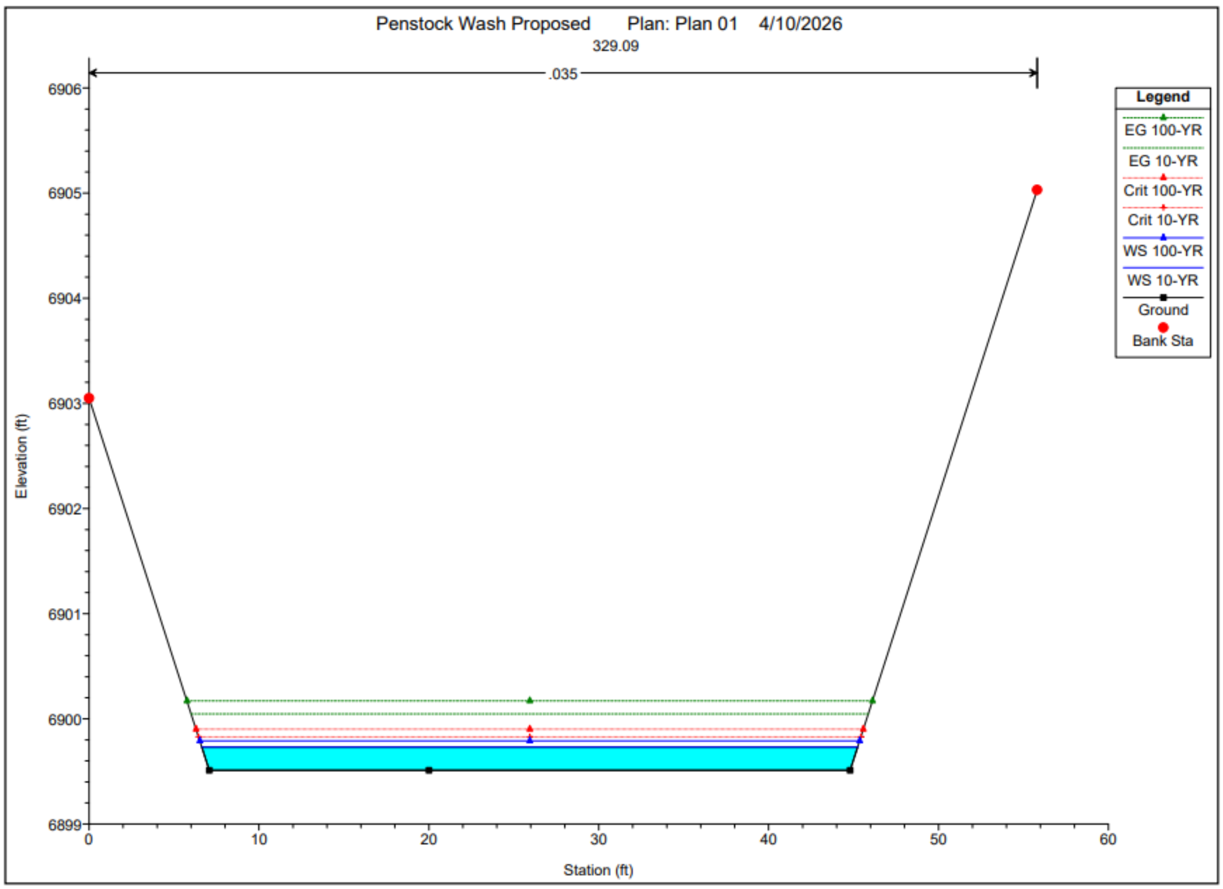

Figure 6-4: River Station 1329 Proposed Design

Figure 6-5 and 6-6 show the brick retaining wall, which can be seen as the left red dot in the cross section profile.

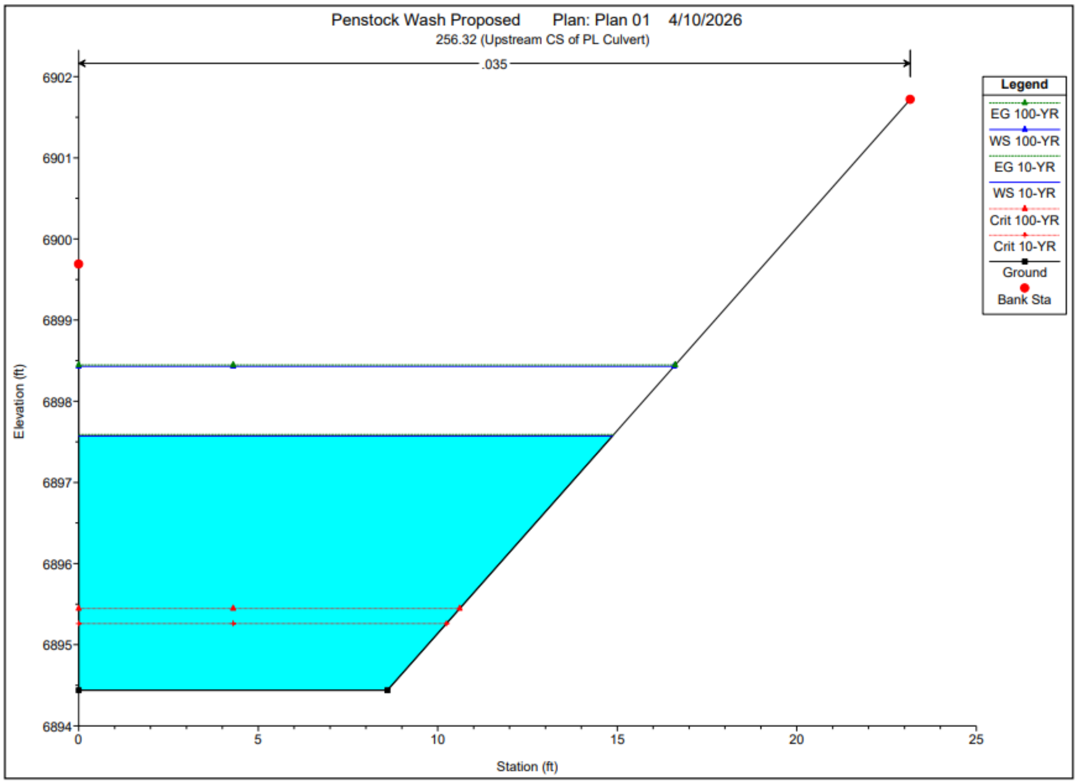

Figure 6-5: River Station 1256 Proposed Design

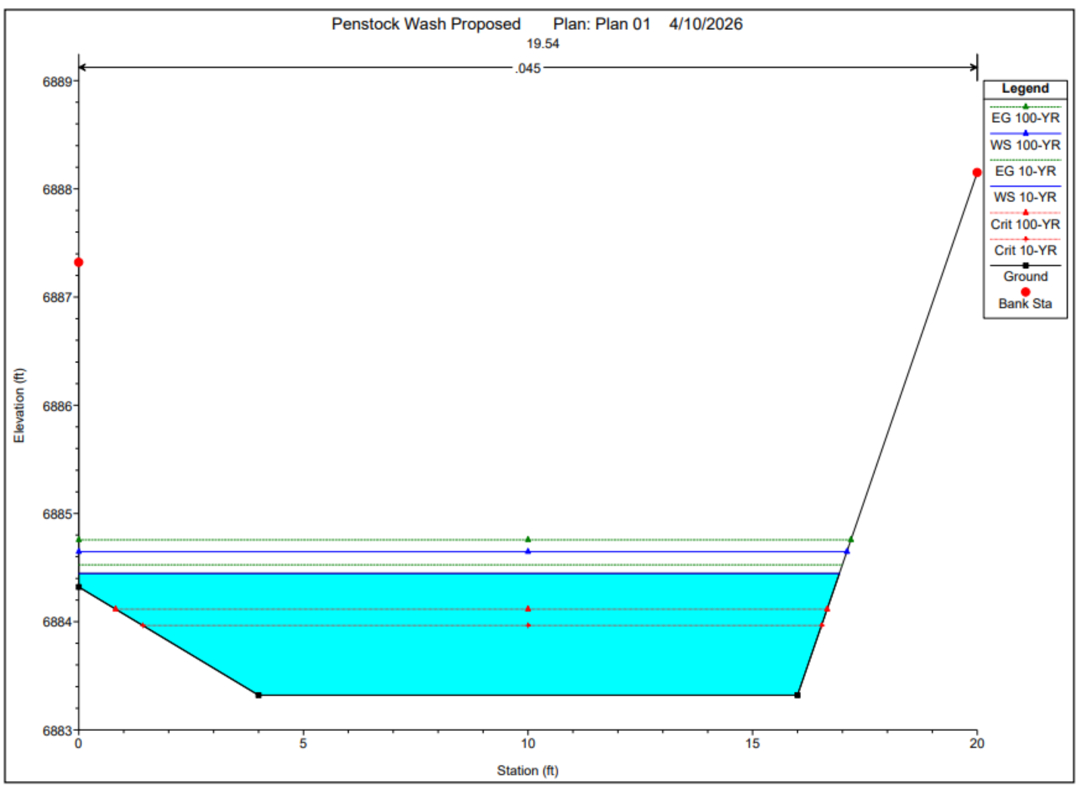

Figure 6-6: River Station 1019 Proposed Design

The 10 year and 100 year storms are being contained with the channel geometry. Table 6-1 shows the proposed outputs for these three cross sections, River Stations 1329, 1256, and 1019 and their corresponding elevations, energy grade (E.G.) slopes, velocities, and Froude numbers. All proposed cross-section data is available in Appendix D.

Table 6-2: Proposed Cross Section Data

River Station	Profile	Flow Total	Min Channel Elevation	Water Surface Elevation	E.G. Elevation	E.G. Slope	Velocity Channel	Flow Area	Top Width	Froude Number
1329	10	38	6899.51	6899.73	6900.05	0.0869	4.52	8.40	38.60	1.71
1329	100	53	6899.51	6899.79	6900.17	0.0760	4.95	10.71	38.84	1.66
1256	10	38	6894.44	6897.57	6897.59	0.0002	1.03	36.76	14.87	0.12
1256	100	53	6894.44	6898.43	6898.45	0.0002	1.05	50.24	16.58	0.11
1019	10	38	6883.32	6884.44	6884.53	0.0053	2.30	16.52	16.93	0.41
1019	100	53	6883.32	6884.65	6884.76	0.0057	2.65	19.96	17.10	0.43

The proposed design evens out the slope imbalances upstream and downstream and creates a more consistent longitudinal profile. Velocities range from 1-5 cfs for these cross sections, rather than 0.47 to 6.13 cfs. Because some cross sections see increased slope and velocity, rip-rap erosion protection will be installed in the channel to stabilize the new sections and prevent scouring or head cutting during flow events.

6.1. <u>Estimate of Construction Costs</u>

An Engineer's Opinion of Probable Cost (EOPC) was developed to estimate the construction cost of the proposed improvements to the Penstock Wash drainage system within the Smokerise Neighborhood. The estimate is based on conceptual-level design quantities, typical unit costs, and engineering judgment consistent with similar stormwater infrastructure projects in the region. Table 6-3 shows the totals of material, contract, and contingency costs. A detailed breakdown of costs is provided in Appendix G.

Table 6-3: Engineers' Opinion of Probable Cost Abridged

Material Cost Totals		Contract and Hidden Costs		Contingency Costs	
Description	**Cost**	**Description**	**Cost**	**Description**	**Cost**
Site Setup	$64,000	Mobilization Adjustment	$13,573	Engineering Design	$7,601
Earthwork	$46,260	Traffic Control	$13,573	Contingency (Concept Level)	$67,865
Material Installation	$56,200	Additional Erosion Control	$8,144		
Geomorphic Restoration	$87,000	Contractor OHP	$40,719		
Site Restoration	$18,000				
	Total		**Total**		**Total**
	$271,460		$76,009		$75,466

Material costs represent the largest portion of the total project cost. These costs are primarily driven by earthwork operations, installation of channel lining materials such as riprap, and construction of structural elements, including the retaining wall. The high material cost reflects the need for durable and erosion-resistant infrastructure capable of conveying design storm flows while maintaining long-term channel stability.

Contract and hidden costs include mobilization, traffic control, additional erosion control measures, and contractor overhead and profit. These costs account for project execution requirements such as site access, construction staging, and maintaining safe traffic operations along adjacent roadways, particularly near Highway 89 and the Forest Service parking lot.

Contingency costs are estimated at approximately 15–20% of the subtotal construction costs. This contingency accounts for uncertainties associated with conceptual-level design, including variability in material quantities, unforeseen site conditions, and potential design refinements during later project phases. Table 6-5 shows the project's total cost at $422,935.

Table 6-4: Summary of Total Construction Estimate

Item	Cost
Material Costs	$271,460
Contract & Hidden Costs	$76,009
Contingency Costs	$75,466
	Total
	$422,935

Overall, the EOPC reflects a planning-level estimate. While the estimate provides a reasonable basis for project budgeting and comparison of alternatives, actual construction costs may vary depending on final design details, market conditions, contractor bids, and site-specific constraints encountered during construction.

7.0 **Project Impact Analysis**

Overall impacts related to the Triple Bottom Line (people, planet, profit) were analyzed for the final hydraulic design for the Smokerise neighborhood. The new design will alleviate some of the flooding happening in the area by providing more defined and stable flow paths, which are expected to reduce sediment mobilization and improve overall channel stability. Controlled flow conditions during storm events support a more stable channel form over time by reducing erosion, limiting channel migration, and decreasing sediment transport within the system. The proposed improvements will reduce flooding frequency and associated property damage within the neighborhood. Improved stormwater conveyance will also enhance roadway safety and accessibility during storm events, resulting in more reliable transportation conditions for residents. These improvements are expected to provide an overall increase in quality of life by reducing recurring disruptions caused by flooding. However, the use of structural stabilization methods like riprap and a retaining wall may reduce the natural characteristics of the channel in localized areas, although improved drainage conditions may contribute to overall neighborhood stability by reducing the risk and impacts of recurring flooding.

At the local scale, redirecting and concentrating flow farther down the street may shift hydraulic loading to downstream portions of the storm sewer network, potentially increasing stress on existing inlets, pipes, and junction structures that were designed for prior flow conditions. While the proposed improvements reduce flooding at the project site, they may transfer or intensify maintenance demands downstream if the receiving infrastructure has limited excess capacity. Higher concentrated discharges could increase velocities entering downstream storm drain systems, potentially accelerating wear, increasing sediment deposition at key structures, or requiring future upgrades to maintain system performance.

Temporary negative impacts are expected during construction, including vegetation removal and channel corridor disturbance. Increased carbon emissions are expected within the neighborhood, and construction will disrupt everyday activities by requiring detours for parking lot entrances. There will be noise, limited access, and short-term traffic disruptions near Highway 89 as well as adjacent local streets. Construction-related disturbances may also temporarily reduce infiltration and increase susceptibility to erosion until disturbed areas are stabilized. The design will enhance public safety by reducing roadway flooding and improving access for residents and people who work in the area. Reduced water on roadways will lower the risk of vehicle damage and decrease the likelihood of accidents and flood-related hazards, as well as overall flood complaints to the City of Flagstaff. Globally, construction materials for this design contribute to resource depletion and cause further environmental degradation through extraction and transportation.

The proposed design for the Smokerise neighborhood will require high investment from the city and another funding source such as grants for the construction of improved stormwater infrastructure. Potential high-cost components include modifications to existing culvert systems, channel improvements, and associated grading and stabilization measures. Unforeseen additional costs for installation of more armoring materials or upgrades to drainage structures will also be costly. Additional costs could arise if redirected flows necessitate modifications to downstream storm sewer components not originally included in the project scope. Expenses for ongoing operation and maintenance will still be required to ensure long-term system performance and include periodic removal of sediment and debris, as well as routine inspection of culverts, channels, and stabilization features. Routine inspection and maintenance may also increase at downstream structures affected by altered discharge patterns. This design is expected to provide economic benefits through the reduction of flood-related damages and associated costs. Decreased frequency of flooding will reduce property damage and associated repair expenses for residents, which can increase property value. At the municipal level, improved system performance may reduce expenditures related to temporary mitigation efforts like sandbags and infrastructure repairs.

8.0 **Summary of Engineering Work**

The engineering work for the Penstock Wash Redesign Project was completed in accordance with the final project schedule, with adjustments made throughout the semester to maintain overall progress and meet key deadlines. While the original Gantt chart outlined a sequential workflow, actual project execution required flexibility due to delays in early tasks and the iterative nature of the design process.

Initial project tasks, including due diligence and site investigation, took longer than originally anticipated. The team was behind schedule on the 30% and 60% deliverable, but the start date of January 12th and end date of May 5th remained the same. These delays were primarily due to the time required to gather, verify, and process existing data, as well as coordinate fieldwork and develop accurate base mapping. As a result, subsequent tasks such as hydrologic and hydraulic analyses began later than planned.

To compensate for early delays and remain on schedule, the team adjusted its workflow by overlapping tasks and beginning later phases earlier than originally scheduled. For example, elements of hydraulic analysis and alternatives development were initiated while hydrologic analysis was still ongoing. Similarly, preparation of plan sets and deliverables began well in advance of the final design phase. This parallel task management approach allowed the team to maintain steady progress despite setbacks.

As shown in the final project schedule, all major technical tasks, including hydrologic analysis, hydraulic modeling, alternatives development, and final design, were completed, while deliverables progressed throughout the project duration and were finalized toward the end of the schedule. This was done by changing the 77 work day schedule to a 90 day schedule still with in the overall timeline, by completing work on seven weekend days and selected days off due to issues with the software for the 30% deliverable and alternatives for the 60% deliverable. A proposed and actual hours log and schedule are available in Appendix F. Project management activities were continuous throughout the entire timeline to coordinate task adjustments and ensure deadlines were met.

Although the project deviated from the original planned timeline, the adaptive scheduling approach enabled the team to complete all required engineering work within the overall project duration. This experience highlights the importance of flexibility, task overlap, and proactive time management in engineering project execution, particularly when working with data limitations and evolving design requirements.

9.0 Summary of Engineering Costs

All tasks that were expected to be completed by the final date have been completed. Tables 9-1 and 9-2 show the proposed and actual engineering hours completed by each role for the tasks outlined. Tasks 1-6 took more hours than expected, but Tasks 7-9 were completed in less time than originally proposed. As a result, the total hours were 654 rather than 611. The entire hours log can be found in Appendix F.

Table 9-1: Proposed Staffing by Task

Task	PE	PrE	EIT	INT	Task Total
Task 1: Due Diligence (Total hrs)	0	9	18	30	**57**
Task 2: Site Investigation (Total hrs)	0	12	24	13	**49**
Task 3: Hydrologic Analysis (Total hrs)	7	17	25	9	**58**
Task 4: Hydraulic Analysis - Existing (Total hrs)	7	21	35	12	**75**
Task 5: Alternatives Development (Total hrs)	6	15	20	9	**50**
Task 6: Final Design (Total hrs)	15	28	45	15	**103**
Task 7: Impacts Analysis (Total hrs)	0	7	4	4	**15**
Task 8: Deliverables (Total hrs)	8	32	40	20	**100**
Task 9: Project Management (Total hrs)	20	44	20	20	**104**
Total hours	**63**	**185**	**231**	**132**	**611**

Table 9-2: Actual Staffing by Task

Task	PE	PrE	EIT	INT	Task Total
Task 1: Due Diligence (Total hrs)	0	18	25	21	**64**
Task 2: Site Investigation (Total hrs)	0	25	23	13	**61**
Task 3: Hydrologic Analysis (Total hrs)	7	13	31	10	**61**
Task 4: Hydraulic Analysis - Existing (Total hrs)	6	19	34	20	**79**
Task 5: Alternatives Development (Total hrs)	2	31	44	20	**97**
Task 6: Final Design (Total hrs)	14	25	50	16	**105**
Task 7: Impacts Analysis (Total hrs)	0	0	2	1	**3**
Task 8: Deliverables (Total hrs)	17	26	42	34	**119**
Task 9: Project Management (Total hrs)	12	31	11	11	**65**
Total hours	**58**	**188**	**262**	**146**	**654**

Tables 9-3 and 9-4 illustrate the total differences from the proposal versus the actual design process.

Table 9-3: Proposed Cost of Engineering Services

Cost Estimate			
Personnel	**Hours**	**Billing Rate ($/hr)**	**Total**
Principal Engineer (PE)	63	270	$17,010
Project Engineer (PrE)	185	186	$34,410
Engineer-in-Training (EIT)	231	138	$31,878
Intern (INT)	132	42	$5,544
Personnel Subtotal			$88,842
Equipment	**Days**	**$/day**	**Total**
Surveying	2	100	$200
Computer Lab	10	100	$1,000
Equipment Subtotal			$1,200
Project Total			**$90,042**

Table 9-4: Actual Cost of Engineering Services

Cost Estimate			
Category	**Hours**	**Billing Rate ($/hr)**	**Total**
Principal Engineer (PE)	58	270	$15,660
Project Engineer (PrE)	188	186	$34,968
Engineer-in-Training (EIT)	262	138	$36,156
Intern (INT)	146	42	$6,132
Personnel Subtotal			$92,916
Equipment	**Days**	**$/day**	**Total**
Surveying	4	100	$400
Computer Lab	10	100	$1,000
Equipment Subtotal			$1,400
Project Total			**$94,316**

The difference between the proposal summary and the actual summary was $4,274, with the major reason for the difference being more Intern and Engineering in Training hours than estimated.

10.0 Conclusion

This report presents the evaluation and redesign of a critical reach of the Penstock Wash drainage system within the Smokerise Neighborhood in Flagstaff, Arizona. Through comprehensive hydrologic and hydraulic analyses, existing deficiencies in stormwater conveyance were identified, including roadway overtopping, channel inefficiencies, and inadequate culvert performance during design storm events.

The final recommended design provides a targeted and effective solution to these deficiencies by improving channel geometry and enhancing key infrastructure components. The incorporation of a trapezoidal channel, installation of a retaining wall to meet slope and space constraints, and implementation of riprap erosion protection collectively improve the system's hydraulic efficiency and structural stability. These improvements create a more defined and controlled flow path, reducing ponding, minimizing sediment accumulation, and increasing overall conveyance capacity.

Hydraulic modeling results demonstrate that the proposed design successfully conveys the design discharge for both the 10-year and 100-year storm events without overtopping adjacent roadways, while also meeting applicable freeboard requirements. Compared to existing conditions, the redesigned system significantly reduces flood risk, improves roadway safety, and enhances the resilience of the drainage infrastructure within the neighborhood. The total estimated project cost is $422,935, representing a cost-effective solution that balances hydraulic performance, constructability, and long-term maintenance considerations.

While evaluation of watershed-scale improvements indicates that the most effective long-term solution would involve diverting peak runoff away from the Smokerise Neighborhood and conveying it parallel to US 89, such an alternative extends beyond the scope and constraints of the current project. As a result, this option was not advanced for detailed consideration. Within the defined project limits, the design team focused on improvements that enhance the performance of the existing drainage system while reducing localized flooding impacts. The proposed alternatives, therefore, represent the most feasible and effective solution under the current project constraints, while still aligning with the broader objective of improving stormwater conveyance and reducing flood risk within the neighborhood. Additionally, a place for future work could be connecting this design to existing drainage systems within so that the road doesn't have to be as much of a floodplain before it reaches downstreams stormwater infrastructure.

As the design is limited to a defined project reach and remains at a preliminary level, it provides a strong technical foundation for future design refinement and potential implementation. The proposed improvements are expected to reduce flooding impacts, improve the quality of life for residents, and support more reliable stormwater management within the Smokerise Neighborhood.

11.0 References

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[3] City of Flagstaff, "2025 Stormwater Management Design Manual," 2025. [Online]. Available: https://www.flagstaff.az.gov/DocumentCenter/View/88520/2025-Stormwater-Management-Design-Manual. [Accessed 18 September 2025].

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[6] USGS, "StreamStats," [Online]. Available: https://www.usgs.gov/streamstats. [Accessed 15 January 2026].

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[11] US Army Corps of Engineers, "Nation Wide Permit 33," 2022.

[12] US Army Corps of Engineers, "Channel Restoration," US Army Corps of Engineers Headquarters Wesite, [Online]. Available: https://www.iwr.usace.army.mil/Missions/Flood-Risk-Management/Flood-Risk-Management-Program/.

Appendices
Appendix A: Photos

Figure A- 1: Gravel Road Area Surveying

Figure A- 2: Existing Conditions Downstream of Culverts

Figure A- 3: Current Conditions Downstream of Hwy 89

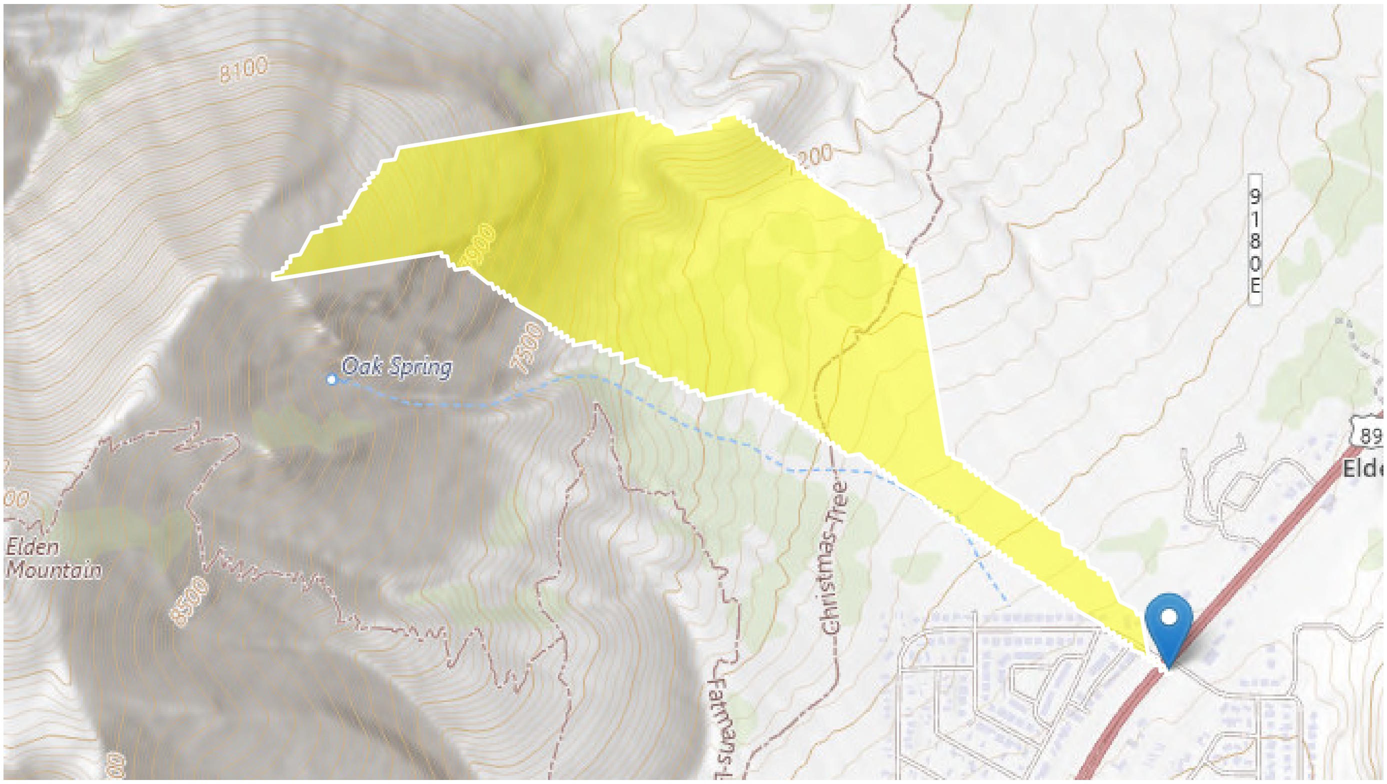
Figure A- 4: Existing Culvert Conditions Downstream of Hwy 89

Appendix B: Hydrologic Analysis

Appendix B1: Stream Stats Report

StreamStats Report

Region ID: AZ
Clicked Point (Latitude, Longitude): 35.23878, -111.57159
Time: 2026-01-22 15:08:33 -0700



StreamStats Update

Starting with version 4.30.0, the StreamStats application uses services that were redeveloped with open-source software components. Users may observe minor variations in computed results when compared to those from previous versions. These differences are expected and do not reflect errors in the underlying data or analytical methods. Users are advised to consider these potential variations when interpreting or comparing results generated across different versions of StreamStats. Please email streamstats@usgs.gov with any questions or concerns. A full list of changes can be found at **https://www.usgs.gov/streamstats/news/streamstats-data-updates-open-source-code-release (https://www.usgs.gov/streamstats/news/streamstats-data-updates-open-source-code-release)** .

Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CONTDA	Area that contributes flow to a point on a stream	0.21	square miles
DRNAREA	Area that drains to a point on a stream	0.21	square miles
ELEV	Mean Basin Elevation	7386.056	feet

Peak-Flow Statistics

Peak_Region_1_High_Elev_2014_5211 equations are not appropriate for this location and have been removed from the final report. This region does not meet the following criteria: ELEV>=7500.0.

Peak-Flow Statistics Parameters [Peak Region 2 Colorado Plateau 2014 5211]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CONTDA	Contributing Drainage Area	0.21	square miles	0.103	16017
ELEV	Mean Basin Elevation	7386.056	feet		

Peak-Flow Statistics Flow Report [Peak Region 2 Colorado Plateau 2014 5211]

PIL: Lower 90% Prediction Interval, PIU: Upper 90% Prediction Interval, ASEp: Average Standard Error of Prediction, SE: Standard Error, PC: Percent Correct, RMSE: Root Mean Squared Error, PseudoR^2: Pseudo R Squared (other -- see report)

Statistic	Value	Unit	PIL	PIU	ASEp
50-percent AEP flood	24.2	ft^3/s	4.81	122	122
20-percent AEP flood	67.6	ft^3/s	18.9	242	87.2
10-percent AEP flood	115	ft^3/s	36.7	360	75.7
4-percent AEP flood	204	ft^3/s	70.8	588	68.6
2-percent AEP flood	292	ft^3/s	103	826	66.6
1-percent AEP flood	403	ft^3/s	142	1140	67.3
0.5-percent AEP flood	540	ft^3/s	186	1570	68.8
0.2-percent AEP flood	762	ft^3/s	249	2330	72.9

Peak-Flow Statistics Citations

Paretti, N.V., Kennedy, J.R., Turney, L.A., and Veilleux, A.G.,2014, Methods for estimating magnitude and frequency of floods in Arizona, developed with unregulated and rural peak-flow data through water year 2010: U.S. Geological Survey Scientific Investigations Report 2014-5211, 61 p., http://dx.doi.org/10.3133/sir20145211. (http://pubs.usgs.gov/sir/2014/5211/)

Maximum Probable Flood Statistics

Maximum Probable Flood Statistics Parameters [69.0 Percent (0.145 square miles) Crippen Bue Region 14]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.21	square miles	0.1	10000

Maximum Probable Flood Statistics Parameters [31.0 Percent (0.0666 square miles) Crippen Bue Region 16]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.21	square miles	0.1	1000

Maximum Probable Flood Statistics Flow Report [69.0 Percent (0.145 square miles) Crippen Bue Region 14]

Statistic	Value	Unit
Maximum Flood Crippen Bue Regional	788	ft^3/s

Maximum Probable Flood Statistics Flow Report [31.0 Percent (0.0666 square miles) Crippen Bue Region 16]

Statistic	Value	Unit
Maximum Flood Crippen Bue Regional	2040	ft^3/s

Maximum Probable Flood Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
Maximum Flood Crippen Bue Regional	1180	ft^3/s

Maximum Probable Flood Statistics Citations

Crippen, J.R. and Bue, Conrad D.1977, Maximum Floodflows in the Conterminous United States, Geological Survey Water-Supply Paper 1887, 52p. (https://pubs.usgs.gov/wsp/1887/report.pdf)

Bankfull Statistics

Bankfull Statistics Parameters [Intermontane Plateau D Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.21	square miles	3.62934	7579.9152

Bankfull Statistics Parameters [Colorado Plateau P Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.21	square miles	3.621618	3649.980906

Bankfull Statistics Parameters [USA Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.21	square miles	0.07722	59927.7393

Bankfull Statistics Disclaimers [Intermontane Plateau D Bieger 2015]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors.

Bankfull Statistics Flow Report [Intermontane Plateau D Bieger 2015]

Statistic	Value	Unit
Bieger_D_channel_width	2.83	ft
Bieger_D_channel_depth	0.188	ft
Bieger_D_channel_cross_sectional_area	0.477	ft^2

Bankfull Statistics Disclaimers [Colorado Plateau P Bieger 2015]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors.

Bankfull Statistics Flow Report [Colorado Plateau P Bieger 2015]

Statistic	Value	Unit
Bieger_P_channel_width	2.63	ft
Bieger_P_channel_depth	0.0776	ft
Bieger_P_channel_cross_sectional_area	0.208	ft^2

Bankfull Statistics Flow Report [USA Bieger 2015]

Statistic	Value	Unit
Bieger_USA_channel_width	7.15	ft
Bieger_USA_channel_depth	0.865	ft
Bieger_USA_channel_cross_sectional_area	7.36	ft^2

Bankfull Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
Bieger_D_channel_width	2.83	ft
Bieger_D_channel_depth	0.188	ft
Bieger_D_channel_cross_sectional_area	0.477	ft^2
Bieger_P_channel_width	2.63	ft
Bieger_P_channel_depth	0.0776	ft
Bieger_P_channel_cross_sectional_area	0.208	ft^2
Bieger_USA_channel_width	7.15	ft
Bieger_USA_channel_depth	0.865	ft
Bieger_USA_channel_cross_sectional_area	7.36	ft^2

Bankfull Statistics Citations

Bieger, Katrin; Rathjens, Hendrik; Allen, Peter M.; and Arnold, Jeffrey G.,2015, Development and Evaluation of Bankfull Hydraulic Geometry Relationships for the Physiographic Regions of the United States, Publications from USDA-ARS / UNL Faculty, 17p. (https://digitalcommons.unl.edu/usdaarsfacpub/1515?utm_source=digitalcommons.unl.edu%2Fusdaarsfacpub%2F1515&utm_medium=PDF&utm_campai

Application Version: 4.30.0
SSHydro Services Version: 1.0.0
SSDelineate Services Version: 1.0.0
NSS Services Version: 2.2.1
GageStats Services Version: 1.2.1
Pourpoint Services Version: 1.2.0
Batch Processor Version: 1.6.0

Appendix B2: Web Soil Survey Report

United States Department of Agriculture

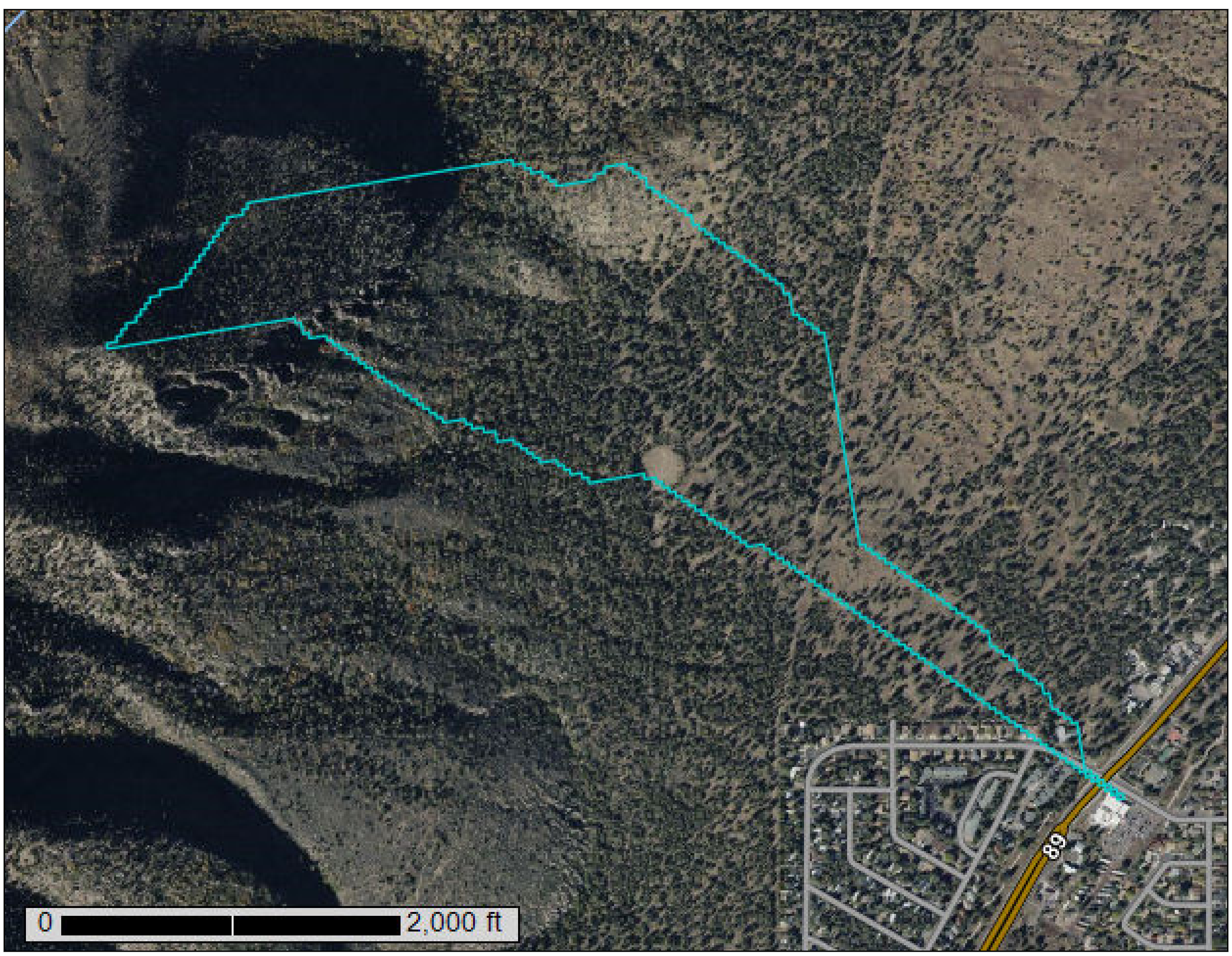
NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for Oak Creek-San Francisco Peaks Area, Arizona, Part of Coconino County

Penstock Wash



January 28, 2026

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

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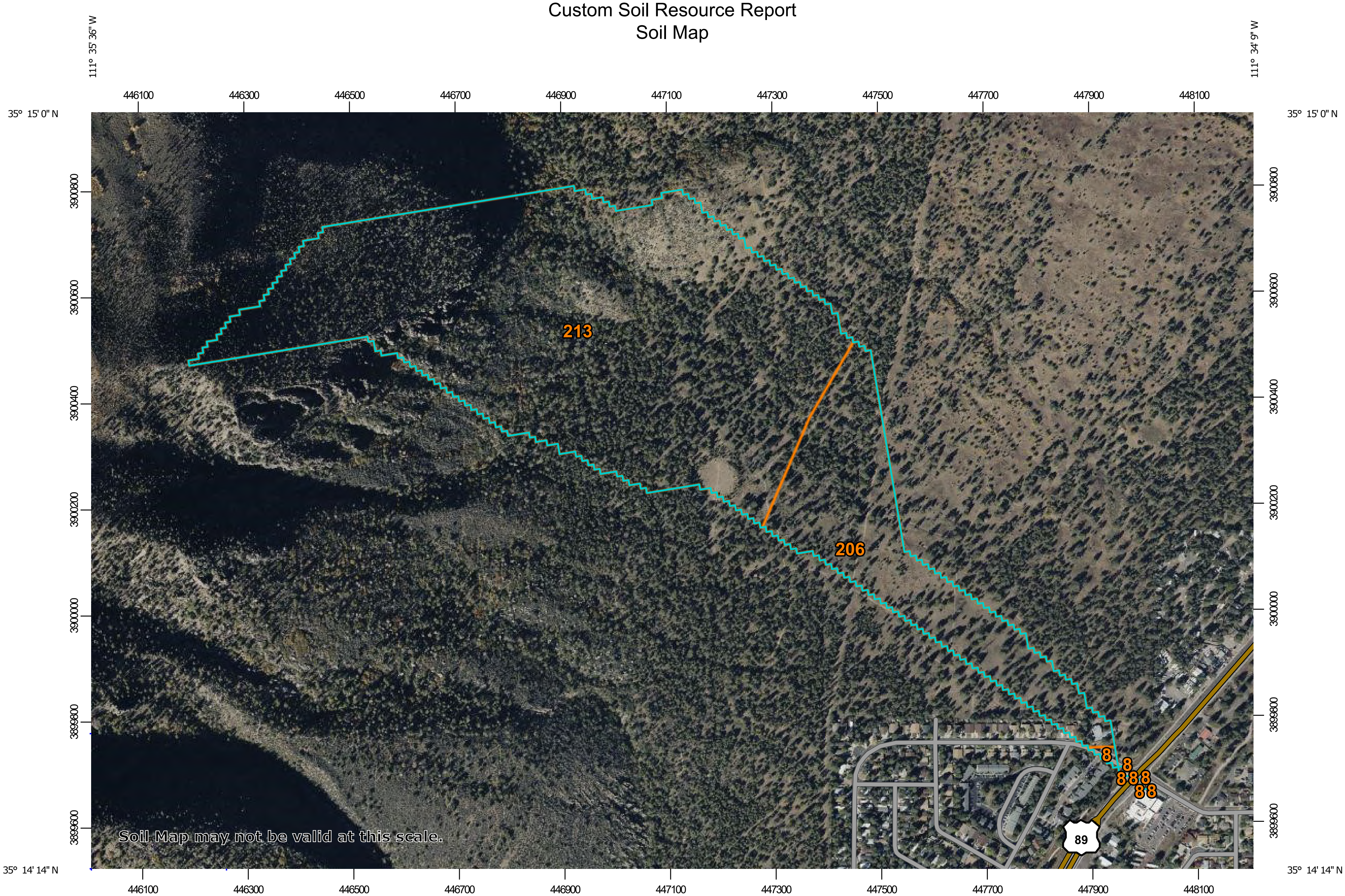
Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map



Map Scale: 1:10,100 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 100, 200, 400, 600

Feet: 0, 450, 900, 1800, 2700

N

Map projection: Web Mercator   Corner coordinates: WGS84   Edge tics: UTM Zone 12N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Unit Polygons

Soil Map Unit Lines

Soil Map Unit Points

Special Point Features

Blowout

Borrow Pit

Clay Spot

Closed Depression

Gravel Pit

Gravelly Spot

Landfill

Lava Flow

Marsh or swamp

Mine or Quarry

Miscellaneous Water

Perennial Water

Rock Outcrop

Saline Spot

Sandy Spot

Severely Eroded Spot

Sinkhole

Slide or Slip

Sodic Spot

Spoil Area

Stony Spot

Very Stony Spot

Wet Spot

Other

Special Line Features

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Oak Creek-San Francisco Peaks Area, Arizona, Part of Coconino County
Survey Area Data: Version 15, Aug 27, 2025

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Oct 19, 2022—Oct 31, 2022

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background

MAP LEGEND	MAP INFORMATION
	imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
8	Paymaster family fine sandy loam, 0 to 3 percent slopes	0.4	0.3%
206	Lithic Argiustolls, Cumulic Haplustolls, rarely flooded, and Typic Ustorthents; warm mesic ustic mountains	29.7	21.9%
213	Lithic Argiustolls, Typic Haplustolls, and Vitrandic Haplustolls; cool mesic ustic mountains	105.4	77.8%
Totals for Area of Interest		**135.5**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Oak Creek-San Francisco Peaks Area, Arizona, Part of Coconino County

8—Paymaster family fine sandy loam, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: 1vhk1
Elevation: 6,650 to 7,040 feet
Mean annual precipitation: 18 to 24 inches
Mean annual air temperature: 43 to 49 degrees F
Frost-free period: 90 to 115 days
Farmland classification: Not prime farmland

Map Unit Composition

Paymaster and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Paymaster

Setting

Landform: Alluvial fans, Flood plains
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Dip
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mixed alluvium

Typical profile

H1 - 0 to 14 inches: fine sandy loam
H2 - 14 to 60 inches: loam

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Available water supply, 0 to 60 inches: Moderate (about 8.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: B
Ecological site: R039XA108AZ - Meadow 17-22" p.z.
Hydric soil rating: No

206—Lithic Argiustolls, Cumulic Haplustolls, rarely flooded, and Typic Ustorthents; warm mesic ustic mountains

Map Unit Setting

National map unit symbol: 31rdc
Landscape: Plateaus
Elevation: 4,200 to 7,050 feet
Mean annual precipitation: 16 to 24 inches
Mean annual air temperature: 48 to 63 degrees F
Frost-free period: 125 to 250 days
Farmland classification: Not prime farmland

Map Unit Composition

Lithic argiustolls and similar soils: 40 percent
Cumulic haplustolls, warm, and similar soils: 31 percent
Typic ustorthents and similar soils: 29 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Lithic Argiustolls

Setting

Landscape: Plateaus
Landform: Hills, Escarpments
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Residuum weathered from limestone and/or colluvium derived from limestone

Typical profile

A - 0 to 3 inches: extremely cobbly loam
Bt - 3 to 8 inches: very gravelly clay loam
Btk - 8 to 13 inches: extremely cobbly clay loam
R - 13 to 23 inches: bedrock

Properties and qualities

Slope: 15 to 55 percent
Surface area covered with cobbles, stones or boulders: 5.0 percent
Depth to restrictive feature: 8 to 20 inches to lithic bedrock
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 14 percent
Available water supply, 0 to 60 inches: Very low (about 0.8 inches)

Description of Cumulic Haplustolls, Warm

Setting

Landscape: Valleys
Landform: Drainageways, Alluvial fans
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread, dip
Down-slope shape: Linear
Across-slope shape: Linear, convex
Parent material: Mixed alluvium derived from igneous, metamorphic and sedimentary rock

Typical profile

A - 0 to 10 inches: clay loam
C - 10 to 60 inches: clay

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: High (about 10.0 inches)

Description of Typic Ustorthents

Setting

Landscape: Mountains
Landform: Fan remnants
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Slope alluvium and/or colluvium derived from sandstone and shale

Typical profile

A - 0 to 3 inches: loam
C - 3 to 60 inches: loam

Properties and qualities

Slope: 2 to 8 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 5 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 2.0

Available water supply, 0 to 60 inches: High (about 11.3 inches)

213—Lithic Argiustolls, Typic Haplustolls, and Vitrandic Haplustolls; cool mesic ustic mountains

Map Unit Setting

National map unit symbol: 31rd9
Landscape: Plateaus
Elevation: 7,220 to 9,820 feet
Mean annual precipitation: 15 to 33 inches
Mean annual air temperature: 43 to 52 degrees F
Frost-free period: 115 to 185 days
Farmland classification: Not prime farmland

Map Unit Composition

Lithic argiustolls and similar soils: 55 percent
Typic haplustolls and similar soils: 30 percent
Vitrandic haplustolls and similar soils: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Lithic Argiustolls

Setting

Landscape: Plateaus
Landform: Hills, Escarpments
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Residuum weathered from limestone and/or colluvium derived from limestone

Typical profile

A - 0 to 3 inches: extremely cobbly loam
Bt - 3 to 8 inches: very gravelly clay loam
Btk - 8 to 13 inches: extremely cobbly clay loam
R - 13 to 23 inches: bedrock

Properties and qualities

Slope: 15 to 55 percent
Surface area covered with cobbles, stones or boulders: 5.0 percent
Depth to restrictive feature: 8 to 20 inches to lithic bedrock
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 14 percent

Available water supply, 0 to 60 inches: Very low (about 0.8 inches)

Description of Typic Haplustolls

Setting

Landscape: Plateaus
Landform: Mountain slopes, Mesas
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Mountainbase, lower third of mountainflank
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Colluvium and/or alluvium derived from igneous rock

Typical profile

A1 - 0 to 5 inches: extremely cobbly loam
A2 - 5 to 12 inches: cobbly clay loam
Bw - 12 to 32 inches: extremely cobbly clay
C - 32 to 60 inches: extremely cobbly clay

Properties and qualities

Slope: 8 to 20 percent
Surface area covered with cobbles, stones or boulders: 5.0 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.07 to 0.21 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 0.5 mmhos/cm)
Available water supply, 0 to 60 inches: Low (about 4.6 inches)

Description of Vitrandic Haplustolls

Setting

Landscape: Mountains
Landform: Mountain slopes
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Mountainflank
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Residuum weathered from tuff and/or colluvium derived from tuff

Typical profile

A1 - 0 to 3 inches: cobbly ashy loam
A2 - 3 to 8 inches: gravelly ashy loam
Bw - 8 to 19 inches: extremely gravelly loam
C - 19 to 52 inches: extremely cobbly sandy loam
R - 52 to 62 inches: bedrock

Properties and qualities

Slope: 30 to 75 percent
Depth to restrictive feature: 40 to 60 inches to lithic bedrock
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 to 0.00 in/hr)

Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Moderate (about 6.4 inches)

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Appendix B3: Rational Method Preliminary Calculations

Rational Method

$$Q = \frac{CIA}{Z}$$

Q = maximum rate of runoff
C = runoff coefficient
I = average rainfall intensity
A = drainage area
Z = conversion factor (1)

10yr storm + 100 yr storm

C = 0.46
C_v = 0.06 C_r = 0.2 C_i = 0.12 C_s = 0.08
I = 2.91 in/hr , I = 4.35 in/hr
A = 0.39 mi^2 → 249.6 acre
Z = 1

Q = (0.46)(2.91)(249.6 acre)
Q = 334.16 ft^3/s → 10yr

Q = (0.46)(4.35)(249.6 acre)
Q = 499.450 ft^3/s → 100 yr

Appendix B4: HEC-HMS 10 Year Report

Project: Penstock_Wash

Simulation Run: Existing 10-yr Flow

Simulation Start: 31 January 2026, 24:00

Simulation End: 2 February 2026, 12:00

HMS Version: 4.13

Executed: 19 February 2026, 03:25

Global Parameter Summary - Subbasin

	Location	
Element Name	**Longitude Degrees**	**Latitude Degrees**
Sb1	-111.58	35.25

	Area (MI2)
Element Name	**Area (MI2)**
Sb1	0.39

	Downstream
Element Name	**Downstream**
Sb1	Sink - 1

	Loss Rate: Scs	
Element Name	**Percent Impervious Area**	**Curve Number**
Sb1	10	80

	Transform: Scs	
Element Name	**Lag**	**Unitgraph Type**
Sb1	30.6	Standard

Global Results Summary

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Sb1	0.39	197.8	01Feb2026, 12:45	1.42
Sink - 1	0.39	197.8	01Feb2026, 12:45	1.42

Subbasin: SB1

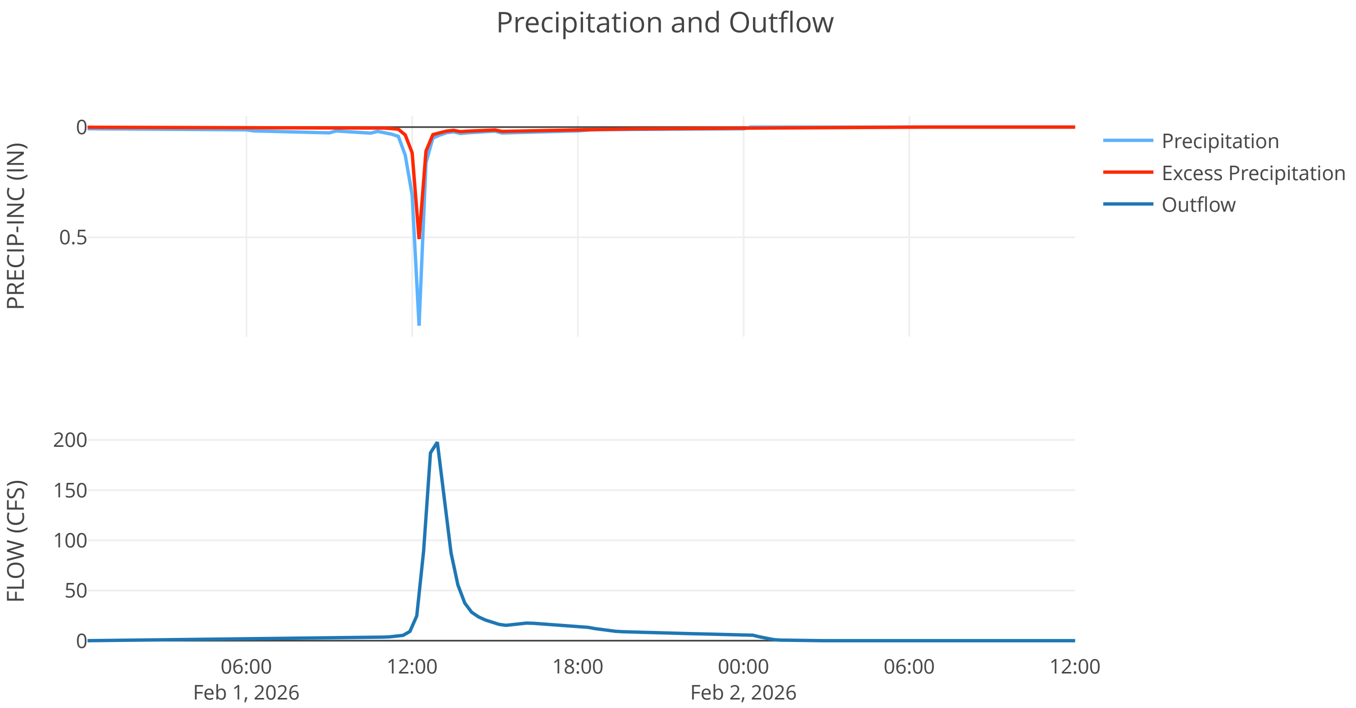
Area (MI2) : 0.39
Latitude Degrees : 35.25
Longitude Degrees : -111.58
Downstream : Sink - 1

Loss Rate: Scs	
Percent Impervious Area	10
Curve Number	80

Transform: Scs	
Lag	30.6
Unitgraph Type	Standard

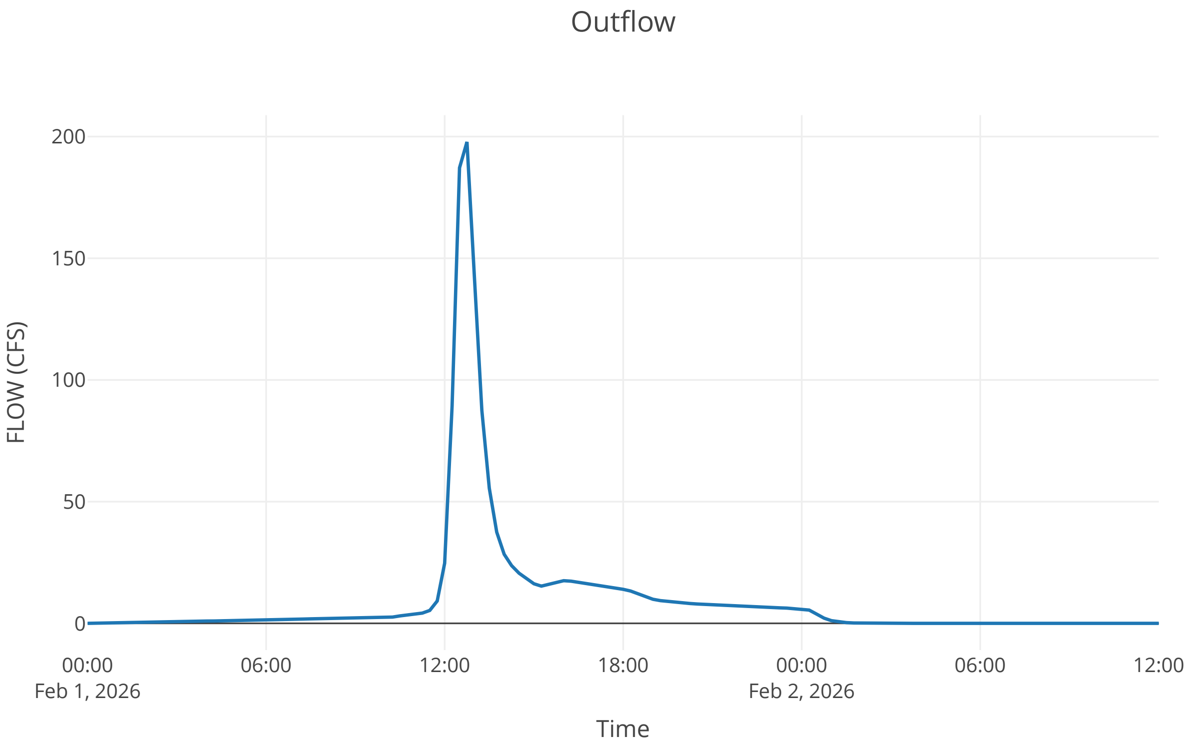
Results: SB1	
Peak Discharge (CFS)	197.8
Time of Peak Discharge	01Feb2026, 12:45
Volume (IN)	1.42
Precipitation Volume (AC - FT)	61.44
Loss Volume (AC - FT)	32.32

Excess Volume (AC - FT)	29.12
Direct Runoff Volume (AC - FT)	29.12
Baseflow Volume (AC - FT)	0



Sink: Sink-1

Results: Sink-1	
Peak Discharge (CFS)	197.8
Time of Peak Discharge	01Feb2026, 12:45
Volume (IN)	1.42



Appendix B5: HEC-HMS 100 Year Report

Project: Penstock_Wash

Simulation Run: Existing 100-yr Flow

Simulation Start: 31 January 2026, 24:00

Simulation End: 2 February 2026, 12:00

HMS Version: 4.13

Executed: 19 February 2026, 03:26

Global Parameter Summary - Subbasin

	Location	
Element Name	**Longitude Degrees**	**Latitude Degrees**
Sb1	-111.58	35.25

	Area (MI2)
Element Name	**Area (MI2)**
Sb1	0.39

	Downstream
Element Name	**Downstream**
Sb1	Sink - 1

	Loss Rate: Scs	
Element Name	**Percent Impervious Area**	**Curve Number**
Sb1	10	80

	Transform: Scs	
Element Name	**Lag**	**Unitgraph Type**
Sb1	30.6	Standard

Global Results Summary

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Sb1	0.39	420.07	01Feb2026, 12:45	2.65
Sink - 1	0.39	420.07	01Feb2026, 12:45	2.65

Subbasin: SB1

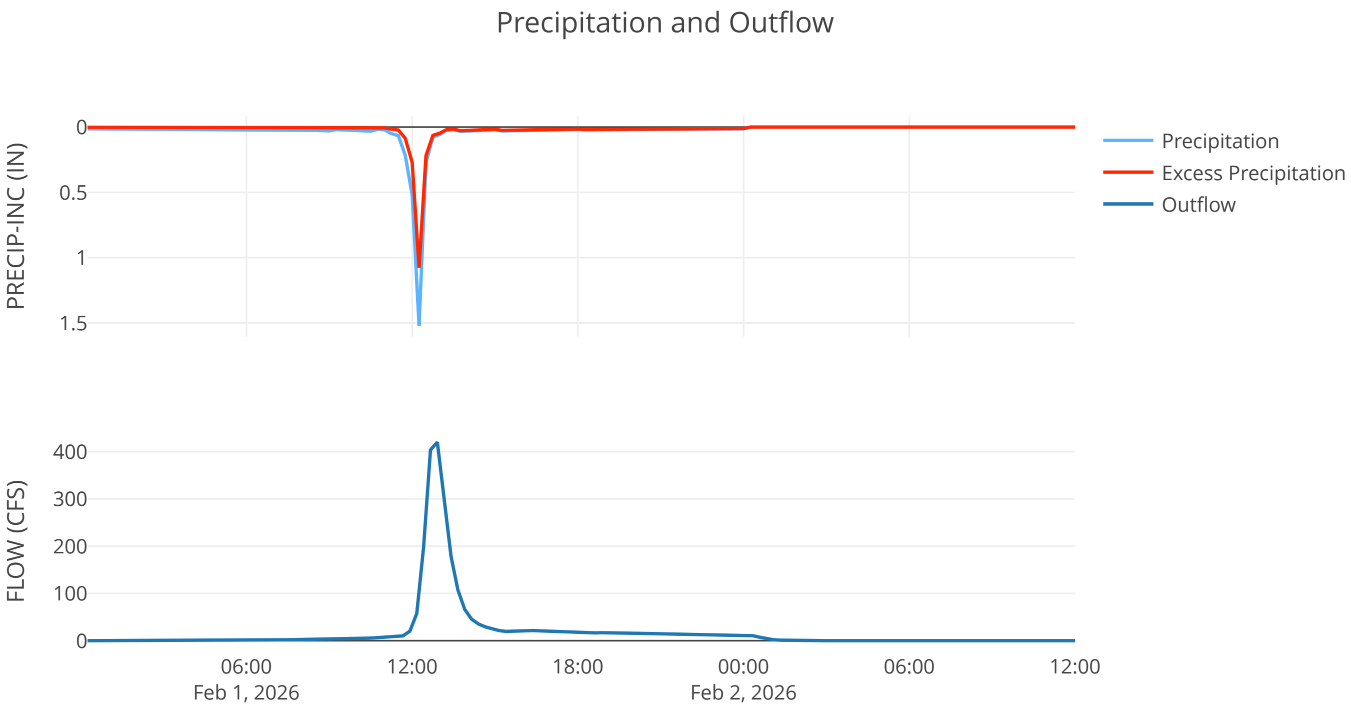
Area (MI2) : 0.39
Latitude Degrees : 35.25
Longitude Degrees : -111.58
Downstream : Sink - 1

Loss Rate: Scs	
Percent Impervious Area	10
Curve Number	80

Transform: Scs	
Lag	30.6
Unitgraph Type	Standard

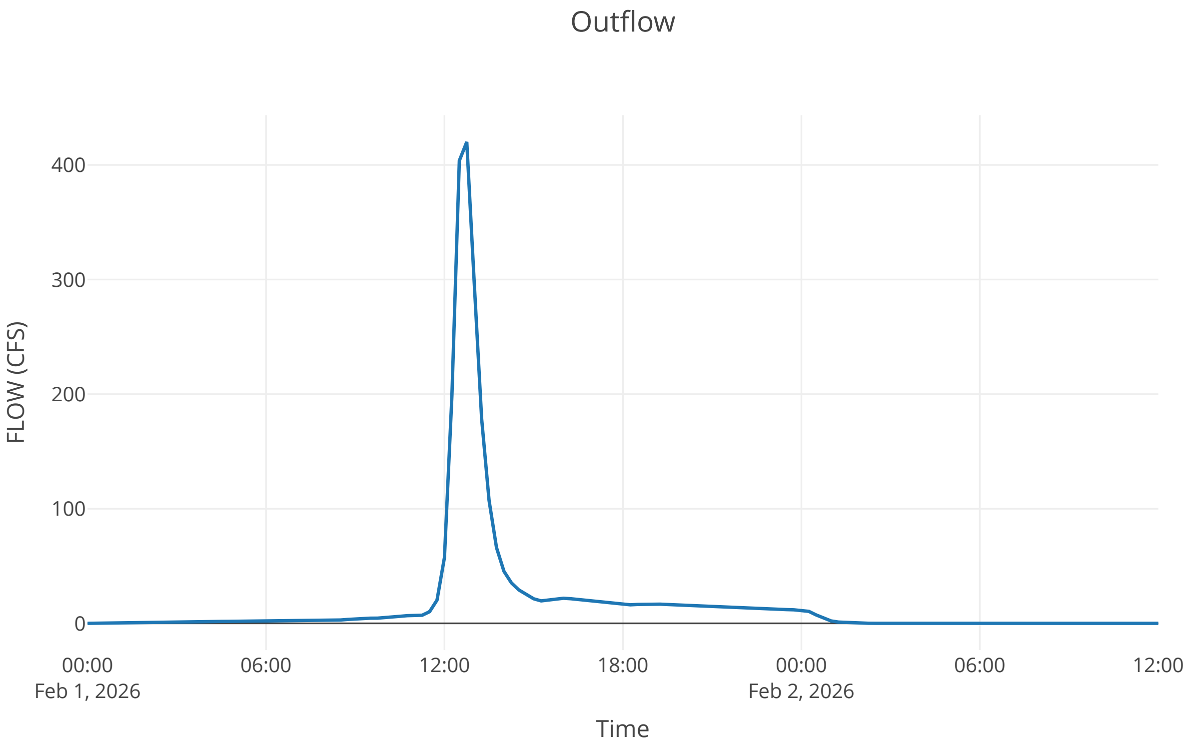
Results: SB1	
Peak Discharge (CFS)	420.07
Time of Peak Discharge	01Feb2026, 12:45
Volume (IN)	2.65
Precipitation Volume (AC - FT)	92.06
Loss Volume (AC - FT)	37.65

Excess Volume (AC - FT)	54.42
Direct Runoff Volume (AC - FT)	54.42
Baseflow Volume (AC - FT)	0



Sink: Sink-1

Results: Sink-1	
Peak Discharge (CFS)	420.07
Time of Peak Discharge	01Feb2026, 12:45
Volume (IN)	2.65



Appendix B6: Culvert Master Report

Culvert Calculator Report
Corrugated Metal Pipe Culvert

Solve For: Discharge

Culvert Summary

Allowable HW Elevation	6,911.19	ft	Headwater Depth/Height	2.94	
Computed Headwater Eleva	6,911.19	ft	Discharge	53.71	cfs
Inlet Control HW Elev.	6,909.43	ft	Tailwater Elevation	6,901.72	ft
Outlet Control HW Elev.	6,911.19	ft	Control Type	Outlet Control	

Grades

Upstream Invert	6,905.31	ft	Downstream Invert	6,901.72	ft
Length	122.07	ft	Constructed Slope	0.029409	ft/ft

Hydraulic Profile

Profile	CompositeM2PressureProfile		Depth, Downstream	1.81	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	1.81	ft
Velocity Downstream	9.00	ft/s	Critical Slope	0.042185	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	2.00	ft
Section Size	24 inch		Rise	2.00	ft
Number Sections	2				

Outlet Control Properties

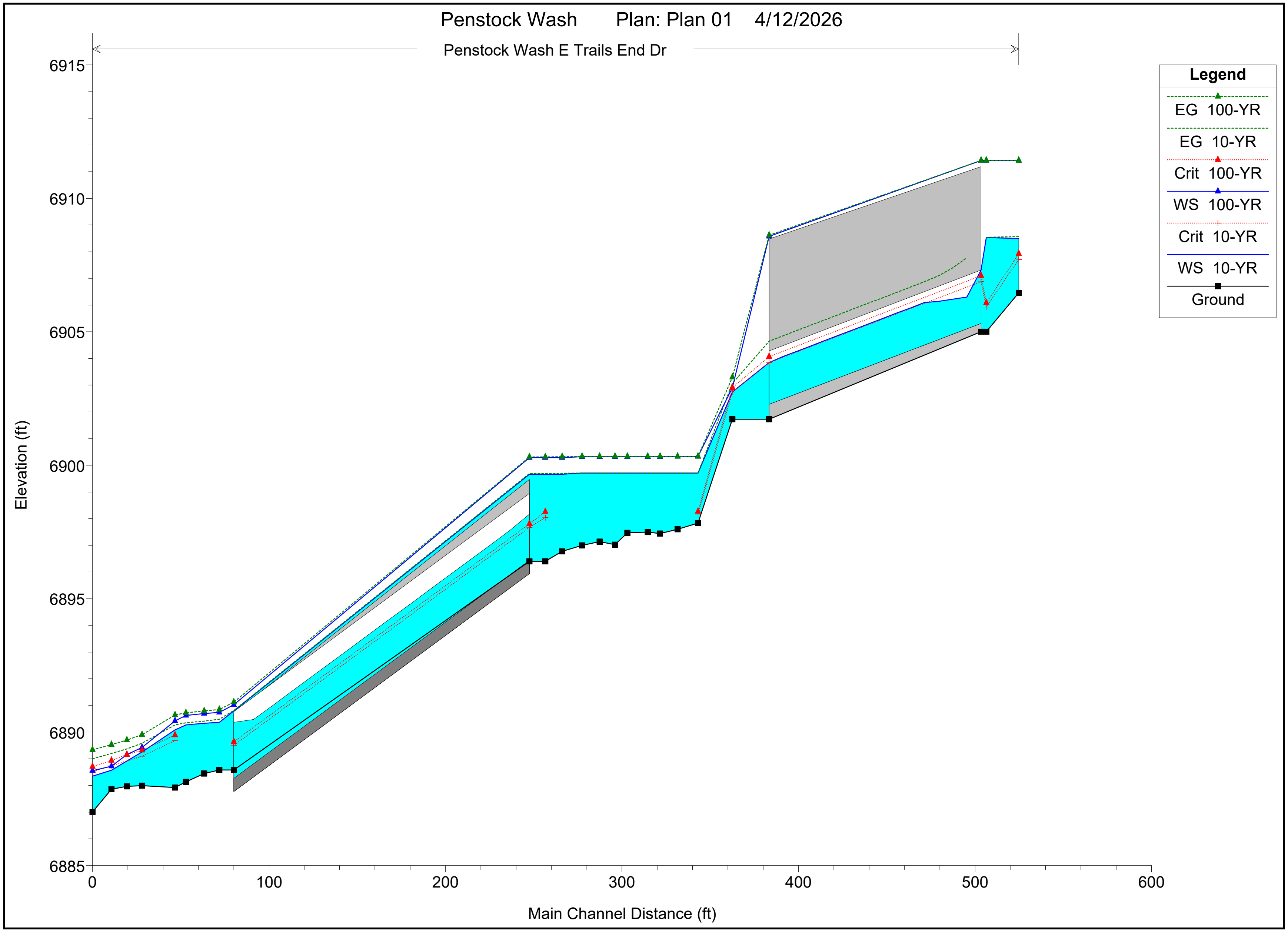
Outlet Control HW Elev.	6,911.19	ft	Upstream Velocity Head	1.14	ft
Ke	0.50		Entrance Loss	0.57	ft

Inlet Control Properties

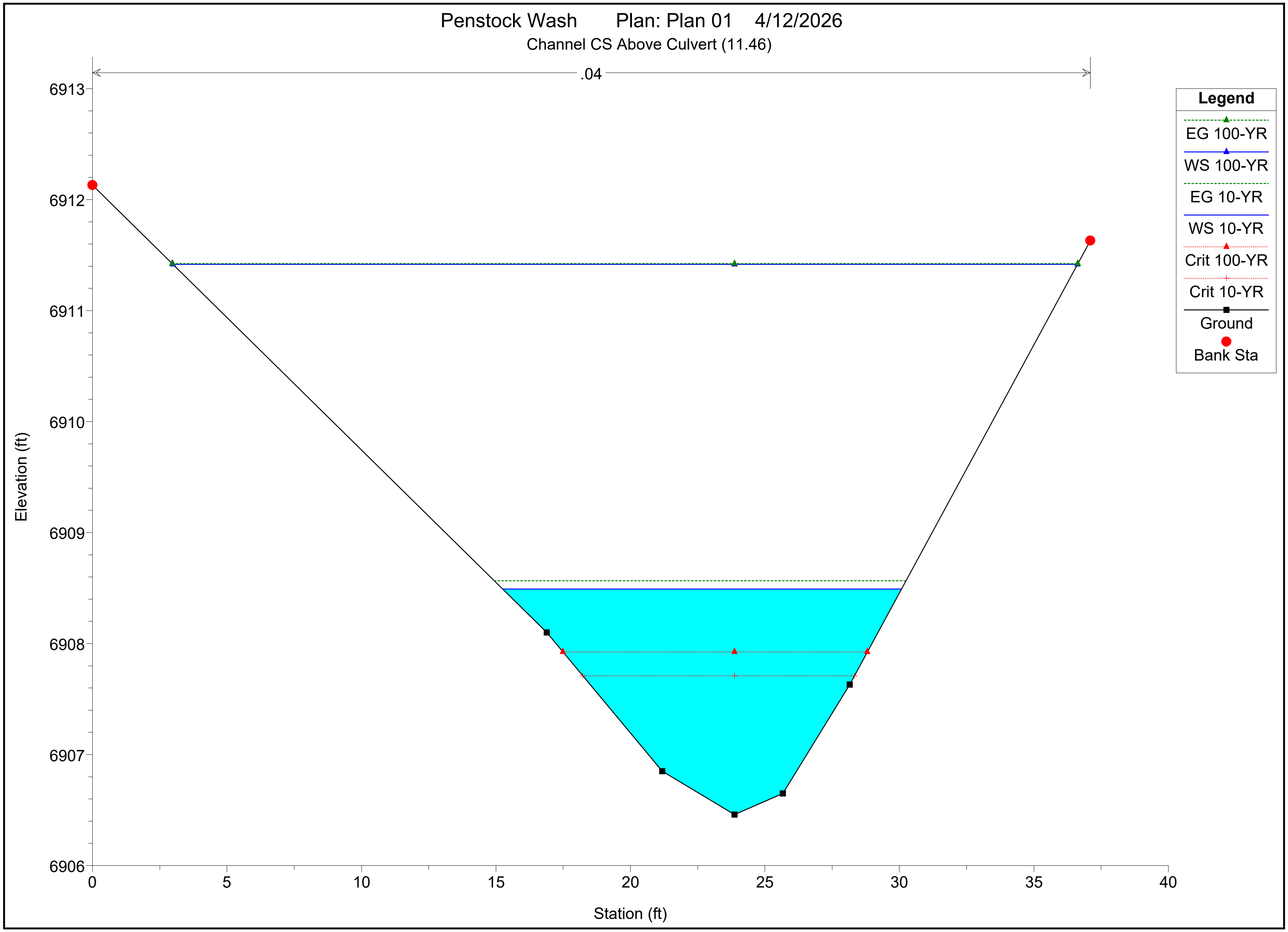
Inlet Control HW Elev.	6,909.43	ft	Flow Control	Submerged	
Inlet Type	Headwall		Area Full	6.3	ft²
K	0.00780		HDS 5 Chart	2	
M	2.00000		HDS 5 Scale	1	
C	0.03790		Equation Form	1	
Y	0.69000				

Appendix C: Existing Hydraulic Analysis Results

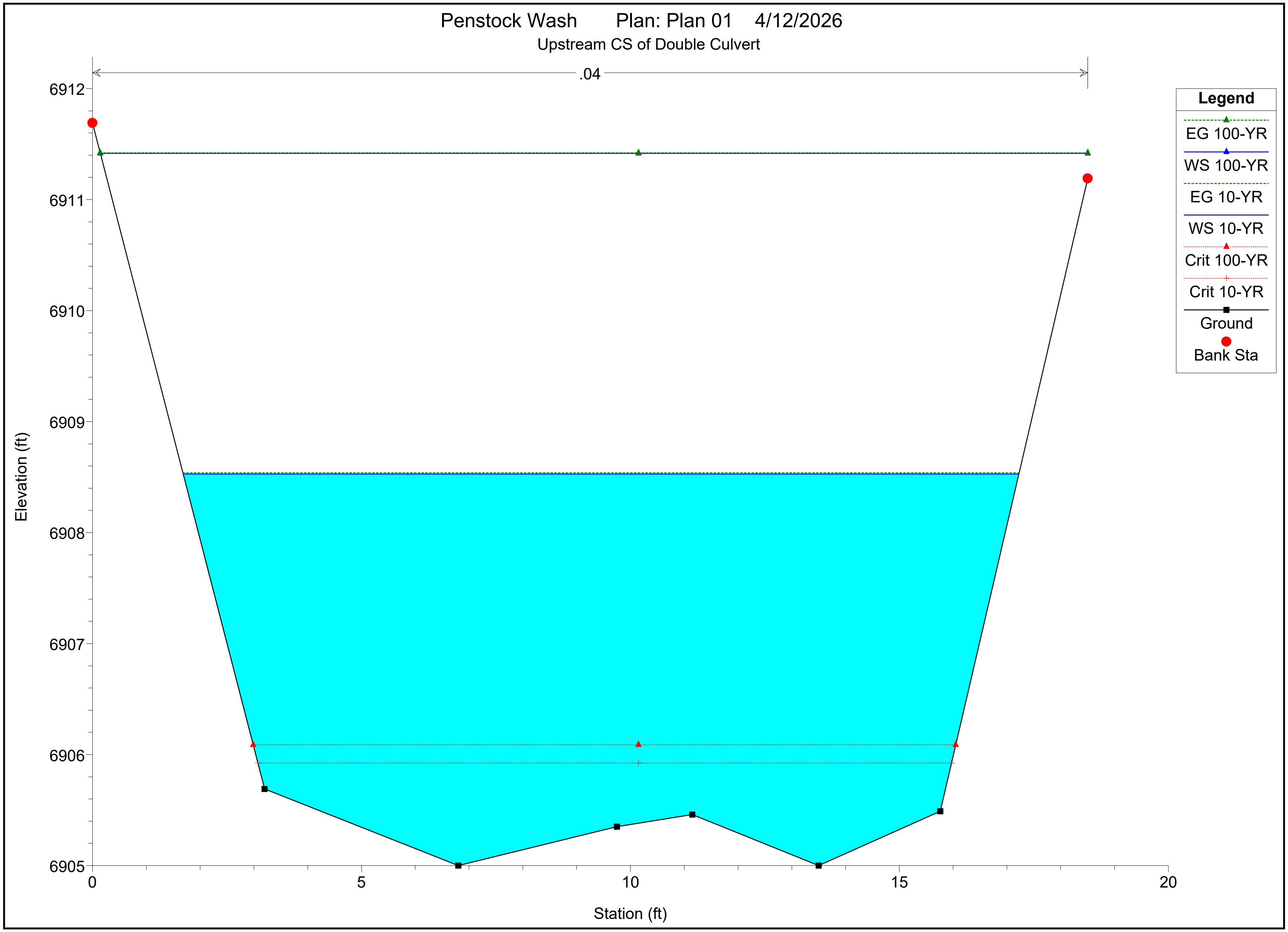
Appendix C1: Full Existing HEC-RAS Profile of Penstock Wash


Penstock Wash Plan: Plan 01 4/12/2026
Penstock Wash E Trails End Dr
Legend
EG 100-YR
EG 10-YR
Crit 100-YR
WS 100-YR
Crit 10-YR
WS 10-YR
Ground
Elevation (ft)
6915
6910
6905
6900
6895
6890
6885
0
100
200
300
400
500
600
Main Channel Distance (ft)

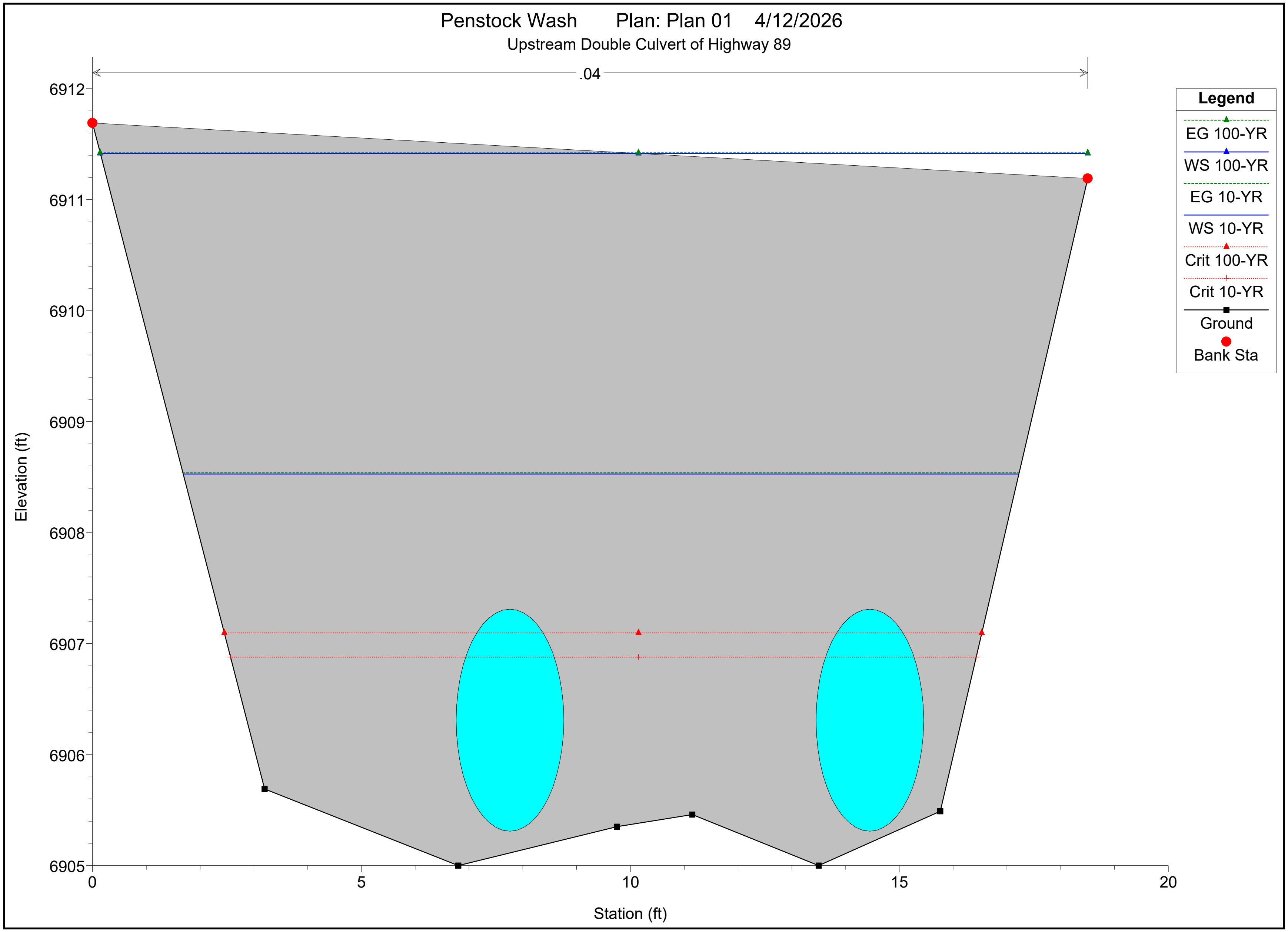
Appendix C2: Individual Cross Section and Culvert Profiles



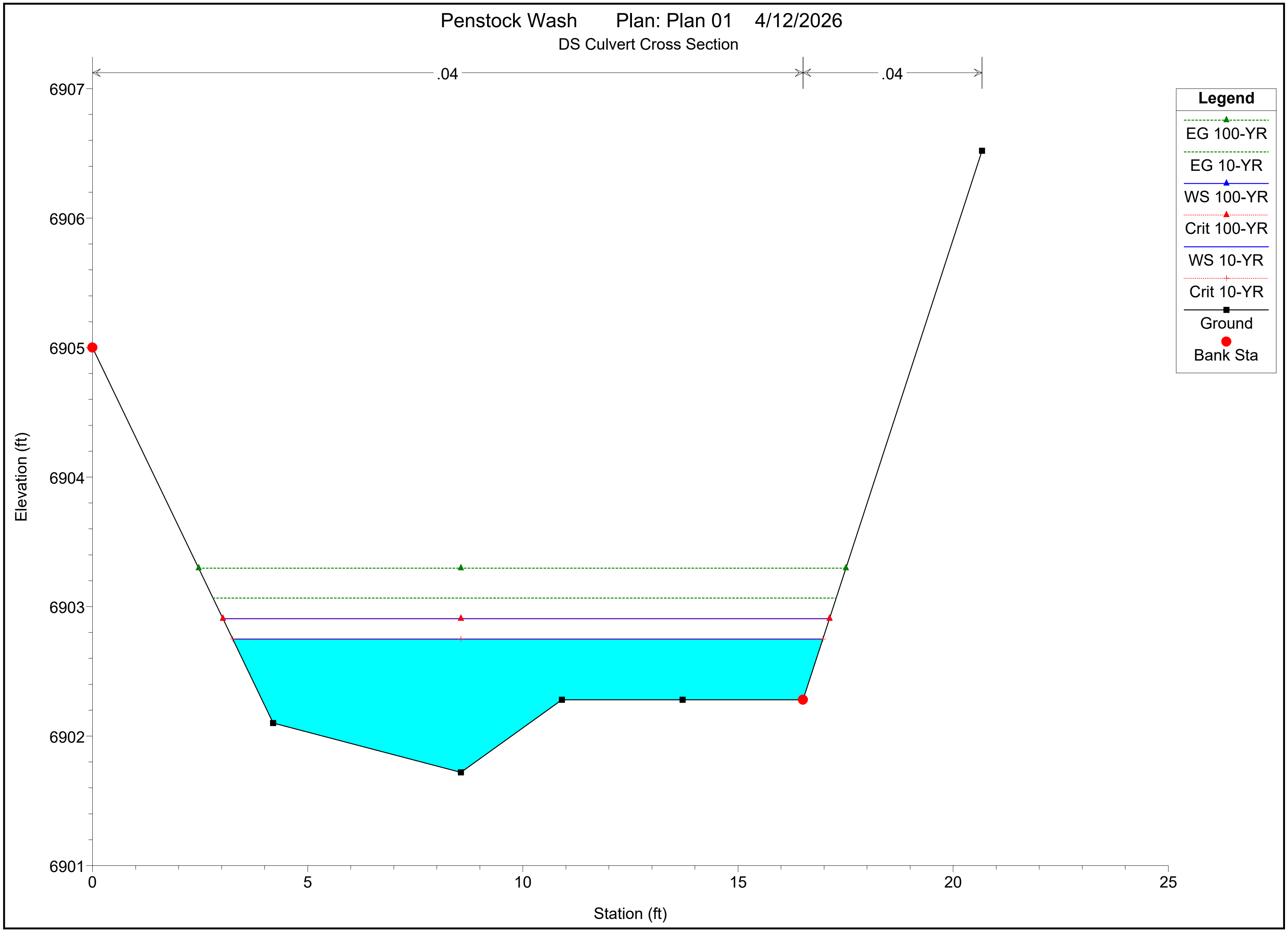
Penstock Wash Plan: Plan 01 4/12/2026
Channel CS Above Culvert (11.46)
.04
Elevation (ft)
6906
6907
6908
6909
6910
6911
6912
6913
Station (ft)
0
5
10
15
20
25
30
35
40
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Crit 100-YR
Crit 10-YR
Ground
Bank Sta



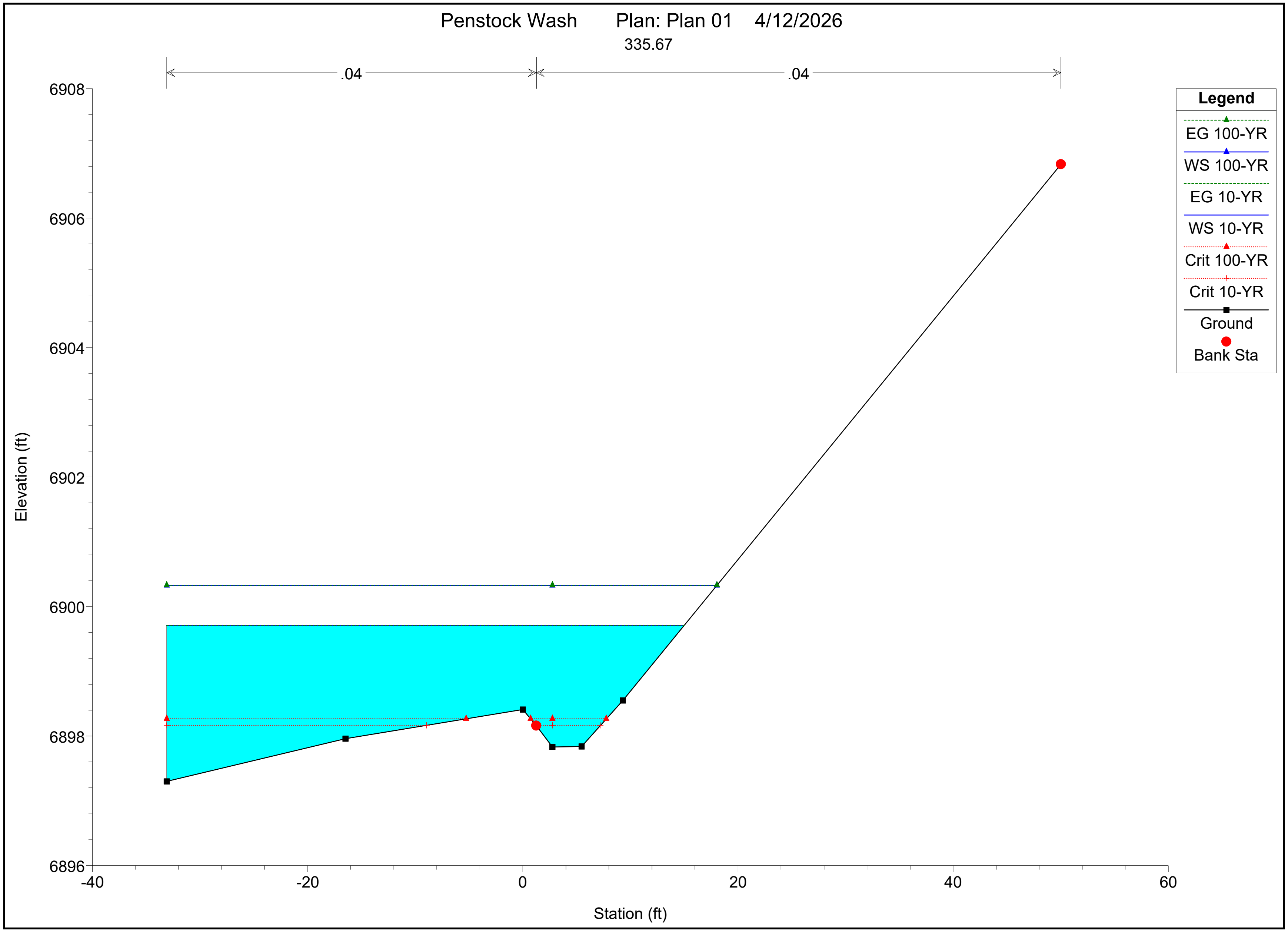
Penstock Wash Plan: Plan 01 4/12/2026
Upstream CS of Double Culvert
.04
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Crit 100-YR
Crit 10-YR
Ground
Bank Sta
Elevation (ft)
6912
6911
6910
6909
6908
6907
6906
6905
0
5
10
15
20
Station (ft)



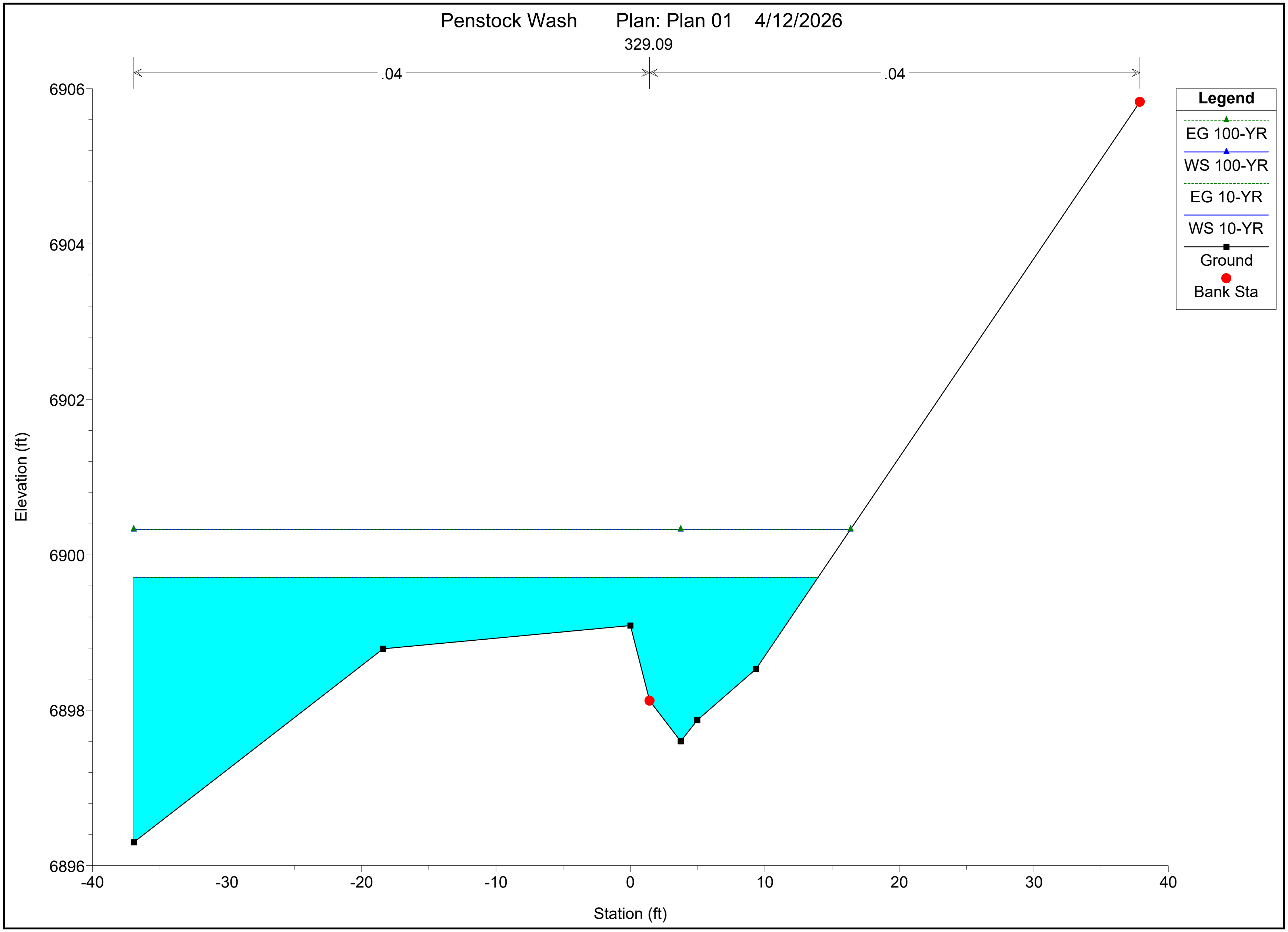
Penstock Wash Plan: Plan 01 4/12/2026
Upstream Double Culvert of Highway 89
.04
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Crit 100-YR
Crit 10-YR
Ground
Bank Sta
Elevation (ft)
6912
6911
6910
6909
6908
6907
6906
6905
0
5
10
15
20
Station (ft)



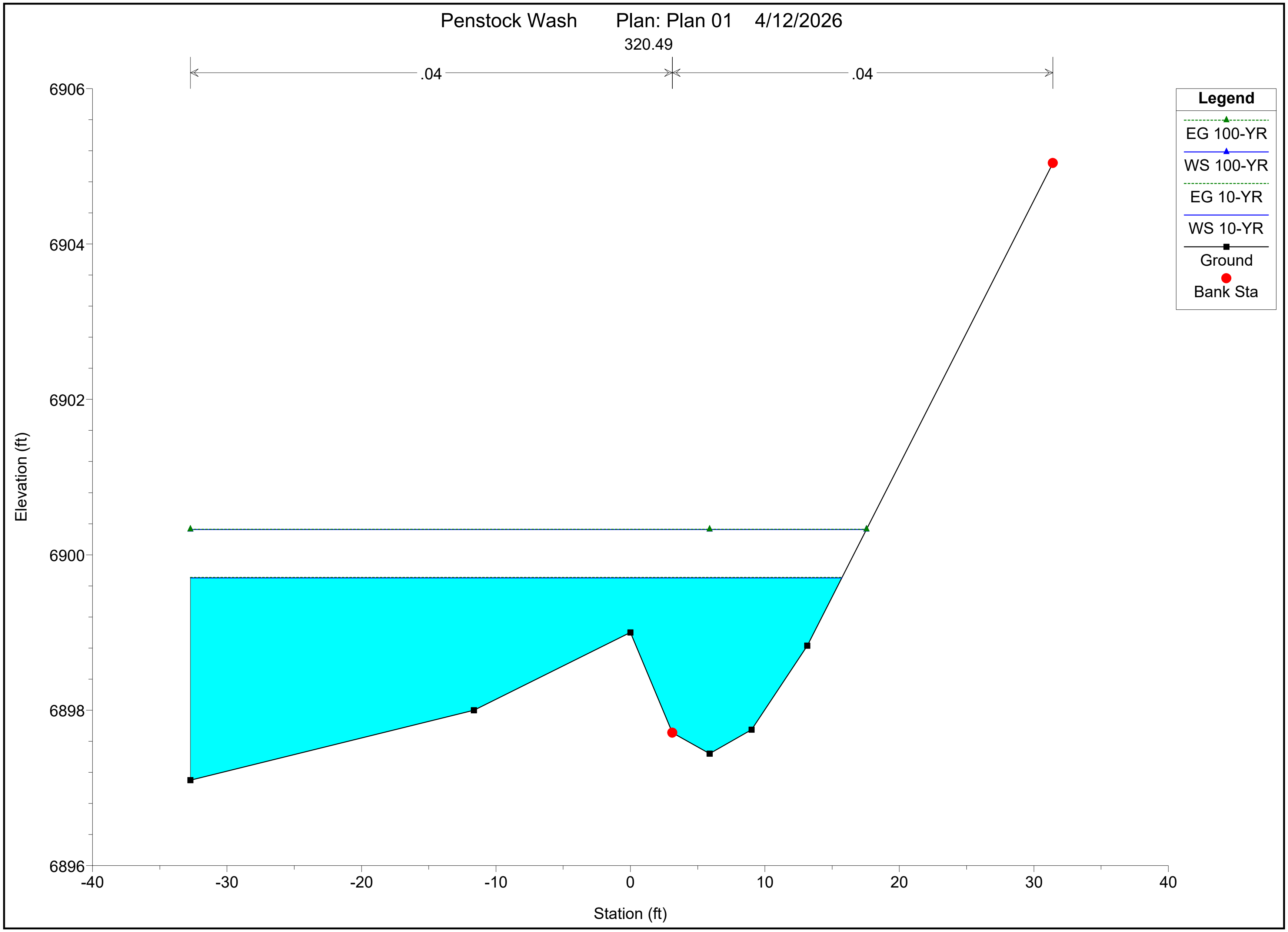
Penstock Wash Plan: Plan 01 4/12/2026
DS Culvert Cross Section
.04
.04
Legend
EG 100-YR
EG 10-YR
WS 100-YR
Crit 100-YR
WS 10-YR
Crit 10-YR
Ground
Bank Sta
Elevation (ft)
6901
6902
6903
6904
6905
6906
6907
Station (ft)
0
5
10
15
20
25



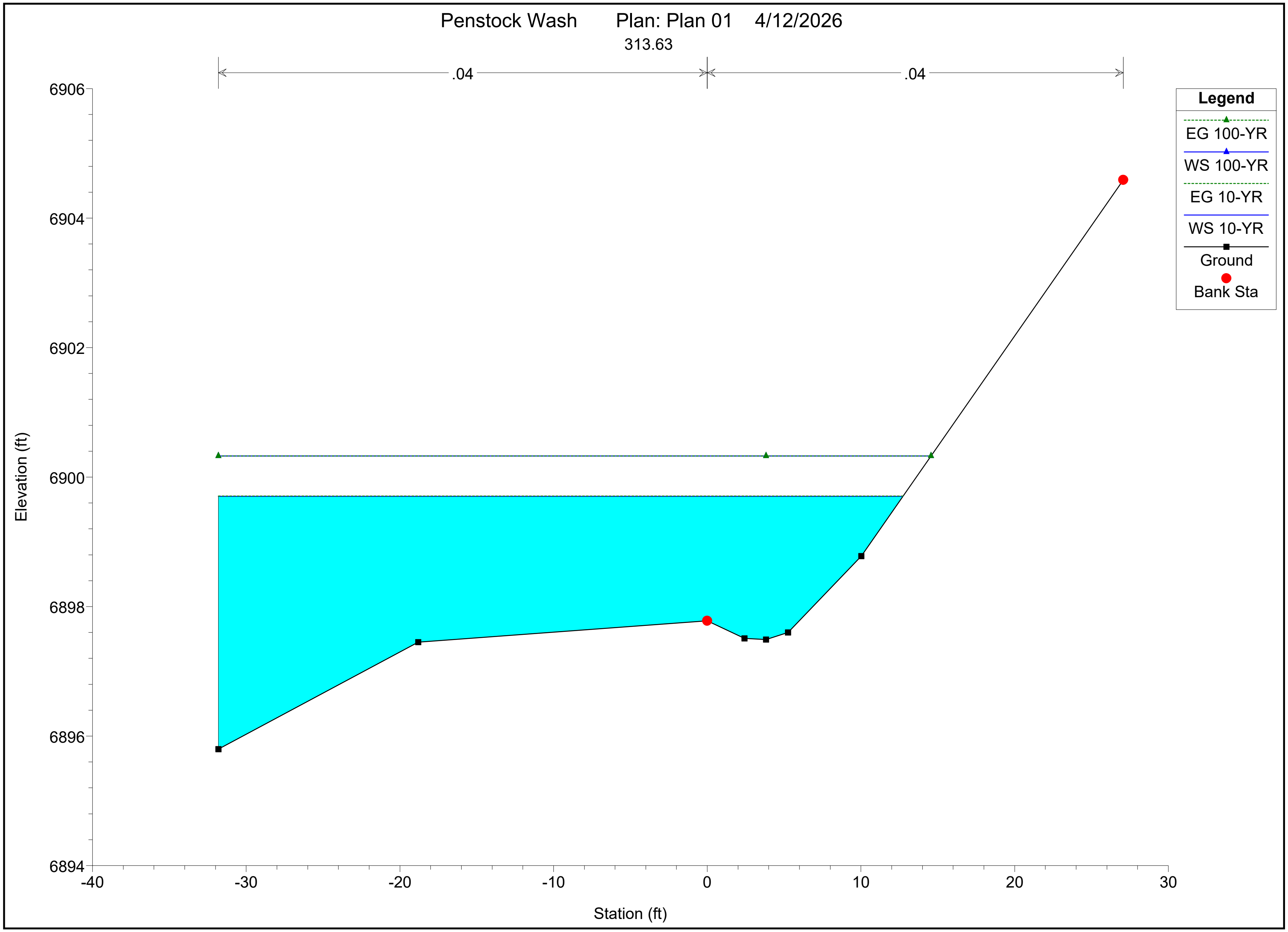
Penstock Wash Plan: Plan 01 4/12/2026
335.67
.04
.04
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Crit 100-YR
Crit 10-YR
Ground
Bank Sta
Elevation (ft)
6908
6906
6904
6902
6900
6898
6896
-40
-20
0
20
40
60
Station (ft)



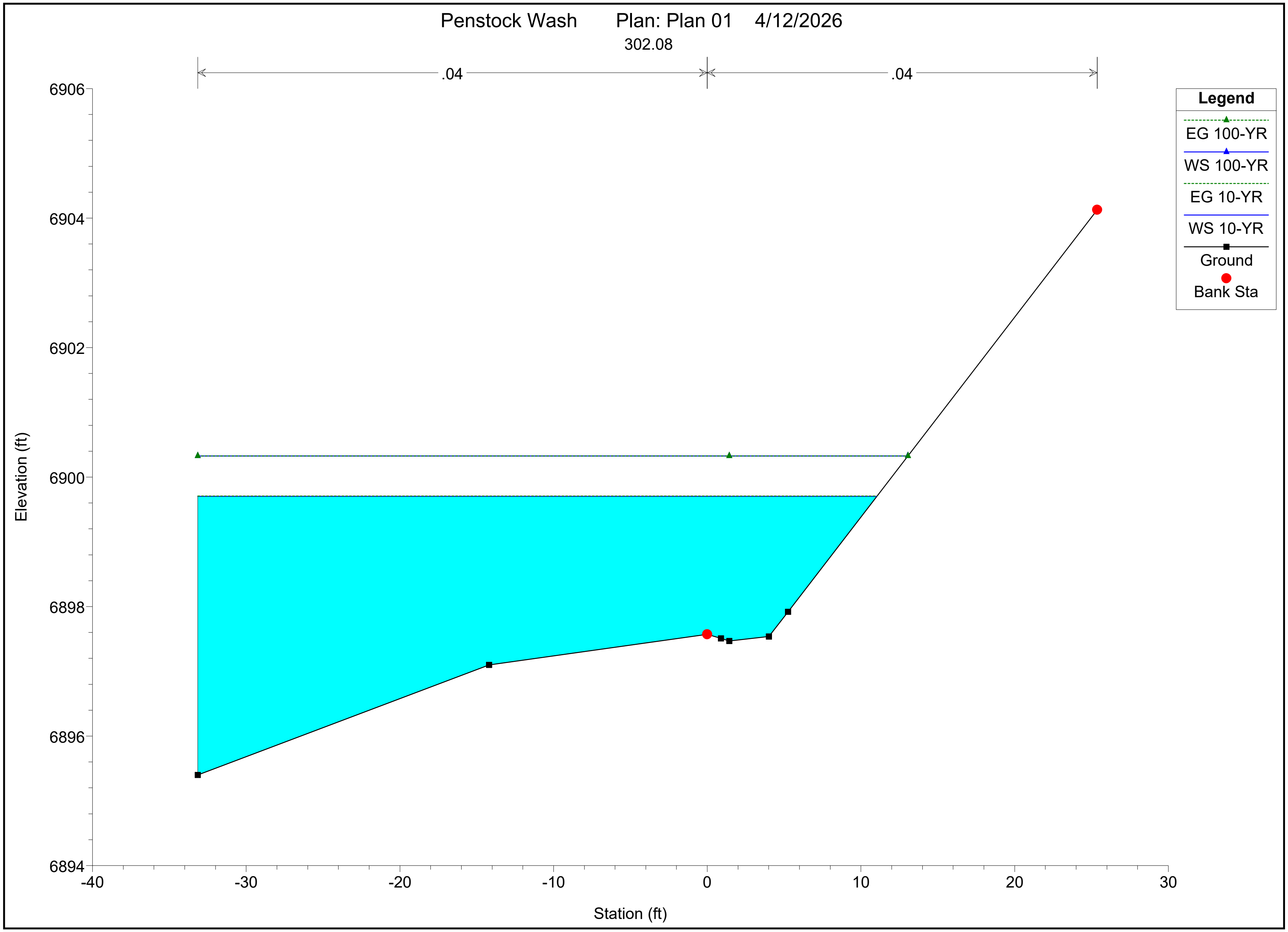
Penstock Wash Plan: Plan 01 4/12/2026
329.09
.04
.04
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)
6906
6904
6902
6900
6898
6896
-40
-30
-20
-10
0
10
20
30
40



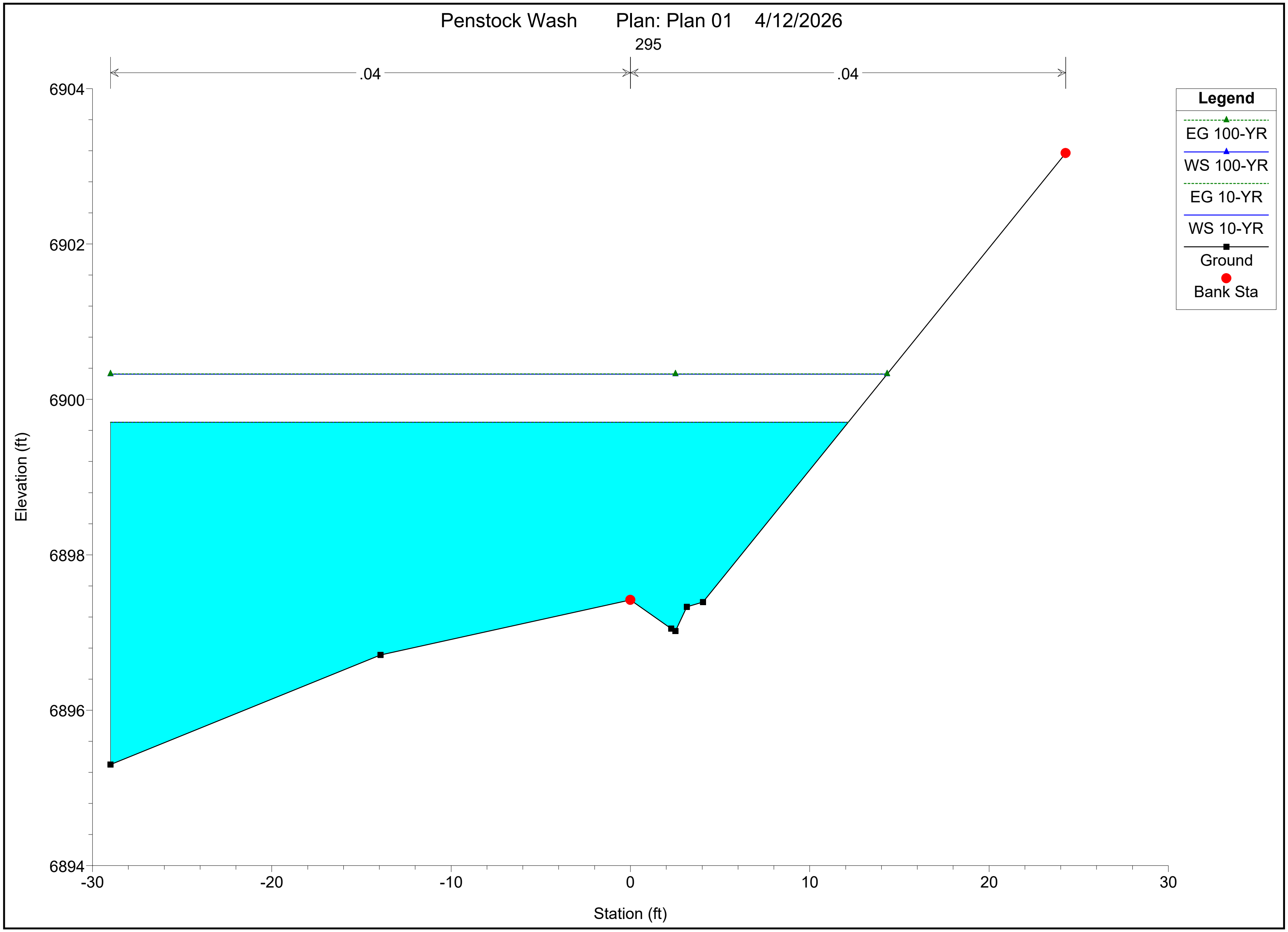
Penstock Wash Plan: Plan 01 4/12/2026
320.49
.04
.04
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6906
6904
6902
6900
6898
6896
-40
-30
-20
-10
0
10
20
30
40
Station (ft)



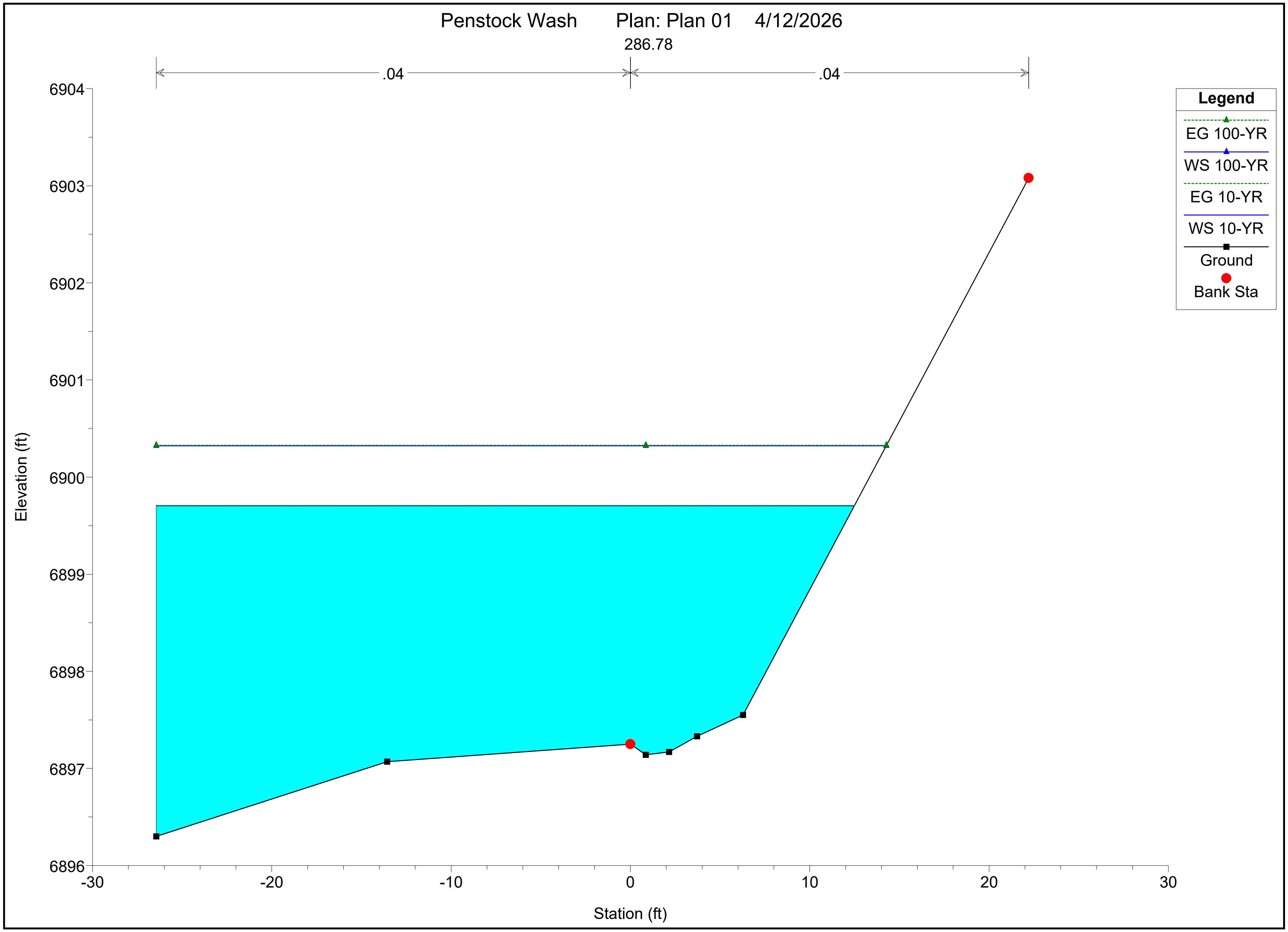
Penstock Wash Plan: Plan 01 4/12/2026
313.63
.04
.04
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Ground
Bank Sta
6906
6904
6902
6900
6898
6896
6894
Elevation (ft)
-40
-30
-20
-10
0
10
20
30
Station (ft)



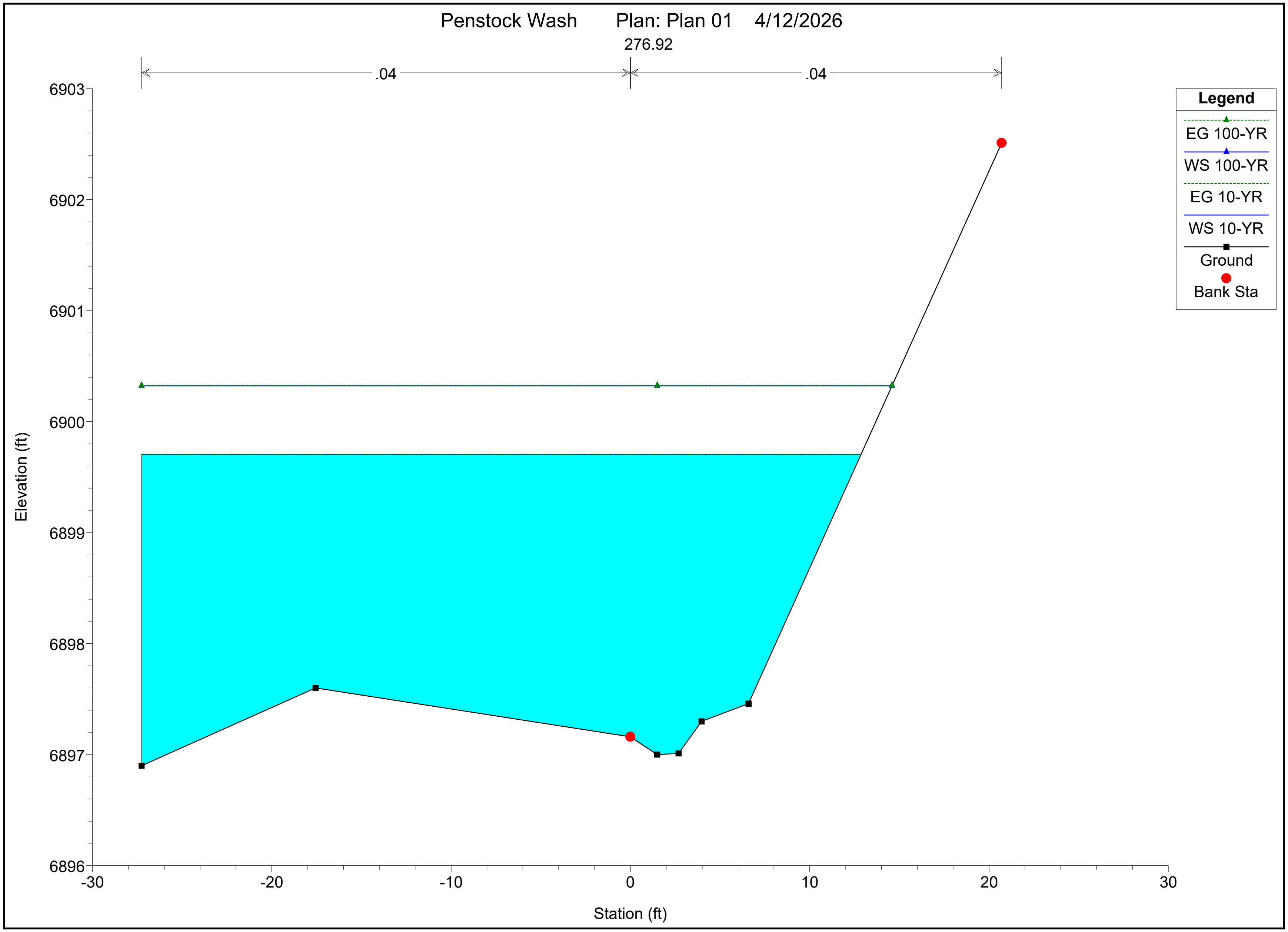
Penstock Wash Plan: Plan 01 4/12/2026
302.08
.04
.04
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6906
6904
6902
6900
6898
6896
6894
-40
-30
-20
-10
0
10
20
30
Station (ft)



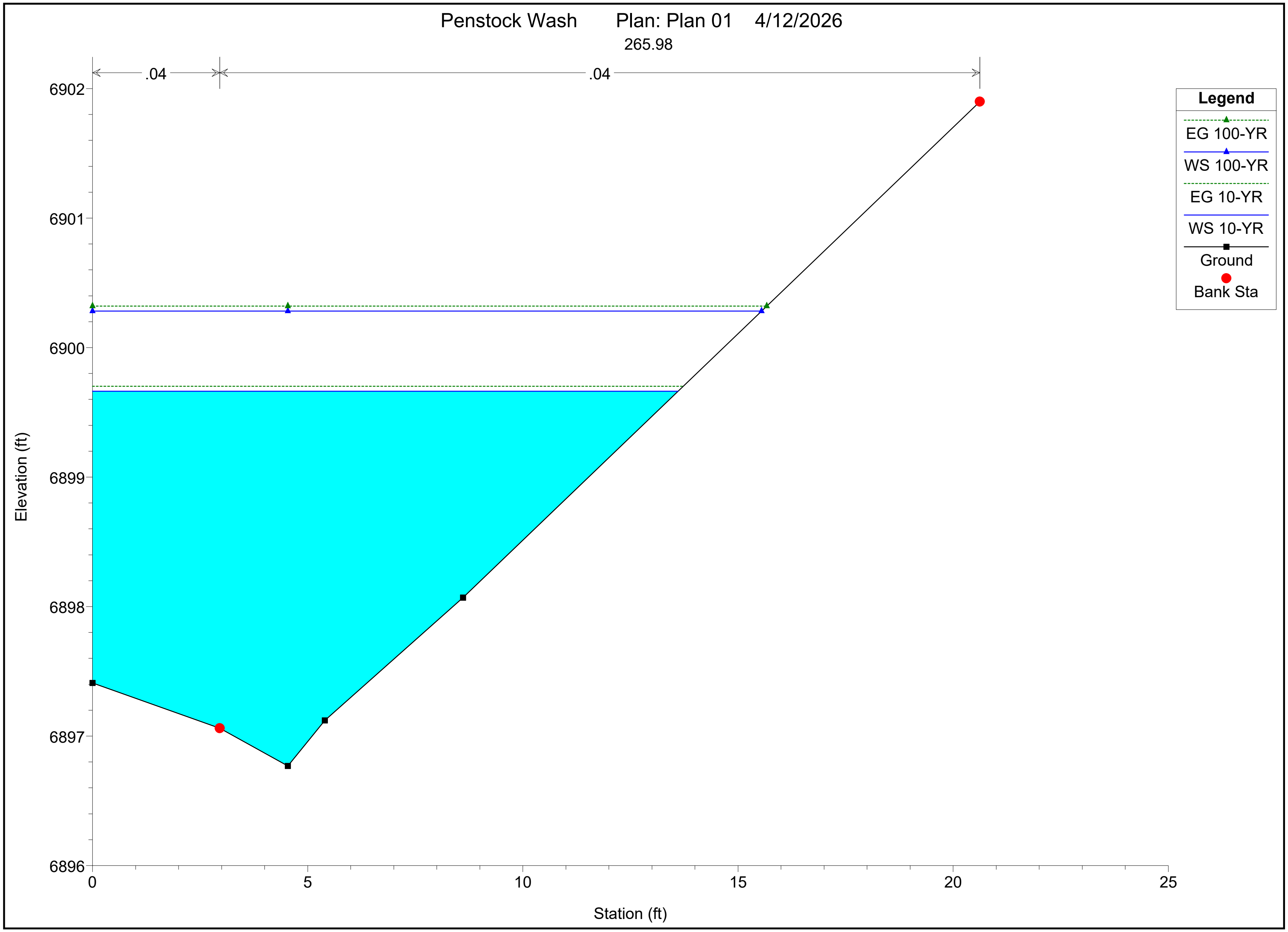
Penstock Wash Plan: Plan 01 4/12/2026
295
.04
.04
6904
6902
6900
6898
6896
6894
Elevation (ft)
-30
-20
-10
0
10
20
30
Station (ft)
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Ground
Bank Sta



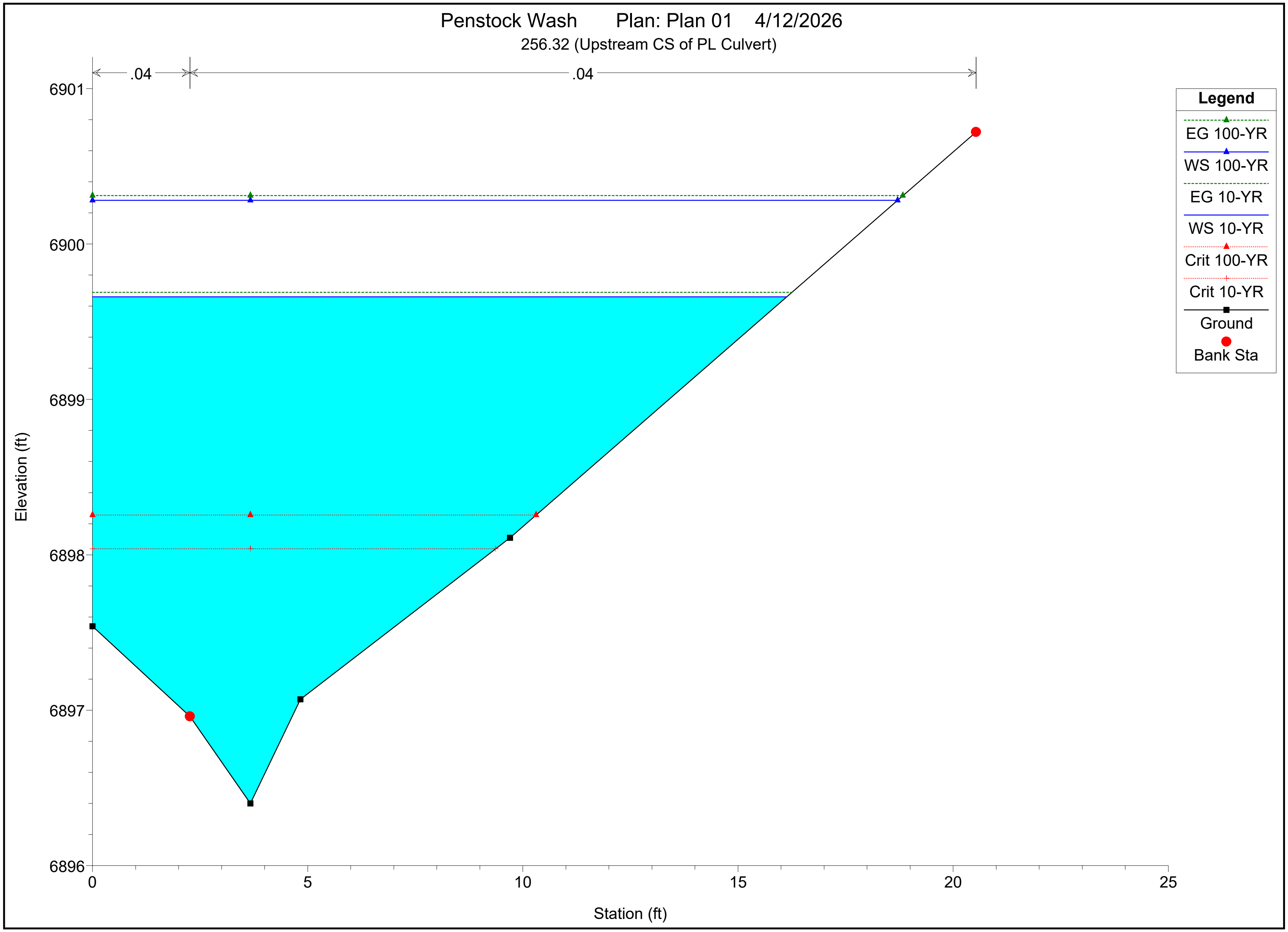
Penstock Wash Plan: Plan 01 4/12/2026
286.78
.04
.04
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6904
6903
6902
6901
6900
6899
6898
6897
6896
-30
-20
-10
0
10
20
30
Station (ft)



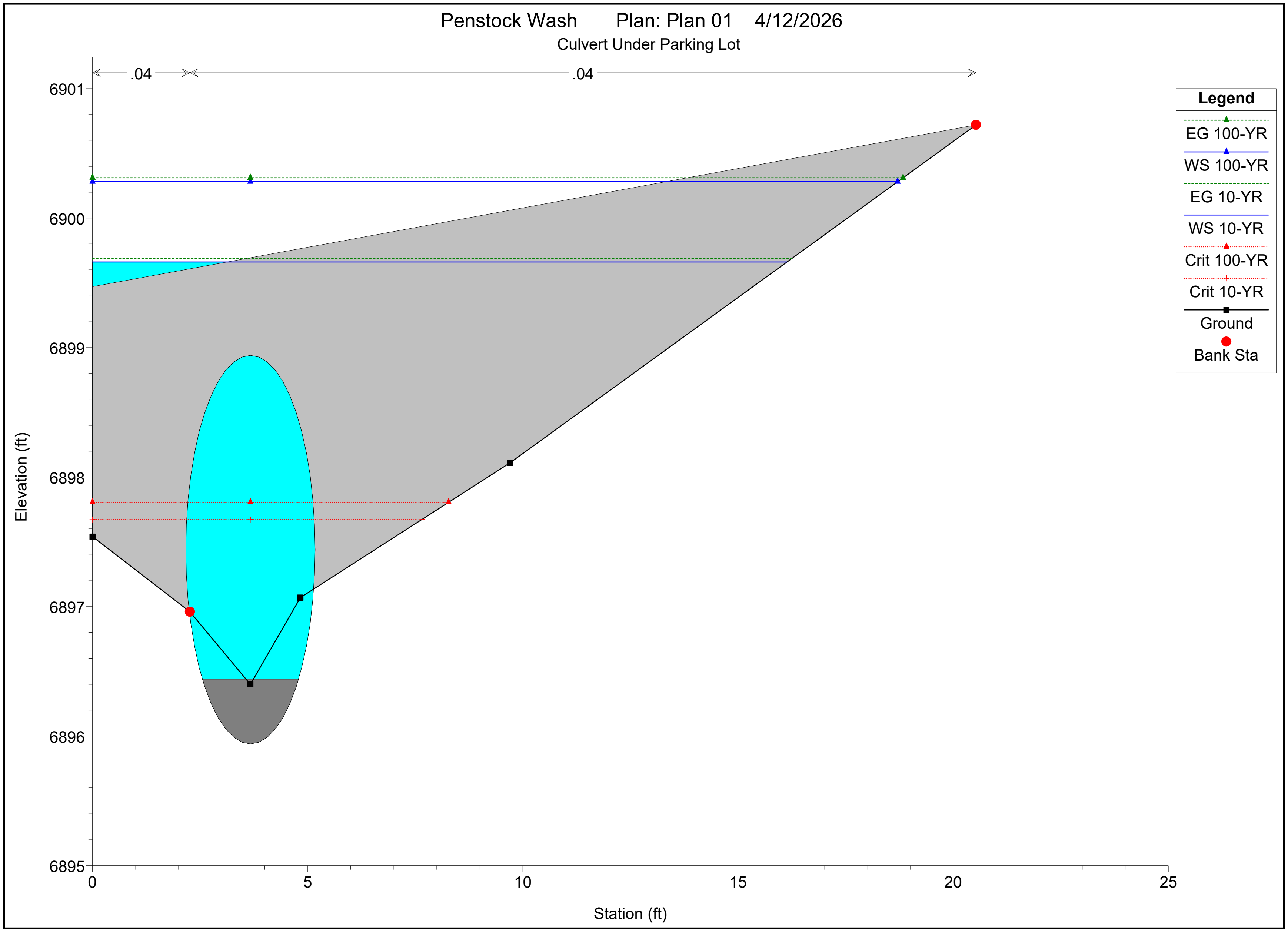
Penstock Wash Plan: Plan 01 4/12/2026
276.92
.04
.04
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Ground
Bank Sta
6903
6902
6901
6900
6899
6898
6897
6896
Elevation (ft)
-30
-20
-10
0
10
20
30
Station (ft)



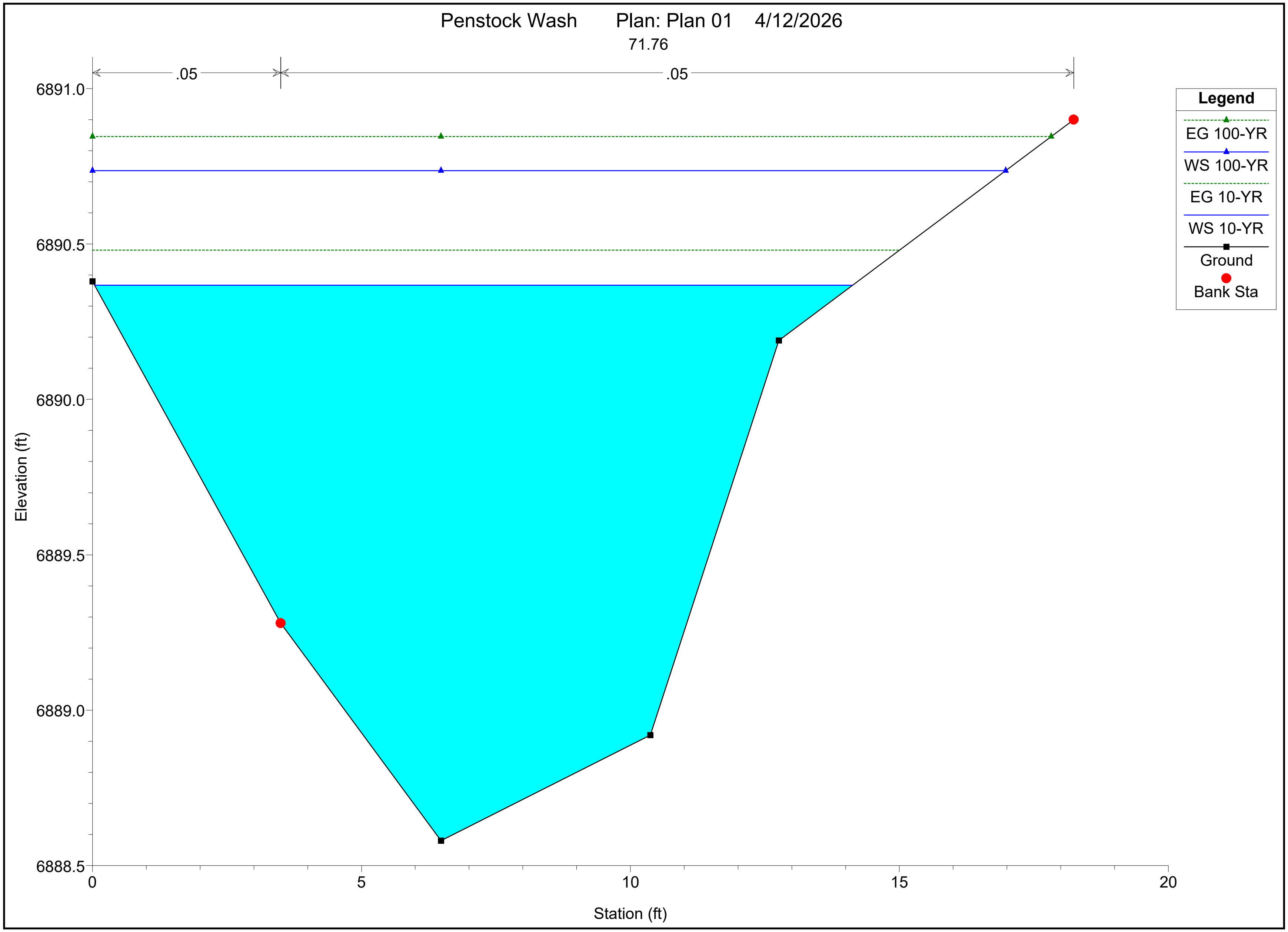
Penstock Wash Plan: Plan 01 4/12/2026
265.98
.04
.04
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6902
6901
6900
6899
6898
6897
6896
0
5
10
15
20
25
Station (ft)



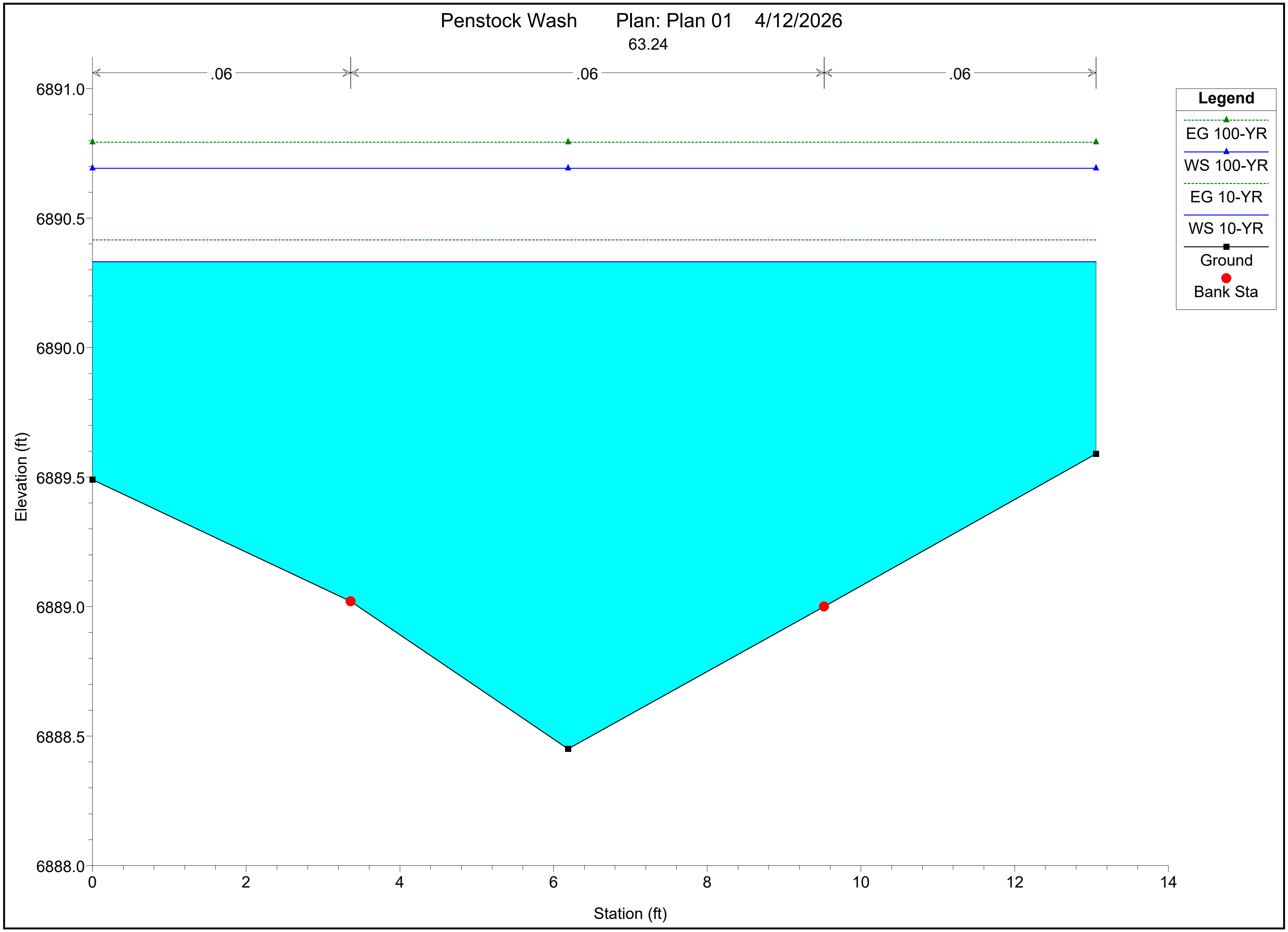
Penstock Wash Plan: Plan 01 4/12/2026
256.32 (Upstream CS of PL Culvert)
.04
.04
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Crit 100-YR
Crit 10-YR
Ground
Bank Sta
Elevation (ft)
6901
6900
6899
6898
6897
6896
0
5
10
15
20
25
Station (ft)

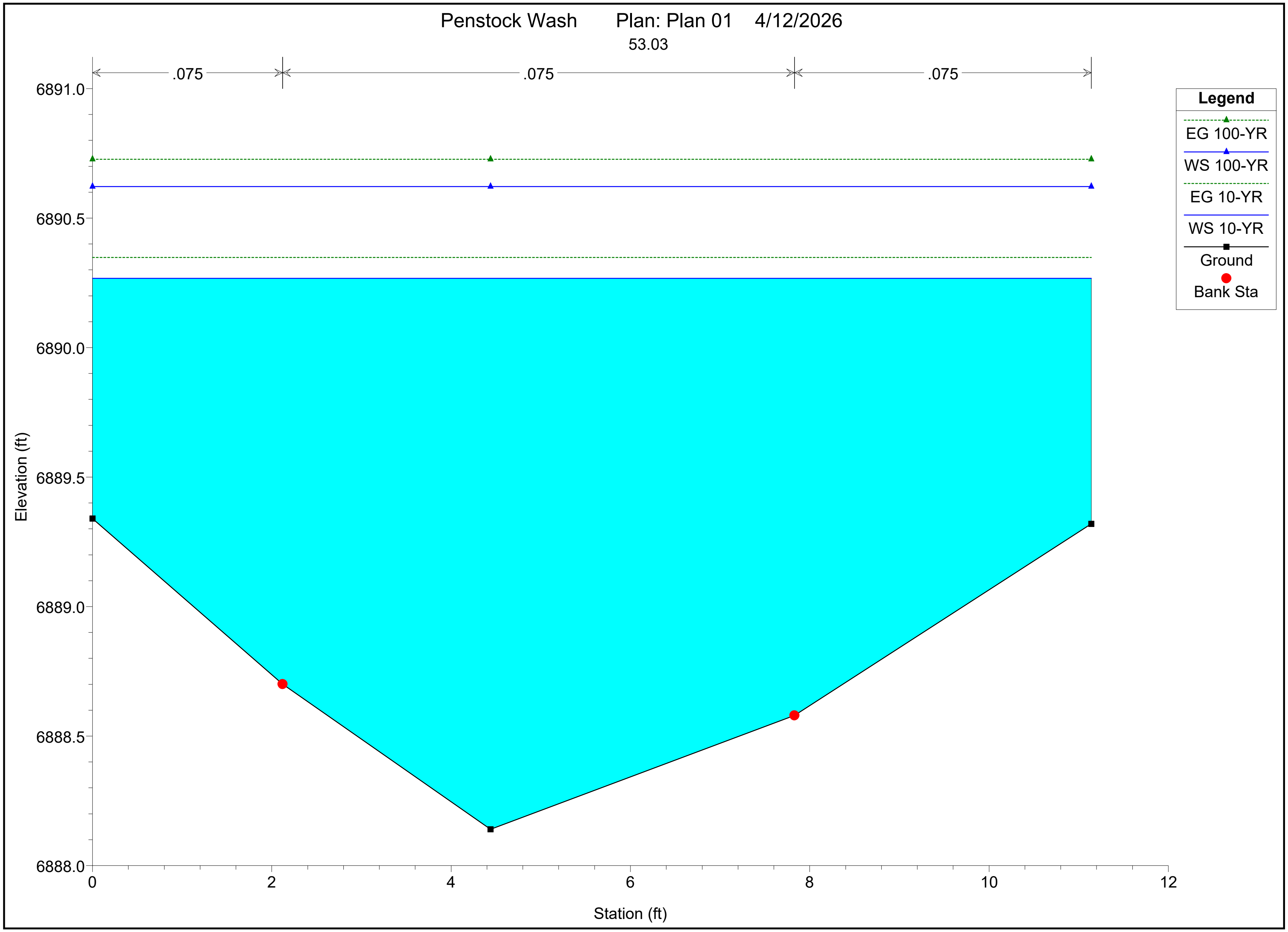


Penstock Wash Plan: Plan 01 4/12/2026
Culvert Under Parking Lot
.04
.04
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Crit 100-YR
Crit 10-YR
Ground
Bank Sta
Elevation (ft)
6895
6896
6897
6898
6899
6900
6901
Station (ft)
0
5
10
15
20
25

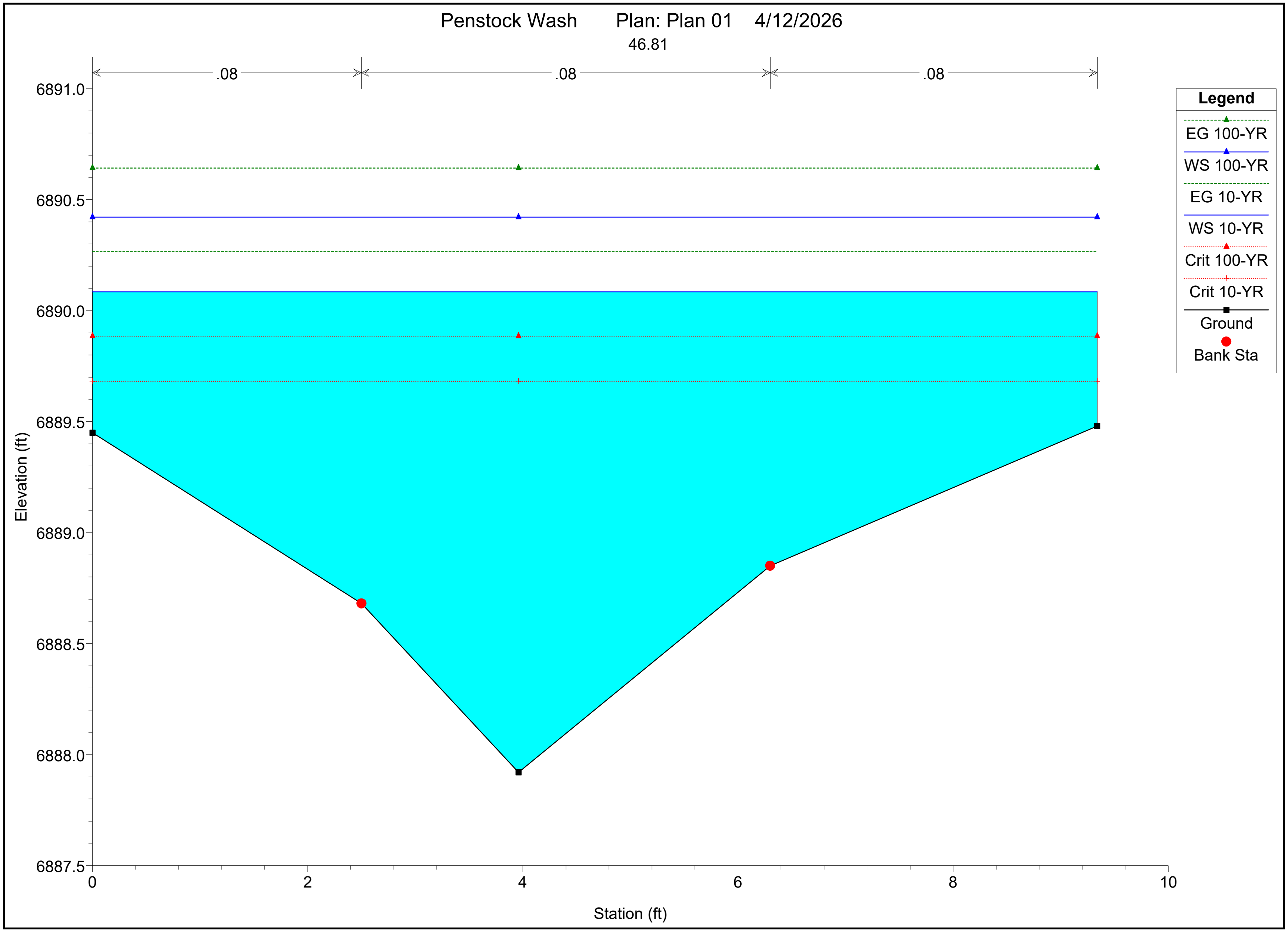


Penstock Wash Plan: Plan 01 4/12/2026
71.76
.05
.05
6891.0
6890.5
6890.0
6889.5
6889.0
6888.5
Elevation (ft)
0
5
10
15
20
Station (ft)
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Ground
Bank Sta

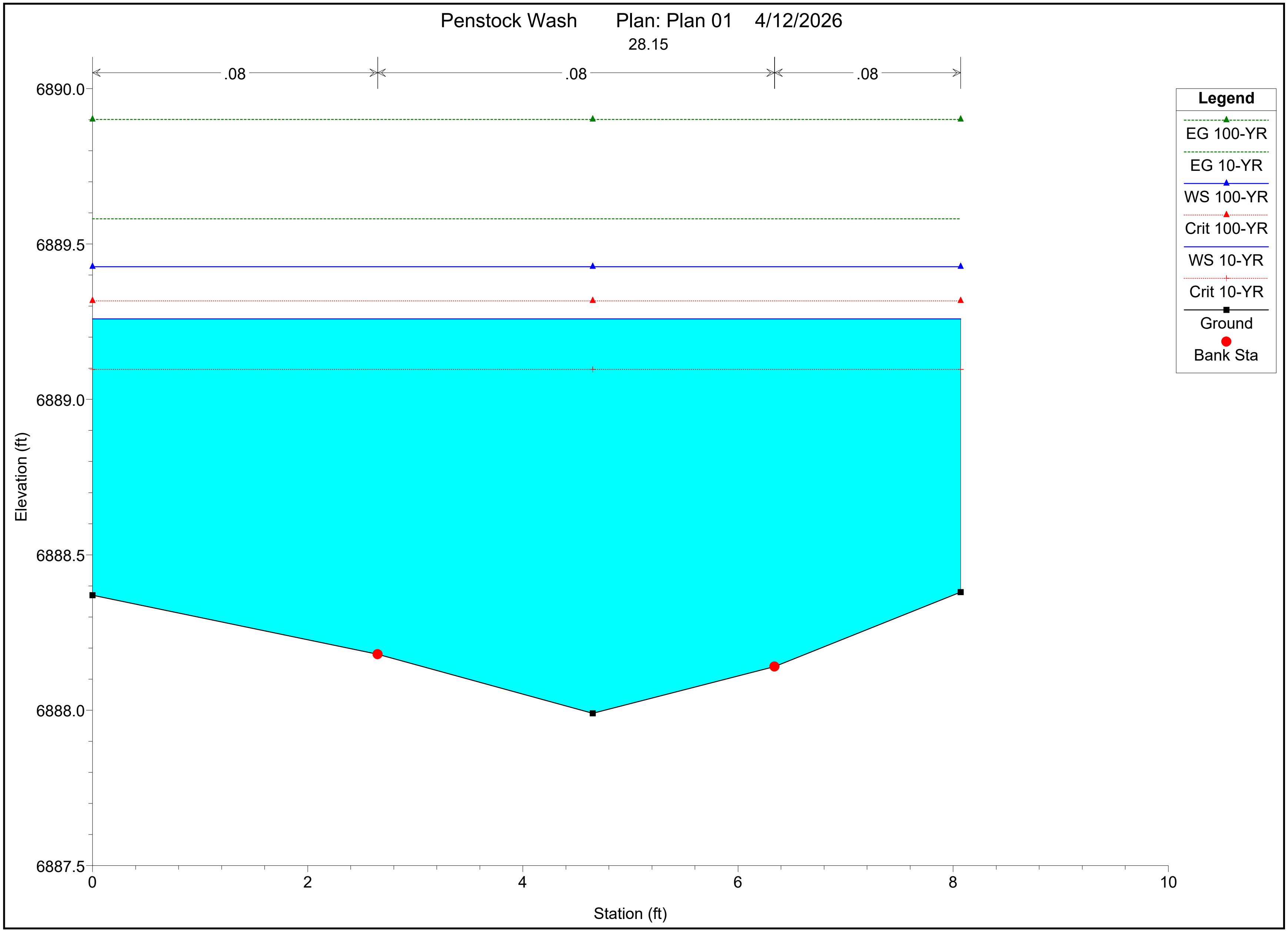

Penstock Wash Plan: Plan 01 4/12/2026
63.24
.06
.06
.06
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6891.0
6890.5
6890.0
6889.5
6889.0
6888.5
6888.0
0
2
4
6
8
10
12
14
Station (ft)

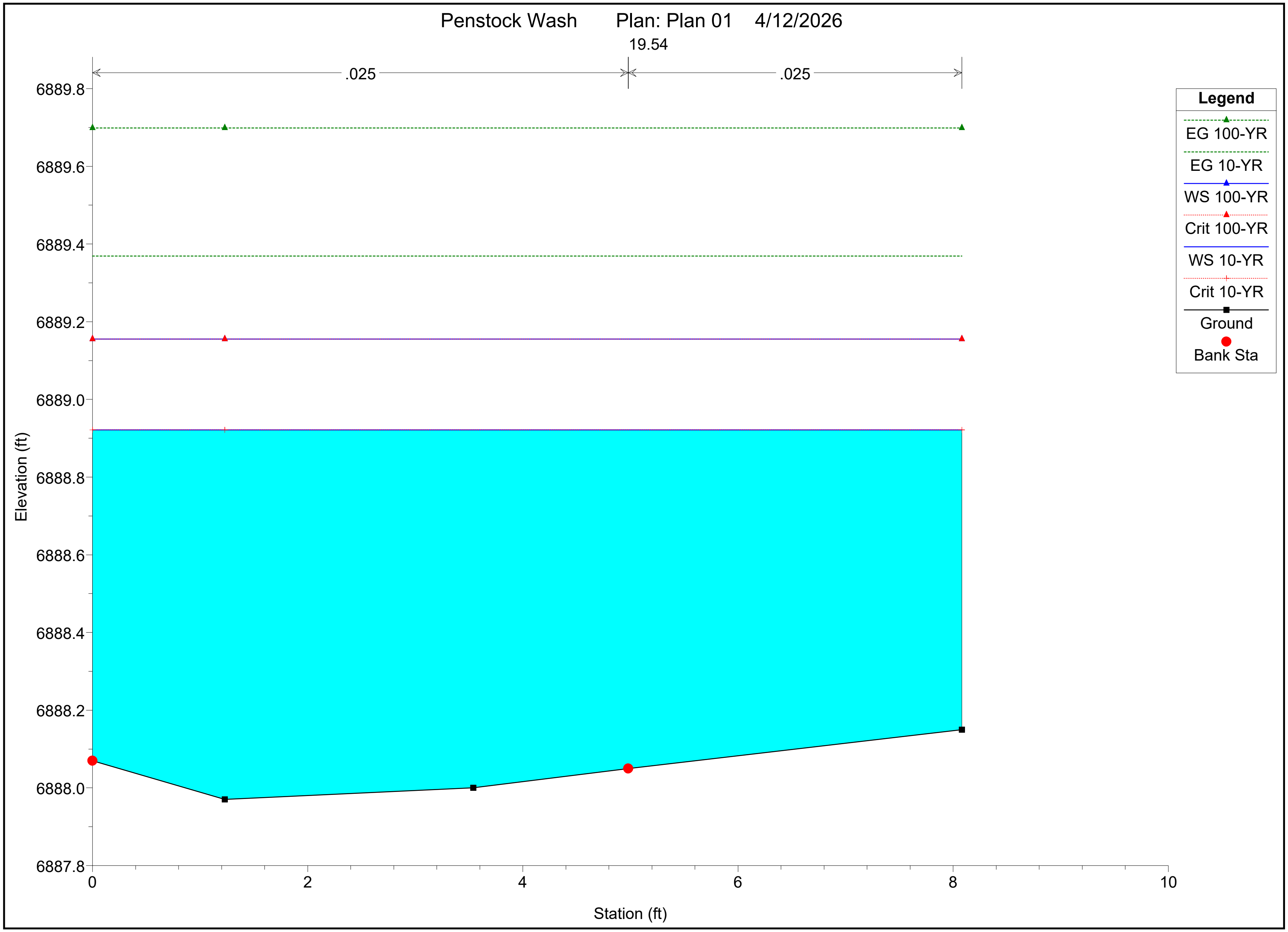


Penstock Wash Plan: Plan 01 4/12/2026
53.03
.075
.075
.075
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6891.0
6890.5
6890.0
6889.5
6889.0
6888.5
6888.0
0
2
4
6
8
10
12
Station (ft)

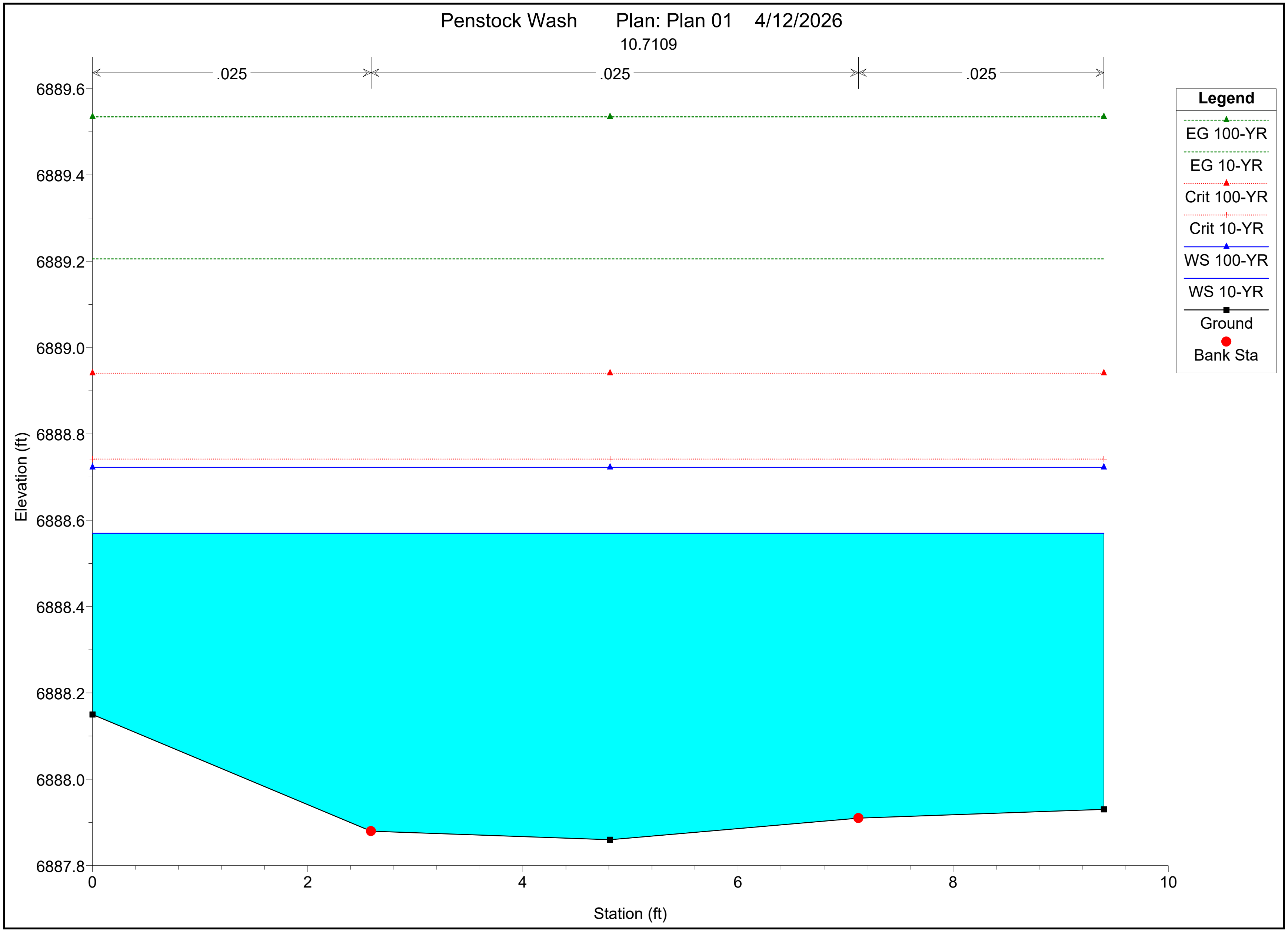


Penstock Wash Plan: Plan 01 4/12/2026
46.81
.08
.08
.08
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Crit 100-YR
Crit 10-YR
Ground
Bank Sta
Elevation (ft)
6891.0
6890.5
6890.0
6889.5
6889.0
6888.5
6888.0
6887.5
Station (ft)
0
2
4
6
8
10

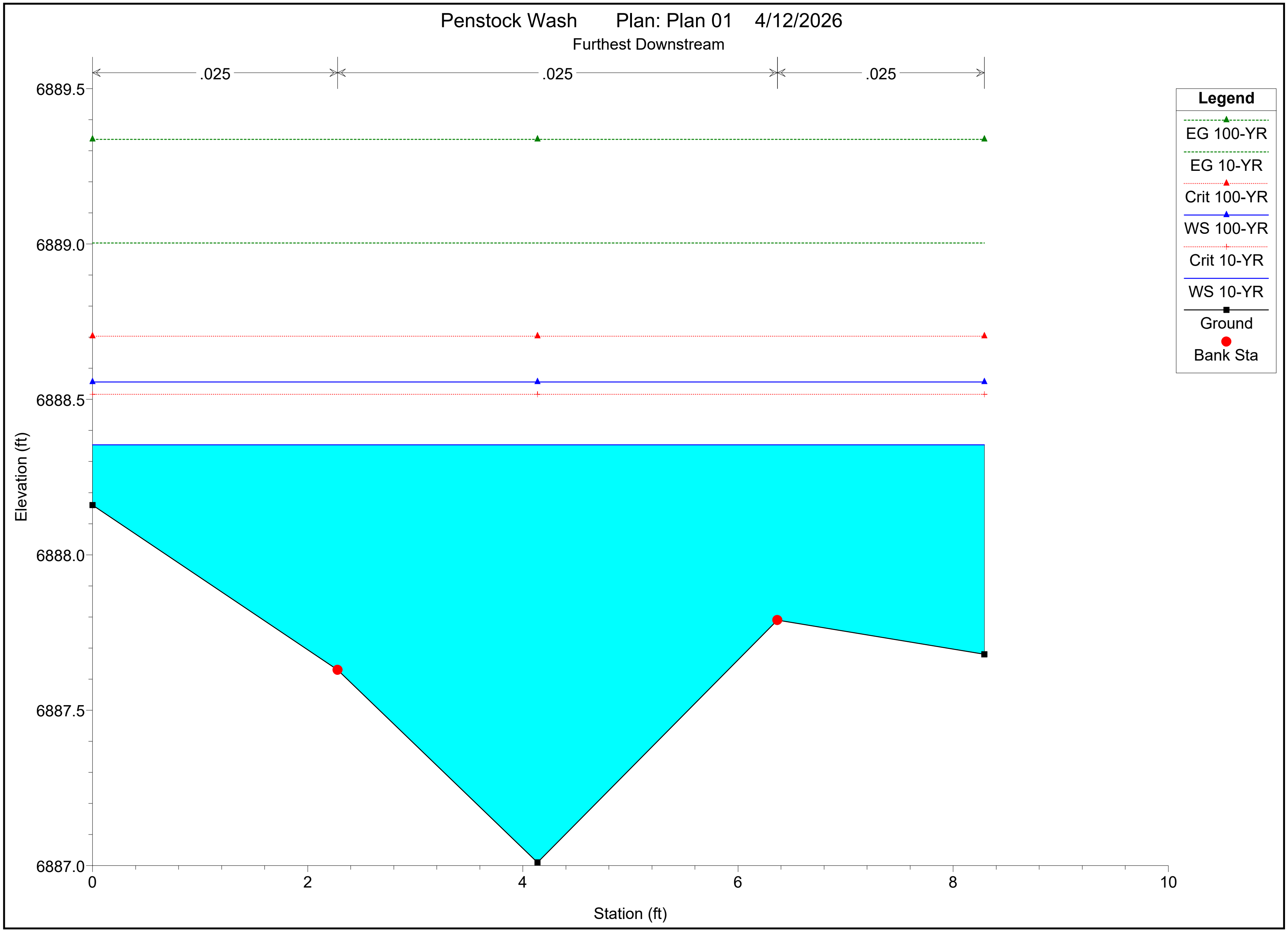

Penstock Wash Plan: Plan 01 4/12/2026
28.15
.08
.08
.08
6890.0
6889.5
6889.0
6888.5
6888.0
6887.5
Elevation (ft)
0
2
4
6
8
10
Station (ft)
Legend
EG 100-YR
EG 10-YR
WS 100-YR
Crit 100-YR
WS 10-YR
Crit 10-YR
Ground
Bank Sta



Penstock Wash Plan: Plan 01 4/12/2026
19.54
.025
.025
6889.8
6889.6
6889.4
6889.2
6889.0
6888.8
6888.6
6888.4
6888.2
6888.0
6887.8
Elevation (ft)
0
2
4
6
8
10
Station (ft)
Legend
EG 100-YR
EG 10-YR
WS 100-YR
Crit 100-YR
WS 10-YR
Crit 10-YR
Ground
Bank Sta



Penstock Wash Plan: Plan 01 4/12/2026
10.7109
.025
.025
.025
Legend
EG 100-YR
EG 10-YR
Crit 100-YR
Crit 10-YR
WS 100-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6889.6
6889.4
6889.2
6889.0
6888.8
6888.6
6888.4
6888.2
6888.0
6887.8
0
2
4
6
8
10
Station (ft)



Penstock Wash Plan: Plan 01 4/12/2026
Furthest Downstream
.025
.025
.025
Legend
EG 100-YR
EG 10-YR
Crit 100-YR
WS 100-YR
Crit 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6889.5
6889.0
6888.5
6888.0
6887.5
6887.0
0
2
4
6
8
10
Station (ft)

Appendix C3: All River Station Summary Tables and Reports

Table C- 1: All Existing Cross Sections

River Station	Profile	Flow Total	Min Channel Elevation	Water Surface Elevation	E.G. Elevation	E.G. Slope	Velocity Channel	Flow Area	Top Width	Froude Number
		(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1488	10	38	6906.46	6908.52	6908.6	0.0029	2.16	17.78	15.04	0.35
1488	100	53	6906.46	6911.42	6911.42	8E-05	0.6	88.2	33.64	0.07
1477	10	38	6905	6908.56	6908.57	0.0002	0.84	45.75	15.57	0.09
1477	100	53	6905	6911.42	6911.42	4E-05	0.56	94.35	18.35	0.04
1354	10	38	6901.72	6902.75	6903.07	0.0281	4.54	8.52	13.72	1
1354	100	53	6901.72	6902.91	6903.3	0.0265	5.03	10.65	14.09	1.01
1335	10	38	6897.83	6899.73	6899.73	9E-05	0.41	79.21	48.19	0.06
1335	100	53	6897.83	6900.33	6900.33	7E-05	0.4	108.79	51.12	0.06
1329	10	38	6897.6	6899.73	6899.73	0.0001	0.51	72.83	50.95	0.08
1329	100	53	6897.6	6900.33	6900.33	9E-05	0.47	103.93	53.29	0.07
1320	10	38	6897.44	6899.73	6899.73	8E-05	0.43	84.26	48.51	0.06
1320	100	53	6897.44	6900.32	6900.33	6E-05	0.43	113.7	50.27	0.05
1313	10	38	6897.49	6899.73	6899.73	4E-05	0.31	100.06	44.61	0.04
1313	100	53	6897.49	6900.32	6900.33	4E-05	0.34	127.16	46.36	0.04
1302	10	38	6897.47	6899.73	6899.73	2E-05	0.23	116.61	44.27	0.03
1302	100	53	6897.47	6900.32	6900.33	2E-05	0.27	143.55	46.2	0.03
1295	10	38	6897.02	6899.73	6899.73	2E-05	0.24	112.84	41.23	0.03
1295	100	53	6897.02	6900.32	6900.33	3E-05	0.28	138.02	43.31	0.04
1286	10	38	6897.14	6899.73	6899.73	4E-05	0.33	96.08	38.99	0.04
1286	100	53	6897.14	6900.32	6900.33	4E-05	0.37	119.82	40.71	0.04
1276	10	38	6897	6899.73	6899.73	5E-05	0.39	89.04	40.18	0.05
1276	100	53	6897	6900.32	6900.33	5E-05	0.42	113.47	41.85	0.05
1265	10	38	6896.77	6899.69	6899.73	0.001	1.58	24.82	13.68	0.22
1265	100	53	6896.77	6900.28	6900.32	0.0008	1.63	33.5	15.55	0.21
1256	10	38	6896.4	6899.69	6899.71	0.0008	1.39	28.52	16.24	0.19
1256	100	53	6896.4	6900.28	6900.31	0.0006	1.41	38.94	18.71	0.18
1071	10	38	6888.58	6890.38	6890.49	0.0072	2.77	14.64	14.18	0.45
1071	100	53	6888.58	6890.74	6890.85	0.0064	2.73	20.26	16.98	0.43
1063	10	38	6888.45	6890.34	6890.43	0.0059	2.59	17.26	13.06	0.36
1063	100	53	6888.45	6890.69	6890.79	0.0055	2.85	21.86	13.06	0.36
1053	10	38	6888.14	6890.28	6890.36	0.007	2.51	17.85	11.14	0.32
1053	100	53	6888.14	6890.62	6890.73	0.0074	2.88	21.7	11.14	0.34
1046	10	38	6887.92	6890.09	6890.28	0.0233	3.86	12	9.34	0.52
1046	100	53	6887.92	6890.42	6890.64	0.0227	4.27	15.07	9.34	0.52
1028	10	38	6887.99	6889.27	6889.59	0.0608	5.13	8.75	8.07	0.83

1028	100	53	6887.99	6889.43	6889.9	0.0755	6.22	10.06	8.07	0.94
1019	10	38	6887.97	6888.93	6889.38	0.0121	5.57	7.17	8.08	1.02
1019	100	53	6887.97	6889.16	6889.7	0.0115	6.13	9	8.08	1.01
1010	10	38	6887.86	6888.57	6889.22	0.0226	7	6.07	9.4	1.48
1010	100	53	6887.86	6888.72	6889.54	0.0222	7.91	7.49	9.4	1.52
1000	10	38	6887.01	6888.36	6889.01	0.0152	7.05	6.34	8.29	1.24
1000	100	53	6887.01	6888.56	6889.34	0.0146	7.79	7.96	8.29	1.26

HEC-RAS HEC-RAS 6.6 September 2024
U.S. Army Corps of Engineers
Hydrologic Engineering Center
609 Second Street
Davis, California

```
X     X  XXXXXX    XXXX        XXXX       XX      XXXX
X     X  X        X    X       X   X     X  X    X
X     X  X        X            X   X    X    X   X
XXXXXXX  XXXX     X       XXX  XXXX     XXXXXX    XXXX
X     X  X        X            X  X     X    X        X
X     X  X        X    X       X   X    X    X        X
X     X  XXXXXX    XXXX        X    X   X    X   XXXXX
```

PROJECT DATA
Project Title: Penstock Wash
Project File : PenstockWash.prj
Run Date and Time: 4/12/2026 8:50:27 AM

Project in English units

PLAN DATA

Plan Title: Plan 01
Plan File : C:\Users\hn273\OneDrive - Northern Arizona University\Downloads\OneDrive_2026-04-06\Existing HEC-RAS Model\PenstockWash.p01

Geometry Title: Penstock Wash Geometry
Geometry File : C:\Users\hn273\OneDrive - Northern Arizona University\Downloads\OneDrive_2026-04-06\Existing HEC-RAS Model\PenstockWash.g01

Flow Title   : Penstock Flow
Flow File   : C:\Users\hn273\OneDrive - Northern Arizona University\Downloads\OneDrive_2026-04-06\Existing HEC-RAS Model\PenstockWash.f01

Plan Summary Information:

```
Number of:  Cross Sections =   21    Multiple Openings  =    0
            Culverts       =    2    Inline Structures  =    0
            Bridges        =    0    Lateral Structures =    0
```

Computational Information

```
    Water surface calculation tolerance  =  0.01
    Critical depth calculation tolerance =  0.01
```

Maximum number of iterations = 20
Maximum difference tolerance = 0.3
Flow tolerance factor = 0.001

Computation Options
Critical depth computed only where necessary
Conveyance Calculation Method: At breaks in n values only
Friction Slope Method: Average Conveyance
Computational Flow Regime: Mixed Flow

FLOW DATA

Flow Title: Penstock Flow
Flow File : C:\Users\hn273\OneDrive - Northern Arizona University\Downloads\OneDrive_2026-04-06\Existing HEC-RAS Model\PenstockWash.f01

Flow Data (cfs)

River	Reach	RS	10-YR	100-YR
Penstock Wash	E Trails End Dr	1488	38	53

Boundary Conditions

River	Reach	Profile	Upstream	Downstream
Penstock Wash	E Trails End Dr	10-YR	Normal S = 0.04	Normal S = 0.04
Penstock Wash	E Trails End Dr	100-YR	Normal S = 0.04	Normal S = 0.04

GEOMETRY DATA

Geometry Title: Penstock Wash Geometry
Geometry File : C:\Users\hn273\OneDrive - Northern Arizona University\Downloads\OneDrive_2026-04-06\Existing HEC-RAS Model\PenstockWash.g01

CROSS SECTION

```
RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1488

INPUT
Description: Channel CS Above Culvert (11.46)
Station Elevation Data    num=       7
     Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev
       0 6912.13    16.89  6908.1    21.18 6906.85    23.87 6906.46    25.67 6906.65
   28.15 6907.63     37.1 6911.63

Manning's n Values        num=       3
     Sta   n Val      Sta   n Val      Sta   n Val
       0     .04        0     .04     37.1     .04

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0    37.1            11.46   18.44   25.09             .1        .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1477

INPUT
Description: Upstream CS of Double Culvert
Station Elevation Data    num=       8
     Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev
       0 6911.69      3.2 6905.69      6.8    6905     9.75 6905.35    11.15 6905.46
    13.5     6905    15.76 6905.49     18.5 6911.19

Manning's n Values        num=       3
     Sta   n Val      Sta   n Val      Sta   n Val
       0     .04        0     .04     18.5     .04

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0    18.5           147.36  143.89   134.5             .1        .3

CULVERT


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1473

INPUT
Description: Upstream Double Culvert of Highway 89
Distance from Upstream XS =       3
Deck/Roadway Width        =     120
Weir Coefficient          =     2.6
Upstream  Deck/Roadway Coordinates
    num=       2
```

```
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
       0 6911.69    6905    18.5 6911.19    6905

Upstream Bridge Cross Section Data
Station Elevation Data    num=       8
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6911.69     3.2 6905.69     6.8    6905    9.75 6905.35   11.15 6905.46
    13.5    6905   15.76 6905.49    18.5 6911.19

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0     .04       0     .04    18.5     .04

Bank Sta: Left   Right    Coeff Contr.   Expan.
            0    18.5             .1       .3

Downstream  Deck/Roadway Coordinates
    num=       2
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
       0 6908.65 6901.72   24.67 6908.44 6901.72

Downstream Bridge Cross Section Data
Station Elevation Data    num=       7
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0    6905     4.2  6902.1    8.56 6901.72   10.91 6902.28   13.71 6902.28
   16.51 6902.28   20.67 6906.52

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0     .04       0     .04   16.51     .04

Bank Sta: Left   Right    Coeff Contr.   Expan.
            0   16.51             .1       .3

Upstream Embankment side slope              =       0 horiz. to 1.0 vertical
Downstream Embankment side slope            =       0 horiz. to 1.0 vertical
Maximum allowable submergence for weir flow =     .98
Elevation at which weir flow begins         =
Energy head used in spillway design         =
Spillway height used in design              =
Weir crest shape                            = Broad Crested

Number of Culverts =  1

Culvert Name     Shape      Rise    Span
Culvert #1      Circular       2       2
FHWA Chart # 2 - Corrugated Metal Pipe Culvert
FHWA Scale # 2 - Mitered to conform to slope
Solution Criteria = Highest U.S. EG
Culvert Upstrm Dist  Length    Top n  Bottom n  Depth Blocked  Entrance Loss Coef
```

```
Exit Loss Coef
                  3     120     .024     .024        0                   .7
      1
Number of Barrels =  2
Upstream   Elevation =  6905.31
Centerline Stations
    Sta.    Sta.
    7.76   14.45
Downstream Elevation =  6902.28
Centerline Stations
    Sta.    Sta.
   10.91   16.51

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1354

INPUT
Description: DS Culvert Cross Section
Station Elevation Data    num=       7
     Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev
       0     6905      4.2  6902.1     8.56 6901.72    10.91 6902.28    13.71 6902.28
   16.51 6902.28    20.67 6906.52

Manning's n Values        num=       3
     Sta   n Val      Sta   n Val      Sta   n Val
       0     .04        0     .04    16.51     .04

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   16.51            26.76   19.44    15.3             .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1335

INPUT
Description: 335.67
Station Elevation Data    num=       8
     Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev
   -33.1  6897.3  -16.48 6897.96        0 6898.41     1.25 6898.16     2.75 6897.83
    5.45 6897.84     9.29 6898.55    50.01 6906.83

Manning's n Values        num=       3
     Sta   n Val      Sta   n Val      Sta   n Val
   -33.1     .04     1.25     .04    50.01     .04
```

```
Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          1.25   50.01           11.15   11.56   12.63              .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1329

INPUT
Description: 329.09
Station Elevation Data    num=       8
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
  -36.93  6896.3  -18.39 6898.79       0 6899.09    1.42 6898.12    3.74  6897.6
    4.97 6897.87    9.34 6898.53   37.88 6905.83

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
  -36.93     .04    1.42     .04   37.88     .04

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          1.42   37.88            8.26    9.85    11.6              .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1320

INPUT
Description: 320.49
Station Elevation Data    num=       8
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
  -32.72  6897.1  -11.63    6898       0    6899    3.12 6897.71    5.88 6897.44
    9.01 6897.75   13.15 6898.83   31.42 6905.04

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
  -32.72     .04    3.12     .04   31.42     .04

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          3.12   31.42            6.99    7.02    7.54              .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1313

INPUT
```

```
Description: 313.63
Station Elevation Data    num=       8
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
  -31.81  6895.8   -18.8 6897.45       0 6897.78    2.42 6897.51    3.82 6897.49
    5.26  6897.6   10.02 6898.78   27.07 6904.59

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
  -31.81     .04       0     .04   27.07     .04

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   27.07            10.93   11.58   12.05              .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1302

INPUT
Description: 302.08
Station Elevation Data    num=       8
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
  -33.15  6895.4  -14.19  6897.1       0 6897.57      .9 6897.51    1.43 6897.47
    4.01 6897.54    5.26 6897.92   25.38 6904.13

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
  -33.15     .04       0     .04   25.38     .04

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   25.38              6.5    6.96    7.71              .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1295

INPUT
Description: 295
295.32
Station Elevation Data    num=       8
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
     -29  6895.3  -13.94 6896.71       0 6897.42  2.2766 6897.05    2.51 6897.02
    3.15 6897.33  4.0455 6897.39   24.27 6903.17

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
     -29     .04       0     .04   24.27     .04
```

```
Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   24.27             8.59    8.69    9.18              .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1286

INPUT
Description: 286.78
Station Elevation Data    num=       8
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
  -26.44  6896.3  -13.56 6897.07       0 6897.25   .8535 6897.14    2.16 6897.17
    3.72 6897.33  6.2795 6897.55   22.21 6903.08

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
  -26.44     .04       0     .04   22.21     .04

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   22.21             9.81   10.03   10.46              .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1276

INPUT
Description: 276.92
Station Elevation Data    num=       8
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
  -27.26  6896.9  -17.56  6897.6       0 6897.16    1.49    6897    2.68 6897.01
    3.96  6897.3    6.58 6897.46   20.71 6902.51

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
  -27.26     .04       0     .04   20.71     .04

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   20.71            11.49   11.27   11.19              .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1265
```

```
INPUT
Description: 265.98
Station Elevation Data    num=       6
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6897.41    2.96 6897.06    4.54 6896.77     5.4 6897.12    8.61 6898.07
   20.62  6901.9

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0     .04    2.96     .04   20.62     .04

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          2.96   20.62             9.47    9.57    9.89              .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1256

INPUT
Description: 256.32 (Upstream CS of PL Culvert)
Station Elevation Data    num=       6
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6897.54  2.2656 6896.96  3.6714  6896.4    4.83 6897.07     9.7 6898.11
   20.53 6900.72

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0     .04  2.2656     .04   20.53     .04

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
        2.2656   20.53           185.65  184.68  183.68              .1       .3

CULVERT


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1248

INPUT
Description: Culvert Under Parking Lot
Distance from Upstream XS =     8.9
Deck/Roadway Width        =   167.5
Weir Coefficient          =     2.6
Upstream  Deck/Roadway Coordinates
    num=       2
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
       0 6899.47 6895.94   20.53 6900.72 6895.94
```

```
Upstream Bridge Cross Section Data
Station Elevation Data    num=       6
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6897.54  2.2656 6896.96  3.6714  6896.4    4.83 6897.07     9.7 6898.11
   20.53 6900.72

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0     .04  2.2656     .04   20.53     .04

Bank Sta: Left   Right    Coeff Contr.   Expan.
        2.2656   20.53             .1       .3

Downstream  Deck/Roadway Coordinates
    num=       2
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
       0 6890.71 6887.77   18.24  6890.9 6887.77

Downstream Bridge Cross Section Data
Station Elevation Data    num=       6
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6890.38     3.5 6889.28    6.48 6888.58   10.37 6888.92   12.76 6890.19
   18.24  6890.9

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0     .05     3.5     .05   18.24     .05

Bank Sta: Left   Right    Coeff Contr.   Expan.
           3.5   18.24             .1       .3

Upstream Embankment side slope             =       0 horiz. to 1.0 vertical
Downstream Embankment side slope           =       0 horiz. to 1.0 vertical
Maximum allowable submergence for weir flow =     .98
Elevation at which weir flow begins        =
Energy head used in spillway design        =
Spillway height used in design             =
Weir crest shape                           = Broad Crested

Number of Culverts =  1

Culvert Name     Shape      Rise    Span
Culvert #1      Circular       3       3
FHWA Chart # 2 - Corrugated Metal Pipe Culvert
FHWA Scale # 3 - Pipe projecting from fill
Solution Criteria = Highest U.S. EG
Culvert Upstrm Dist  Length    Top n  Bottom n  Depth Blocked  Entrance Loss Coef
Exit Loss Coef
                8.9   167.5     .024      .05       .5                  .7
      1
```

```
Upstream   Elevation =  6895.94
           Centerline Station =  3.6714
Downstream Elevation =  6887.77
           Centerline Station =  6.48

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1071

INPUT
Description: 71.76
Station Elevation Data    num=       6
     Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev
       0 6890.38      3.5 6889.28     6.48 6888.58    10.37 6888.92    12.76 6890.19
   18.24  6890.9

Manning's n Values        num=       3
     Sta    n Val      Sta    n Val      Sta    n Val
       0      .05      3.5      .05    18.24      .05

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
           3.5   18.24             6.78    8.57   10.15             .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1063

INPUT
Description: 63.24
Station Elevation Data    num=       5
     Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev
       0 6889.49     3.36 6889.02     6.19 6888.45     9.52     6889    13.06 6889.59

Manning's n Values        num=       3
     Sta    n Val      Sta    n Val      Sta    n Val
       0      .06     3.36      .06     9.52      .06

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          3.36    9.52            10.66   10.29   10.54             .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1053
```

INPUT
Description: 53.03

Station Elevation Data num= 5

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	6889.34	2.12	6888.7	4.44	6888.14	7.83	6888.58	11.14	6889.32

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.075	2.12	.075	7.83	.075

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
2.12	7.83	6.36	6.22	5.36	.1	.3

CROSS SECTION

RIVER: Penstock Wash
REACH: E Trails End Dr RS: 1046

INPUT
Description: 46.81

Station Elevation Data num= 5

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	6889.45	2.5	6888.68	3.96	6887.92	6.3	6888.85	9.34	6889.48

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.08	2.5	.08	6.3	.08

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
2.5	6.3	19.58	18.72	18.39	.1	.3

CROSS SECTION

RIVER: Penstock Wash
REACH: E Trails End Dr RS: 1028

INPUT
Description: 28.15

Station Elevation Data num= 5

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	6888.37	2.65	6888.18	4.65	6887.99	6.34	6888.14	8.07	6888.38

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.08	2.65	.08	6.34	.08

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
2.65	6.34	8.89	8.61	8	.1	.3

CROSS SECTION

RIVER: Penstock Wash
REACH: E Trails End Dr   RS: 1019

INPUT
Description: 19.54
Station Elevation Data   num=   5

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	6888.07	1.23	6887.97	3.54	6888	4.98	6888.05	8.08	6888.15

Manning's n Values   num=   3

Sta	n Val	Sta	n Val	Sta	n Val
0	.025	0	.025	4.98	.025

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
0	4.98	9.08	8.7	8.74	.1	.3

CROSS SECTION

RIVER: Penstock Wash
REACH: E Trails End Dr   RS: 1010

INPUT
Description: 10.7109
Station Elevation Data   num=   5

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	6888.15	2.59	6887.88	4.81	6887.86	7.12	6887.91	9.4	6887.93

Manning's n Values   num=   3

Sta	n Val	Sta	n Val	Sta	n Val
0	.025	2.59	.025	7.12	.025

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
2.59	7.12	10.16	10.71	11.57	.1	.3

CROSS SECTION

RIVER: Penstock Wash
REACH: E Trails End Dr   RS: 1000

INPUT
Description: Furthest Downstream
Station Elevation Data   num=   5

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	6888.16	2.2784	6887.63	4.1369	6887.01	6.3663	6887.79	8.2905	6887.68

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.025	2.2784	.025	6.3663	.025

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
2.2784	6.3663	0	0	0	.1	.3

SUMMARY OF MANNING'S N VALUES

River:Penstock Wash

Reach	River Sta.	n1	n2	n3
E Trails End Dr	1488	.04	.04	.04
E Trails End Dr	1477	.04	.04	.04
E Trails End Dr	1473	Culvert		
E Trails End Dr	1354	.04	.04	.04
E Trails End Dr	1335	.04	.04	.04
E Trails End Dr	1329	.04	.04	.04
E Trails End Dr	1320	.04	.04	.04
E Trails End Dr	1313	.04	.04	.04
E Trails End Dr	1302	.04	.04	.04
E Trails End Dr	1295	.04	.04	.04
E Trails End Dr	1286	.04	.04	.04
E Trails End Dr	1276	.04	.04	.04
E Trails End Dr	1265	.04	.04	.04
E Trails End Dr	1256	.04	.04	.04
E Trails End Dr	1248	Culvert		
E Trails End Dr	1071	.05	.05	.05
E Trails End Dr	1063	.06	.06	.06
E Trails End Dr	1053	.075	.075	.075
E Trails End Dr	1046	.08	.08	.08
E Trails End Dr	1028	.08	.08	.08
E Trails End Dr	1019	.025	.025	.025
E Trails End Dr	1010	.025	.025	.025
E Trails End Dr	1000	.025	.025	.025

SUMMARY OF REACH LENGTHS

River: Penstock Wash

Reach	River Sta.	Left	Channel	Right
E Trails End Dr	1488	11.46	18.44	25.09

E Trails End Dr	1477	147.36	143.89	134.5
E Trails End Dr	1473	Culvert		
E Trails End Dr	1354	26.76	19.44	15.3
E Trails End Dr	1335	11.15	11.56	12.63
E Trails End Dr	1329	8.26	9.85	11.6
E Trails End Dr	1320	6.99	7.02	7.54
E Trails End Dr	1313	10.93	11.58	12.05
E Trails End Dr	1302	6.5	6.96	7.71
E Trails End Dr	1295	8.59	8.69	9.18
E Trails End Dr	1286	9.81	10.03	10.46
E Trails End Dr	1276	11.49	11.27	11.19
E Trails End Dr	1265	9.47	9.57	9.89
E Trails End Dr	1256	185.65	184.68	183.68
E Trails End Dr	1248	Culvert		
E Trails End Dr	1071	6.78	8.57	10.15
E Trails End Dr	1063	10.66	10.29	10.54
E Trails End Dr	1053	6.36	6.22	5.36
E Trails End Dr	1046	19.58	18.72	18.39
E Trails End Dr	1028	8.89	8.61	8
E Trails End Dr	1019	9.08	8.7	8.74
E Trails End Dr	1010	10.16	10.71	11.57
E Trails End Dr	1000	0	0	0

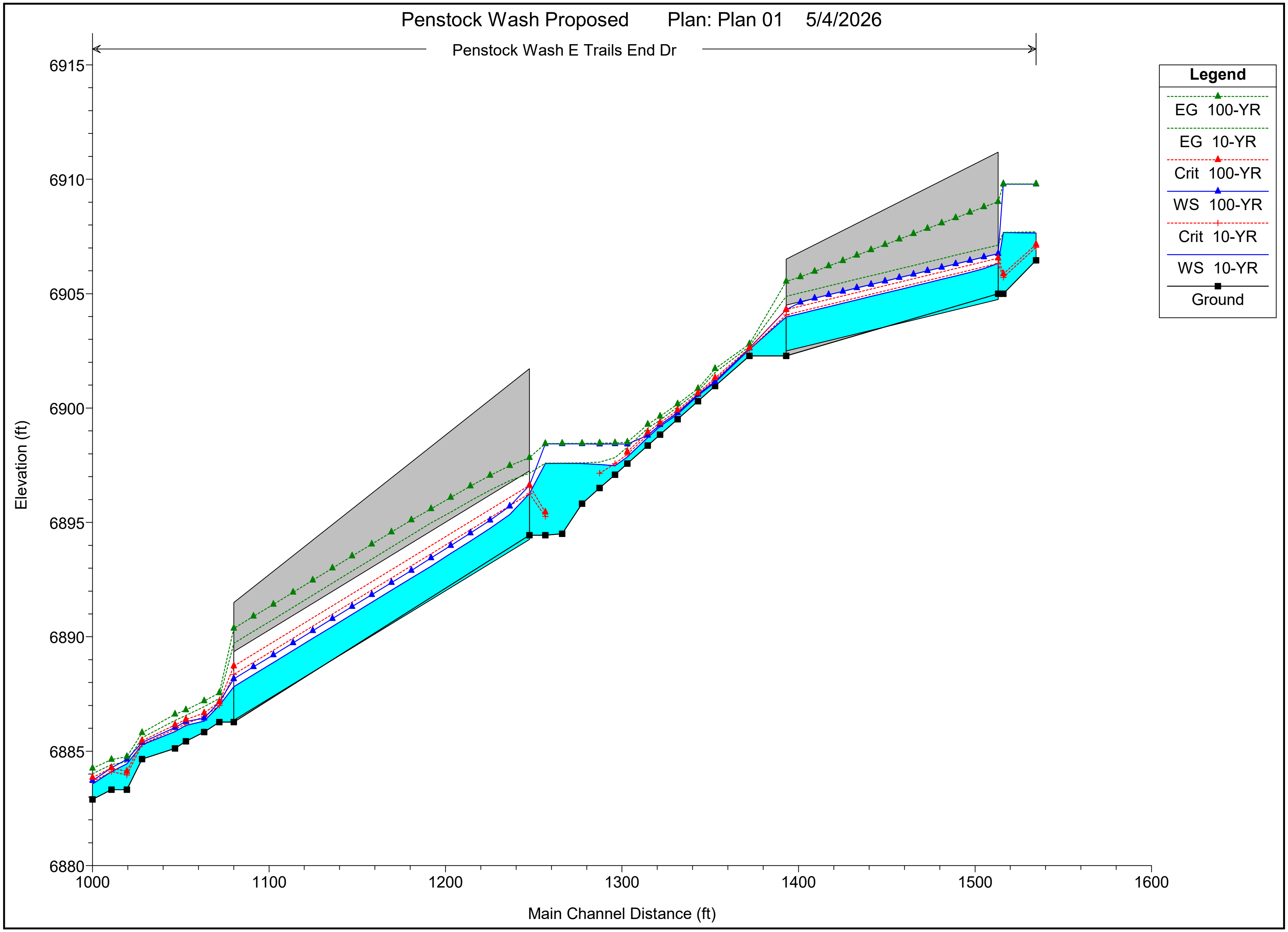
SUMMARY OF CONTRACTION AND EXPANSION COEFFICIENTS
River: Penstock Wash

Reach	River Sta.	Contr.	Expan.
E Trails End Dr	1488	.1	.3
E Trails End Dr	1477	.1	.3
E Trails End Dr	1473	Culvert	
E Trails End Dr	1354	.1	.3
E Trails End Dr	1335	.1	.3
E Trails End Dr	1329	.1	.3
E Trails End Dr	1320	.1	.3
E Trails End Dr	1313	.1	.3
E Trails End Dr	1302	.1	.3
E Trails End Dr	1295	.1	.3
E Trails End Dr	1286	.1	.3
E Trails End Dr	1276	.1	.3
E Trails End Dr	1265	.1	.3
E Trails End Dr	1256	.1	.3
E Trails End Dr	1248	Culvert	
E Trails End Dr	1071	.1	.3
E Trails End Dr	1063	.1	.3
E Trails End Dr	1053	.1	.3

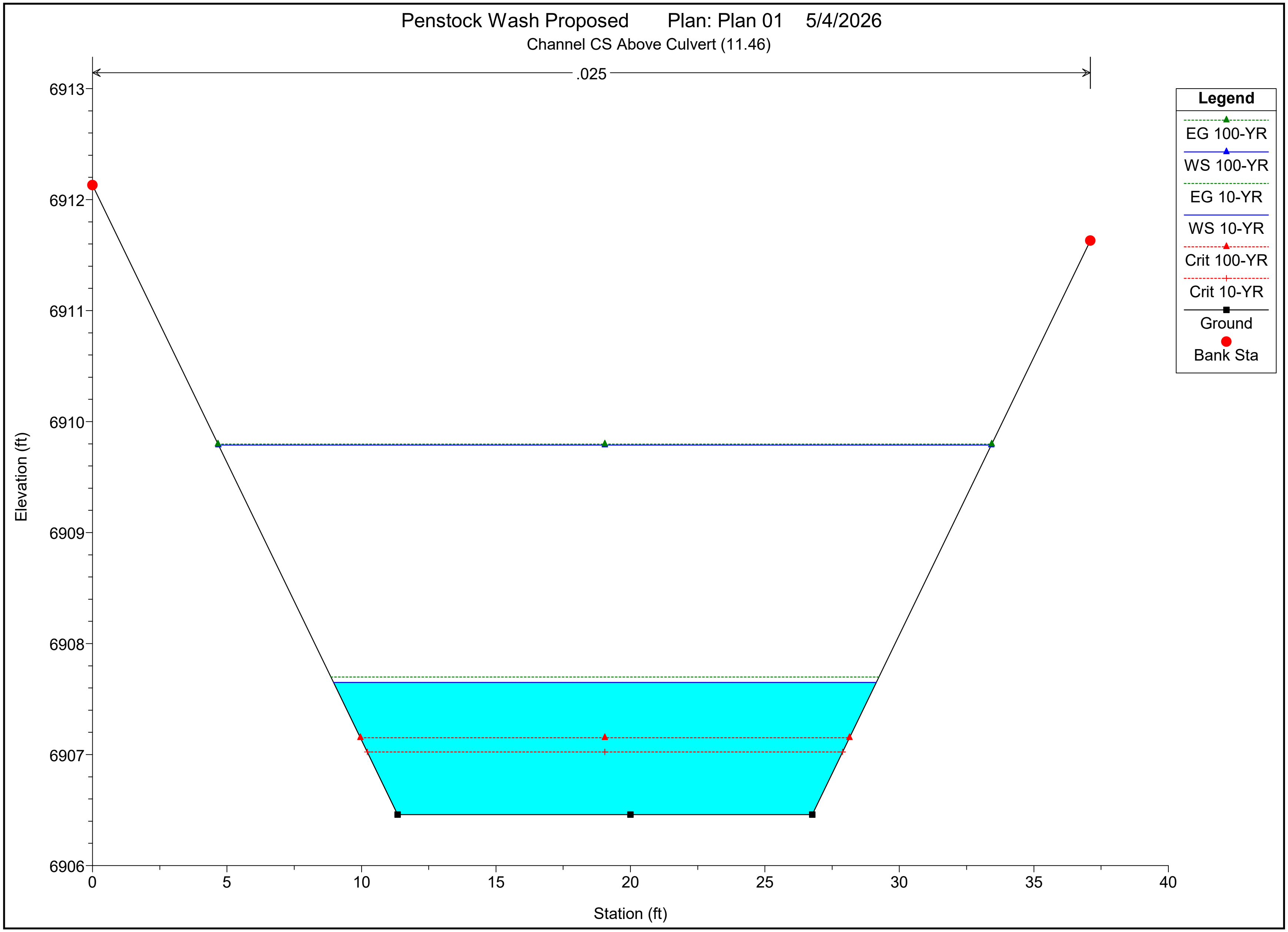
E Trails End Dr	1046	.1	.3
E Trails End Dr	1028	.1	.3
E Trails End Dr	1019	.1	.3
E Trails End Dr	1010	.1	.3
E Trails End Dr	1000	.1	.3

Appendix D: Proposed Hydraulic Results

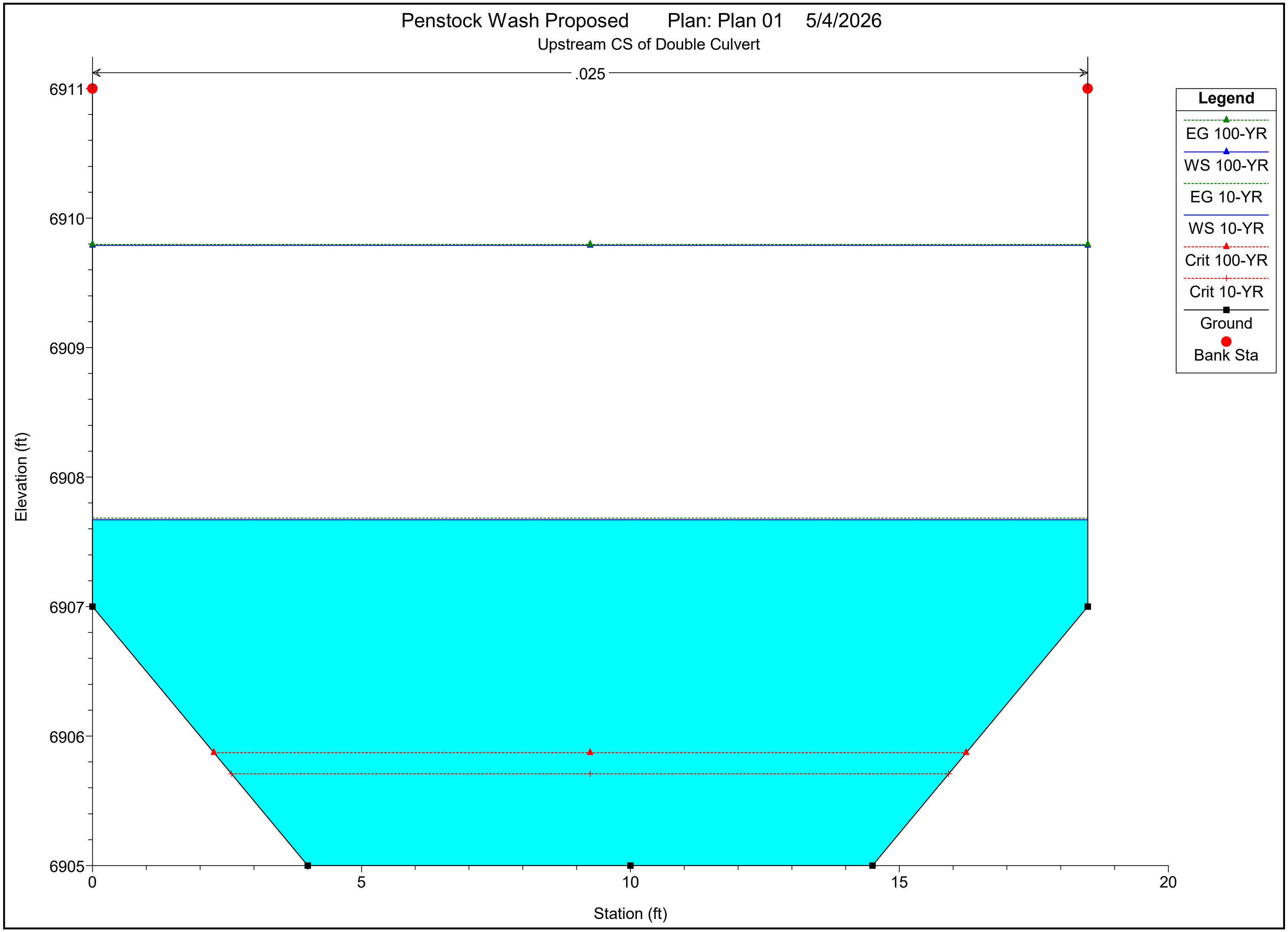
Appendix D1: Full Proposed HEC-RAS Profile of Penstock Wash


Penstock Wash Proposed Plan: Plan 01 5/4/2026
Penstock Wash E Trails End Dr
Legend
EG 100-YR
EG 10-YR
Crit 100-YR
WS 100-YR
Crit 10-YR
WS 10-YR
Ground
Elevation (ft)
Main Channel Distance (ft)
6880
6885
6890
6895
6900
6905
6910
6915
1000
1100
1200
1300
1400
1500
1600

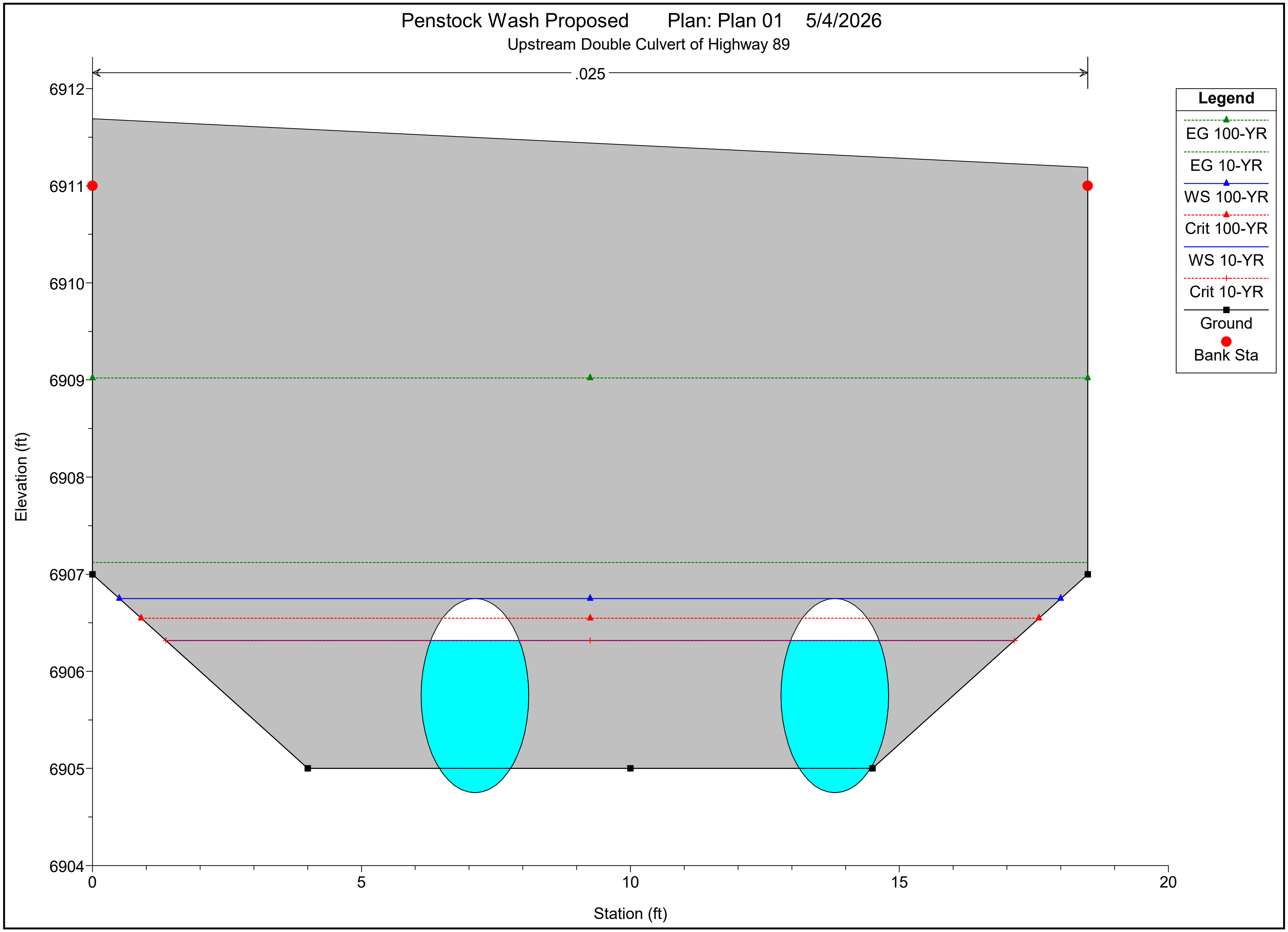
Appendix D2: Individual Cross Section and Culvert Profiles

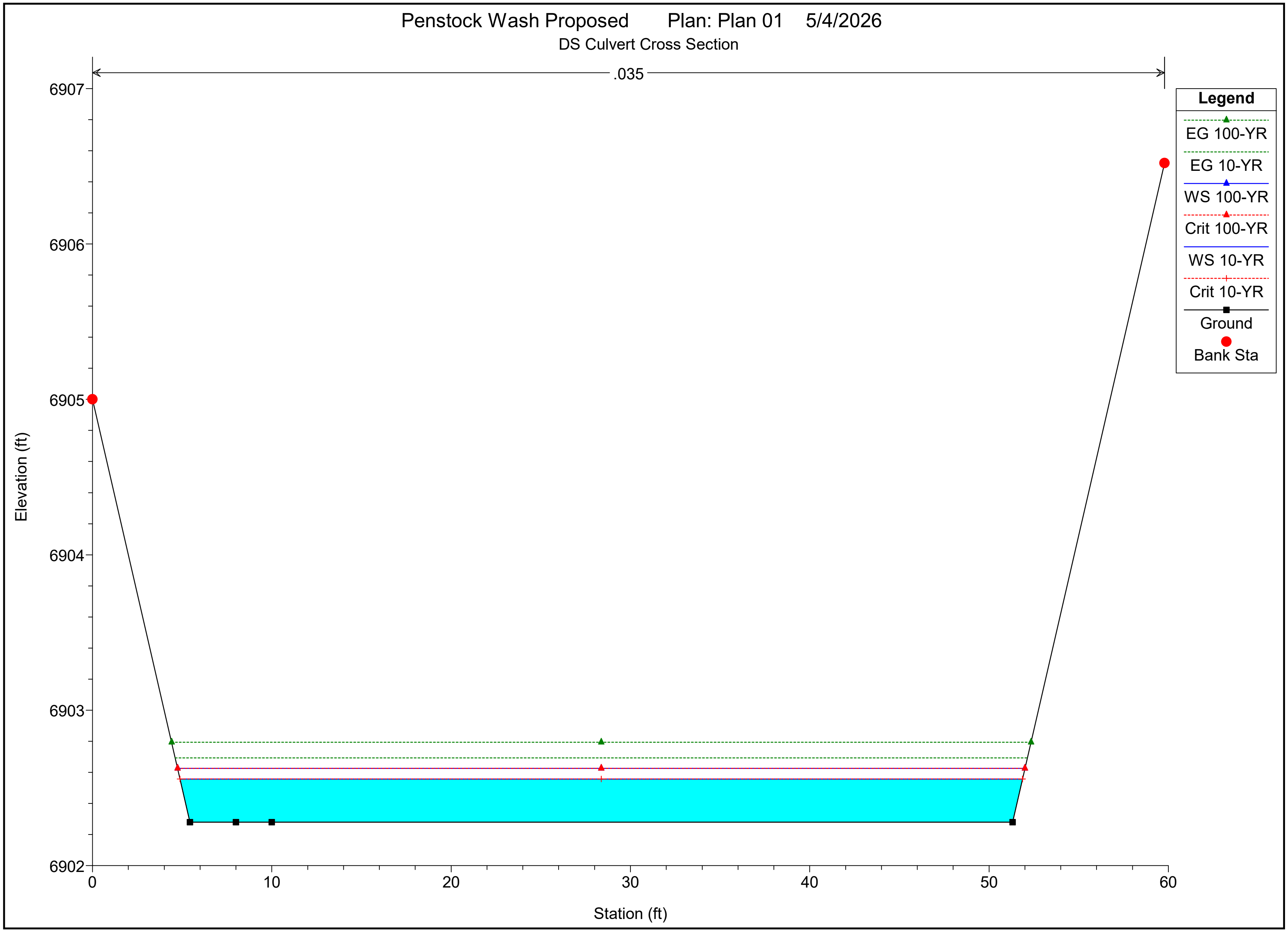


Penstock Wash Proposed Plan: Plan 01 5/4/2026
Channel CS Above Culvert (11.46)
.025
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Crit 100-YR
Crit 10-YR
Ground
Bank Sta
Elevation (ft)
6906
6907
6908
6909
6910
6911
6912
6913
Station (ft)
0
5
10
15
20
25
30
35
40

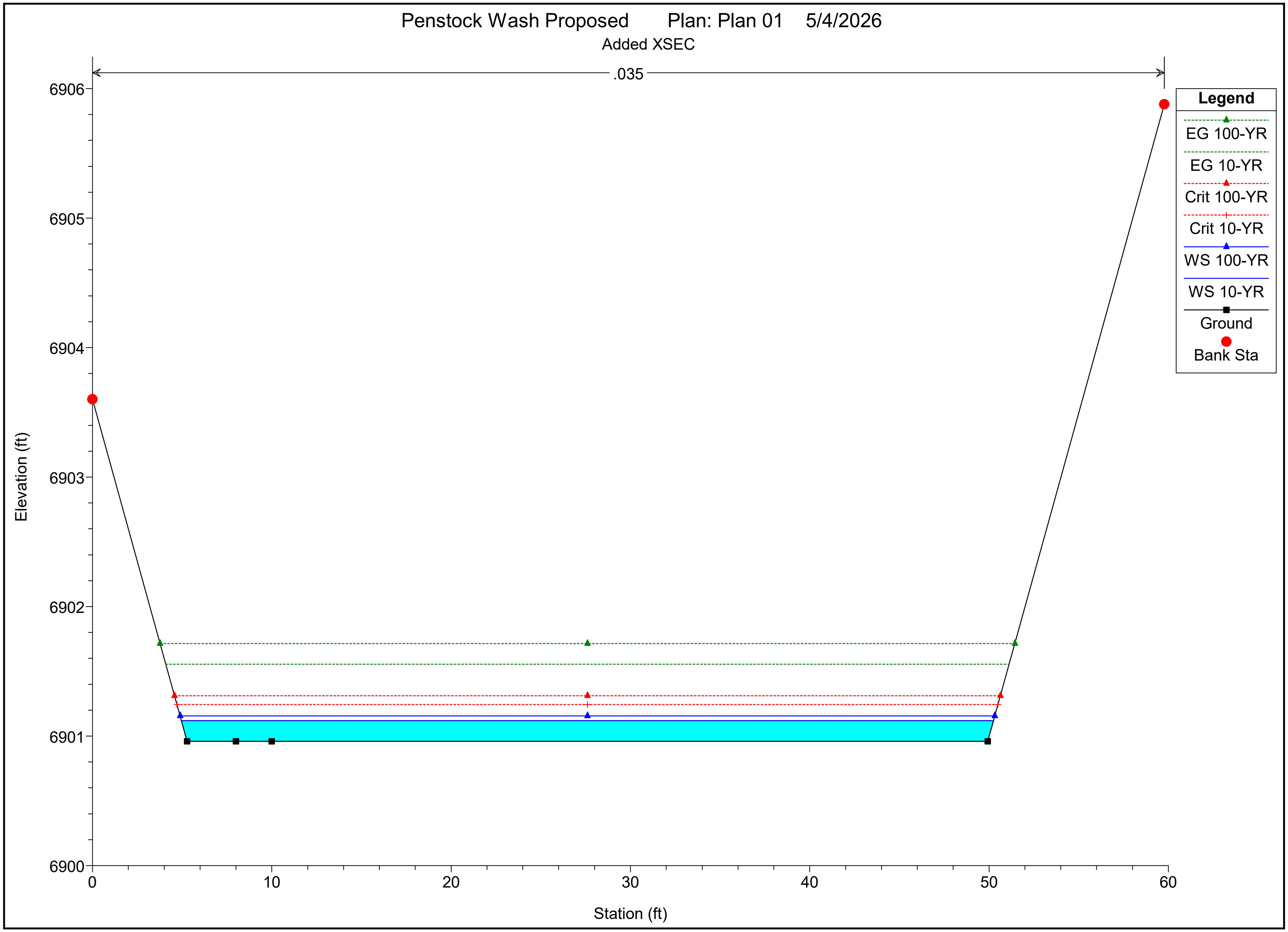


Penstock Wash Proposed Plan: Plan 01 5/4/2026
Upstream CS of Double Culvert
.025
Elevation (ft)
6911
6910
6909
6908
6907
6906
6905
0
5
10
15
20
Station (ft)
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Crit 100-YR
Crit 10-YR
Ground
Bank Sta

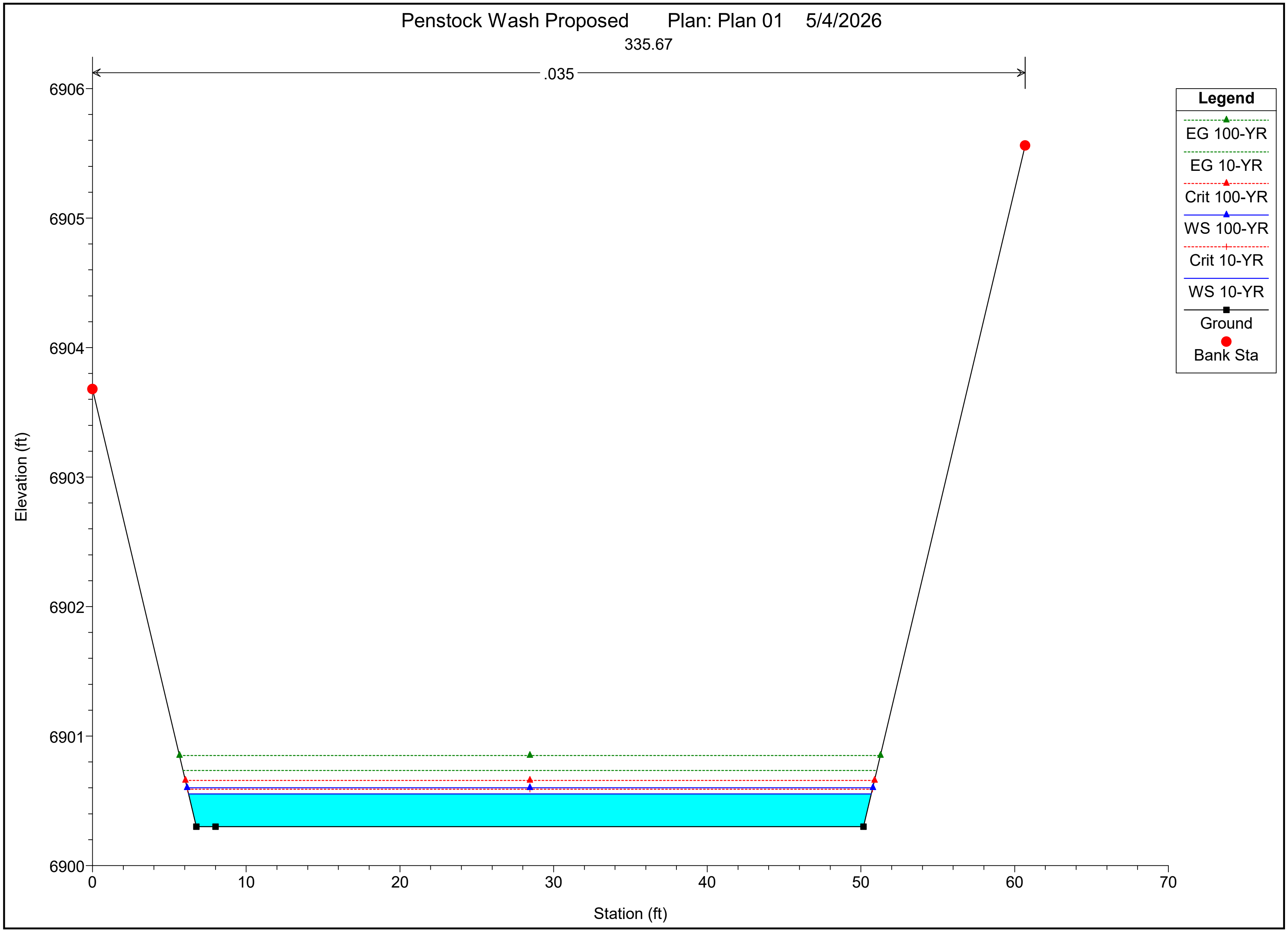

Penstock Wash Proposed Plan: Plan 01 5/4/2026
Upstream Double Culvert of Highway 89
.025
Legend
EG 100-YR
EG 10-YR
WS 100-YR
Crit 100-YR
WS 10-YR
Crit 10-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)
6904
6905
6906
6907
6908
6909
6910
6911
6912
0
5
10
15
20



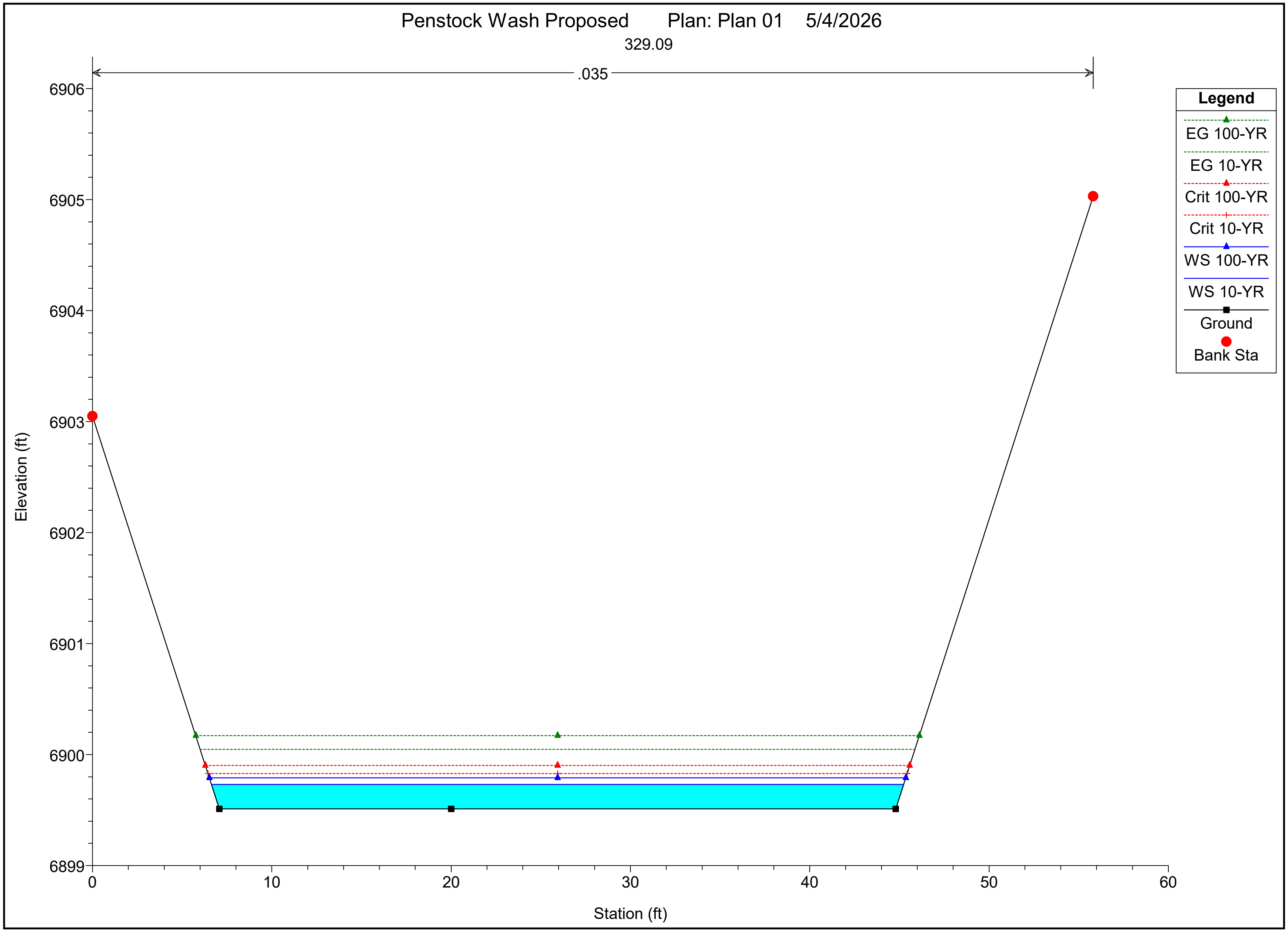
Penstock Wash Proposed Plan: Plan 01 5/4/2026
DS Culvert Cross Section
.035
Legend
EG 100-YR
EG 10-YR
WS 100-YR
Crit 100-YR
WS 10-YR
Crit 10-YR
Ground
Bank Sta
Elevation (ft)
6907
6906
6905
6904
6903
6902
0
10
20
30
40
50
60
Station (ft)

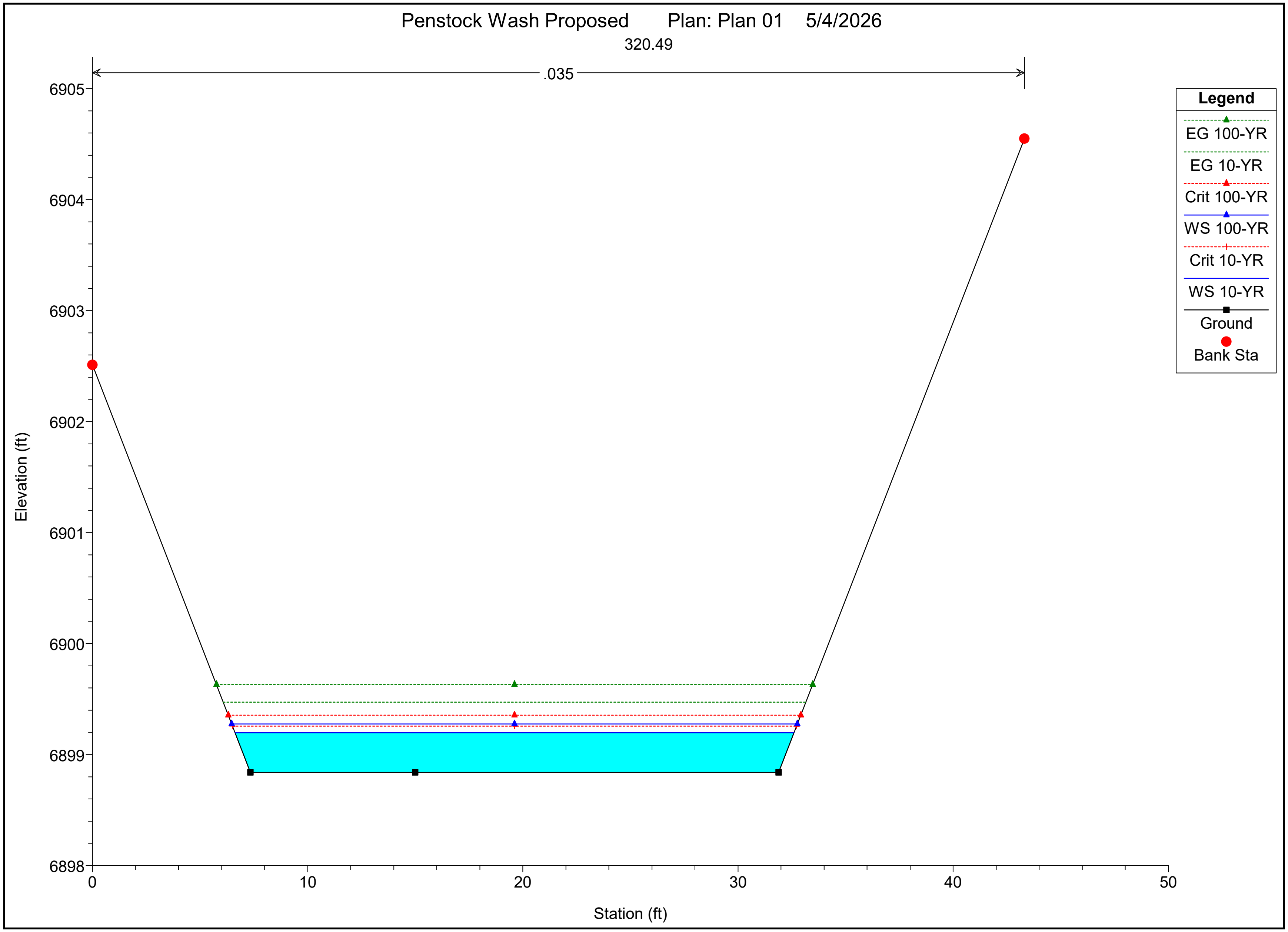


Penstock Wash Proposed Plan: Plan 01 5/4/2026
Added XSEC
.035
Legend
EG 100-YR
EG 10-YR
Crit 100-YR
Crit 10-YR
WS 100-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6900
6901
6902
6903
6904
6905
6906
Station (ft)
0
10
20
30
40
50
60

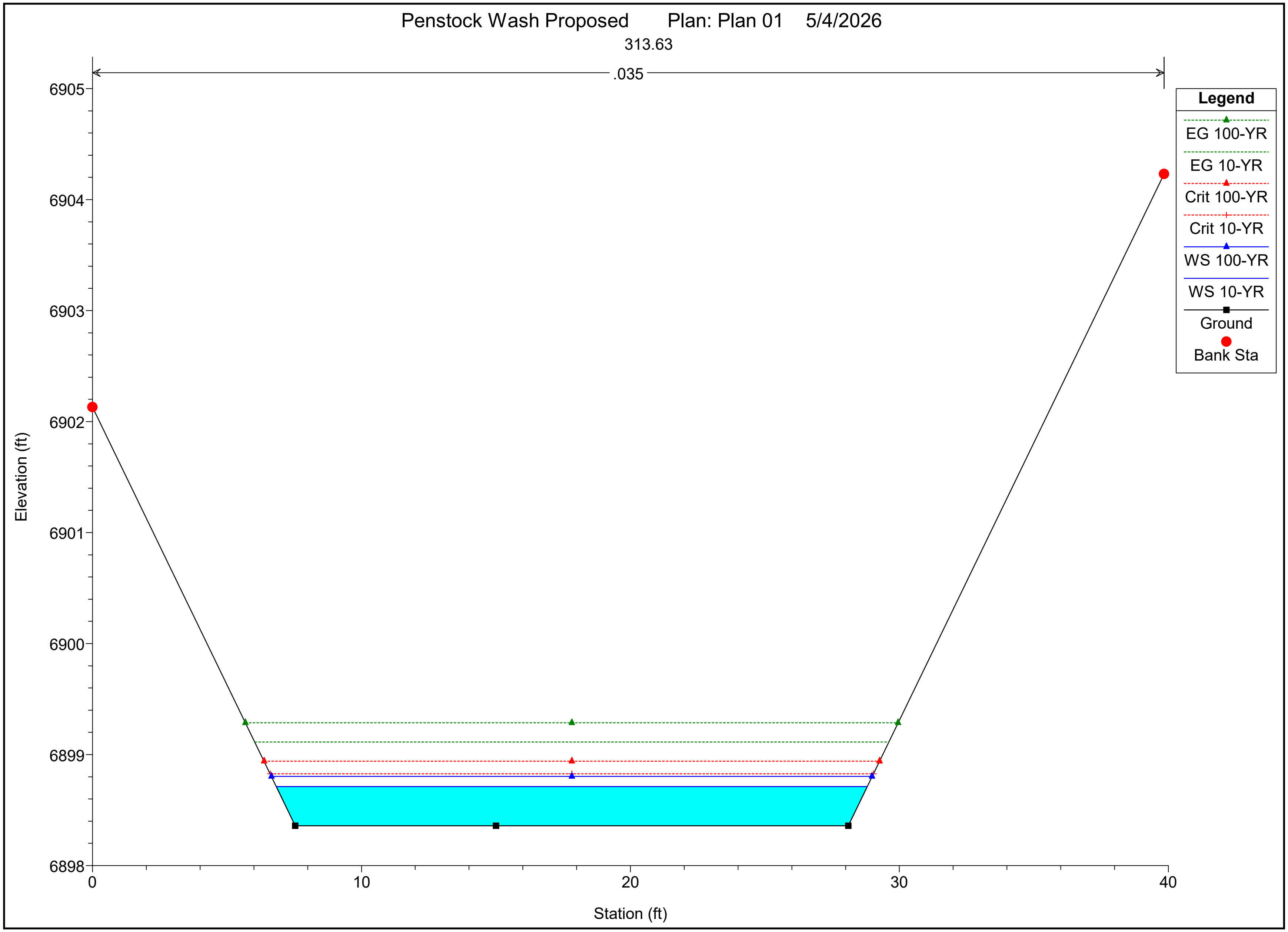


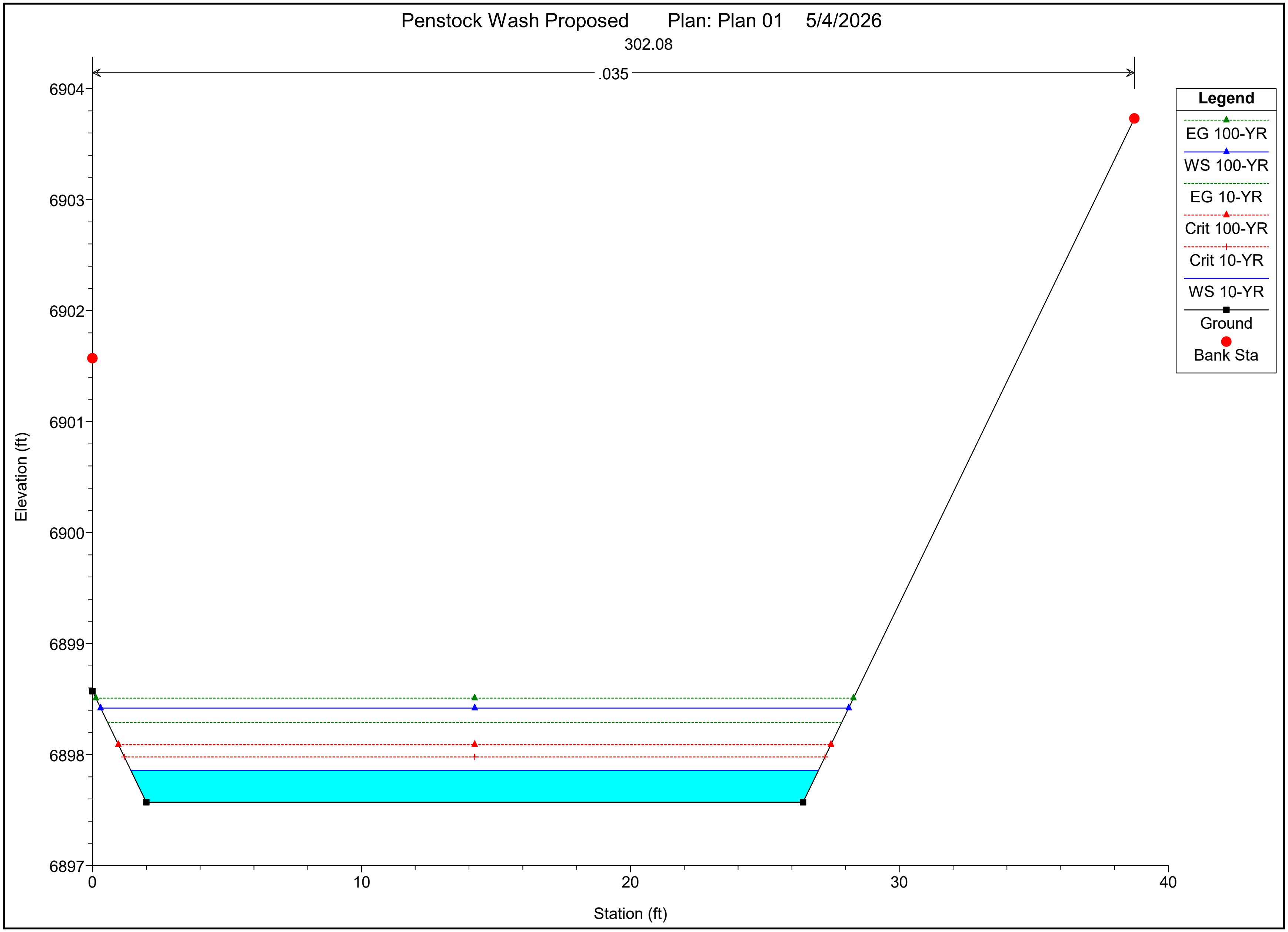
Penstock Wash Proposed Plan: Plan 01 5/4/2026
335.67
.035
Legend
EG 100-YR
EG 10-YR
Crit 100-YR
WS 100-YR
Crit 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6906
6905
6904
6903
6902
6901
6900
Station (ft)
0
10
20
30
40
50
60
70

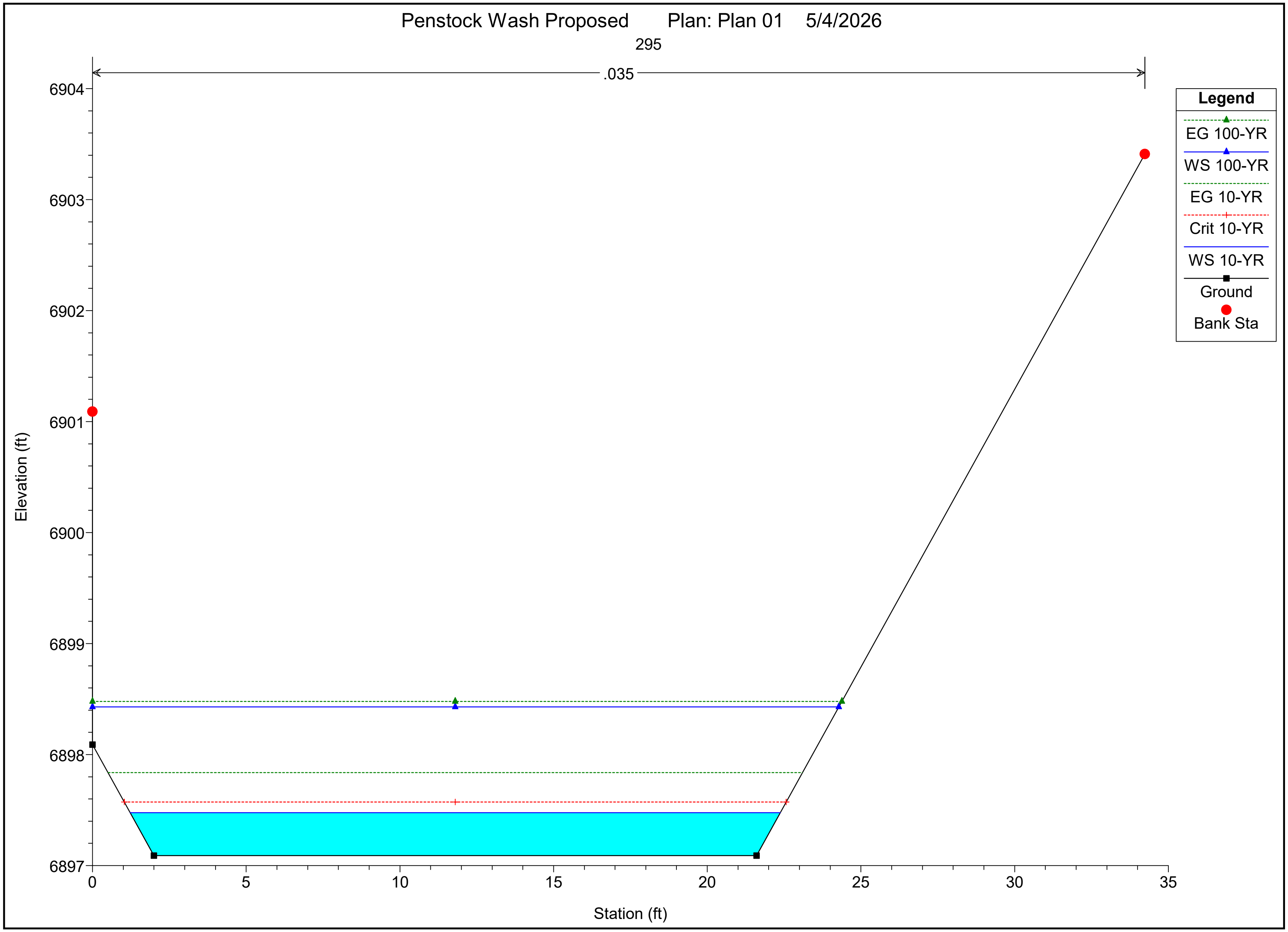

Penstock Wash Proposed Plan: Plan 01 5/4/2026
329.09
.035
Legend
EG 100-YR
EG 10-YR
Crit 100-YR
Crit 10-YR
WS 100-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)
6906
6905
6904
6903
6902
6901
6900
6899
0
10
20
30
40
50
60

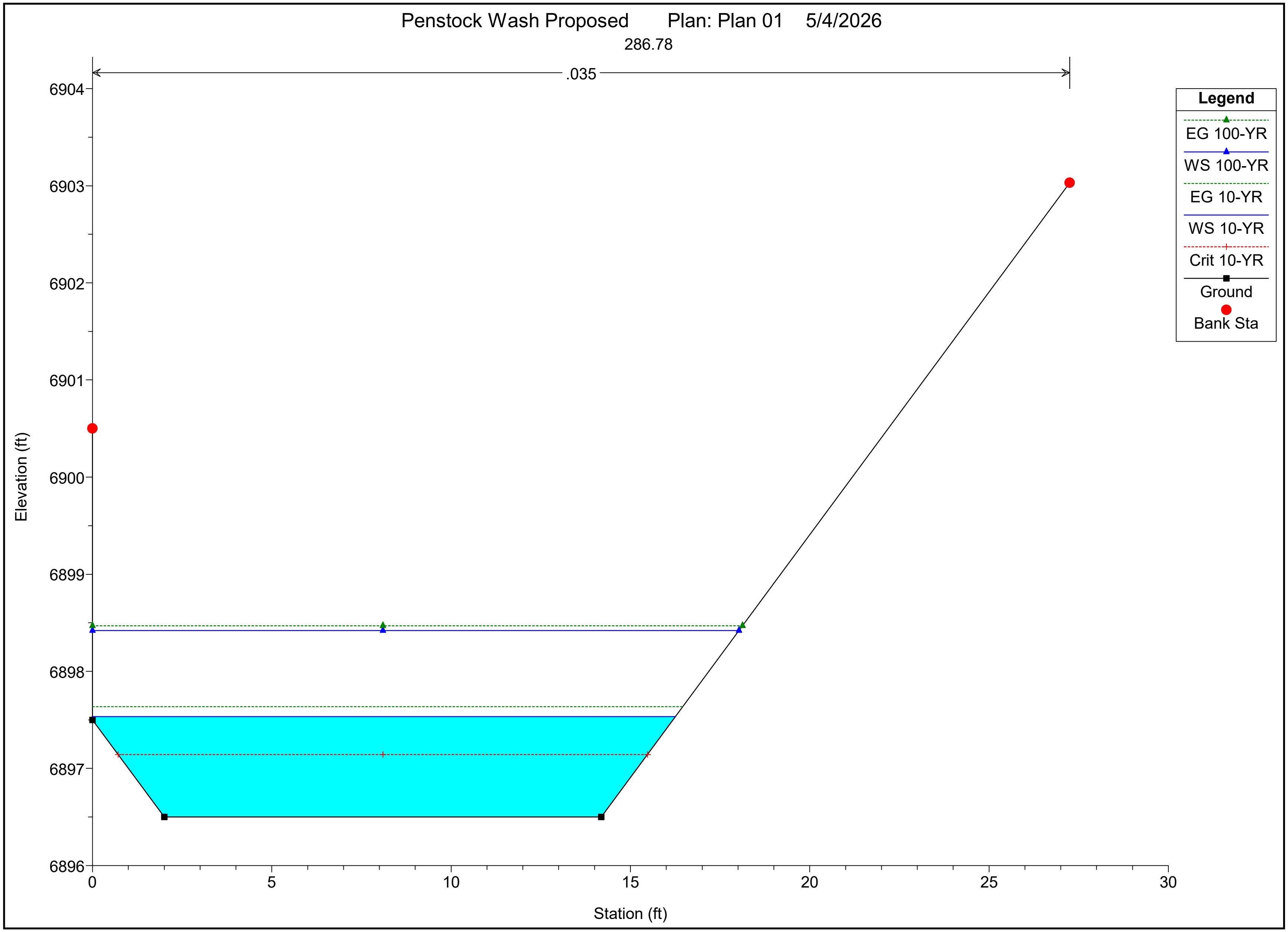


Penstock Wash Proposed Plan: Plan 01 5/4/2026
320.49
.035
Legend
EG 100-YR
EG 10-YR
Crit 100-YR
WS 100-YR
Crit 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6905
6904
6903
6902
6901
6900
6899
6898
0
10
20
30
40
50
Station (ft)

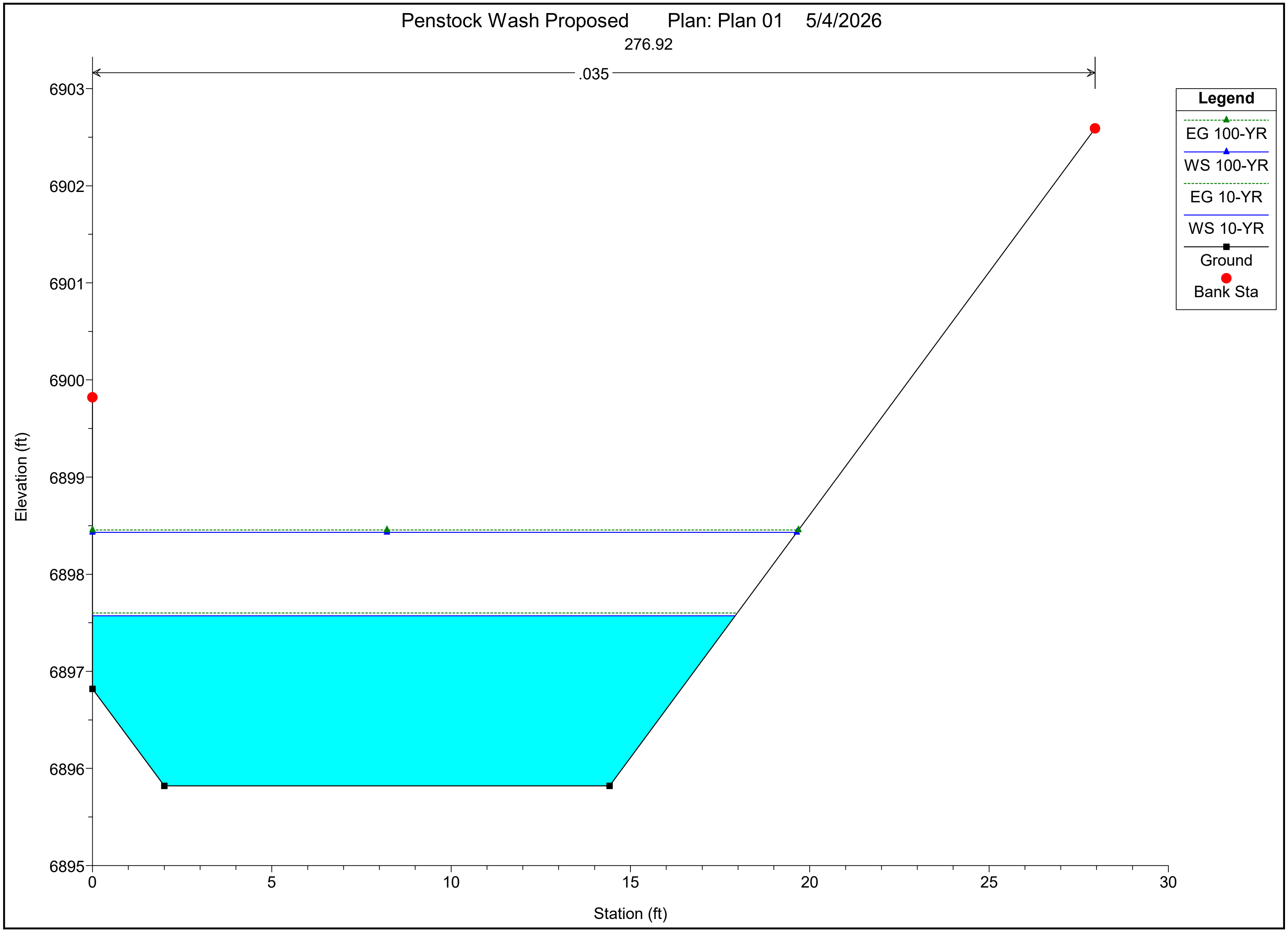

Penstock Wash Proposed Plan: Plan 01 5/4/2026
313.63
.035
Legend
EG 100-YR
EG 10-YR
Crit 100-YR
Crit 10-YR
WS 100-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6905
6904
6903
6902
6901
6900
6899
6898
0
10
20
30
40
Station (ft)


Penstock Wash Proposed Plan: Plan 01 5/4/2026
302.08
.035
Legend
EG 100-YR
WS 100-YR
EG 10-YR
Crit 100-YR
Crit 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6904
6903
6902
6901
6900
6899
6898
6897
0
10
20
30
40
Station (ft)

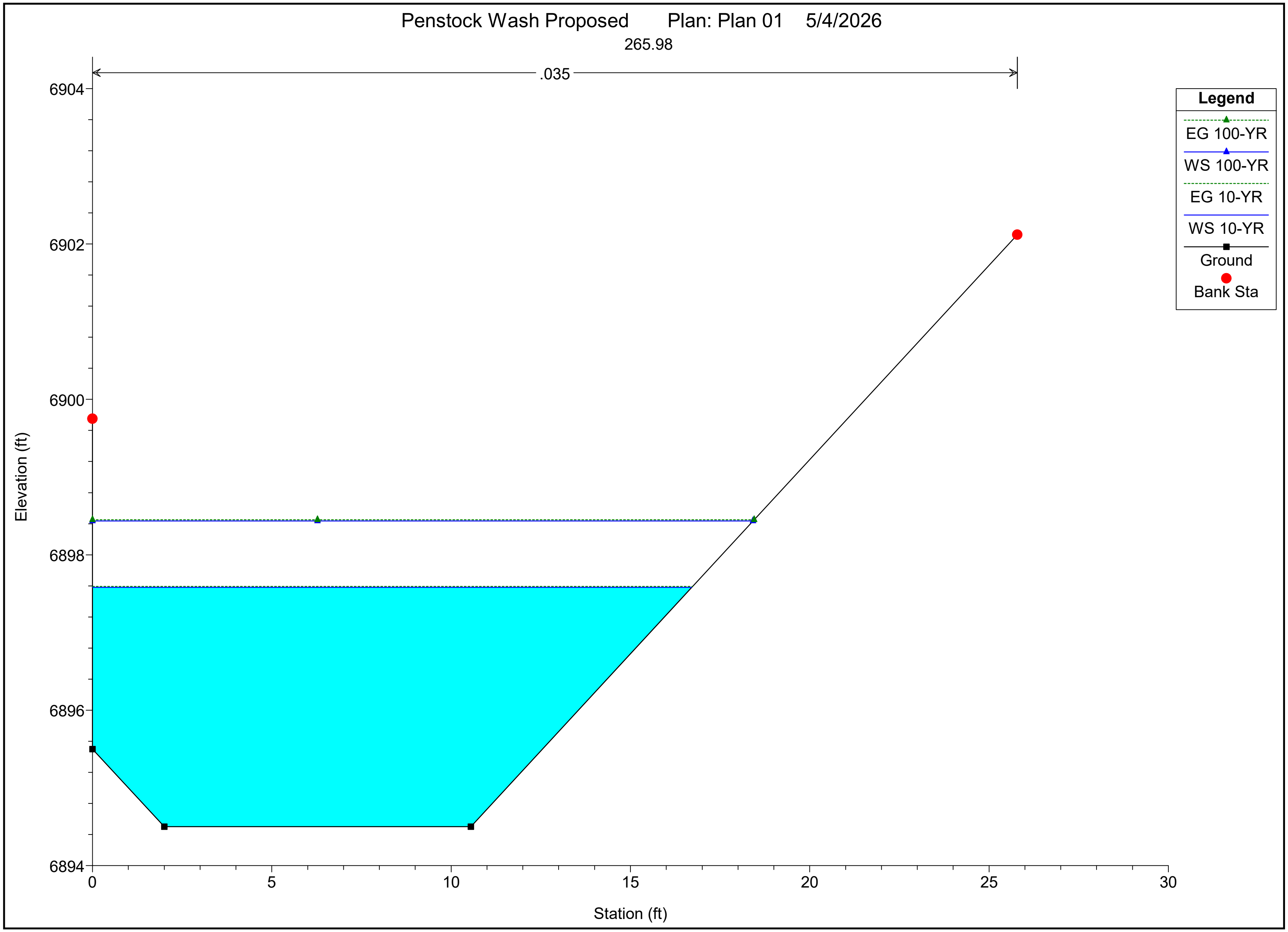

Penstock Wash Proposed Plan: Plan 01 5/4/2026
295
.035
Legend
EG 100-YR
WS 100-YR
EG 10-YR
Crit 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6904
6903
6902
6901
6900
6899
6898
6897
0
5
10
15
20
25
30
35
Station (ft)



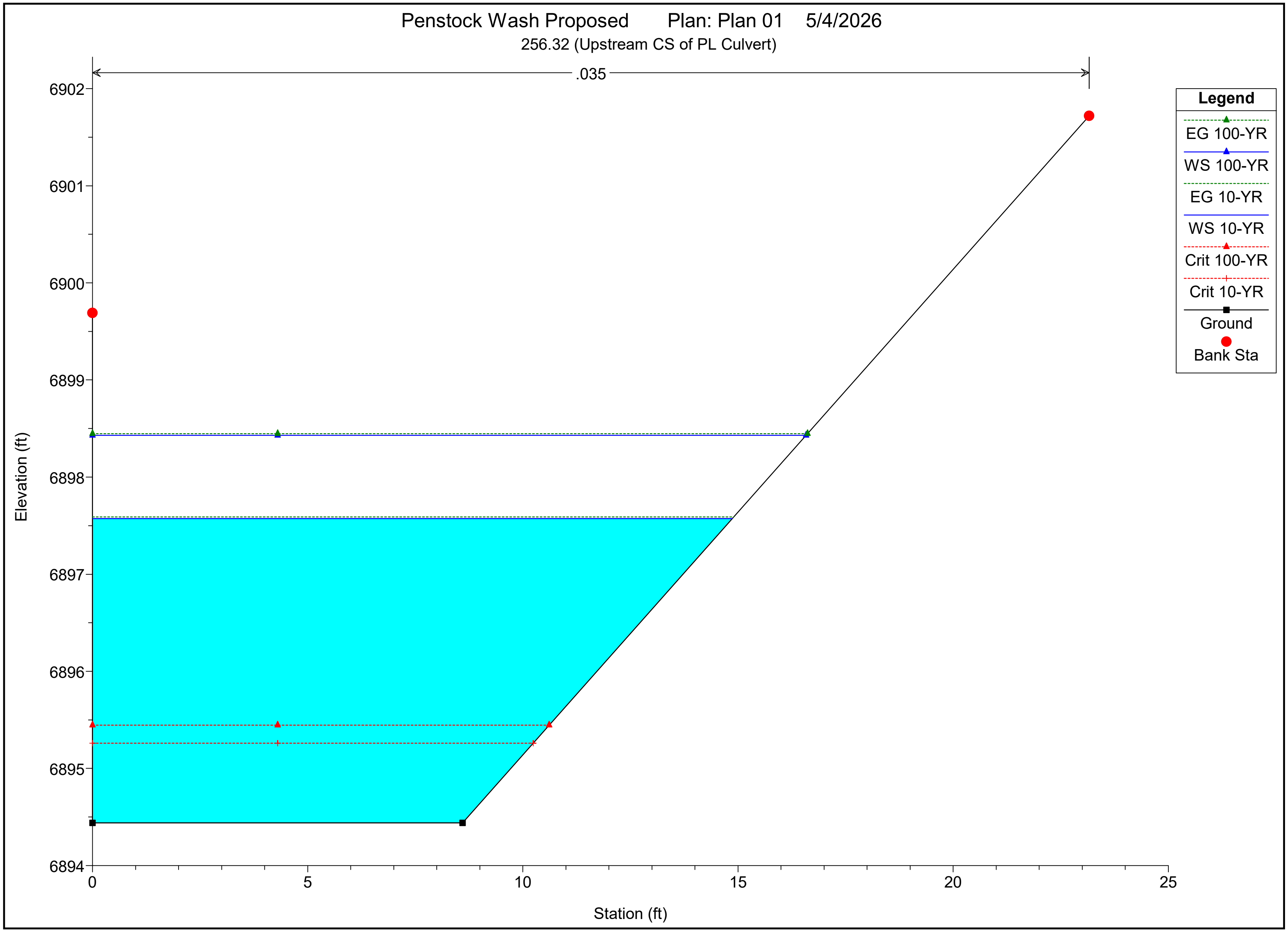
Penstock Wash Proposed Plan: Plan 01 5/4/2026
286.78
.035
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Crit 10-YR
Ground
Bank Sta
Elevation (ft)
6904
6903
6902
6901
6900
6899
6898
6897
6896
Station (ft)
0
5
10
15
20
25
30

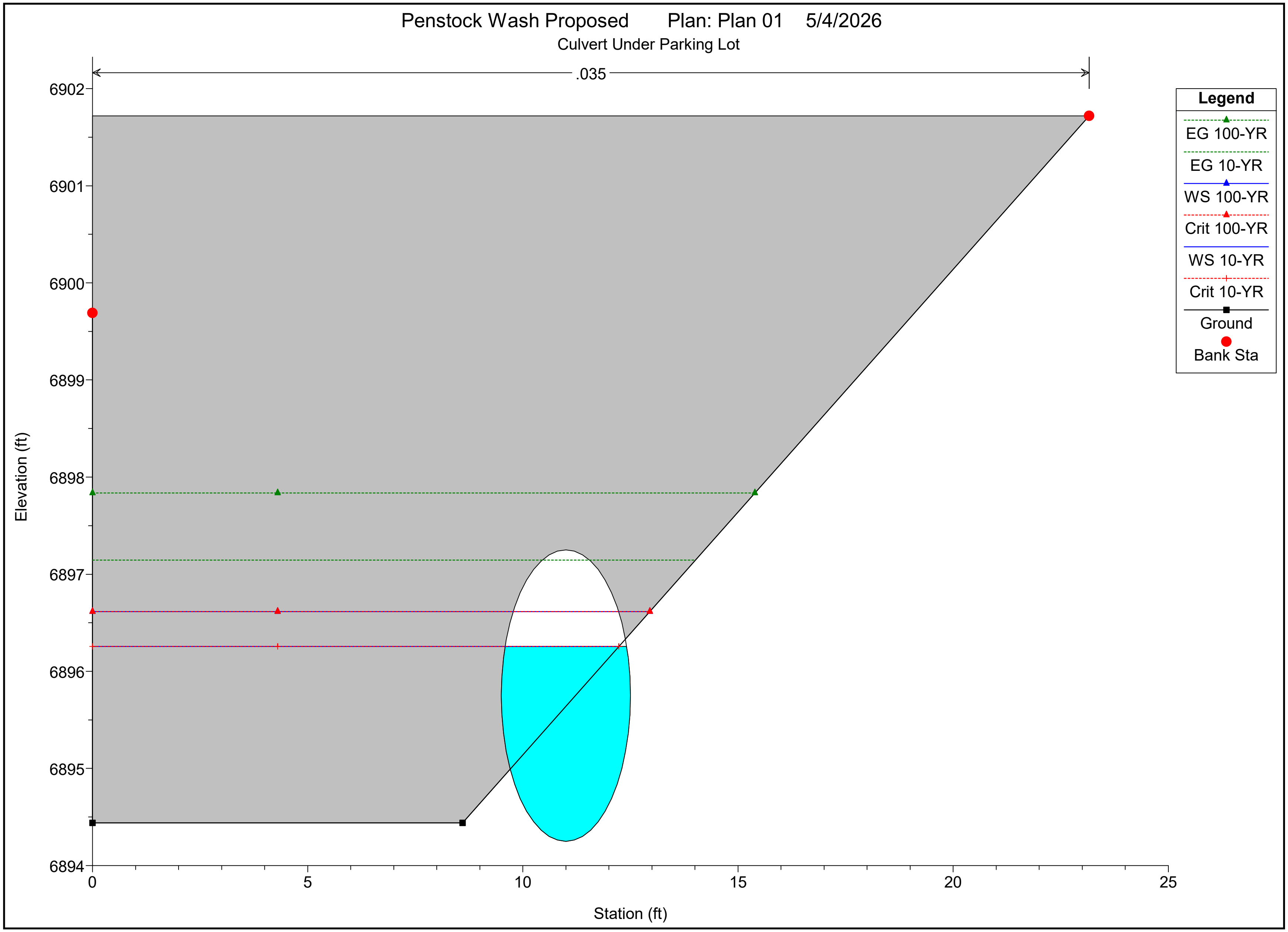


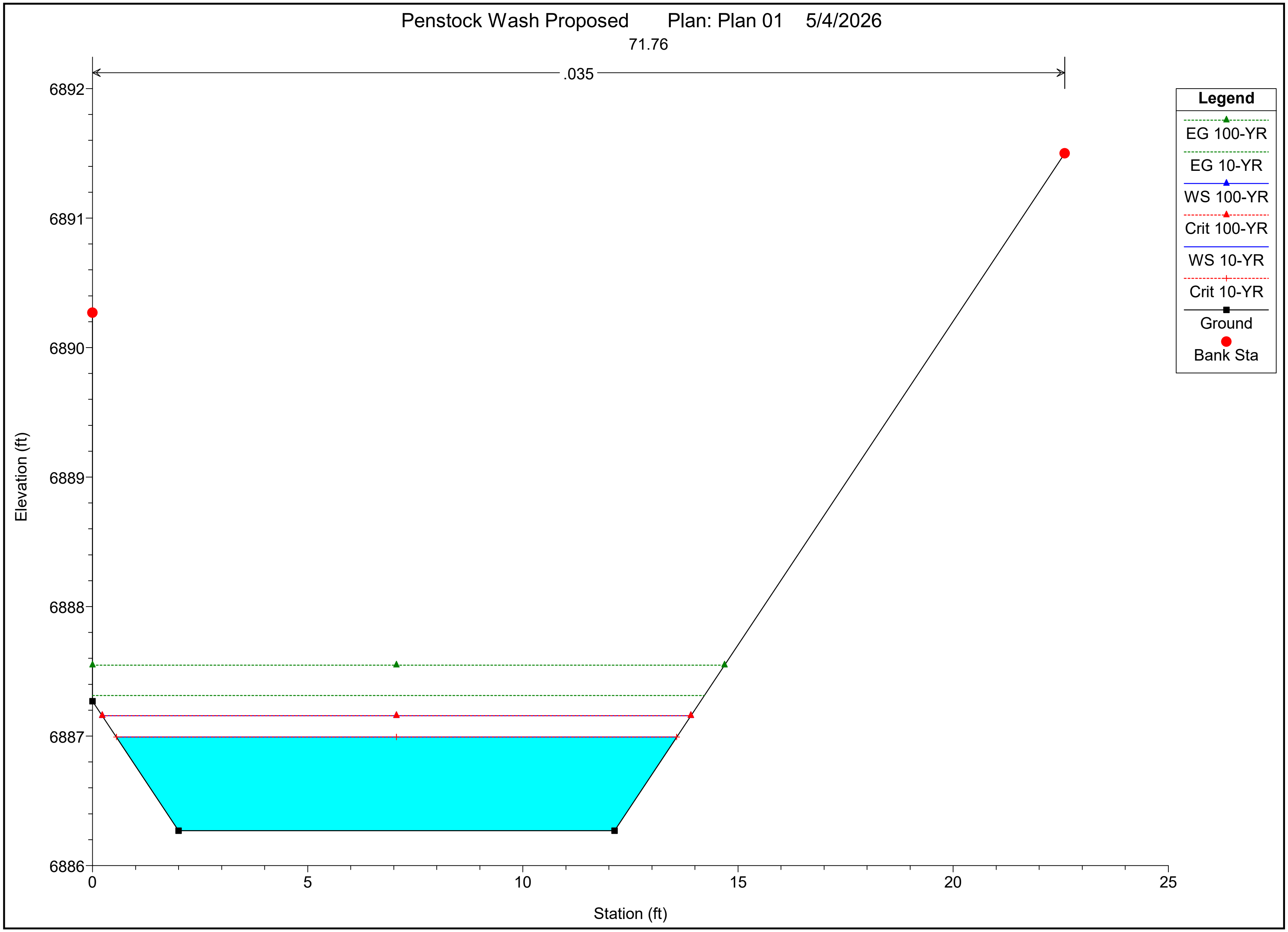
Penstock Wash Proposed Plan: Plan 01 5/4/2026
276.92
.035
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6903
6902
6901
6900
6899
6898
6897
6896
6895
0
5
10
15
20
25
30
Station (ft)



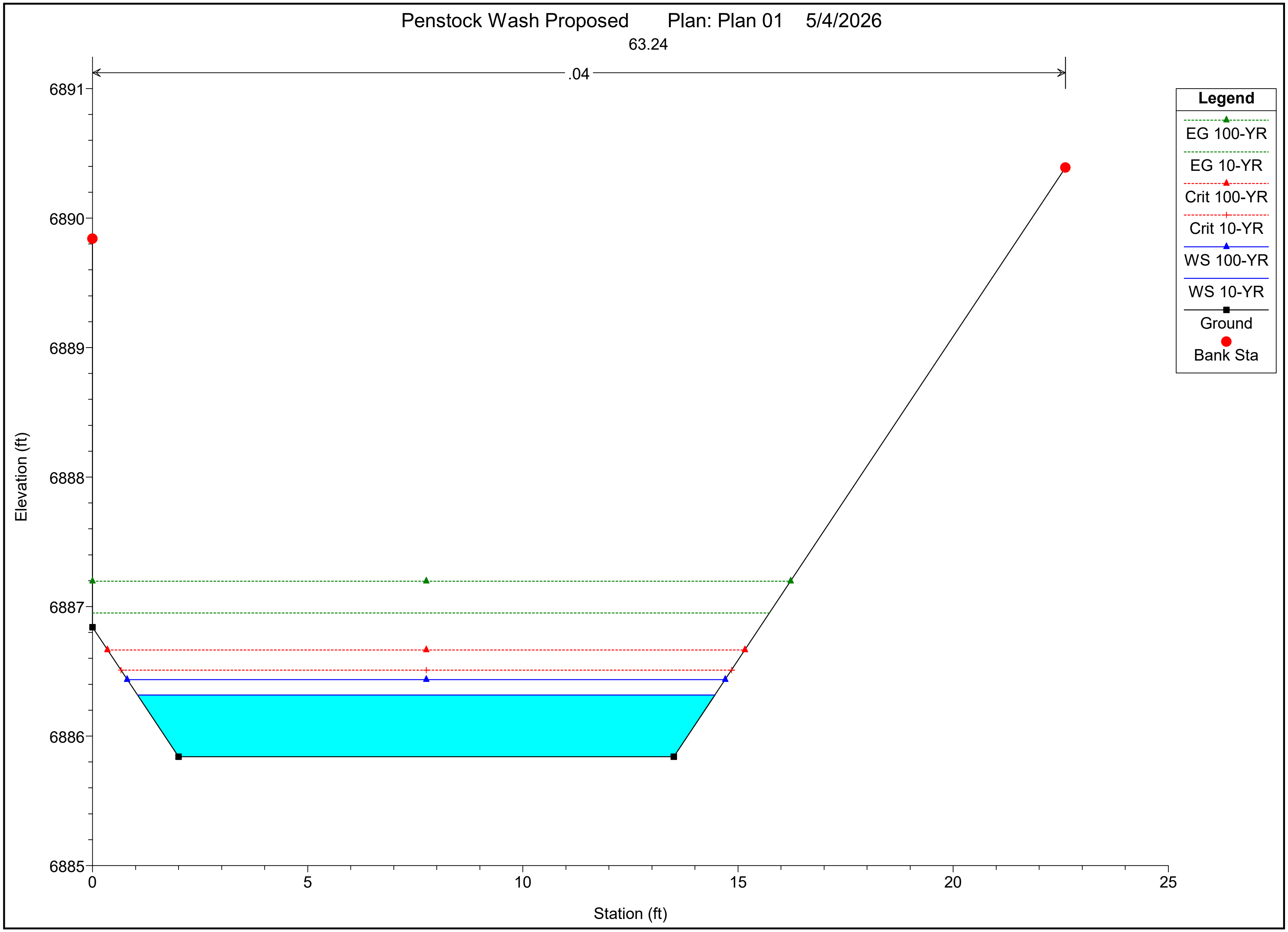
Penstock Wash Proposed Plan: Plan 01 5/4/2026
265.98
.035
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6904
6902
6900
6898
6896
6894
Station (ft)
0
5
10
15
20
25
30


Penstock Wash Proposed Plan: Plan 01 5/4/2026
256.32 (Upstream CS of PL Culvert)
.035
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Crit 100-YR
Crit 10-YR
Ground
Bank Sta
Elevation (ft)
6894
6895
6896
6897
6898
6899
6900
6901
6902
Station (ft)
0
5
10
15
20
25

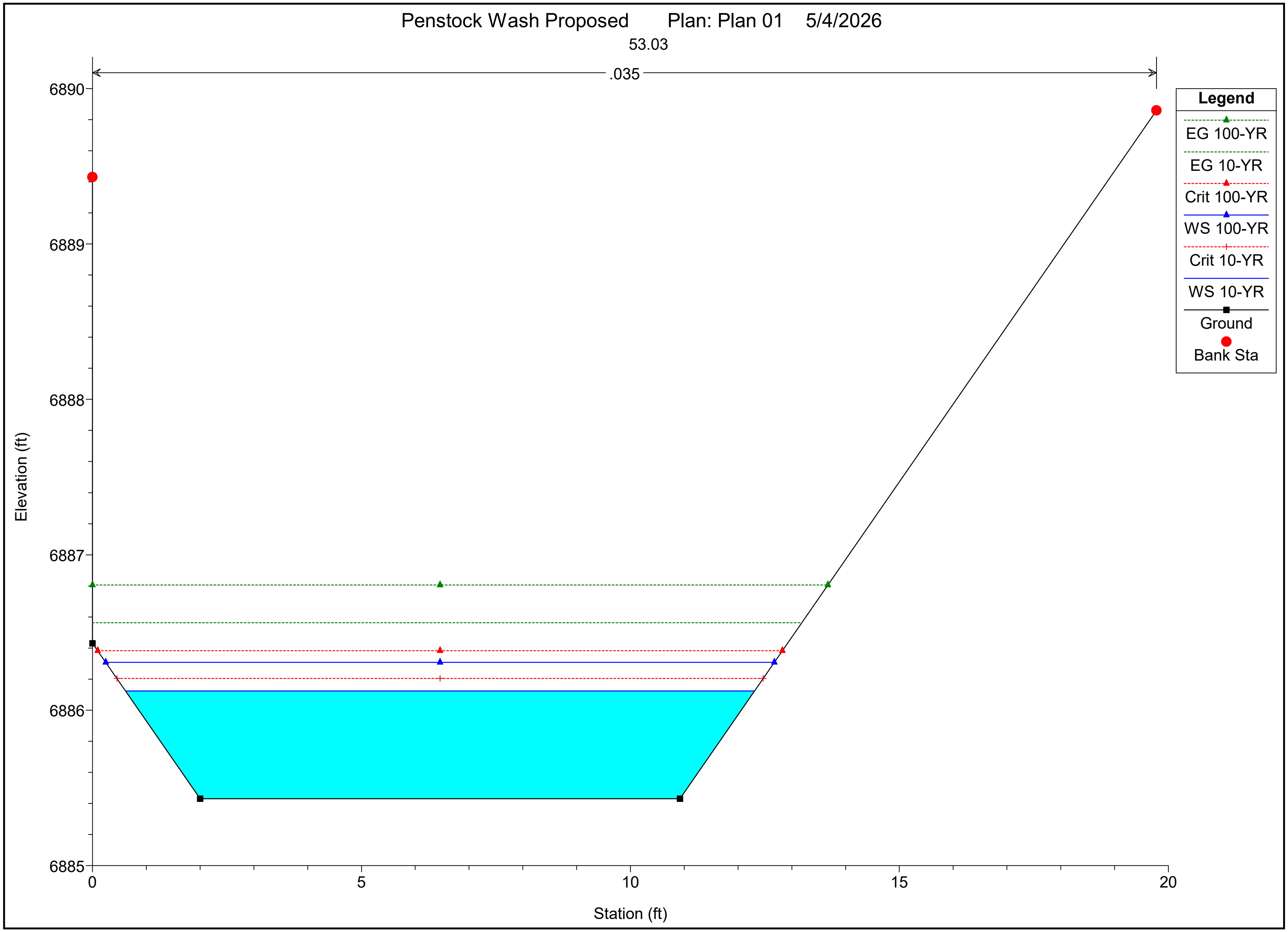

Penstock Wash Proposed Plan: Plan 01 5/4/2026
Culvert Under Parking Lot
.035
Elevation (ft)
Station (ft)
6894
6895
6896
6897
6898
6899
6900
6901
6902
0
5
10
15
20
25
Legend
EG 100-YR
EG 10-YR
WS 100-YR
Crit 100-YR
WS 10-YR
Crit 10-YR
Ground
Bank Sta



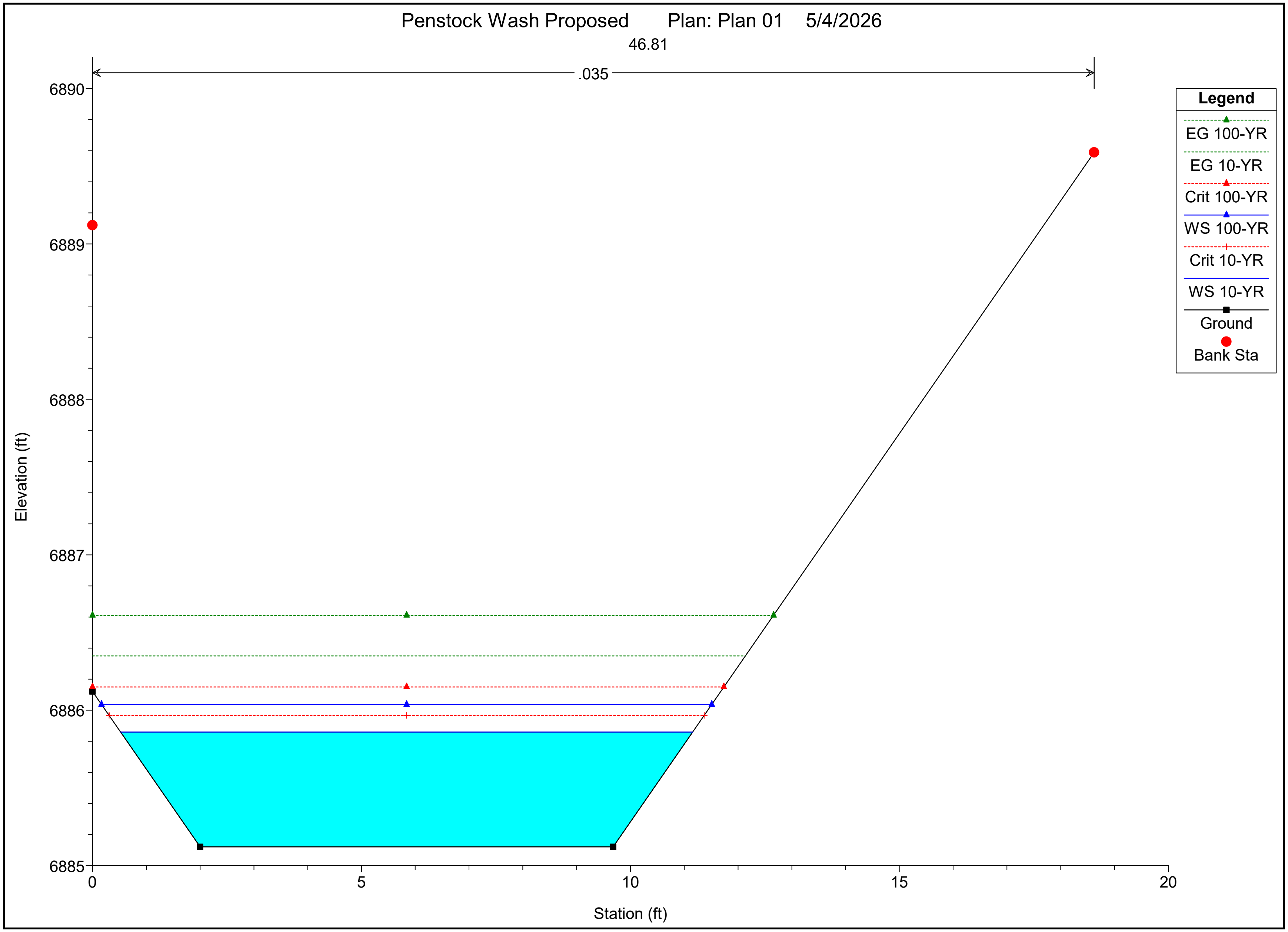
Penstock Wash Proposed Plan: Plan 01 5/4/2026
71.76
.035
Elevation (ft)
Station (ft)
6886
6887
6888
6889
6890
6891
6892
0
5
10
15
20
25
Legend
EG 100-YR
EG 10-YR
WS 100-YR
Crit 100-YR
WS 10-YR
Crit 10-YR
Ground
Bank Sta



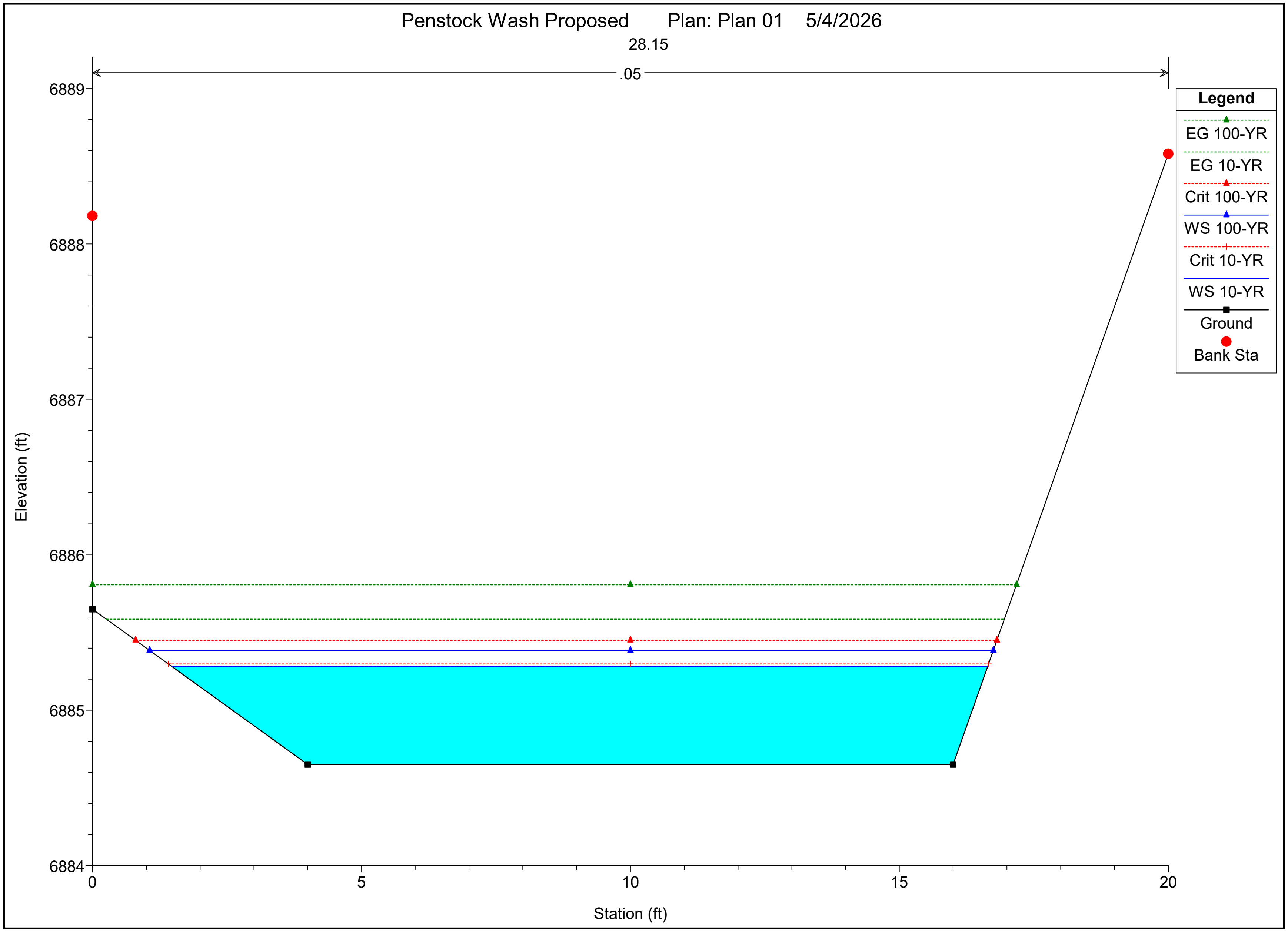
Penstock Wash Proposed Plan: Plan 01 5/4/2026
63.24
.04
Legend
EG 100-YR
EG 10-YR
Crit 100-YR
Crit 10-YR
WS 100-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6891
6890
6889
6888
6887
6886
6885
0
5
10
15
20
25
Station (ft)



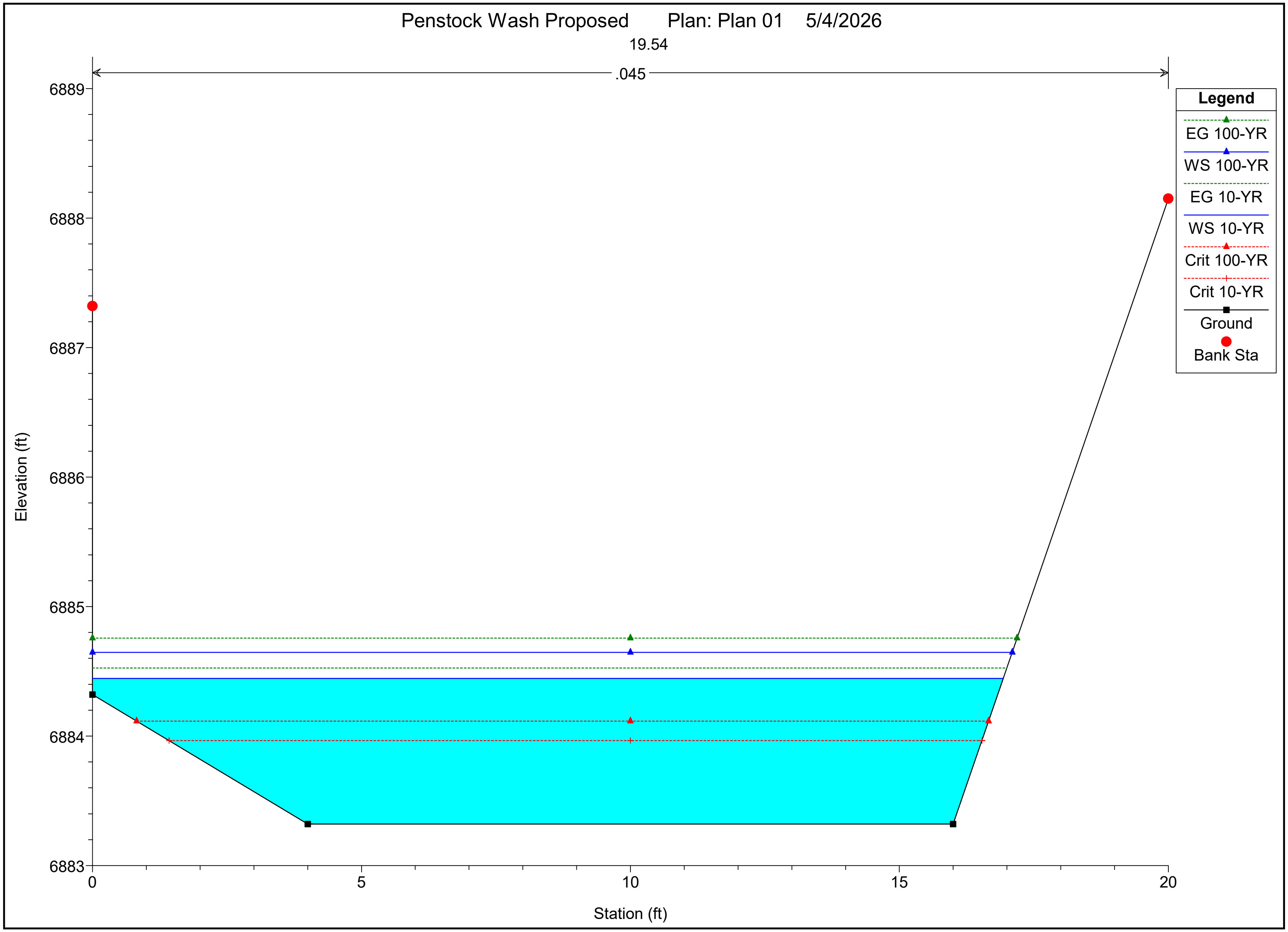
Penstock Wash Proposed Plan: Plan 01 5/4/2026
53.03
.035
Legend
EG 100-YR
EG 10-YR
Crit 100-YR
WS 100-YR
Crit 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6890
6889
6888
6887
6886
6885
0
5
10
15
20
Station (ft)



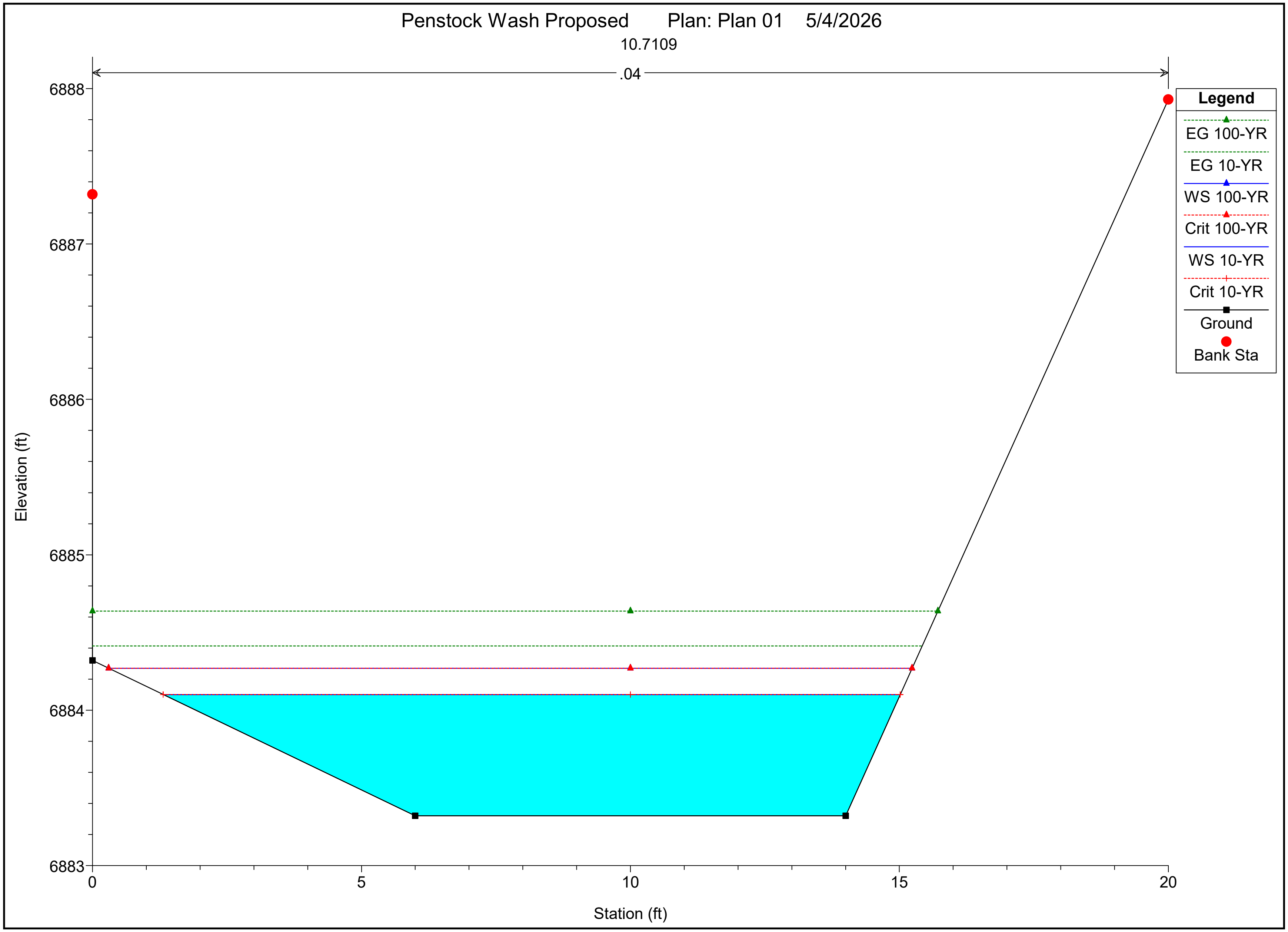
Penstock Wash Proposed Plan: Plan 01 5/4/2026
46.81
.035
Legend
EG 100-YR
EG 10-YR
Crit 100-YR
WS 100-YR
Crit 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6890
6889
6888
6887
6886
6885
0
5
10
15
20
Station (ft)



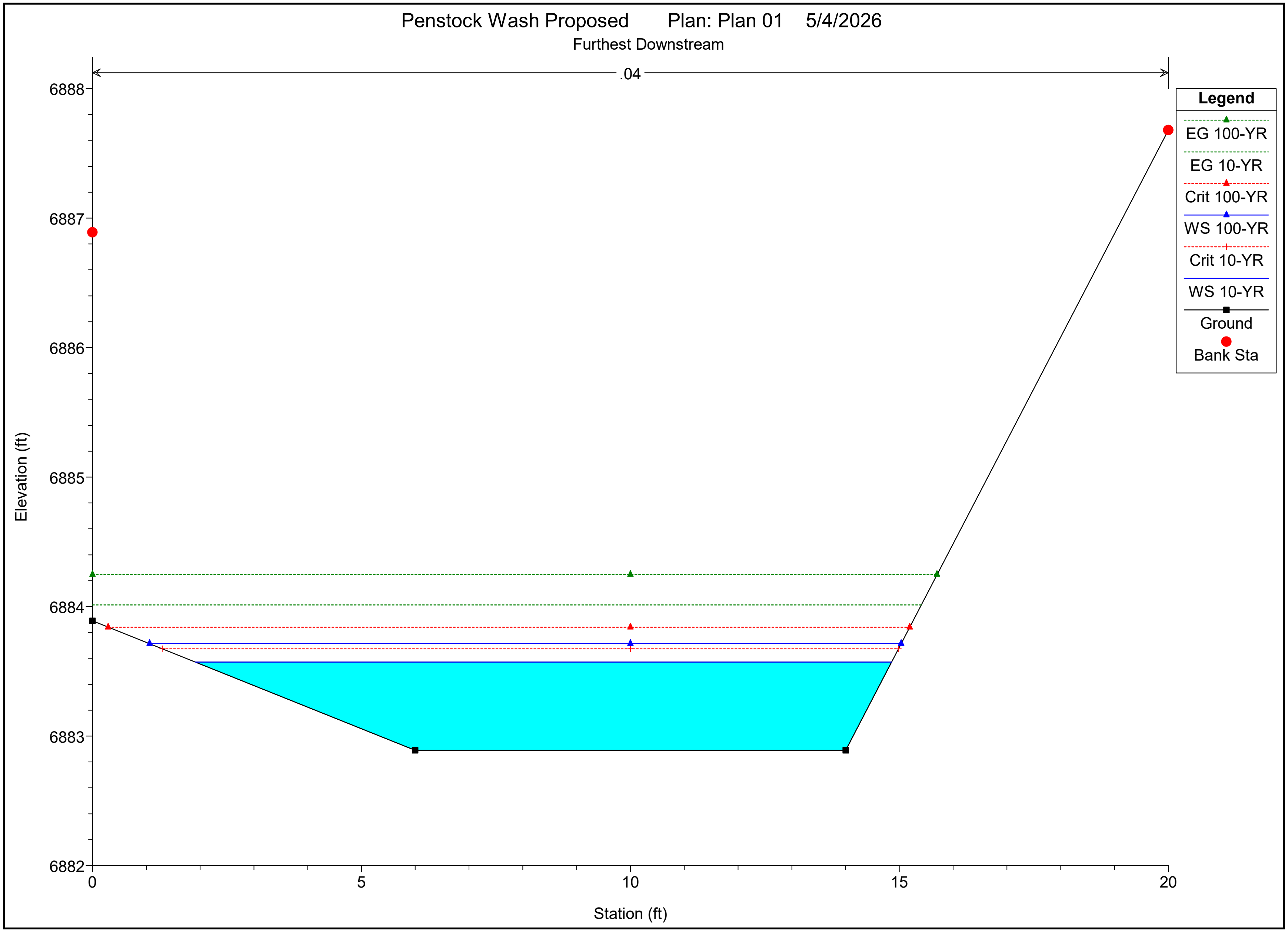
Penstock Wash Proposed Plan: Plan 01 5/4/2026
28.15
.05
Legend
EG 100-YR
EG 10-YR
Crit 100-YR
WS 100-YR
Crit 10-YR
WS 10-YR
Ground
Bank Sta
Elevation (ft)
6889
6888
6887
6886
6885
6884
0
5
10
15
20
Station (ft)



Penstock Wash Proposed Plan: Plan 01 5/4/2026
19.54
.045
Legend
EG 100-YR
WS 100-YR
EG 10-YR
WS 10-YR
Crit 100-YR
Crit 10-YR
Ground
Bank Sta
Elevation (ft)
6889
6888
6887
6886
6885
6884
6883
0
5
10
15
20
Station (ft)



Penstock Wash Proposed Plan: Plan 01 5/4/2026
10.7109
.04
Legend
EG 100-YR
EG 10-YR
WS 100-YR
Crit 100-YR
WS 10-YR
Crit 10-YR
Ground
Bank Sta
Elevation (ft)
6888
6887
6886
6885
6884
6883
0
5
10
15
20
Station (ft)



Penstock Wash Proposed Plan: Plan 01 5/4/2026
Furthest Downstream
.04
Elevation (ft)
6888
6887
6886
6885
6884
6883
6882
0
5
10
15
20
Station (ft)
Legend
EG 100-YR
EG 10-YR
Crit 100-YR
WS 100-YR
Crit 10-YR
WS 10-YR
Ground
Bank Sta

Appendix D3: All River Station Summary Tables and Reports

Table D- 1: All Proposed Cross Sections

River Station	Profile	Flow Total	Min Channel Elevation	Water Surface Elevation	E.G. Elevation	E.G. Slope	Velocity Channel	Flow Area	Top Width	Froude Number
		(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1488	10	38	6906.46	6907.65	6907.7	0.000889	1.8	21.16	20.18	0.31
1488	100	53	6906.46	6909.79	6909.8	0.000045	0.72	73.49	28.73	0.08
1477	10	38	6905	6907.67	6907.68	0.000095	0.92	41.4	18.5	0.11
1477	100	53	6905	6909.79	6909.8	0.000026	0.66	80.6	18.5	0.06
1354	10	38	6902.28	6902.56	6902.69	0.027246	2.95	12.88	46.98	0.99
1354	100	53	6902.28	6902.63	6902.79	0.0254	3.29	16.1	47.25	0.99
1345	10	38	6900.96	6901.12	6901.56	0.181502	5.29	7.18	45.29	2.34
1345	100	53	6900.96	6901.16	6901.72	0.177284	5.99	8.84	45.44	2.4
1335	10	38	6900.3	6900.55	6900.73	0.041367	3.42	11.11	44.42	1.21
1335	100	53	6900.3	6900.6	6900.85	0.044883	4	13.26	44.61	1.29
1329	10	38	6899.51	6899.73	6900.05	0.086937	4.52	8.4	38.6	1.71
1329	100	53	6899.51	6899.79	6900.17	0.076043	4.95	10.71	38.84	1.66
1320	10	38	6898.84	6899.2	6899.47	0.040549	4.21	9.03	25.98	1.26
1320	100	53	6898.84	6899.28	6899.63	0.040696	4.79	11.07	26.29	1.3
1313	10	38	6898.36	6898.71	6899.11	0.060951	5.08	7.48	21.97	1.54
1313	100	53	6898.36	6898.8	6899.29	0.054692	5.58	9.5	22.33	1.51
1302	10	38	6897.57	6897.86	6898.29	0.083351	5.26	7.23	25.58	1.74
1302	100	53	6897.57	6898.42	6898.51	0.00436	2.39	22.19	27.82	0.47
1295	10	38	6897.09	6897.48	6897.84	0.048285	4.81	7.9	21.15	1.39
1295	100	53	6897.09	6898.43	6898.48	0.001411	1.78	29.74	24.28	0.28
1286	10	38	6896.5	6897.53	6897.64	0.004383	2.58	14.74	16.26	0.48
1286	100	53	6896.5	6898.42	6898.47	0.000993	1.77	29.92	18.03	0.24
1276	10	38	6895.82	6897.57	6897.6	0.000677	1.39	27.31	17.92	0.2
1276	100	53	6895.82	6898.43	6898.46	0.000334	1.22	43.48	19.64	0.14
1265	10	38	6894.5	6897.58	6897.59	0.00018	0.93	40.97	16.71	0.1
1265	100	53	6894.5	6898.44	6898.45	0.000147	0.95	56.01	18.42	0.1
1256	10	38	6894.44	6897.57	6897.59	0.000241	1.03	36.76	14.87	0.12
1256	100	53	6894.44	6898.43	6898.45	0.000199	1.05	50.24	16.58	0.11
1071	10	38	6886.27	6886.99	6887.31	0.021329	4.54	8.37	13.02	1
1071	100	53	6886.27	6887.16	6887.55	0.020494	5.01	10.57	13.68	1.01
1063	10	38	6885.84	6886.32	6886.95	0.089264	6.38	5.95	13.42	1.69
1063	100	53	6885.84	6886.44	6887.2	0.081656	6.99	7.58	13.9	1.67
1053	10	38	6885.43	6886.12	6886.56	0.031535	5.33	7.13	11.69	1.2
1053	100	53	6885.43	6886.31	6886.81	0.027062	5.66	9.37	12.43	1.15
1046	10	38	6885.12	6885.86	6886.35	0.033401	5.62	6.77	10.64	1.24

1046	100	53	6885.12	6886.04	6886.61	0.030619	6.08	8.72	11.35	1.22
1028	10	38	6884.65	6885.28	6885.59	0.049214	4.44	8.56	15.16	1.04
1028	100	53	6884.65	6885.39	6885.81	0.056576	5.21	10.17	15.69	1.14
1019	10	38	6883.32	6884.44	6884.53	0.005328	2.3	16.52	16.93	0.41
1019	100	53	6883.32	6884.65	6884.76	0.005703	2.65	19.96	17.1	0.43
1010	10	38	6883.32	6884.1	6884.41	0.028571	4.49	8.47	13.7	1.01
1010	100	53	6883.32	6884.27	6884.64	0.02709	4.87	10.89	14.93	1
1000	10	38	6882.89	6883.57	6884.01	0.046919	5.33	7.13	12.94	1.27
1000	100	53	6882.89	6883.71	6884.25	0.045965	5.86	9.04	13.97	1.28

```
                     HEC-RAS HEC-RAS 6.6 September 2024
                       U.S. Army Corps of Engineers
                      Hydrologic Engineering Center
                            609 Second Street
                            Davis, California

            X     X  XXXXXX    XXXX        XXXX       XX      XXXX
            X     X  X        X    X       X   X     X  X    X
            X     X  X        X            X   X    X    X   X
            XXXXXXX  XXXX     X       XXX  XXXX     XXXXXX    XXXX
            X     X  X        X            X  X     X    X        X
            X     X  X        X    X       X   X    X    X        X
            X     X  XXXXXX    XXXX        X    X   X    X   XXXXX
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PROJECT DATA
Project Title: Penstock Wash Proposed
Project File : PenstockWashPropo.prj
Run Date and Time: 5/4/2026 11:42:06 AM

Project in English units

PLAN DATA

Plan Title: Plan 01
Plan File : o:\Downloads\OneDrive_2026-05-04\Final HEC-RAS (Retaining Wall) use for EOPC1\PenstockWashPropo.p01

Geometry Title: Penstock Wash Geometry
Geometry File : o:\Downloads\OneDrive_2026-05-04\Final HEC-RAS (Retaining Wall) use for EOPC1\PenstockWashPropo.g01

Flow Title   : Penstock Flow
Flow File   : o:\Downloads\OneDrive_2026-05-04\Final HEC-RAS (Retaining Wall) use for EOPC1\PenstockWashPropo.f01

Plan Summary Information:
```
Number of:  Cross Sections =   22    Multiple Openings  =    0
            Culverts       =    2    Inline Structures  =    0
            Bridges        =    0    Lateral Structures =    0
```

Computational Information
    Water surface calculation tolerance = 0.01
    Critical depth calculation tolerance = 0.01

Maximum number of iterations = 20
Maximum difference tolerance = 0.3
Flow tolerance factor = 0.001

Computation Options
Critical depth computed only where necessary
Conveyance Calculation Method: At breaks in n values only
Friction Slope Method: Average Conveyance
Computational Flow Regime: Mixed Flow

FLOW DATA

Flow Title: Penstock Flow
Flow File : o:\Downloads\OneDrive_2026-05-04\Final HEC-RAS (Retaining Wall) use for EOPC1\PenstockWashPropo.f01

Flow Data (cfs)

River	Reach	RS	10-YR	100-YR
Penstock Wash	E Trails End Dr	1488	38	53

Boundary Conditions

River	Reach	Profile	Upstream	Downstream
Penstock Wash	E Trails End Dr	10-YR	Normal S = 0.01875	Normal S = 0.05
Penstock Wash	E Trails End Dr	100-YR	Normal S = 0.01875	Normal S = 0.05

GEOMETRY DATA

Geometry Title: Penstock Wash Geometry
Geometry File : o:\Downloads\OneDrive_2026-05-04\Final HEC-RAS (Retaining Wall) use for EOPC1\PenstockWashPropo.g01

CROSS SECTION

RIVER: Penstock Wash
REACH: E Trails End Dr   RS: 1488

INPUT
Description: Channel CS Above Culvert (11.46)
Station Elevation Data   num=   5

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	6912.13	11.34	6906.46	20	6906.46	26.76	6906.46	37.1	6911.63

Manning's n Values   num=   3

Sta	n Val	Sta	n Val	Sta	n Val
0	.025	0	.025	37.1	.025

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
0	37.1	11.46	18.44	25.09	.1	.3

CROSS SECTION

RIVER: Penstock Wash
REACH: E Trails End Dr   RS: 1477

INPUT
Description: Upstream CS of Double Culvert
Station Elevation Data   num=   7

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	6911	0	6907	4	6905	10	6905	14.5	6905
18.5	6907	18.5	6911						

Manning's n Values   num=   3

Sta	n Val	Sta	n Val	Sta	n Val
0	.025	0	.025	18.5	.025

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
0	18.5	147.36	143.89	134.5	.5	.7

CULVERT

RIVER: Penstock Wash
REACH: E Trails End Dr   RS: 1473

INPUT
Description: Upstream Double Culvert of Highway 89
Distance from Upstream XS =   3
Deck/Roadway Width   =   120
Weir Coefficient   =   2.6
Upstream Deck/Roadway Coordinates
num=   2

Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord

```
       0 6911.69    6905    18.5 6911.19    6905

Upstream Bridge Cross Section Data
Station Elevation Data    num=       7
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0    6911       0    6907       4    6905      10    6905    14.5    6905
    18.5    6907    18.5    6911

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .025       0    .025    18.5    .025

Bank Sta: Left   Right    Coeff Contr.   Expan.
             0    18.5             .5       .7

Downstream  Deck/Roadway Coordinates
    num=       2
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
       0 6908.65 6901.72   59.77 6908.44 6901.72

Downstream Bridge Cross Section Data
Station Elevation Data    num=       6
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0    6905    5.44 6902.28       8 6902.28      10 6902.28   51.31 6902.28
   59.79 6906.52

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   59.79    .025

Bank Sta: Left   Right    Coeff Contr.   Expan.
             0   59.79             .1       .3

Upstream Embankment side slope             =       0 horiz. to 1.0 vertical
Downstream Embankment side slope           =       0 horiz. to 1.0 vertical
Maximum allowable submergence for weir flow =     .98
Elevation at which weir flow begins        =
Energy head used in spillway design        =
Spillway height used in design             =
Weir crest shape                           = Broad Crested

Number of Culverts =  1

Culvert Name     Shape      Rise    Span
Culvert #1      Circular       2       2
FHWA Chart # 1 - Concrete Pipe Culvert
FHWA Scale # 2 - Groove end entrance with headwall
Solution Criteria = Highest U.S. EG
Culvert Upstrm Dist  Length    Top n  Bottom n  Depth Blocked  Entrance Loss Coef
Exit Loss Coef
```

```
                  3     120     .019     .019        0                   .7
      1
Number of Barrels =  2
Upstream   Elevation =  6904.75
Centerline Stations
    Sta.    Sta.
    7.11    13.8
Downstream Elevation =  6902.5
Centerline Stations
    Sta.    Sta.
    7.57   14.26

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1354

INPUT
Description: DS Culvert Cross Section
Station Elevation Data    num=       6
     Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev
       0     6905     5.44 6902.28        8 6902.28       10 6902.28    51.31 6902.28
   59.79 6906.52

Manning's n Values         num=       3
     Sta    n Val      Sta    n Val      Sta    n Val
       0     .015        0     .035    59.79     .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
            0    59.79            26.76   19.44    15.3             .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1345

INPUT
Description: Added XSEC
Station Elevation Data    num=       6
     Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev      Sta     Elev
       0   6903.6     5.28 6900.96        8 6900.96       10 6900.96    49.93 6900.96
   59.77 6905.88

Manning's n Values         num=       3
     Sta    n Val      Sta    n Val      Sta    n Val
       0     .015        0     .035    59.77     .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
```

```
             0   59.77           13.38    9.72    7.65            .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1335

INPUT
Description: 335.67
Station Elevation Data    num=       5
     Sta     Elev     Sta     Elev     Sta     Elev     Sta     Elev     Sta     Elev
       0 6903.68    6.76  6900.3       8  6900.3   50.17  6900.3   60.69 6905.56

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   60.69    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   60.69           11.15   11.56   12.63            .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1329

INPUT
Description: 329.09
Station Elevation Data    num=       5
     Sta     Elev     Sta     Elev     Sta     Elev     Sta     Elev     Sta     Elev
       0 6903.05    7.08 6899.51      20 6899.51    44.8 6899.51   55.81 6905.03

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   55.81    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   55.81            8.26    9.85    11.6            .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1320

INPUT
Description: 320.49
Station Elevation Data    num=       5
     Sta     Elev     Sta     Elev     Sta     Elev     Sta     Elev     Sta     Elev
```

```
       0 6902.51    7.34 6898.84      15 6898.84   31.89 6898.84   43.31 6904.55

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   43.31    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   43.31             6.99    7.02    7.54             .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1313

INPUT
Description: 313.63
Station Elevation Data    num=       5
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6902.13    7.54 6898.36      15 6898.36    28.1 6898.36   39.84 6904.23

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   39.84    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   39.84            10.93   11.58   12.05             .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1302

INPUT
Description: 302.08
Station Elevation Data    num=       5
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6901.57       0 6898.57       2 6897.57   26.42 6897.57   38.74 6903.73

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   38.74    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   38.74              6.5    6.96    7.71             .1       .3

CROSS SECTION
```

```
RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1295

INPUT
Description: 295
295.32
Station Elevation Data    num=       5
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6901.09       0 6898.09       2 6897.09    21.6 6897.09   34.24 6903.41

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   34.24    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   34.24             8.59    8.69    9.18             .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1286

INPUT
Description: 286.78
Station Elevation Data    num=       5
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0  6900.5       0  6897.5       2  6896.5   14.19  6896.5   27.25 6903.03

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   27.25    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   27.25             9.81   10.03   10.46             .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1276

INPUT
Description: 276.92
Station Elevation Data    num=       5
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6899.82       0 6896.82       2 6895.82   14.42 6895.82   27.96 6902.59

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
```

```
       0    .015       0    .035   27.96    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   27.96            11.49   11.27   11.19             .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1265

INPUT
Description: 265.98
Station Elevation Data    num=       5
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6899.75       0  6895.5       2  6894.5   10.55  6894.5   25.79 6902.12

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   25.79    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   25.79             9.47    9.57    9.89             .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1256

INPUT
Description: 256.32 (Upstream CS of PL Culvert)
Station Elevation Data    num=       4
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6899.69       0 6894.44     8.6 6894.44   23.16 6901.72

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   23.16    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   23.16           185.65  184.68  183.68             .5       .7

CULVERT


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1248

INPUT
```

```
Description: Culvert Under Parking Lot
Distance from Upstream XS =     8.9
Deck/Roadway Width        =   167.5
Weir Coefficient          =     2.6
Upstream  Deck/Roadway Coordinates
    num=       2
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
       0 6901.72 6894.44   23.16 6901.72 6894.44

Upstream Bridge Cross Section Data
Station Elevation Data    num=       4
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6899.69       0 6894.44     8.6 6894.44   23.16 6901.72

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   23.16    .025

Bank Sta: Left   Right    Coeff Contr.   Expan.
             0   23.16             .5       .7

Downstream  Deck/Roadway Coordinates
    num=       2
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
       0  6891.5 6885.27   22.59  6891.5 6885.27

Downstream Bridge Cross Section Data
Station Elevation Data    num=       5
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6890.27       0 6887.27       2 6886.27   12.13 6886.27   22.59  6891.5

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   22.59    .025

Bank Sta: Left   Right    Coeff Contr.   Expan.
             0   22.59             .1       .3

Upstream Embankment side slope             =       0 horiz. to 1.0 vertical
Downstream Embankment side slope           =       0 horiz. to 1.0 vertical
Maximum allowable submergence for weir flow =     .98
Elevation at which weir flow begins        =
Energy head used in spillway design        =
Spillway height used in design             =
Weir crest shape                           = Broad Crested

Number of Culverts =  1

Culvert Name     Shape      Rise    Span
Culvert #1      Circular       3       3
```

```
FHWA Chart # 2 - Corrugated Metal Pipe Culvert
FHWA Scale # 1 - Headwall
Solution Criteria = Highest U.S. EG
Culvert Upstrm Dist  Length    Top n  Bottom n  Depth Blocked  Entrance Loss Coef
Exit Loss Coef
                8.9   167.5     .024     .024        0                   .5
      1
Upstream   Elevation =  6894.25
           Centerline Station =  11
Downstream Elevation =  6886.35
           Centerline Station =  11

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1071

INPUT
Description: 71.76
Station Elevation Data    num=       5
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6890.27       0 6887.27       2 6886.27   12.13 6886.27   22.59  6891.5

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   22.59    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   22.59             6.78    8.57   10.15             .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1063

INPUT
Description: 63.24
Station Elevation Data    num=       5
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6889.84       0 6886.84       2 6885.84   13.51 6885.84   22.61 6890.39

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0     .04   22.61    .035

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   22.61            10.66   10.29   10.54             .1       .3
```

```
CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1053

INPUT
Description: 53.03
Station Elevation Data    num=       5
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6889.43       0 6886.43       2 6885.43   10.92 6885.43   19.78 6889.86

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   19.78    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   19.78             6.36    6.22    5.36              .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1046

INPUT
Description: 46.81
Station Elevation Data    num=       5
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6889.12       0 6886.12       2 6885.12    9.68 6885.12   18.62 6889.59

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .035   18.62    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   18.62            19.58   18.72   18.39              .1       .3

CROSS SECTION


RIVER: Penstock Wash
REACH: E Trails End Dr    RS: 1028

INPUT
Description: 28.15
Station Elevation Data    num=       5
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6888.18       0 6885.65       4 6884.65      16 6884.65      20 6888.58
```

```
Manning's n Values         num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0     .05      20    .035

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0      20             8.89    8.61       8              .1       .3
```

CROSS SECTION

RIVER: Penstock Wash
REACH: E Trails End Dr   RS: 1019

INPUT
Description: 19.54

```
Station Elevation Data    num=       5
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6887.32       0 6884.32       4 6883.32      16 6883.32      20 6888.15

Manning's n Values         num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0    .045      20    .035

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0      20             9.08     8.7    8.74              .1       .3
```

CROSS SECTION

RIVER: Penstock Wash
REACH: E Trails End Dr   RS: 1010

INPUT
Description: 10.7109

```
Station Elevation Data    num=       5
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0 6887.32       0 6884.32       6 6883.32      14 6883.32      20 6887.93

Manning's n Values         num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
       0    .015       0     .04      20    .035

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0      20            10.16   10.71   11.57              .1       .3
```

CROSS SECTION

RIVER: Penstock Wash
REACH: E Trails End Dr   RS: 1000

INPUT
Description: Furthest Downstream
Station Elevation Data num= 5

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	6886.89	0	6883.89	6	6882.89	14	6882.89	20	6887.68

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.015	0	.04	20	.035

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
0	20	0	0	0	.1	.3

SUMMARY OF MANNING'S N VALUES

River:Penstock Wash

Reach	River Sta.	n1	n2	n3
E Trails End Dr	1488	.025	.025	.025
E Trails End Dr	1477	.025	.025	.025
E Trails End Dr	1473	Culvert		
E Trails End Dr	1354	.015	.035	.025
E Trails End Dr	1345	.015	.035	.025
E Trails End Dr	1335	.015	.035	.025
E Trails End Dr	1329	.015	.035	.025
E Trails End Dr	1320	.015	.035	.025
E Trails End Dr	1313	.015	.035	.025
E Trails End Dr	1302	.015	.035	.025
E Trails End Dr	1295	.015	.035	.025
E Trails End Dr	1286	.015	.035	.025
E Trails End Dr	1276	.015	.035	.025
E Trails End Dr	1265	.015	.035	.025
E Trails End Dr	1256	.015	.035	.025
E Trails End Dr	1248	Culvert		
E Trails End Dr	1071	.015	.035	.025
E Trails End Dr	1063	.015	.04	.035
E Trails End Dr	1053	.015	.035	.025
E Trails End Dr	1046	.015	.035	.025
E Trails End Dr	1028	.015	.05	.035
E Trails End Dr	1019	.015	.045	.035
E Trails End Dr	1010	.015	.04	.035
E Trails End Dr	1000	.015	.04	.035

SUMMARY OF REACH LENGTHS

River: Penstock Wash

Reach	River Sta.	Left	Channel	Right
E Trails End Dr	1488	11.46	18.44	25.09
E Trails End Dr	1477	147.36	143.89	134.5
E Trails End Dr	1473	Culvert		
E Trails End Dr	1354	26.76	19.44	15.3
E Trails End Dr	1345	13.38	9.72	7.65
E Trails End Dr	1335	11.15	11.56	12.63
E Trails End Dr	1329	8.26	9.85	11.6
E Trails End Dr	1320	6.99	7.02	7.54
E Trails End Dr	1313	10.93	11.58	12.05
E Trails End Dr	1302	6.5	6.96	7.71
E Trails End Dr	1295	8.59	8.69	9.18
E Trails End Dr	1286	9.81	10.03	10.46
E Trails End Dr	1276	11.49	11.27	11.19
E Trails End Dr	1265	9.47	9.57	9.89
E Trails End Dr	1256	185.65	184.68	183.68
E Trails End Dr	1248	Culvert		
E Trails End Dr	1071	6.78	8.57	10.15
E Trails End Dr	1063	10.66	10.29	10.54
E Trails End Dr	1053	6.36	6.22	5.36
E Trails End Dr	1046	19.58	18.72	18.39
E Trails End Dr	1028	8.89	8.61	8
E Trails End Dr	1019	9.08	8.7	8.74
E Trails End Dr	1010	10.16	10.71	11.57
E Trails End Dr	1000	0	0	0

SUMMARY OF CONTRACTION AND EXPANSION COEFFICIENTS
River: Penstock Wash

Reach	River Sta.	Contr.	Expan.
E Trails End Dr	1488	.1	.3
E Trails End Dr	1477	.5	.7
E Trails End Dr	1473	Culvert	
E Trails End Dr	1354	.1	.3
E Trails End Dr	1345	.1	.3
E Trails End Dr	1335	.1	.3
E Trails End Dr	1329	.1	.3
E Trails End Dr	1320	.1	.3
E Trails End Dr	1313	.1	.3
E Trails End Dr	1302	.1	.3

E Trails End Dr	1295		.1	.3
E Trails End Dr	1286		.1	.3
E Trails End Dr	1276		.1	.3
E Trails End Dr	1265		.1	.3
E Trails End Dr	1256		.5	.7
E Trails End Dr	1248	Culvert		
E Trails End Dr	1071		.1	.3
E Trails End Dr	1063		.1	.3
E Trails End Dr	1053		.1	.3
E Trails End Dr	1046		.1	.3
E Trails End Dr	1028		.1	.3
E Trails End Dr	1019		.1	.3
E Trails End Dr	1010		.1	.3
E Trails End Dr	1000		.1	.3

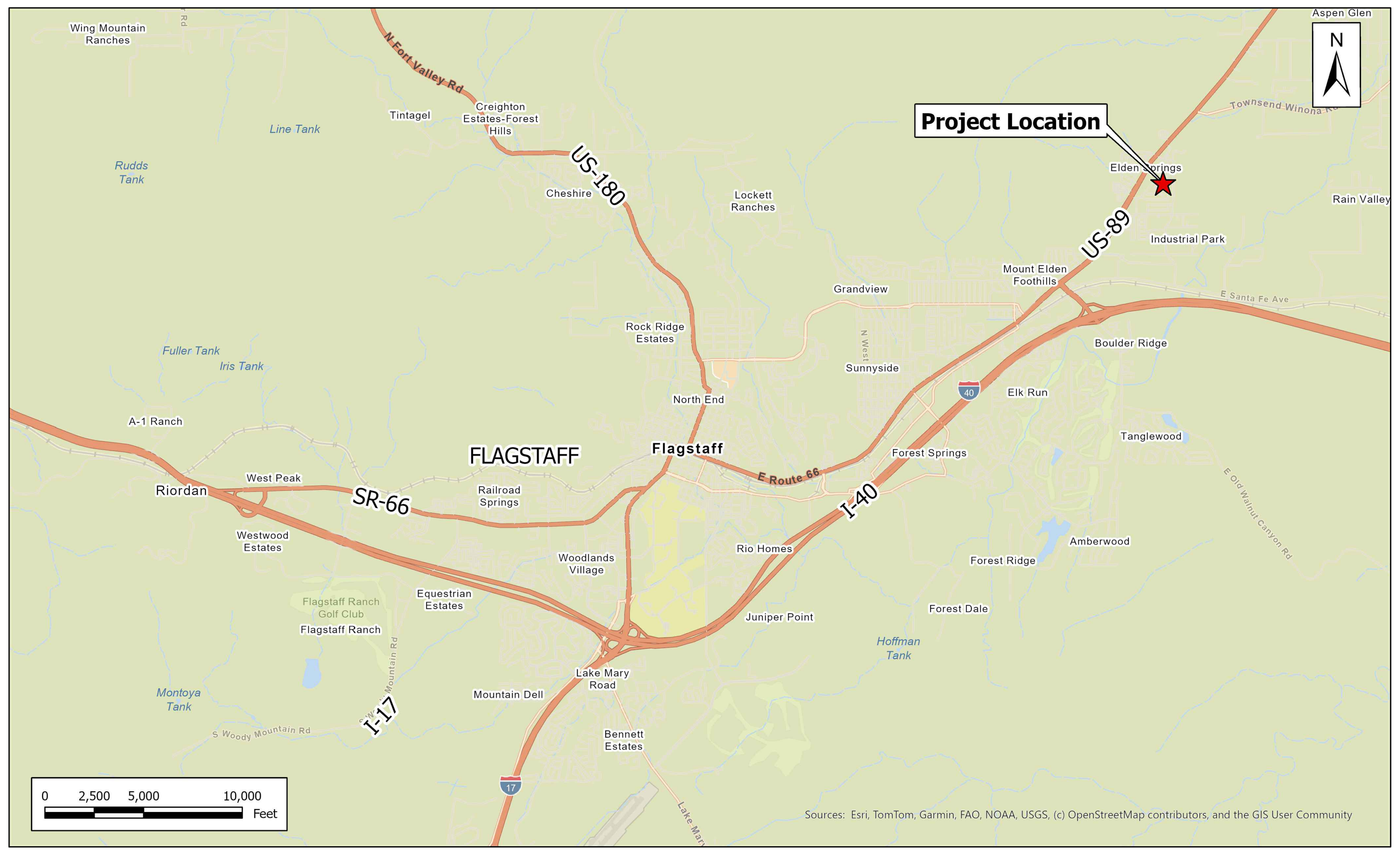
Appendix E: Plan Set Details

REDESIGN OF PENSTOCK WASH FOR THE SMOKERISE NEIGHBORHOOD

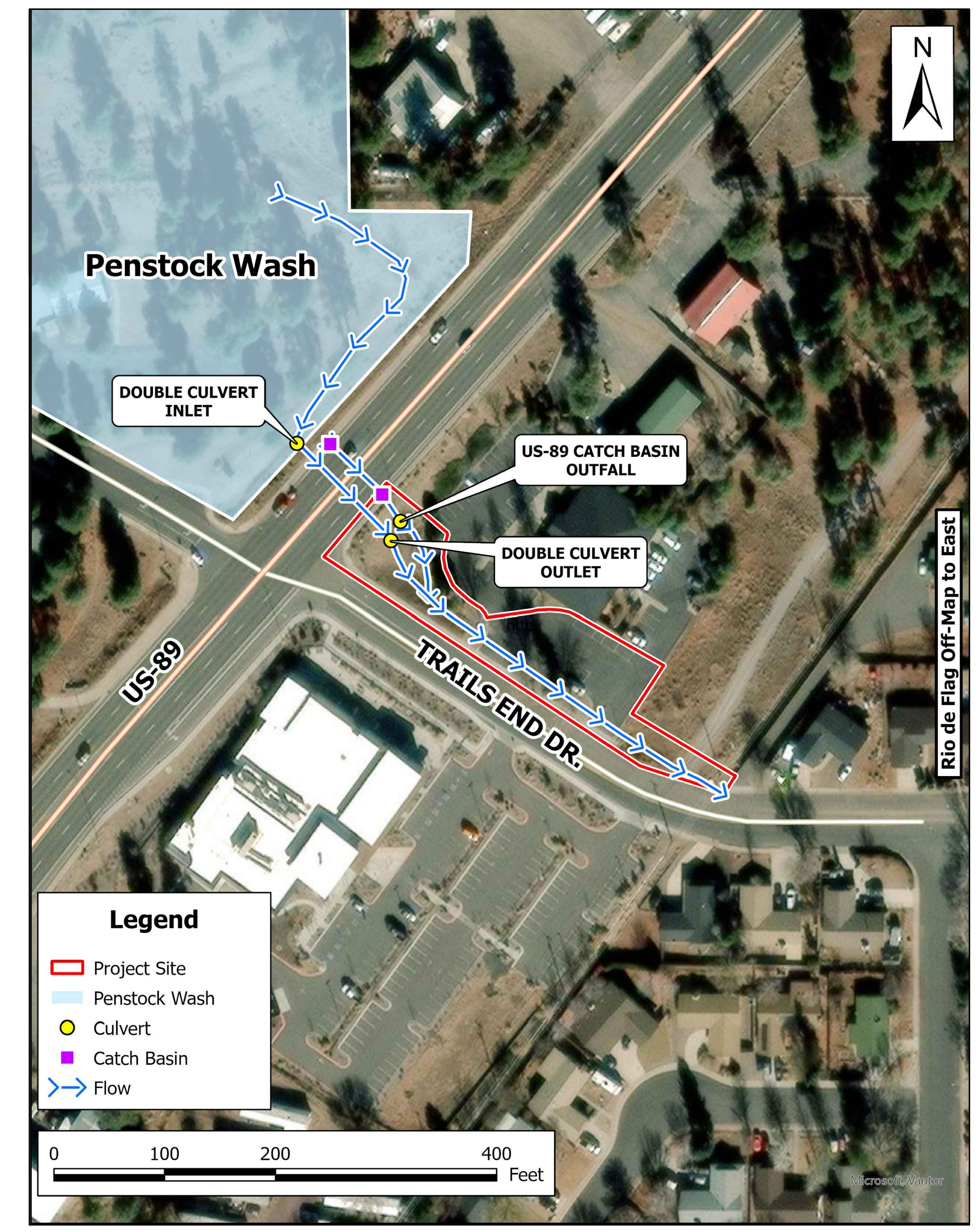
AGUA JACKS

NORTHERN ARIZONA UNIVERSITY

PROJECT VICINITY MAP



SITE MAP



INDEX OF SHEETS
1 COVER SHEET
2 GENERAL NOTES
3 TOPOGRAPHIC MAP
4 EXISTING MAP
5 PROPOSED MAP
6 FLOODPLAIN MAP
7 GENERAL DETAILS
8 CULVERT DESIGN

PREPARED FOR:

CITY OF FLAGSTAFF–STORMWATER DIVISION
CHASE MCLEOD, STORMWATER ENGINEER

DESIGN STANDARDS:

CITY OF FLAGSTAFF STORMWATER DESIGN MANUAL
FEMA FLOODPLAIN MANAGEMENT REGULATIONS
NRCS TR–55

PROJECT OBJECTIVE:

THE OBJECTIVE OF THIS PROJECT IS TO REDUCE FLOODING IMPACTS IN THE SMOKERISE NEIGHBORHOOD BY EVALUATING AND REDESIGNING PENSTOCK WASH IN COMPLIANCE WITH CITY OF FLAGSTAFF AND FEMA STANDARDS.

CREATED BY:	QY	COVER SHEET	SHEET NUMBER:	01
CHECKED BY:	MJB		TOTAL SHEET NUMBER:	08
DATE:	05/2026			
PROJECT:	SMOKERISE			

FEET
00 00 00 00 00

N

AGUA JACKS WATER MANAGEMENT

SECTION 13–06–007 GENERAL NOTES

A. GENERAL

1. APPROVAL OF THESE PLANS BY THE CITY OF FLAGSTAFF IS VALID FOR ONE (1) YEAR. IF CONSTRUCTION IS NOT INITIATED WITHIN THIS PERIOD, PLANS SHALL BE RESUBMITTED FOR REVIEW.

2. ALL WORK SHALL CONFORM TO THE CITY OF FLAGSTAFF STORMWATER MANAGEMENT DESIGN MANUAL (2025) AND APPLICABLE LOCAL, STATE, AND FEDERAL REGULATIONS.

3. THE CONTRACTOR SHALL OBTAIN ALL REQUIRED PERMITS PRIOR TO CONSTRUCTION.

4. THE CONTRACTOR SHALL NOTIFY THE CITY ENGINEER AT LEAST 24 HOURS PRIOR TO START OF CONSTRUCTION.

5. ALL MATERIALS AND WORKMANSHIP SHALL MEET ASTM, AASHTO, AND CITY STANDARDS.

6. THE CONTRACTOR SHALL LOCATE AND PROTECT ALL EXISTING UTILITIES. CALL ARIZONA 811 PRIOR TO EXCAVATION.

7. THE CONTRACTOR SHALL MAINTAIN TRAFFIC CONTROL IN ACCORDANCE WITH MUTCD.

8. ANY DAMAGE TO EXISTING IMPROVEMENTS SHALL BE REPAIRED AT THE CONTRACTOR'S EXPENSE.

B. SITE CONDITIONS

9. THE CONTRACTOR SHALL VERIFY ALL FIELD CONDITIONS AND DIMENSIONS PRIOR TO CONSTRUCTION.

10. EXISTING DRAINAGE PATTERNS SHALL BE MAINTAINED UNLESS OTHERWISE APPROVED.

11. ALL SEDIMENT, VEGETATION, AND DEBRIS SHALL BE REMOVED FROM CHANNELS AND CULVERTS PRIOR TO INSTALLATION OF IMPROVEMENTS.

12. ALL DISTURBED AREAS SHALL BE STABILIZED AFTER CONSTRUCTION.

C. DRAINAGE AND CULVERT DESIGN

13. PROVIDE 18–INCH DIAMETER CULVERT PIPE AT GRAVEL ROAD CROSSING.

14. PROVIDE MINIMUM 6–INCH CONCRETE COVER ABOVE CULVERT PIPE.

15. CULVERT SHALL BE INSTALLED WITH PROPER BEDDING, BACKFILL, AND COMPACTION PER CITY STANDARDS.

16. DRAINAGE IMPROVEMENTS ARE DESIGNED TO INCREASE FLOW CONVEYANCE AND REDUCE ROADWAY FLOODING.

17. CHANNEL GRADING MAY BE REQUIRED TO DIRECT FLOW INTO CULVERT.

18. DESIGN SHALL ACCOMMODATE 10–YEAR AND 100–YEAR STORM EVENTS.

D. EROSION CONTROL

19. IMPLEMENT EROSION AND SEDIMENT CONTROL MEASURES PER ADEQ AND CITY REQUIREMENTS.

20. INSTALL AND MAINTAIN BEST MANAGEMENT PRACTICES (BMPS) DURING CONSTRUCTION.

21. STABILIZE DISTURBED AREAS USING APPROVED METHODS.

E. CONSTRUCTION

22. CONSTRUCTION STAKING SHALL BE PERFORMED BY A QUALIFIED SURVEYOR OR ENGINEER.

23. DISPOSE OF EXCESS MATERIALS IN ACCORDANCE WITH LOCAL REGULATIONS.

24. TEMPORARY ACCESS AND STAGING SHALL COMPLY WITH CITY REQUIREMENTS.

25. MINIMIZE IMPACTS TO TRAFFIC AND NEARBY RESIDENTS.

F. FINAL ACCEPTANCE

26. FINAL ACCEPTANCE SHALL BE SUBJECT TO CITY ENGINEER APPROVAL.

27. ALL DEFICIENCIES SHALL BE CORRECTED PRIOR TO FINAL ACCEPTANCE.

CREATED BY:	QY
CHECKED BY:	MJB
DATE:	05/2026
PROJECT:	SMOKERISE

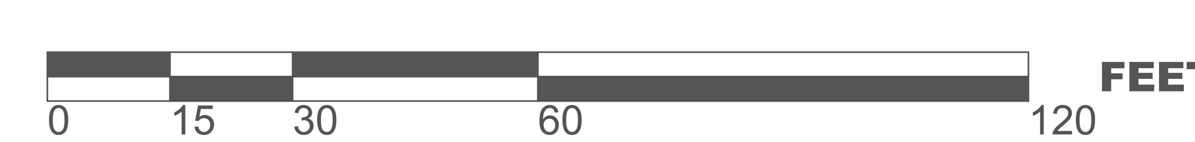
GENERAL NOTES

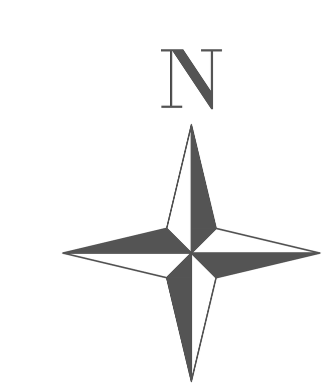
SHEET NUMBER:	02
TOTAL SHEET NUMBER:	08

00 00 00 00 00 FEET

N

CREATED BY:	QY	TOPOGRAPHIC MAP	SHEET NUMBER:	03
CHECKED BY:	MJB		TOTAL SHEET NUMBER:	08
DATE:	05/2026			
PROJECT:	SMOKERISE			





AGUA JACKS WATER MANAGEMENT

CREATED BY:	QY	EXISTING SITE	SHEET NUMBER:	04
CHECKED BY:	MJB		TOTAL SHEET NUMBER:	08
DATE:	05/2026			
PROJECT:	SMOKERISE			

0 15 30 60 120 FEET

N

AGUA JACKS WATER MANAGEMENT

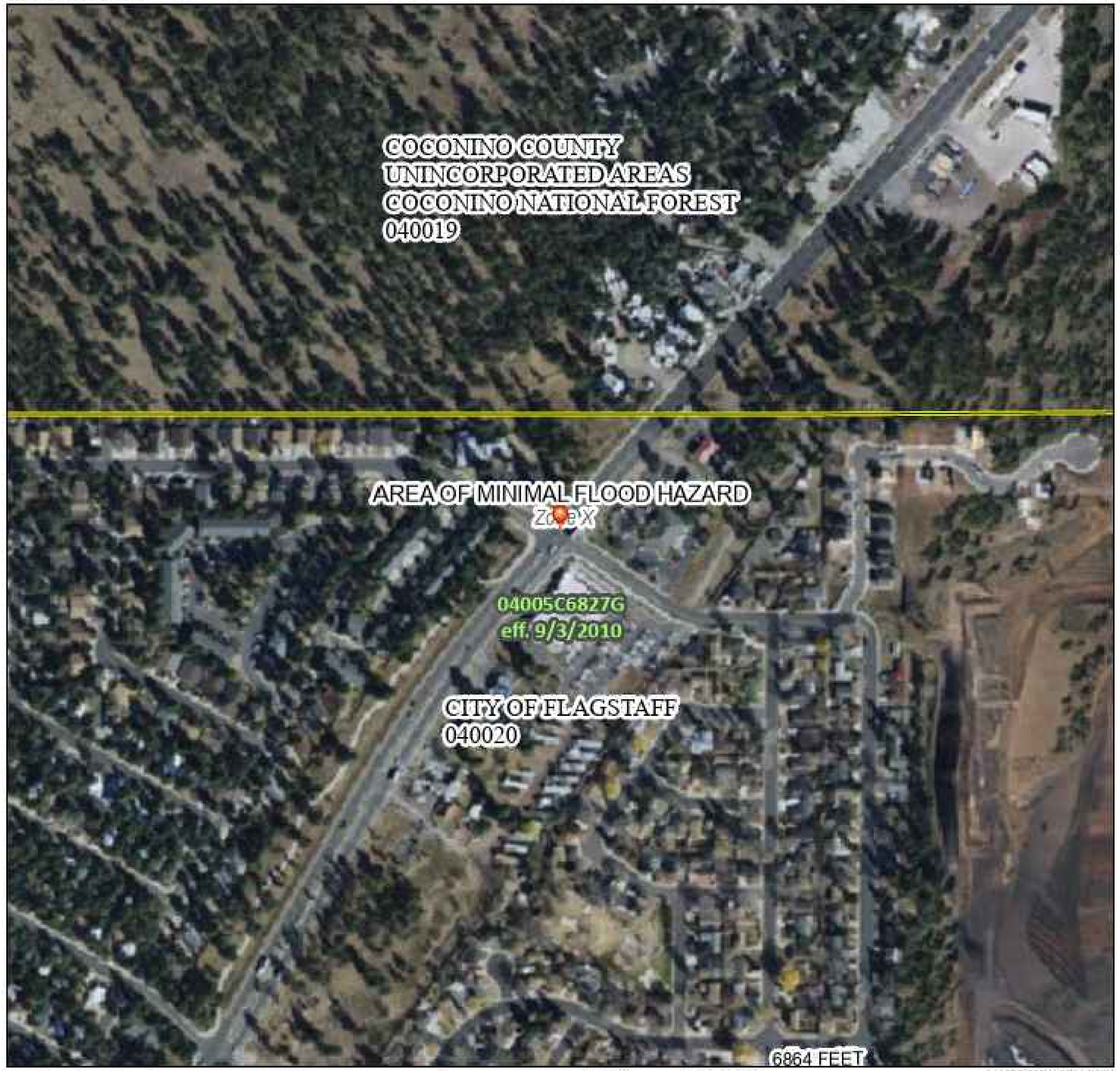
CREATED BY:	QY	PROPOSED SITE	SHEET NUMBER:	05	N
CHECKED BY:	MJB		TOTAL SHEET NUMBER:	08	
DATE:	05/2026		0 15 30 60 120 FEET		
PROJECT:	SMOKERISE				

AGUA JACKS WATER MANAGEMENT

National Flood Hazard Layer FIRMette

FEMA

111°34'36"W 35°14'35"N



111°33'59"W 35°14'6"N

Feet: 0 | 250 | 500 | 1,000 | 1,500 | 2,000

1:6,000

Basemap Imagery Source: USGS National Map 2023

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS	Without Base Flood Elevation (BFE) *Zone A, V, A99*
	With BFE or Depth *Zone AE, AO, AH, VE, AR*
	Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD	0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
	Future Conditions 1% Annual Chance Flood Hazard *Zone X*
	Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
	Area with Flood Risk due to Levee *Zone D*
OTHER AREAS	NO SCREEN Area of Minimal Flood Hazard *Zone X*
	Effective LOMRs
	Area of Undetermined Flood Hazard *Zone D*
GENERAL STRUCTURES	Channel, Culvert, or Storm Sewer
	Levee, Dike, or Floodwall
OTHER FEATURES	20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
	Coastal Transect
	Base Flood Elevation Line (BFE)
	Limit of Study
	Jurisdiction Boundary
	Coastal Transect Baseline
	Profile Baseline
	Hydrographic Feature
MAP PANELS	Digital Data Available
	No Digital Data Available
	Unmapped

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 5/5/2026 at 6:43 AM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

CREATED BY:	QY	FEMA Floodplain	SHEET NUMBER:	06
CHECKED BY:	MJB		TOTAL SHEET NUMBER:	08
DATE:	05/2026			
PROJECT:	SMOKERISE			

0 | 00 | 00 | 00 | 00 FEET

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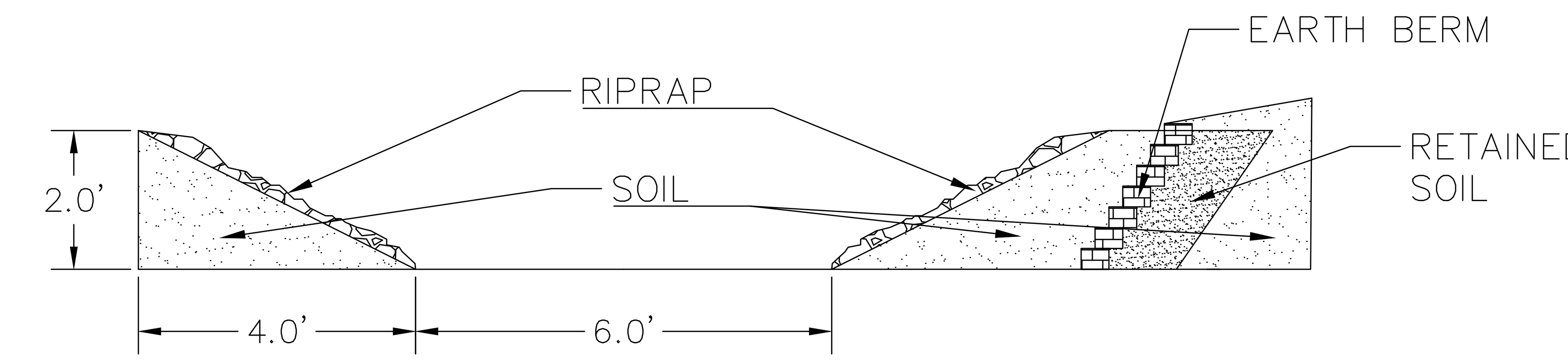
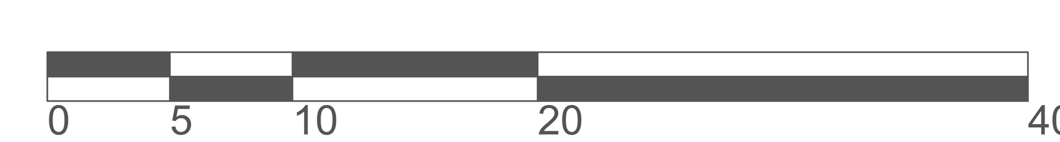
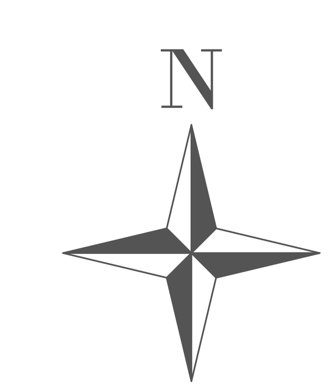
AGUA JACKS WATER MANAGEMENT

EARTH BERM



CREATED BY:	QY	DESIGN DETAILS	SHEET NUMBER:	07	
CHECKED BY:	MJB		TOTAL SHEET NUMBER:	08	
DATE:	05/2026				
PROJECT:	SMOKERISE				

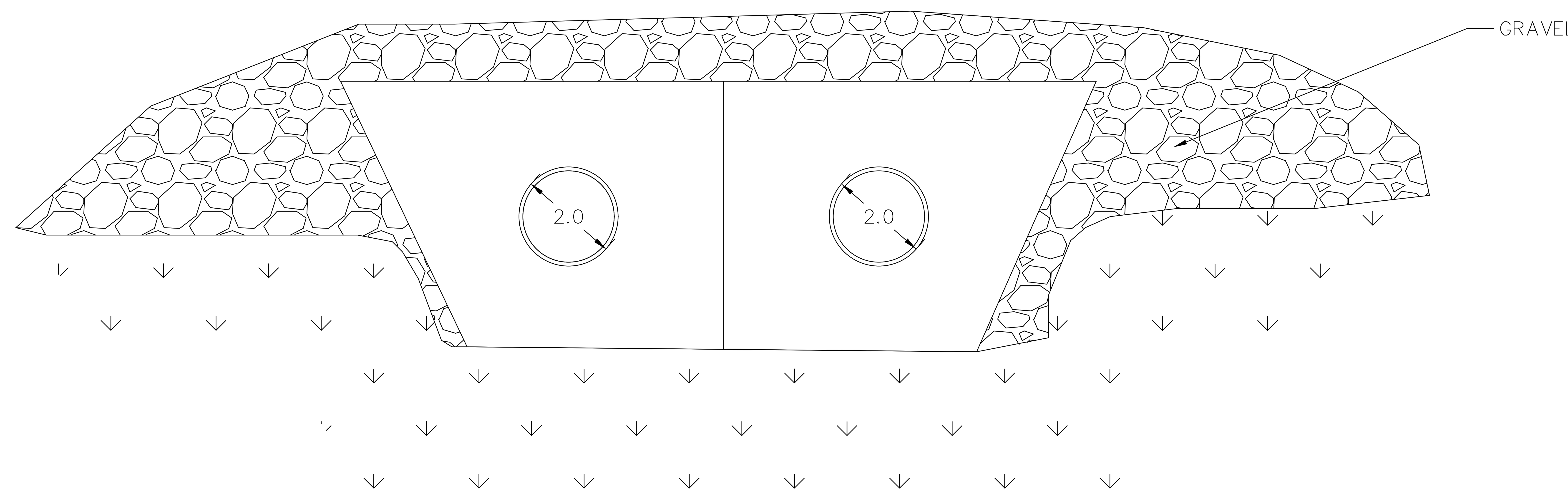




AGUA JACKS WATER MANAGEMENT

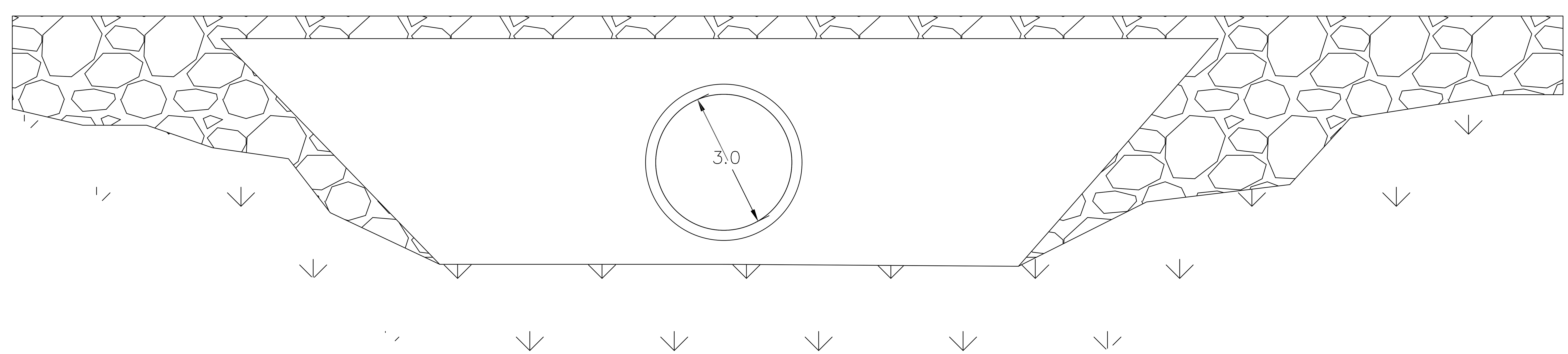
HIGHWAY 89 CULVERT (DOUBLE CIRCULAR CULVERT)

HWY 89 CULVERT	
LENGTH	120'-0"
MANNING N	0.0190
INLET ELEV	6904.7500
OUTLET ELEV	6902.5000
DIAMETER	2*2.0



PARKING LOT CULVERT (SINGLE CIRCULAR CULVERT)

PARKING LOT CULVERT	
LENGTH	167.5000
MANNING N	0.0240
INLET ELEV	6894.2500
OUTLET ELEV	6886.3500
DIAMETER	3.0



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CHECKED BY:	MJB		TOTAL SHEET NUMBER:	08
DATE:	05/2026			
PROJECT:	SMOKERISE			

0 5 10 20 40 FEET

N

AGUA JACKS WATER MANAGEMENT

CREATED BY:	QY	ALTERNATIVE 1 PLAN VIEW	SHEET NUMBER:	A1
CHECKED BY:	MJB		TOTAL SHEET NUMBER:	A3
DATE:	05/2026		0 15 30 60 120 FEET	
PROJECT:	SMOKERISE			

N

CREATED BY:	QY	ALTERNATIVE 2 PLAN VIEW	SHEET NUMBER:	A2
CHECKED BY:	MJB		TOTAL SHEET NUMBER:	A3
DATE:	05/2026			
PROJECT:	SMOKERISE			

FEET 0 15 30 60 120

N

AGUA JACKS WATER MANAGEMENT

CREATED BY:	QY	ALTERNATIVE 3 PLAN VIEW	SHEET NUMBER:	A3	N	AGUA JACKS WATER MANAGEMENT
CHECKED BY:	MJB		TOTAL SHEET NUMBER:	A3		
DATE:	05/2026		0 15 30 60 120 FEET			
PROJECT:	SMOKERISE					

Appendix F: Project Schedule & Hours Log

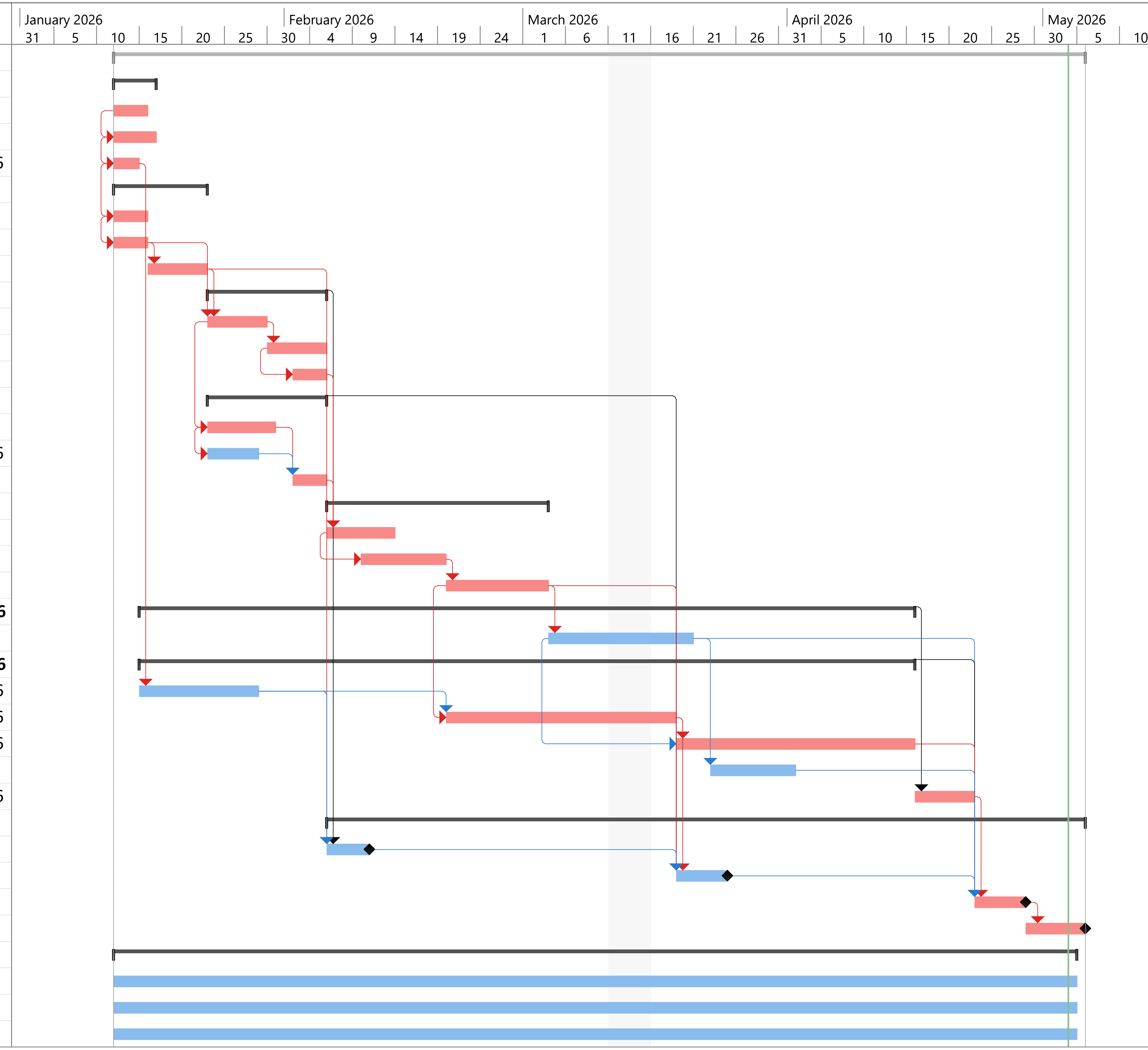
Table F- 1: Proposed Hours Log

Task	PE (hrs)	PrE (hrs)	EIT (hrs)	INT (hrs)	Task Total
Task 1: Due Diligence (Total hrs)	**0**	**9**	**18**	**30**	**57**
1.1 Identify Existing Issues	0	3	6	5	14
1.2 Records Review	0	3	6	10	19
1.3 Research Existing Topo	0	3	6	15	24
Task 2: Site Investigation (Total hrs)	**0**	**12**	**24**	**13**	**49**
2.1 Document Existing Conditions	0	4	8	4	16
2.2 Surveying	0	4	8	4	16
2.3 Data Analysis and Mapping	0	4	8	5	17
Task 3: Hydrologic Analysis (Total hrs)	**7**	**17**	**25**	**9**	**58**
3.1 Watershed Delineation	2	7	15	3	27
3.2 Time of Concentration (Tc) Analysis	3	5	5	3	16
3.3 Design Storm Modeling (HEC-HMS)	2	5	5	3	15
Task 4: Hydraulic Analysis - Existing (Total hrs)	**7**	**21**	**35**	**12**	**75**
4.1 Culvert Analysis	2	7	10	4	23
4.2 Channel Analysis	3	7	15	4	29
4.3 Deficiency Identification	2	7	10	4	23
Task 5: Alternatives Development (Total hrs)	**6**	**15**	**20**	**9**	**50**
5.1 Identify Constraints and Criteria	2	5	10	3	20
5.2 Develop Conceptual Alternatives	2	5	5	3	15
5.3 Select Best Alternative	2	5	5	3	15
Task 6: Final Design (Total hrs)	**15**	**28**	**45**	**15**	**103**
6.1 Final Hydraulic Design	5	8	10	3	26
6.2 Plan Set Creation (Total hrs)	7	15	30	9	61
6.2.1 Cover Sheet & Existing Site Plan	2	5	10	3	20
6.2.2 Proposed Site Plan	2	5	10	3	20
6.2.3 Detailed Design Drawings	3	5	10	3	21
6.3 Construction Cost Estimate (EOPC)	3	5	5	3	16
Task 7: Impacts Analysis (Total hrs)	**0**	**7**	**4**	**4**	**15**
Task 8: Deliverables (Total hrs)	**8**	**32**	**40**	**20**	**100**
8.1 30% Deliverable	2	8	10	5	25
8.2 60% Deliverable	2	8	10	5	25
8.3 90% Deliverable	2	8	10	5	25
8.4 Final Deliverable	2	8	10	5	25
Task 9: Project Management (Total hrs)	**20**	**44**	**20**	**20**	**104**
9.1 Schedule Management	0	12	0	0	12
9.2 Resource & Budget Management	0	12	0	0	12
9.3 Meetings & Quality Assurance	20	20	20	20	80
Total hours	**63**	**185**	**231**	**132**	**611**

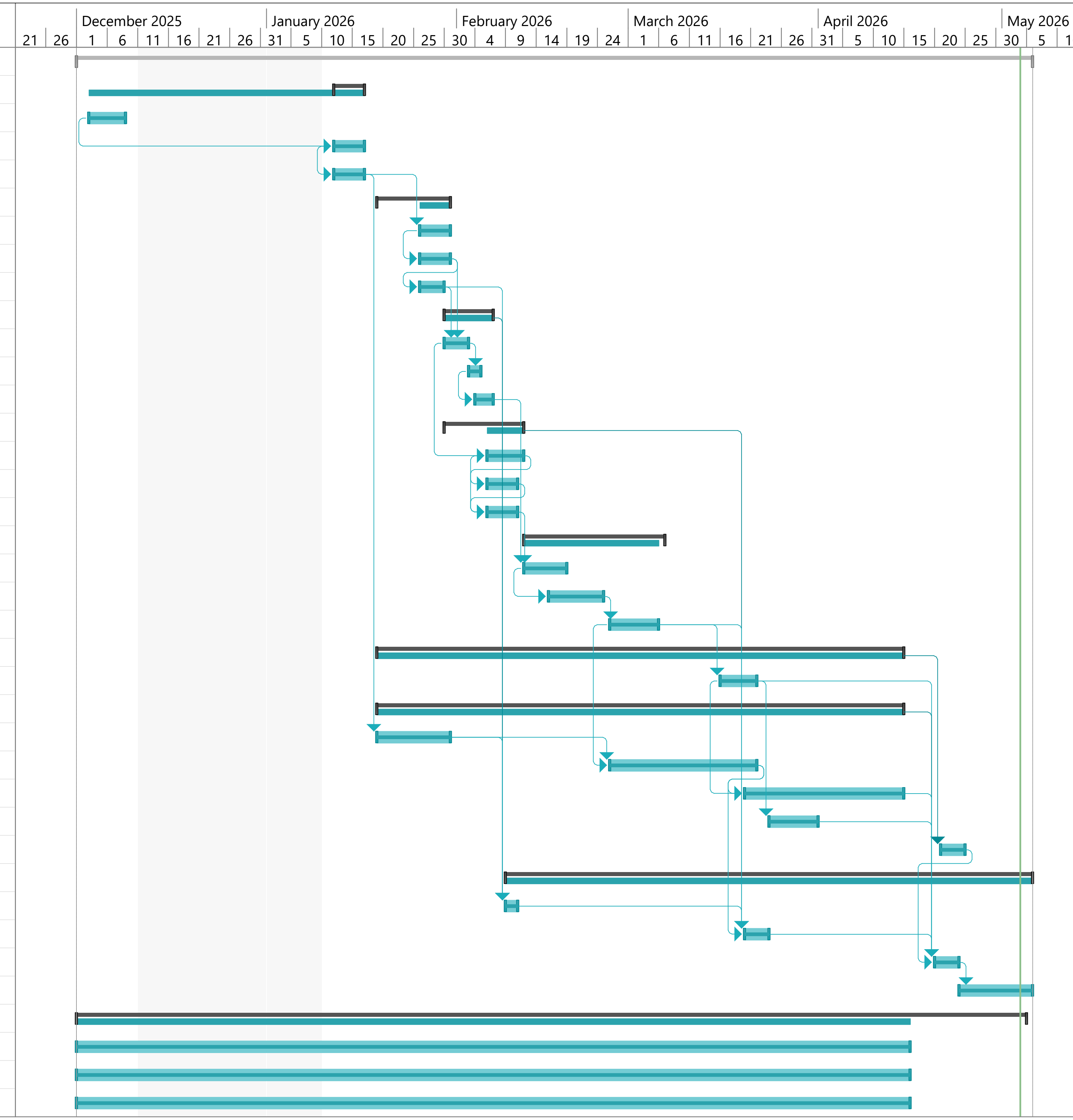
Table F- 2: Actual Hours Log

Task	PE (hrs)	PrE (hrs)	EIT (hrs)	INT (hrs)	Task Total
Task 1: Due Diligence (Total hrs)	**0**	**18**	**25**	**21**	**64**
1.1 Identify Existing Issues	0	7	11	7	25
1.2 Records Review	0	6	9	7	22
1.3 Research Existing Topo	0	5	5	7	17
Task 2: Site Investigation (Total hrs)	**0**	**25**	**23**	**13**	**61**
2.1 Document Existing Conditions	0	5	5	4	14
2.2 Surveying	0	12	10	5	27
2.3 Data Analysis and Mapping	0	8	8	4	20
Task 3: Hydrologic Analysis (Total hrs)	**7**	**13**	**31**	**10**	**61**
3.1 Watershed Delineation	3	6	16	1	26
3.2 Time of Concentration (Tc) Analysis	3	5	9	6	23
3.3 Design Storm Modeling (HEC-HMS)	1	2	6	3	12
Task 4: Hydraulic Analysis - Existing (Total hrs)	**6**	**19**	**34**	**20**	**79**
4.1 Culvert Analysis	1	6	10	5	22
4.2 Channel Analysis	3	6	14	7	30
4.3 Deficiency Identification	2	7	10	8	27
Task 5: Alternatives Development (Total hrs)	**2**	**31**	**44**	**20**	**97**
5.1 Identify Constraints and Criteria	2	7	10	5	24
5.2 Develop Conceptual Alternatives	0	14	27	8	49
5.3 Select Best Alternative	0	10	7	7	24
Task 6: Final Design (Total hrs)	**14**	**25**	**50**	**16**	**105**
6.1 Final Hydraulic Design	7	4	11	3	25
6.2 Plan Set Creation (Total hrs)	6	16	31	11	64
6.2.1 Cover Sheet & Existing Site Plan	3	5	10	6	24
6.2.2 Proposed Site Plan	2	3	8	3	16
6.2.3 Detailed Design Drawings	1	8	8	2	19
6.3 Construction Cost Estimate (EOPC)	1	5	8	2	16
Task 7: Impacts Analysis (Total hrs)	0	0	0	0	0
Task 8: Deliverables (Total hrs)	**17**	**26**	**44**	**35**	**122**
8.1 30% Deliverable	6	9	15	11	41
8.2 60% Deliverable	4	9	9	7	29
8.3 90% Deliverable	3	2	10	12	27
8.4 Final Deliverable	4	6	10	5	25
Task 9: Project Management (Total hrs)	**12**	**31**	**11**	**11**	**65**
9.1 Schedule Management	0	10	0	0	10
9.2 Resource & Budget Management	0	10	0	0	10
9.3 Meetings & Quality Assurance	12	11	11	11	45
Total hours	**58**	**188**	**262**	**146**	**654**

ID	Task Name	Duration	Start	Finish
0	**Penstock Wash Project Schedule**	**77 days**	**Mon 1/12/2(**	**Tue 5/5/26**
1	**Task 1: Due Diligence**	**5 days**	**Mon 1/12/26**	**Fri 1/16/26**
2	1.1 Identify Existing Issues	4 days	Mon 1/12/26	Thu 1/15/26
3	1.2 Records Review	5 days	Mon 1/12/26	Fri 1/16/26
4	1.3 Research Existing Topo	3 days	Mon 1/12/26	Wed 1/14/26
5	**Task 2: Site Investigation**	**9 days**	**Mon 1/12/26**	**Thu 1/22/26**
6	2.1 Document Existing Conditions	4 days	Mon 1/12/26	Thu 1/15/26
7	2.2 Surveying	4 days	Mon 1/12/26	Thu 1/15/26
8	2.3 Data Analysis and Mapping	5 days	Fri 1/16/26	Thu 1/22/26
9	**Task 3: Hydrologic Analysis**	**10 days**	**Fri 1/23/26**	**Thu 2/5/26**
10	3.1 Watershed Delineation	5 days	Fri 1/23/26	Thu 1/29/26
11	3.2 Time of Concentration (Tc) Analysis	5 days	Fri 1/30/26	Thu 2/5/26
12	3.3 Design Storm Modeling (HEC-HMS)	4 days	Mon 2/2/26	Thu 2/5/26
13	**Task 4: Hydraulic Analysis - Existing**	**10 days**	**Fri 1/23/26**	**Thu 2/5/26**
14	4.1 Culvert Analysis	6 days	Fri 1/23/26	Fri 1/30/26
15	4.2 Channel Analysis	4 days	Fri 1/23/26	Wed 1/28/26
16	4.3 Deficiency Identification	4 days	Mon 2/2/26	Thu 2/5/26
17	**Task 5: Alternatives Development**	**18 days**	**Fri 2/6/26**	**Tue 3/3/26**
18	5.1 Identify Constraints and Criteria	6 days	Fri 2/6/26	Fri 2/13/26
19	5.2 Develop Conceptual Alternatives	8 days	Tue 2/10/26	Thu 2/19/26
20	5.3 Select Best Alternative	8 days	Fri 2/20/26	Tue 3/3/26
21	**Task 6: Final Design**	**60 days**	**Thu 1/15/26**	**Wed 4/15/26**
22	6.1 Final Hydraulic Design	8 days	Wed 3/4/26	Fri 3/20/26
23	**6.2 Plan Set Creation**	**60 days**	**Thu 1/15/26**	**Wed 4/15/26**
24	6.2.1 Cover Sheet & Existing Site Plan	10 days	Thu 1/15/26	Wed 1/28/26
25	6.2.2 Proposed Site Plan	14 days	Fri 2/20/26	Wed 3/18/26
26	6.2.3 Detailed Design Drawings	20 days	Thu 3/19/26	Wed 4/15/26
27	6.3 Construction Cost Estimate (EOPC)	8 days	Mon 3/23/26	Wed 4/1/26
28	Task 7: Impacts Analysis	5 days	Thu 4/16/26	Wed 4/22/26
29	**Task 8: Deliverables**	**58 days**	**Fri 2/6/26**	**Tue 5/5/26**
30	8.1 30% Deliverable	3 days	Fri 2/6/26	Tue 2/10/26
31	8.2 60% Deliverable	4 days	Thu 3/19/26	Tue 3/24/26
32	8.3 90% Deliverable	4 days	Thu 4/23/26	Tue 4/28/26
33	8.4 Final Deliverable	5 days	Wed 4/29/26	Tue 5/5/26
34	**Task 9: Project Management**	**76 days**	**Mon 1/12/26**	**Mon 5/4/26**
35	9.1 Schedule Management	76 days	Mon 1/12/26	Mon 5/4/26
36	9.2 Resource & Budget Management	76 days	Mon 1/12/26	Mon 5/4/26
37	9.3 Meetings & Quality Assurance	76 days	Mon 1/12/26	Mon 5/4/26



ID		Task Name	Duration	Start	Finish	% Complete
0	✓	**Penstock Wash Project Schedule**	**90 days**	**Mon 12/1/25**	**Tue 5/5/26**	**100%**
1	✓	**Task 1: Due Diligence**	**4 days**	**Mon 1/12/26**	**Fri 1/16/26**	**100%**
2	✓	1.1 Identify Existing Issues	4 days	Wed 12/3/25	Mon 12/8/25	100%
3	✓	1.2 Records Review	5 days	Mon 1/12/26	Fri 1/16/26	100%
4	✓	1.3 Research Existing Topo	5 days	Mon 1/12/26	Fri 1/16/26	100%
5	✓	**Task 2: Site Investigation**	**10 days**	**Mon 1/19/26**	**Fri 1/30/26**	**100%**
6	✓	2.1 Document Existing Conditions	5 days	Mon 1/26/26	Fri 1/30/26	100%
7	✓	2.2 Surveying	5 days	Mon 1/26/26	Fri 1/30/26	100%
8	✓	2.3 Data Analysis and Mapping	4 days	Mon 1/26/26	Thu 1/29/26	100%
9	✓	**Task 3: Hydrologic Analysis**	**6 days**	**Fri 1/30/26**	**Fri 2/6/26**	**100%**
10	✓	3.1 Watershed Delineation	2 days	Fri 1/30/26	Mon 2/2/26	100%
11	✓	3.2 Time of Concentration (Tc) Analysis	2 days	Tue 2/3/26	Wed 2/4/26	100%
12	✓	3.3 Design Storm Modeling (HEC-HMS)	3 days	Wed 2/4/26	Fri 2/6/26	100%
13	✓	**Task 4: Hydraulic Analysis - Existing**	**10 days**	**Fri 1/30/26**	**Wed 2/11/26**	**100%**
14	✓	4.1 Culvert Analysis	5 days	Fri 2/6/26	Wed 2/11/26	100%
15	✓	4.2 Channel Analysis	4 days	Fri 2/6/26	Tue 2/10/26	100%
16	✓	4.3 Deficiency Identification	4 days	Fri 2/6/26	Tue 2/10/26	100%
17	✓	**Task 5: Alternatives Development**	**20 days**	**Thu 2/12/26**	**Fri 3/6/26**	**100%**
18	✓	5.1 Identify Constraints and Criteria	6 days	Thu 2/12/26	Wed 2/18/26	100%
19	✓	5.2 Develop Conceptual Alternatives	8 days	Mon 2/16/26	Tue 2/24/26	100%
20	✓	5.3 Select Best Alternative	7 days	Thu 2/26/26	Thu 3/5/26	100%
21	✓	**Task 6: Final Design**	**64 days**	**Mon 1/19/26**	**Tue 4/14/26**	**100%**
22	✓	6.1 Final Hydraulic Design	6 days	Mon 3/16/26	Sat 3/21/26	100%
23	✓	**6.2 Plan Set Creation**	**64 days**	**Mon 1/19/26**	**Tue 4/14/26**	**100%**
24	✓	6.2.1 Cover Sheet & Existing Site Plan	10 days	Mon 1/19/26	Fri 1/30/26	100%
25	✓	6.2.2 Proposed Site Plan	16 days	Thu 2/26/26	Sat 3/21/26	100%
26	✓	6.2.3 Detailed Design Drawings	19 days	Fri 3/20/26	Tue 4/14/26	100%
27	✓	6.3 Construction Cost Estimate (EOPC)	6 days	Tue 3/24/26	Tue 3/31/26	100%
28	✓	Task 7: Impacts Analysis	4 days	Tue 4/21/26	Fri 4/24/26	100%
29	✓	**Task 8: Deliverables**	**63 days**	**Mon 2/9/26**	**Tue 5/5/26**	**100%**
30	✓	8.1 30% Deliverable	2 days	Mon 2/9/26	Tue 2/10/26	100%
31	✓	8.2 60% Deliverable	3 days	Fri 3/20/26	Mon 3/23/26	100%
32	✓	8.3 90% Deliverable	4 days	Mon 4/20/26	Thu 4/23/26	100%
33	✓	8.4 Final Deliverable	8 days	Fri 4/24/26	Tue 5/5/26	100%
34	✓	**Task 9: Project Management**	**89 days**	**Mon 12/1/25**	**Mon 5/4/26**	**100%**
35	✓	9.1 Schedule Management	76 days	Mon 12/1/25	Wed 4/15/26	100%
36	✓	9.2 Resource & Budget Management	76 days	Mon 12/1/25	Wed 4/15/26	100%
37	✓	9.3 Meetings & Quality Assurance	76 days	Mon 12/1/25	Wed 4/15/26	100%



Appendix G: Full EOPC Breakdown

Table G- 1: Material Costs

Site Setup					
Description	**Unit**	**Qty**	**Unit Cost**	**Total**	**Source**
Mobilization / Demobilization	LS	1	$25,000	$25,000	RSMeans (Heavy Civil, 2024)
Erosion & Sediment Control	LF	600	$15	$9,000	EPA / DOT erosion control averages
Temporary Stream Diversion	LS	1	$20,000	$20,000	USACE temporary works guidance
Clearing / Demolition	LS	1	$10,000	$10,000	RSMeans + DOT bid tabs
				Total	
				$64,000	
Earthwork					
Description	**Unit**	**Qty**	**Unit Cost**	**Total**	**Source**
Clearing & Grubbing	AC	1.5	$8,000	$12,000	RSMeans / ADOT bid tabs
Channel Excavation (Cut)	CY	127	$22	$2,798	ADOT + MAG ($10–16/CY adj.)
Channel Fill / Regrading	CY	458.5	$25	$11,463	ADOT + RSMeans ($18–30/CY)
Excavation (Channel Bank)	CY	800	$25	$20,000	Phoenix drainage report + RSMeans
				Total	
				$46,260	
Material Installation					
Description	**Unit**	**Qty**	**Unit Cost**	**Total**	**Source**
Structural Bedding	CY	120	$60	$7,200	RSMeans aggregates
Headwalls / Wingwalls	CY	80	$500	$40,000	USACE concrete structures
Backfill & Compaction	CY	300	$30	$9,000	RSMeans earthwork
				Total	
				$56,200	
Geomorphic Restoration					
Description	**Unit**	**Qty**	**Unit Cost**	**Total**	**Source**

Channel Grading / Shaping	LF	500	$50	$25,000	USACE channel restoration
Bank Stabilization (Riprap)	CY	400	$120	$48,000	USACE riprap design guidance
Engineered Channel Substrate	CY	200	$70	$14,000	NRCS stream restoration
				Total	
				$87,000	
Site Restoration					
Description	**Unit**	**Qty**	**Unit Cost**	**Total**	**Source**
Topsoil Placement & Seeding	SY	2,000	$5	$10,000	NRCS + RSMeans landscaping
Erosion Control Blanket	SY	2,000	$4	$8,000	DOT erosion control standards
				Total	
				$18,000	
				Total of Materials	
				$271,460	

Table G- 2: Contract and Hidden Costs

Item	%	Cost	Source
Mobilization Adjustment	5%	$13,573	RSMeans typical range
Traffic Control	5%	$13,573	DOT standards
Additional Erosion Control	3%	$8,144	EPA / DOT
Contractor OHP	15%	$40,719	Industry standard
		Total	
		$76,009	

Table G- 3: Contingency Costs

Item	%	Cost	Source
Engineering Design	10%	$7,601	Industry standard (AACE Class 4–5)
Contingency (Concept Level)	25%	$67,865	AACE Recommended Practice
		Total	
		$75,466	