Denver Water

Gross Reservoir Hydroelectric Project
FERC Project No. 2035

DRAFT QUARRY OPERATIONS PLAN

DRAFT May 3, 2021

Prepared by:

DENVER WATER

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Glossary

CM	Construction Manager
CM/GC	Construction Manager/General Contractor
CVC	Conventionally Vibrated Concrete
CY	Cubic Yard
Denver Water	Board of Water Commissioners for the City and County of Denver
Design Engineer	Stantec Consulting Engineers/AECOM
FEIS	Final Environmental Impact Statement
FERC	Federal Energy Regulatory Commission
GC	General Contractor
GRE Project	Gross Reservoir Expansion Project
ICE	Independent Cost Estimator
Independent Cost Estimator	Stanton Constructability Services
IPT	Integrated Project Team
KBJV	Kiewit-Barnard Joint Venture
KIE	Kiewit Infrastructure Engineers
NHWL	Normal High-Water Level
OPCC	Opinion of Probable Construction Costs
QOP	Quarry Operations Plan
RCC	Roller Compacted Concrete
TN	Ton
USACE	United States Army Corps of Engineers
USFS	United States Forest Service

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1. Introduction

The Board of Water Commissioners for the City and County of Denver (Denver Water) is in the process of obtaining the necessary permissions to expand Gross Dam and Reservoir (the Gross Reservoir Expansion Project or GRE Project). Since Gross Reservoir is within a federal hydropower reserve and is subject to an existing Federal Energy Regulatory Commission (FERC or Commission) hydropower license — Gross Reservoir Hydroelectric Project No. 2025 — Denver Water had to amend its existing hydropower license to pursue the GRE Project. The FERC order amending this license (FERC Order) was issued on July 16, 2020 and mandates the creation of several plans to address impacts related to the expansion and operation of Gross Dam and Reservoir. This Draft Quarry Operations Plan has been prepared consistent with the 2020 FERC Order, including requirements of Article 424 and applicable measures of 4(e) Conditions 23 and 26. The 2020 FERC Order requires Denver Water to submit this draft plan for review by the U.S. Forest Service (USFS), Colorado Division of Reclamation, Mining, and Safety, Boulder County, and the U.S. Army Corps of Engineers.

1.1 Scope and Objectives of the Quarry Operations Plan

The GRE Project is located on South Boulder Creek in Boulder County, Colorado, on land owned by Denver Water and on land contained within the Arapaho-Roosevelt National Forest managed by the USFS. The objective of the GRE Project is to raise the existing Gross Dam by 131 feet to a height of 471 feet, increasing the storage capacity from approximately 42,000 acre-feet to approximately 119,000 acre-feet.

The 2020 FERC Order requires Denver Water to start and complete construction of the raised dam by July 16, 2022, and July 16, 2027, respectively, and to submit Quarry Operations and Reclamation Plans by July 16, 2021. The Quarry Reclamation Plan (QRP) is provided under separate cover. The purpose of this Quarry Operations Plan (QOP) is to address plans for quarry development, operation, and mitigation associated with impacts related to construction of the quarry to support the GRE Project. A summary of the QOP objectives of this plan include:

- Providing results from geotechnical evaluations to locate and size the quarry.
- Quantifying the amount of material that will be necessary to support construction.
- Confirming the quality and quantity of material expected from the quarry.
- Describing stability analyses conducted and providing results indicating a safe design.
- Providing plans for ongoing monitoring of slopes throughout quarry development.
- Detailing criteria used to minimize visual impacts.
- Describing the means and methods for excavation of the insitu material.
- Providing water management/sediment control plans for quarry during construction.
- Addressing worker and public safety during quarry operations.
- Outlining a schedule for quarry development and operations throughout construction.

1.2 Gross Reservoir Hydroelectric Project License Conditions

The 2020 FERC Order contains specific elements to be addressed in the QOP. Article 424, Quarry Operation and Reclamation Plans is the primary article governing the QOP with additional requirements contained within the USFS 4(e) Conditions 23 and 26, as applicable. For example, 4(e) Condition 23 relates to USFS scenery management guidelines for visual resource mitigation of the quarry to National Forest System lands and 4(e) Condition 26 is not applicable at this time since there are no planned quarry operations on National Forest System lands. The Osprey Point Quarry location, shown in Figure 1, is located entirely on Denver Water property. See the discussion on previous quarry studies in section 1.5 for more information on alternative quarry locations considered by Denver Water.

Article 424 summarizes the purpose and requirements of the QOP:

> *Article 424. Quarry Operation and Reclamation Plans. Within one year of the date of this order, the licensee must file, for Commission approval, a Quarry Operation Plan and a Quarry Reclamation Plan that addresses quarry development, operation, and reclamation activities, and mitigation measures. If determined necessary and appropriate, and with the agreement of the agencies listed below, the licensee may file only the Quarry Operation Plan, to include a schedule for filing a separate Quarry Reclamation Plan at a later time.*
>
> *The Quarry Operation and Reclamation Plans must include: (1) details of quarry design, including quarry-related work areas, access areas, and details of grading; (2) measures to control erosion during quarry operation and reclamation; (3) measures to ensure quarry features do not create isolated areas that could cause fish stranding during normal reservoir operations; (4) measures to ensure the safety of recreational boaters at normal reservoir operations, and (5) measures to reduce the visual impacts of quarry features during normal reservoir operations. The plans must be consistent with quarry operation and reclamation measures needed to comply with U.S. Forest Service (Forest Service) section 4(e) conditions 23 and 26, as applicable.*
>
> *The licensee must prepare the plan after consultation with the Forest Service; Colorado Division of Reclamation, Mining, and Safety; Boulder County; and the U.S. Army Corps of Engineers (USACE). The licensee must include with the plan documentation of consultation, copies of comments and recommendations on the completed plan after it has been prepared and provided to the agencies, and specific descriptions of how agency comments are accommodated by the plan. The licensee must allow a minimum of 30 days for the agencies to comment and to make recommendations before filing the plan with the Commission. If the licensee does not adopt a recommendation, the filing must include the licensee's reasons, based on project-specific information.*
>
> *The Commission reserves the right to require changes to the plan. Implementation of the plan must not begin until the licensee is notified by the Commission that the plan is approved. Upon Commission approval, the licensee*

must implement the plan, including any changes required by the Commission.

This QOP does not include the QRP, which is being delivered as a separate stand-alone document. While the QOP and QRP are being delivered as stand-alone documents, the intent is that the plans are complimentary and that they, in combination, will satisfy the requirements of FERC Order Article 424.

The following specific measures of FERC Order Article 424 have been addressed in the QRP and this QOP as summarized in Table 1.

Table 1:
Measures Required by Article 424

FERC Requirements	Section of QOP
Details of quarry design, including quarry-related work areas, access areas, and details of grading;	Sections 1.5, 2.1, 2.1.2, 2.1.3 (including Tables 3, 4, and 5), 2.2, and 2.4, Appendix A (Section 2.3, Section 4), Appendix C, Appendix D and in QRP Sections 1.4 and 2.3
Measures to control erosion during quarry operation and reclamation;	Section 2.3, Section 2.3.3, Appendix A (Section 5) and in QRP Sections 2.3, 2.5, 2.6, 2.7, and 2.11
Measures to ensure quarry features do not create isolated areas that could cause fish stranding during normal reservoir operations;	Section 2.2.7, Appendix A (Section 6.2)
Measures to ensure the safety of recreational boaters at normal reservoir operations,	Sections 2.4 and 2.4.2, Appendix A (Section 4)
Measures to reduce the visual impacts of quarry features during normal reservoir operations.	Section 1.5, Section 2.1.1, Appendix A (Section 6.2) and in QRP Sections 1.4 and 2.32

1.3 Agency Consultation

Article 424 requires Denver Water to consult with the USFS; Colorado Division of Reclamation, Mining, and Safety; Boulder County; and U.S. Army Corps of Engineers. A minimum 30-day review period must be provided to the consulting agencies for review and comment on the QOP. Denver Water will review all comments provided by consulting agencies for implementation into the QOP and provide a list of responses and any actions taken along with a completed plan for FERC submission by July 16, 2021.

1.4 Previous Quarry Studies

Development of a quarry to provide material needed for the dam raise was analyzed in the 2014 Final Environmental Impact Statement (FEIS) for the GRE Project. Denver Water has conducted several quarry studies with the goal of avoiding and minimizing impacts of the quarry operations. A high-level summary of the quarry studies completed to date is presented here with additional information provided in Appendix D – Final Quarry Location Report.

Approximately 807,000 cubic yards (CY) of concrete are required to raise the dam. The concrete consists of approximately 90% sand and gravel aggregate and 10% cement and fly ash materials. As part of preliminary engineering evaluations completed by Denver Water, multiple alternatives were considered for obtaining the aggregate necessary to complete the GRE Project.

Producing fine aggregate (sand-sized fraction) can be difficult and options for importing material from an offsite source were considered in addition to scouting multiple onsite quarry locations. Impacts to the natural topography and National Forest System lands were considered for evaluating potential onsite sources. Denver Water also considered impacts to local communities and traffic associated with transporting aggregates from offsite for importing the necessary sand material.

Denver Water evaluated the bedrock as a parent source for sand and gravel aggregate in 2013. The evaluation produced positive results in regard to the ability to manufacture sand and gravel aggregate of sufficient quality onsite with standard crushing equipment. A subsequent 2015 study found that the onsite granodiorite material could be crushed down to aggregate efficiently with minimal waste material that would not meet aggregate specifications. By producing both the sand and gravel aggregate onsite, Denver Water estimates that the amount of spoil material needed to be disposed of onsite would be reduced significantly. In addition, Denver Water estimates that more than 16,000 truck trips would be eliminated from the roads by producing all aggregate onsite. This would be a reduction in approximately 70% of the truck traffic necessary for material deliveries to the site related to concrete construction. Based on these evaluations, Denver Water elected to design the dam using an onsite quarry to produce both the sand and gravel aggregate.

Several geotechnical studies were conducted across the site to identify suitable onsite quarry locations to support construction. Ultimately, two potential onsite quarry locations were identified for the project. A location north of the existing boat ramp area within the FERC Project boundary, on both Denver Water property as well as National Forest System lands, was identified and included in the FEIS for the project. This site became known as the FEIS Quarry. An alternative quarry site located exclusively on Denver Water property along the existing access road to the Osprey Point boat ramp was identified in subsequent studies following the FEIS in an effort to further reduce the impacts of quarry operations. The alternative site became known as the Osprey Point Quarry. The Osprey Point Quarry is located within the new reservoir inundation area, and therefore the primary benefit of this location is that nearly all of the quarry will be submerged during normal reservoir operations following completion of the GRE Project. Impacts associated with the Osprey Point Quarry and FEIS Quarry were discussed in a memo prepared by Denver Water in 2016. In 2017, the Corps concurred with Denver Water’s impact assessment of the Osprey Point Quarry.

Based on an evaluation of the two primary sites, the Osprey Point Quarry location provides several advantages over the FEIS Quarry location. For example, the Osprey Point Quarry occupies a smaller footprint than the FEIS Quarry. The FEIS Quarry would occupy a total area of approximately 29 acres compared to 17 acres for the Osprey Point Quarry. In addition, the Osprey Point Quarry is located exclusively on Denver Water land and significantly reduces National Forest System resource impacts related to the GRE Project. The most notable advantage is that the majority of the Osprey Point Quarry is located within the expanded reservoir footprint and will be almost entirely submerged during normal reservoir operations. This location reduces the total land disturbance related to project construction and minimizes the visual impacts associated with the quarry and surrounding topography. In summary, Denver Water selected the Osprey Point Quarry location in an effort to reduce:

1. Impacts to National Forest System lands.
2. The number of surface acres requiring mitigation or reclamation.
3. Visual impacts to the viewshed of residences and recreationists.
4. Impacts associated with trucking in aggregates.

In 2017, the U.S. Army Corps of Engineers approved development of the Osprey Point Quarry, due to the minimization of resource impacts as compared to the FEIS Quarry, as noted in its Record of Decision and 404 Permit for the GRE Project. See Appendix D - Final Quarry Location Report, for more information on the alternatives considered and additional supporting information on the Osprey Point Quarry selection.

2. Quarry Operations Plan

The GRE Project will require significant quantities of roller compacted concrete (RCC) and conventionally vibrated concrete (CVC) that will be produced from an onsite concrete batch plant. The aggregates for this concrete will be produced from an onsite crushing plant with the rock supplied from the Osprey Point Quarry as shown in Figures 1 and 2. KBJV has incorporated the details of the design and operation of the Osprey Point Quarry in this QOP as follows:

- Summary of the design of the quarry including location, quality, and quantities of the rock.
- Excavation Plan including excavation procedures, blasting operations, and measures used to ensure that quarry features do not cause fish stranding.
- Environmental management including water management, groundwater management, and sediment control.
- Safety considerations for both the workers and the public during quarry operations.
- Planned schedule activities for operation of the quarry.

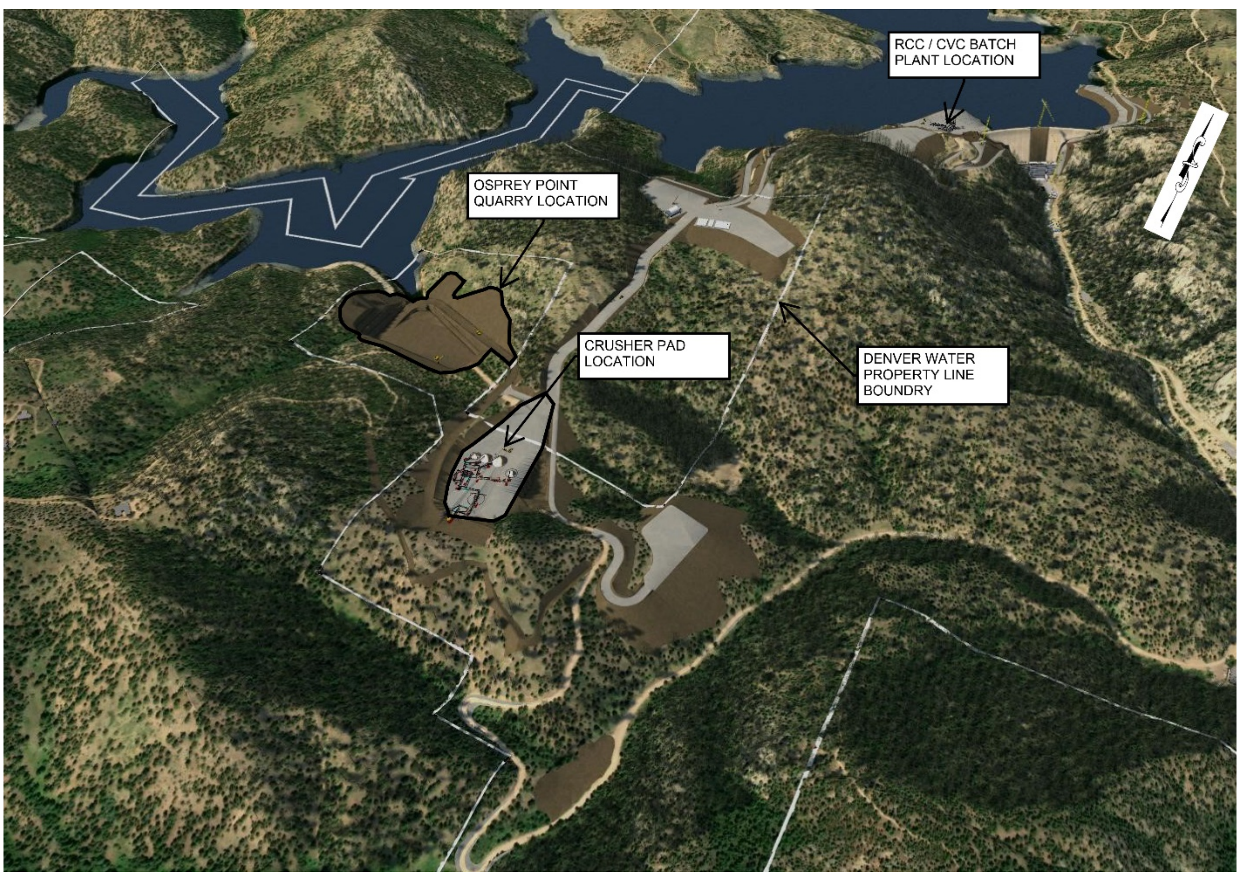


Figure 1: Osprey Point Quarry Location

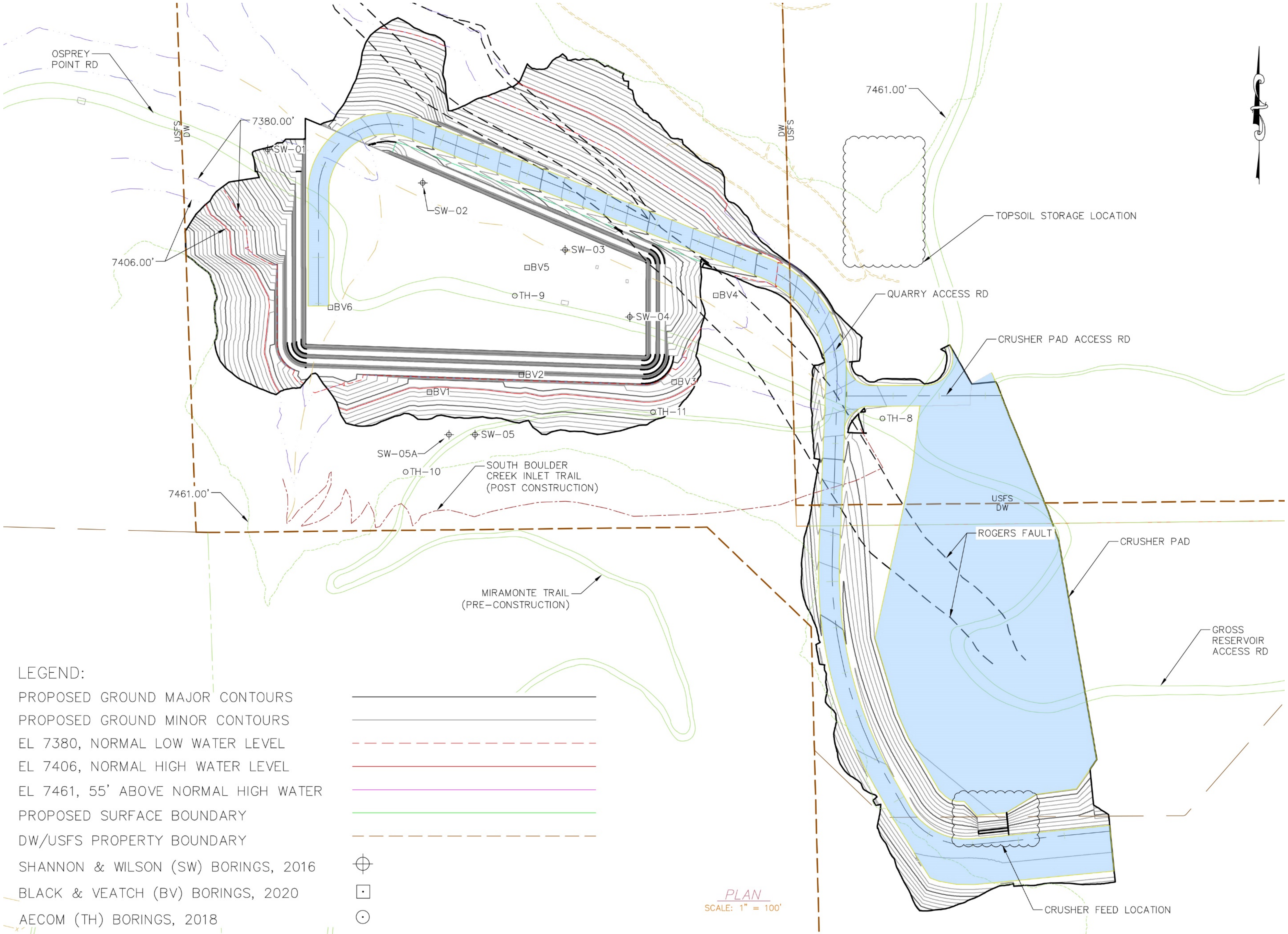


Figure 2: Plan View of Osprey Point Quarry

2.1 Quarry Design

Kiewit Infrastructure Engineers (KIE) along with KBJV are in the process of developing the design for the Osprey Point Quarry and will continue to progress the design to completion. Close interaction with Denver Water during the design development has been an important factor in this process. The Osprey Point Quarry design incorporates the results of previous geotechnical investigation reports prepared for the GRE Project. Requirements from the FEIS, Record of Decision/404 Permit, FERC Order, and Denver Water commitments and analyses for efficient and safe construction operations all played a key role in the design of the quarry. Please refer to Appendix A, Production Quarry Design Narrative, and Appendix C, Quarry Design PDF Files, for Osprey Point Quarry design drawings for additional detail on the quarry design and layout.

2.1.1 Quarry Design Key Elements

The following are the key elements that have been incorporated into the Osprey Point Quarry design:

- To reduce the visual impacts of quarry features during normal reservoir operations, the design minimizes the exposed slopes of the quarry above elevation 7406[1] Normal High-Water Level (NHWL) of the expanded reservoir. The quarry design encompasses 16.87 acres, of which 2.64 acres is above the NHWL as shown in yellow in Table 2 and Figure 3.
- To further reduce visual impacts, the exposed slopes are limited to no more than 55 feet above elevation 7406 (NHWL). This contour line, elevation 7461, is shown on Figure 2 along with the quarry grading contours, which are all below elevation 7461. A key factor in achieving this reduction in visual impacts was locating the Quarry Access Road (shown in Figure 2) on the north side of the quarry, which allowed for the southern quarry slopes to be lowered below elevation 7461.
- Local and global stability was evaluated for the overburden and rock cut slopes for both the temporary and permanent conditions. A uniform surcharge load from loaded CAT773 haul trucks was considered for design of temporary slopes. Significant surcharges are not anticipated for permanent conditions. The stability of overburden slopes was evaluated using limit-equilibrium analysis. The kinematic stability analysis of the rock cuts was performed to identify potential instabilities. A rockfall analysis was also performed to evaluate the proposed bench widths. Analyses and recommendations can be found in Appendix A, Production Quarry Design Narrative, Section 4.0 Geotechnical Design Recommendations. The following is a summary of the slope designs for the quarry (refer to Figure 4).

    1. Rock slopes are 0.25:1 with 10-foot benches every 40-vertical foot.

[1] Elevation 7406 will be the new high-water level after the GRE Project is built. The current high-water level elevation is 7282.

2. Overburden above elevation 7406 (NHWL) is sloped at a 2:1.
3. Ten-foot bench at the top of rock and start of 2:1 overburden slope.

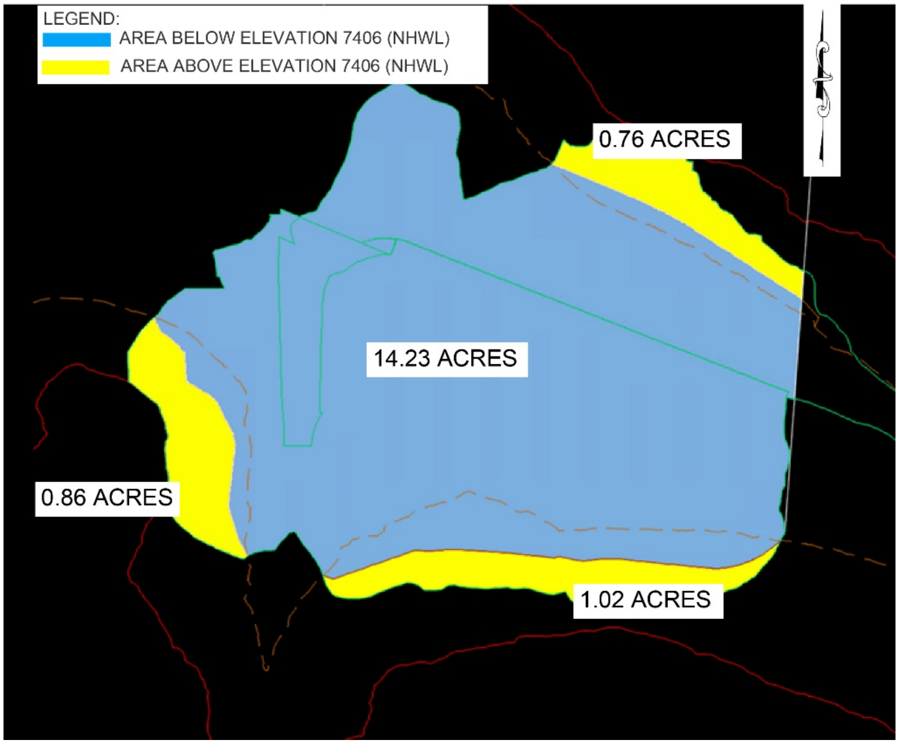
- To reduce impacts to National Forest System lands, the Osprey Point Quarry has been designed to be located completely within Denver Water property as shown on Figure 2.
- The Osprey Point Quarry design locates the quarry to minimize potential impacts related to unsuitable materials within the Rogers Fault area, which is located along the northeast corner of the quarry as shown on Figure 2. The Rogers Fault is well documented from previous geotechnical reports and additional information is contained within Appendix A,-Production Quarry Design Narrative section 3.2-Subsurface Conditions.
- The quarry design includes limiting the quarry access road to a maximum 10% profile to optimize the efficiencies of the haul trucks.
- The quarry location was designed to not interfere with the planned location of the post-construction South Boulder Creek Inlet Trail. Refer to Figure 2.
- Rock boring information was incorporated into the quarry design to determine the elevation of the suitable rock within the quarry. Refer to Figure 2 for the boring locations. These borings and elevations were inserted into AutoCAD Civil3D to create a rock surface as shown in the Figure 4 cross section. This information allows for more accurate quantity analyses of overburden (as defined in section 2.2.1 below) and competent rock to ensure the quarry is adequately sized for the required aggregates needed for the project. See section 2.1.3 for additional information on the process used to estimate the quantity of aggregate necessary for the project. Table 3 below shows the elevations that were input into the AutoCAD design to develop the competent rock layer.

Table 2:
Osprey Point Quarry Footprint Disturbance Area Calculations

Below 7406' Contour Line		
Side	**Area (ft^2)**	**Area (Acre)**
Mid	620,051	14.23
	620,051	**14.23**

Above 7406' Contour Line		
Side	**Area (ft^2)**	**Area (Acre)**
North	32,957	0.76
West	37,556	0.86
South	44,584	1.02
	115,097	**2.64**
	Total	**16.87**

Total Disturbance Area (Quarry and Access Road)		
Location	**Area (ft^2)**	**Area (Acre)**
Quarry	735,561	16.87
Quarry Road	274,114	6.29
Crusher Pad	336,418	7.72
	1,346,093	**30.90**



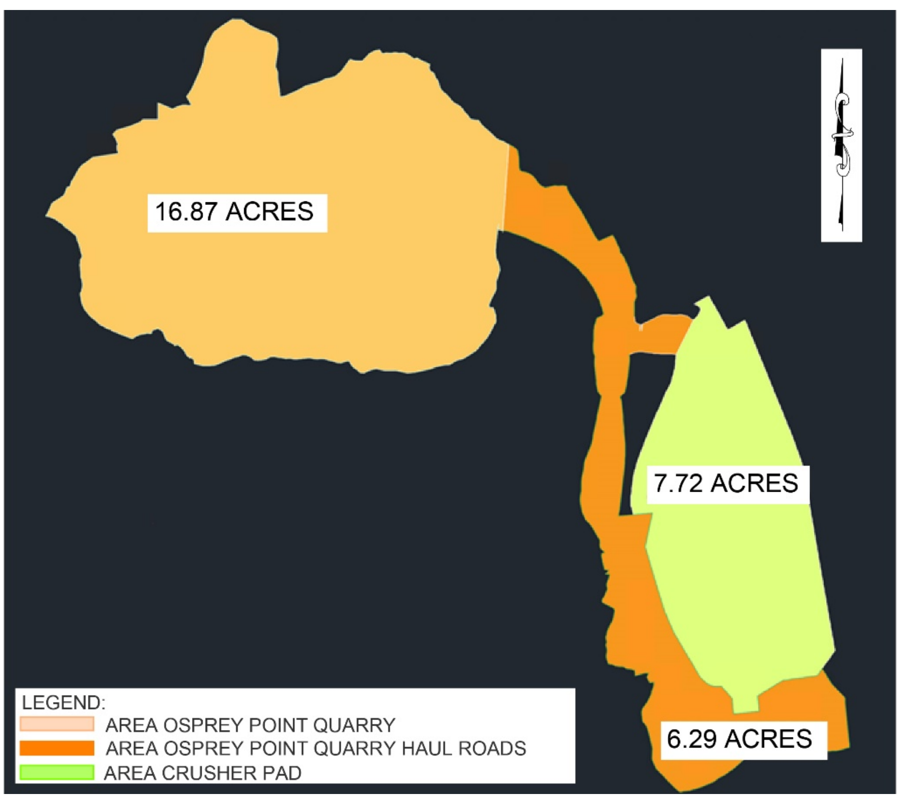


Figure 3: Osprey Point Quarry Limits of Disturbance –

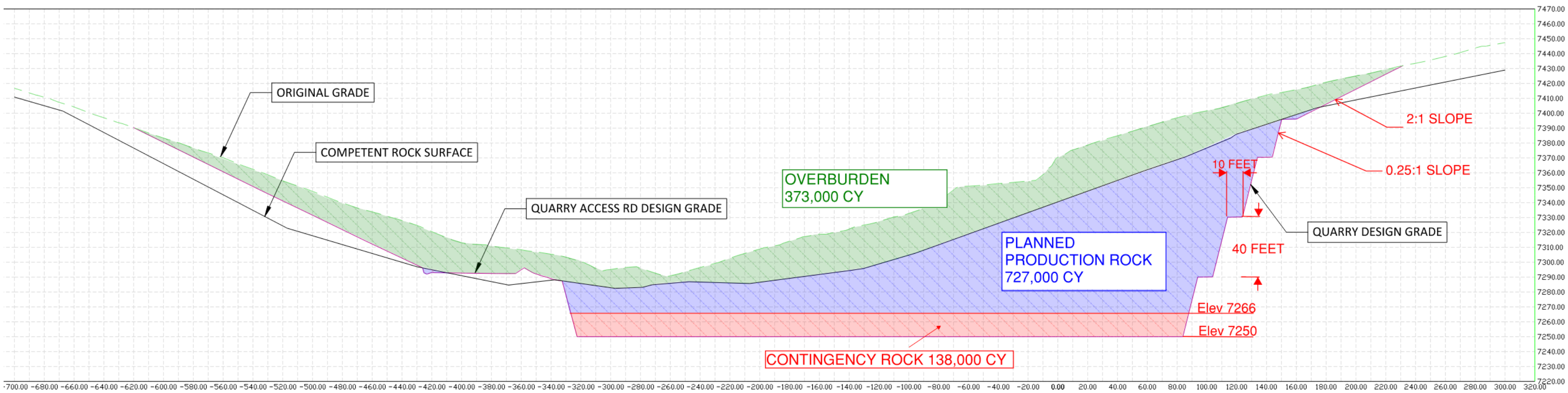


Figure 4: Quarry Section with Quantities (Includes Quarry Access Road)

Table 3:
Boring Summary Table

Boring #	Surface Elevation	Elevation Competent Rock	Overburden Depth to Competent Rock (FT)
SW-01	7313.0	7299.0	14.0
SW-02	7304.0	7281.0	23.0
SW-03	7345.0	7324.0	21.0
SW-04	7385.0	7340.0	45.0
SW-05	7455.0	7428.0	27.0
SW-05A	7458.0	7448.8	9.2
TH-9	7364.0	7334.0	30.0
TH-10	7459.0	7443.0	16.0
TH-11	7424.0	7413.0	11.0
BV1	7424.0	7413.0	11.0
BV2	7406.0	7394.5	11.5
BV3	7411.5	7387.5	24.0
BV4	7372.0	7328.0	44.0
BV5	7350.0	7327.0	23.0
BV6	7350.0	7344.0	6.0

2.1.2 Quarry Rock Quality

Aggregate quality testing has been performed from the rock cores drilled within the limits of the Osprey Point Quarry. Representative portions of the granodiorite rock that would be used for crushing and producing aggregates was determined from visual inspection of the cores. The rock cores were crushed with small laboratory crushing equipment intended to replicate the full-size equipment that will be used for the production crushing. Quality testing was then performed on the aggregates produced. The following tests were completed: Wet Wash Gradation, Los Angeles Abrasion, Elongation, Sand Equivalent, and Specific Gravity and Absorption. The quality results from these tests indicate that the material meets the concrete aggregate quality requirements for the GRE Project. Additional testing of Osprey Point Quarry aggregates and further mix design development is ongoing to develop final RCC and CVC mixes for use on the GRE Project.

2.1.3 Osprey Point Quarry Rock Quantities

There have been extensive analyses on the quantities of RCC and CVC that are required for the GRE Project, and these will continue as the design progresses. The quantity analyses included two independent RCC and CVC design drawing reviews that were compared and ultimately agreed to between the ICE and KBJV. When calculating concrete quantities for batching, several elements need to be considered. The first is the neatline quantity that is derived from the analysis from the design drawings. Neatline quantity is defined as the theoretical quantity calculated from the proposed design. Second, generally an additional quantity of concrete is placed due to such things as the surface the concrete is placed on is lower than the neatline drawing surface. This is called placement waste. The last factor is the waste associated with batching the concrete, which accounts for ancillary items such as additional concrete batched for testing the concrete. This is called batch waste. The CVC placement waste has been included for each of the work operations, as shown in Table 4. The RCC placement waste has not been included for the RCC because the final foundation excavation surface will fluctuate up and down depending on the geology of the rock, so it is difficult to determine what the placement waste value will be. The potential increase in RCC quantity due to the foundation surface changes and the corresponding potential increase of concrete aggregate required is accounted for in the contingency portion of the production quarry, which will be discussed in more detail later in this section. The batch waste and the total planned batched quantities for CVC and RCC are shown at the bottoms of Table 4 and Table 5, respectively.

Table 4:
Onsite Batch CVC — 60% Design Quantities

Description	CVC Neatline (CY)	CVC Place Waste (%)	CVC Waste (CY)	CVC Quantity (CY)
OGEE	611	7.0%	43	654
Training Wall	700	7.0%	49	749
Crest Road Slab	2100	7.0%	147	2247
Parapet Wall- sub out	650	7.0%	46	696
Bridge	335	10.0%	34	369
End Sill	135	7.0%	9	144
Chute & Baffle	132	10.0%	13	145
Apron Wall	5388	7.0%	377	5765
CVC Facing — U/S	12413	16.7%	2068	14481
CVC Facing — D/S	28013	12.6%	3523	31536
CVC Facing — Spillway Footings	140	0.0%	0	140
CVC Facing — Waterstop	5732	12.0%	688	6420
Saddle Dam (Grout Pad)	510	5.1%	26	536
Test Section (Toe of Dam)	128	35.2%	45	173
Gallery	590	10.0%	59	649
Adit Access Stairs	102	9.8%	10	112
New HPU Building	41	7.0%	3	44
Main stilling slab (2nd Season)	1079	5.0%	54	1133
Total Place CVC	**58,799**		**7,193**	**65,992**
Total CVC Batch (with 2.5% Batch Loss)				**67,642**

Table 5:
RCC Quantity Table

Description	RCC Quantity (CY)
Gross Reservoir Dam Raise	
Arch/Thrust Blocks/LT Shaping Block	709,790
Subtotal	709,790
Other	
Saddle Dam	8,500
Test Section (Toe of Dam)	925
Slope Protection/Access Road	5,985
Subtotal	15,410
Total Place RCC	**725,200**
Total RCC Batch (with 2% Batch Loss)	**739,704**

Once the total volumes of RCC and CVC have been determined as described above, the required quantities of aggregate are calculated. The unit weight for the aggregate was determined from laboratory testing during the trial concrete mix design process. For the RCC aggregates, the unit weight has been determined to be 1.7761 tons/cubic yard (TN/CY) and for the CVC, 1.622 TN/CY as shown in Table 6. The only other waste factor needed to determine the total concrete aggregate is the stockpile loss associated with the aggregate. Stockpile loss occurs because the aggregate at the bottom of the stockpiles will never completely be used to avoid contamination of the material. As seen in Table 6, a 3% stockpile loss for both RCC and CVC aggregates has been included. With all the waste factors accounted for, the total aggregate required is 1,466,208 TN as shown in Table 6. This will be updated as the GRE Project design progresses. In addition, a detailed analysis has been done on the expected split of the coarse aggregate and the sand during the aggregate processing. Because of the characteristics of the rock, additional sand is created in excess of what is required from the concrete mix design during the aggregate processing. Table 6 shows an additional 162,948 TN of waste sand produced and a total of 1,629,156 TN of aggregate produced. This is the quantity that the Osprey Point Quarry is currently sized for. The in-place unit weight of the rock in the quarry is 2.24 TN/CY, which equates to a total volume of rock required from the quarry of 727,000 CY as shown in Table 6.

When the volume of the Osprey Point Quarry was sized, it was important to understand the volume of the rock that would be required, as described in the above paragraph. It was also important to have a contingency volume of rock available to account for potential unsuitable material within the quarry or unforeseen overruns of quantities required for the GRE Project. Figure 4 cross sections show the 727,000 CY of expected volume required is attained by excavating the quarry to elevation 7266. The quarry design allows for the bottom of the quarry to be excavated to elevation 7250, which equates to an additional 138,000 CY of rock that is considered contingency rock. This volume equates to 309,000 TN of contingency aggregate, which is about an additional 19 percent.

Table 6:
RCC/CVC Aggregate Required Table

RCC Aggregates				
RCC Placement (CY)	**2% RCC Batch Loss (CY)**	**RCC 1.7761 TN/CY (TN)**	**3% RCC Stockpile Loss (TN)**	**Total RCC Aggregate (TN)**
725,200	739,704	1,313,788	39,414	1,353,202
CVC Aggregates				
CVC Placement (CY)	**2.5% CVC Batch Loss (CY)**	**CVC 1.622 TN/CY (TN)**	**3% CVC Stockpile Loss (TN)**	**3% CVC Stockpile Loss (TN)**
65,992	67,642	109,715	3,291	113,006
Total Aggregate Required				1,466,208 TN
Additional Sand Produced				162,948 TN
Total Aggregate Produced				1,629,156 TN
Volume of Rock Required at Quarry (2.24 TN/CY Unit Weight)				727,300 CY

2.2 Excavation Plan

The following Excavation Plan for the Osprey Point Quarry was developed by KBJV to describe the means and methods planned for the quarry work operations. All aspects of the Excavation Plan will be in accordance with the final quarry design.

2.2.1 Overburden Excavation

Overburden is defined as the non-rock material that overlays the competent rock layer in the quarry as shown in green shading in Figure 4. Overburden will be separated into two categories: topsoil/organics and non-rock overburden. The quarry limits will be surveyed based on the final quarry design. This survey will include property lines, contour lines at future elevation 7406 (NHWL), contour lines at the maximum level of disturbance (7461), and the designed top of cut and toe of embankment locations. The survey will also include locations of anticipated drainage features and ancillary work so the clearing and topsoil stripping can be completed for this work at the same time.

Clearing the vegetation within quarry disturbance footprint will begin prior to overburden removal. Debris and trees will be processed and/or removed from the site as needed. Topsoil will be excavated and stockpiled at an onsite location. The topsoil stockpile location is currently planned to be north of the proposed Saddle Dam and west of the road between the crusher pad and office pad. See Figure 2 for location of the Topsoil Storage Location. Topsoil material will be used for future onsite reclamation work.

For the sequencing of the overburden excavation, please refer to Figure 5. The excavation will begin at the top of the Quarry Access Road where it joins the crusher pad and will proceed up-station along the alignment of the road. This Quarry Access Road overburden excavation will create the haul road that will be used for transporting the quarry overburden to the crusher pad and other site embankments. Once this haul road to the quarry has been established, a series of temporary access/haul roads starting near the top of the slopes and proceeding downward as shown in Figure 6 will be utilized.

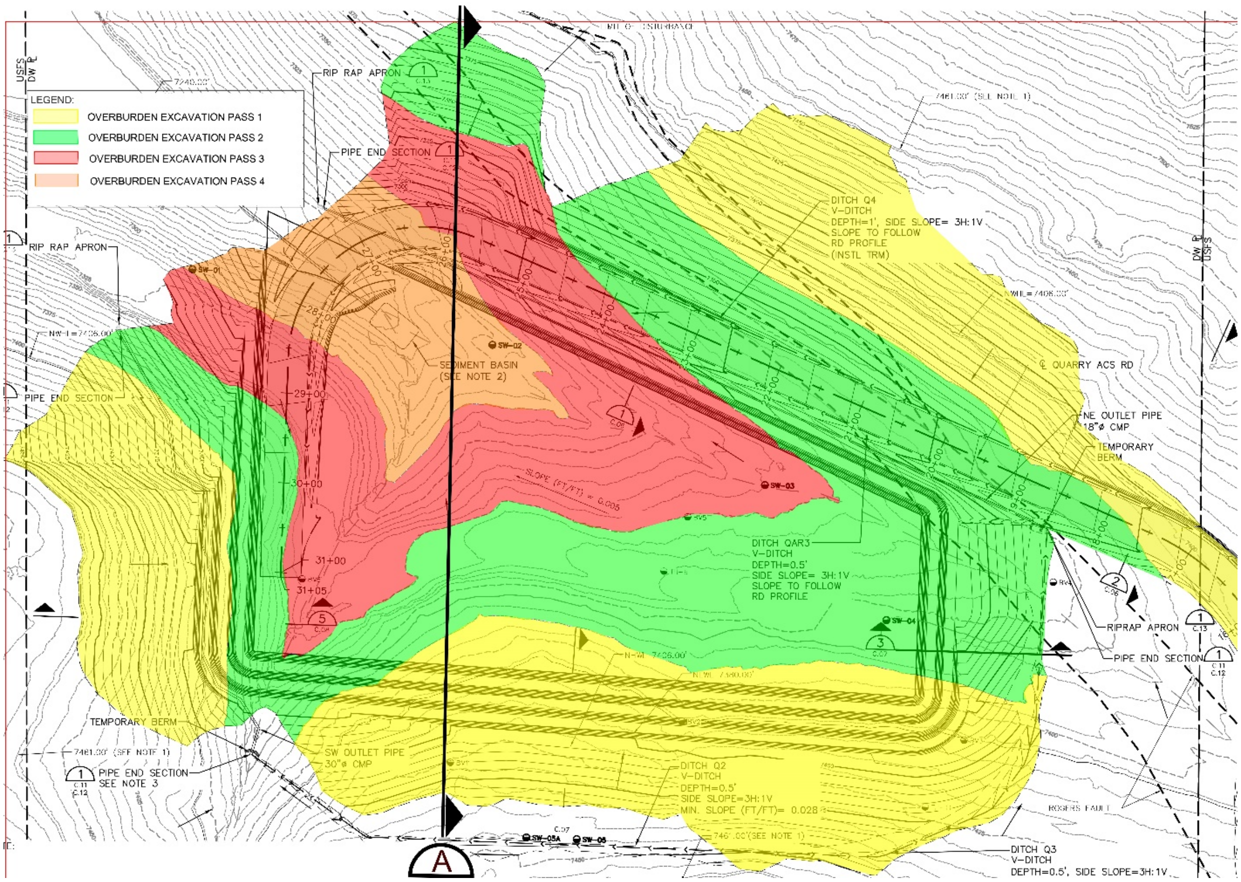


Figure 5: Overburden Excavation Sequence Plan

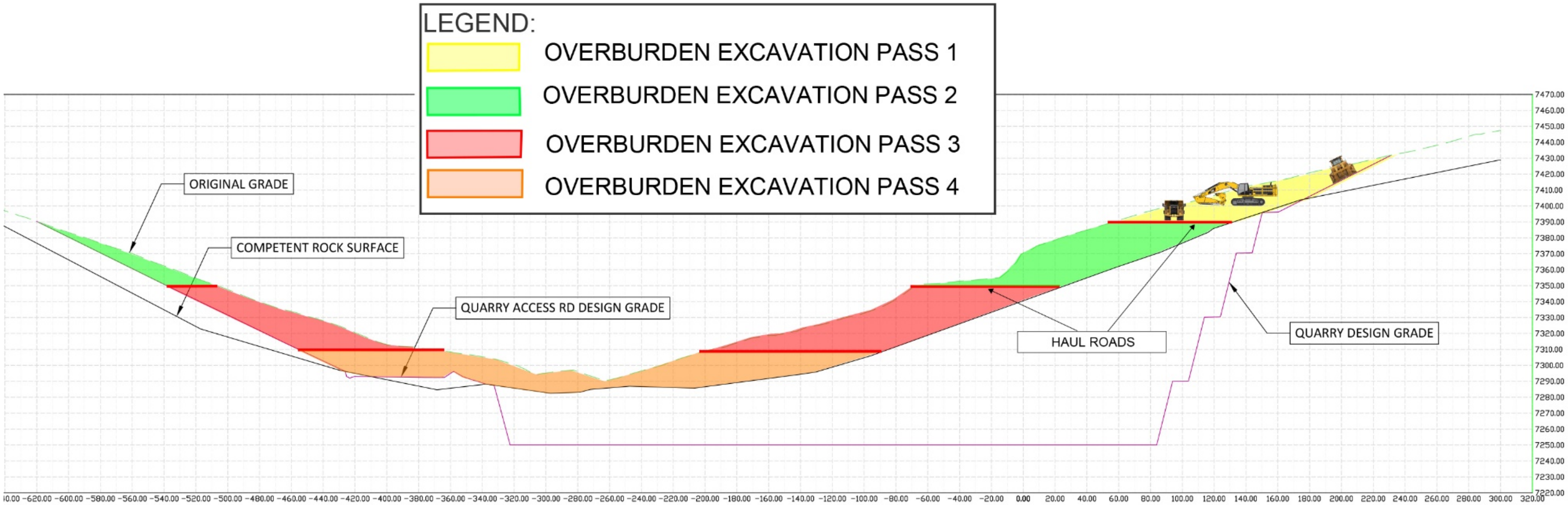


Figure 6: Overburden Excavation Sequence Section (A)

2.2.2 Weathered Rock Excavation

Weathered rock is a weaker rock material that is generally not suitable for concrete aggregates. Weathered rock removal will follow the overburden excavation sequence as described above. Removal of the weathered rock will be achieved by ripping and/or blasting to get to competent rock that is acceptable for use as RCC and CVC aggregates. Ripping will be accomplished with a Caterpillar D8 or D9 size bulldozer. If productive ripping cannot be accomplished, the weathered rock will be drilled and blasted so productive excavation can continue. As with the overburden material, the weathered rock will be used for building the crusher pad and other site embankments as well as for site road and pad surfacing.

2.2.3 Competent Rock Excavation

Competent rock is the layer of rock considered to be suitable for concrete aggregates as shown in blue shading in Figure 4.

Once competent rock has been reached, additional surveying will be completed to define the top of the slopes and indicate cut depth to the next bench. If needed, line drilling (as described in section 2.2.4) to define the final wall will proceed along with production drilling for crusher feed rock. Blasting will be completed in a controlled manner to maintain a clean and stable backwall while producing a rock gradation that is acceptable for crusher feed. Competent rock will be loaded and hauled to the crusher to maintain adequate supply of rock for the crushing operation. A small stockpile of crusher feed rock will be stockpiled near the primary crusher feed to allow continuous crushing when there is an interruption of rock being hauled to the Crusher Feed Location as shown in Figure 2.

The sequencing of the competent rock excavation will begin at the upper elevations of the quarry, as shown in blue in Figures 7, 8, and 9, and follow the bench elevation until it daylights from the excavation. As much as possible, an excavation lift will start where a design bench intersects the existing top of rock and proceed to the deeper portions of the lift. The first excavation area is represented in blue shown in Figures 7 and 8. The red color in the figures would be the next sequencing of competent rock to be excavated, followed by the green and finally the tan. Figure 9 illustrates that more than one of the bench excavations may proceed at the same time. Excavation operations may advance on an upper bench, represented in blue, with the drilling and blasting operations following behind on the next bench elevation, represented in green.

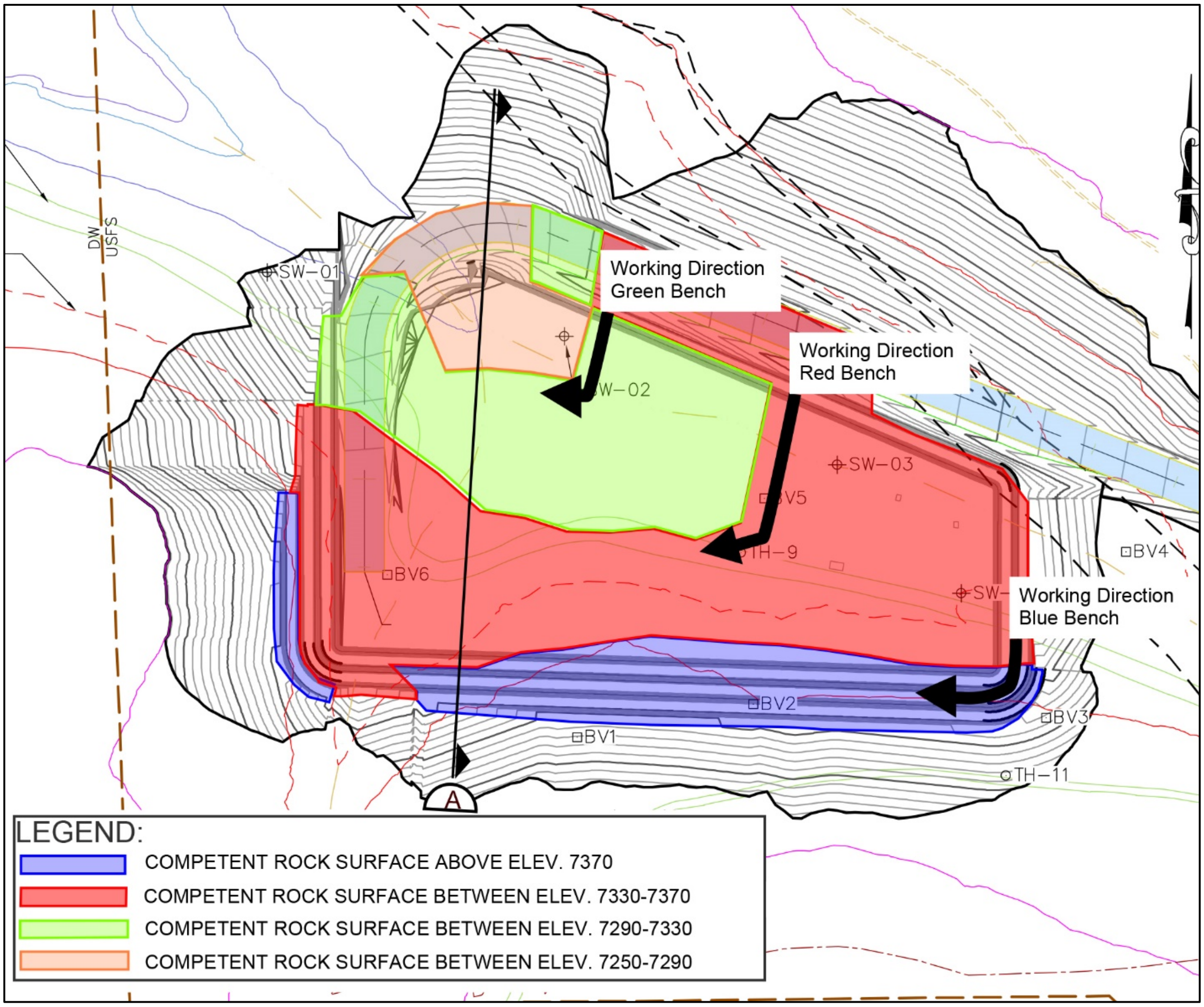


Figure 7: Competent Rock Excavation Sequence

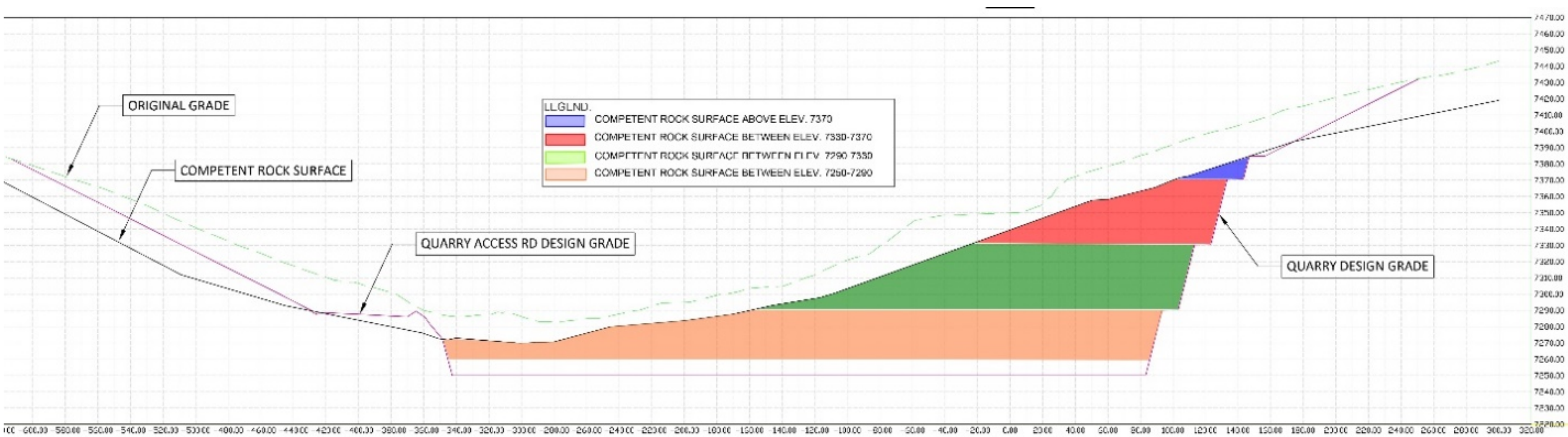
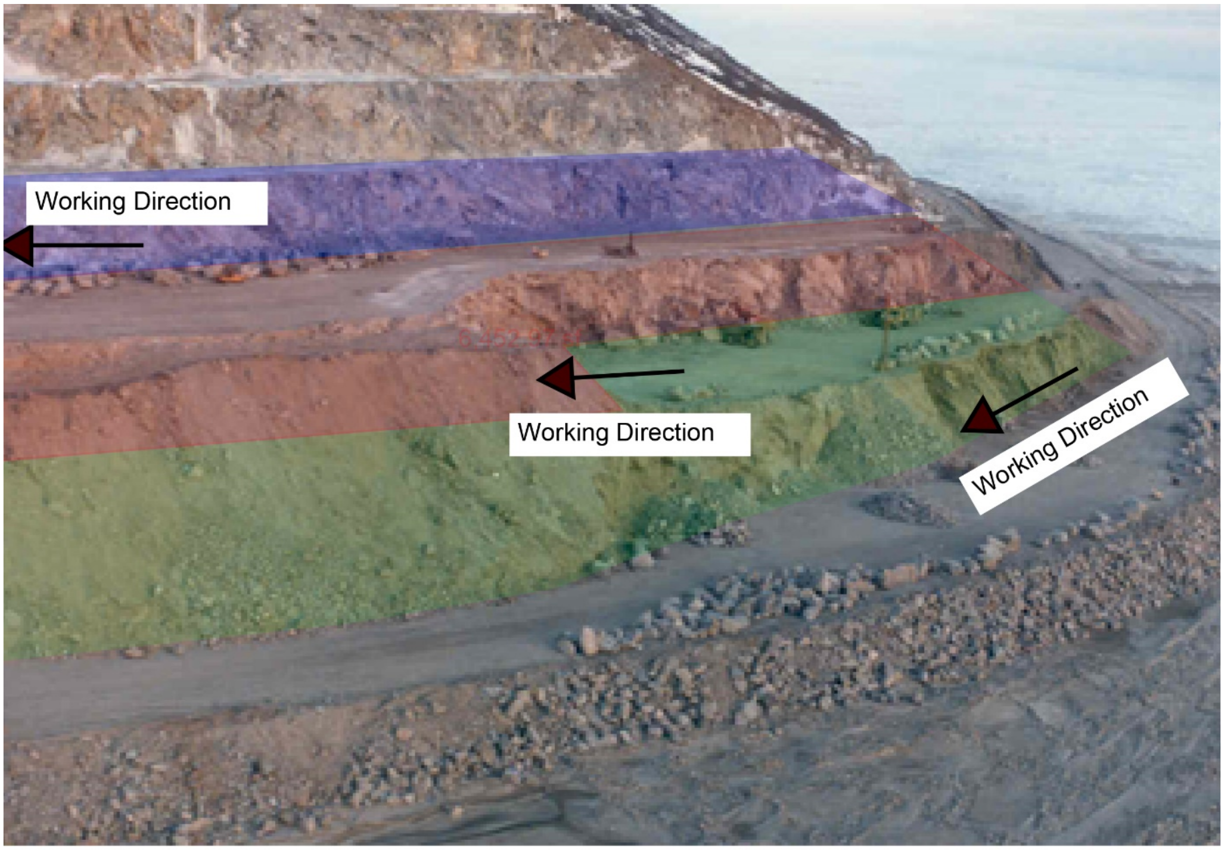


Figure 8: Competent Rock Excavation Typical Section (A)



Similar experience working on three separate benches concurrently at a quarry in Nome, Alaska

Figure 9: Competent Rock Working Sequence Image

2.2.4 Drilling and Blasting

Drilling and blasting activities are required within the quarry area to prepare the rock for extraction and develop the necessary crusher feed for aggregate production. All blasting operations will be monitored for vibration and air overpressure to limit unexpected damage to other features in the area. All blasting operations will have a designated clear zone that will be cleared of non-essential personnel prior to initiating any blast. The clear zone will vary depending on the location of the blast, weather conditions, and other factors but will always be larger than the anticipated potential danger area. This subject will be discussed further in section 2.4 — Safety. Line drilling, if needed, will be done with closely spaced parallel holes that will define the final slope. These holes are typically less than 4 inches in diameter with spacing up to 6 feet between holes. Typically, line drilling will start with a 30 inch +/- spacing and load to approximately 0.10 pounds of explosive per square foot of final wall. Depending on results, the spacing and loading will be adjusted to leave a competent wall without excessive back breaking.

Example of Line Drill Holes

Drill Rigs Drilling Line Holes

Production drilling and blasting will be done in the deepest practical lift but will not exceed the depth between permanent benches. Current design is 40 feet between benches, so the anticipated maximum lift depth is 40 feet. Drill holes will typically be 3.5 to 4.5 inches in diameter and will not exceed 6.5 inches in diameter. Typical patterns will range from approximately 7 by 7 feet to 10 by 10 feet depending on lift height and hole diameter. Blasting will be done with ammonium nitrate fuel oil as much as possible, but it may be done with bulk emulsion when excessive water is encountered. Typical blast loading will be done with non-electric initiation, a cast booster or other high energy primer will charge the blast. A typical production blasting powder load is 1.5 pounds of explosive per cubic yard of rock. Blast loading, powder factors, and drill patterns will be continually analyzed and adjusted based on the condition of the material to ensure a quality crusher feed, the vibration measurements, final wall conditions, and cost efficiency. A detailed typical blast plan will be developed for the quarry drill and blast operations prior to construction for review and approval by the Design Engineer and Denver Water.

Quarry Benching

Production Drills

2.2.5 Measures to Protect Nearby Structures

The nearest permanent structures to the quarry are an out-building and a house off of Miramonte Rd. These structures are approximately 1,600 feet to the southwest of the nearest point in the quarry as shown in Figure 10. Seismograph(s) will be placed between the quarry and these structures to measure vibration and/or overpressure to ensure damage is not caused to the structure. KBJV recommends a pre-blast survey be conducted to document the condition of existing structures prior to construction. The next closest structure to the quarry besides the described buildings is the Denver Water yurt located near the maintenance building, and it is more than 4,600 feet way from the quarry, a distance that is outside of any foreseeable blasting influence as shown in Figure 10.

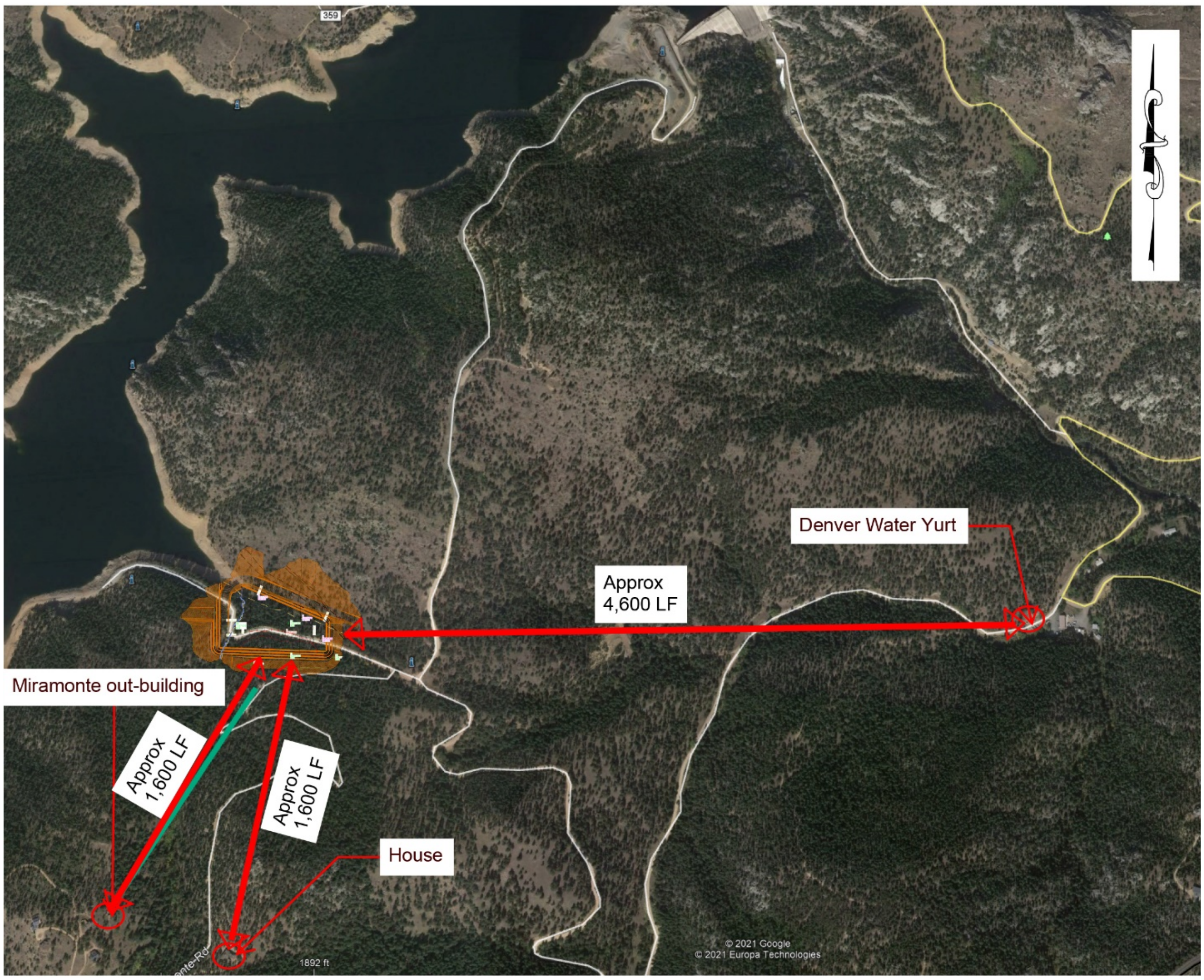


Figure 10: Blasting Distance to Structures

2.2.6 Handling/Hauling/Stockpiling Unprocessed Material

Quarry operations will be planned and scheduled so that adequate work areas are available for the various operations. To ensure an adequate supply of unprocessed material, activities will be staged so that areas will be available for drilling, blasting, and excavation operations. This process is described in section 2.2.3 and is depicted in Figure 9.

Unprocessed material will be loaded and hauled to the crusher with a large excavator or loader and off-highway trucks. A stockpile of crusher feed material will be established near the crusher feed location so that a loader can feed the crusher if the rock supply from the quarry is interrupted. If the crusher cannot handle the output of the quarry excavation operation (due to downtime or other reasons), and the stockpile location near the crusher is full, the quarry excavation equipment will be redirected to other operations. These operations may include surfacing/maintaining roadways or scaling quarry slopes. Trucks that feed the crusher will be used as needed, possibly on a different shift, to supply processed aggregates to the RCC and CVC batch plant operations to allow continuous batching during the dam raise work.

2.2.7 Fish Stranding Measures

After the GRE Project has been completed, the normal low water level will be elevation 7380, well above the bottom of the planned quarry elevation of 7266. This is more than 100 feet of water that will eliminate the risk of fish stranding during normal reservoir operations. Upon completion of the quarry excavation, positive drainage will be established by shaping the quarry floor to drain toward the reservoir. Once the quarry floor has been graded to drain, potential isolated ponding areas will be identified and eliminated by re-grading or backfilling. These measures will mitigate the potential risk for fish to be trapped within the quarry footprint during extreme water drawdown periods below the bottom of the quarry elevation (7266).

During the quarry operation period there is little risk of fish standing within the quarry because the reservoir water level will be at elevation 7250 or lower, well below the elevation of the quarry during construction. If the reservoir water level does rise during quarry operations any potential risk areas for fish stranding will be addressed by creating positive drainage and eliminating any ponding within this area.

2.3 Water Management

2.3.1 Drainage Management

As shown in Appendix C, Quarry Design PDF Files, sheet number C.02, all runoff draining naturally toward the quarry footprint will be collected and diverted around the quarry. Drainage from the south will be collected at the top of the cut slope and diverted east around the excavation in a ditch. The large basin draining to the southwest corner will be collected in a pipe or possibly in a lined V-ditch depending on the final slope of the upper slope cut. Drainage from the north (including the north cut slope area) will be collected in the quarry access road ditch and conveyed west toward the reservoir. A small berm will be constructed as needed to create sufficient headwater in the pipe option at the southwest corner or to provide a downslope bank in cases where containment of flows is needed. The two outfall points shown on the drawings will have sediment traps to slow velocities sufficiently to drop sediment before drainage enters the reservoir, but no storage or detainment of flows will occur. These sediment traps will be maintained through the life of quarry operations. Maintenance of these sediment traps involves removing excess sediment buildup within the rip-rap rock by hand or with equipment. The removed sediment will be tested for contaminates. If material is free of contaminates, it will disposed of on site. If the material can not be disposed of on site due to level of contaminates, it will be disposed of at an approved off-site location. As the quarry excavation progresses, the drainage within the quarry footprint will drain naturally or through temporary ditching to the northwest corner collection pond with a 30-inch outlet pipe as shown in Appendix C, Quarry Design PDF Files, sheet number C.02. Maintenance of this collection pond will consist of routine inspections and removals of collected sediments. A detailed Storm Water Management Plan will be developed as part of the Colorado Dishcharge Permit System-Sormwater Construction Permit which will include specific maintenance procedures for all the best management practices.

2.3.2 Groundwater Management

Groundwater was recorded in borings TH-9, TH-10, and TH-11 (refer to Figure 2 for boring locations) during drilling, indicating groundwater elevations of 7335, 7414, and 7404 feet, respectively. Though the observed groundwater elevations likely do not represent the normal water table because water was used during drilling; the recorded water elevations in these borings vary following the ground surface topography. A piezometer was installed in boring TH-8 and a reading from September 2018 recorded groundwater at elevation 7377 feet. As the bottom of quarry elevation is 7250, groundwater inflow to the quarry should be expected. As the quarry excavation progresses, areas of groundwater ponding may occur which, if necessary, will be handled with either temporary ditching or grading to the northwest corner of the quarry to a collection pond with a 30” outlet pipe.

2.3.3 Sediment Control

The primary short-term concern for sediment control is steepness of excavated slopes in overburden and roadside ditch sections, which can result in high velocities that can transport sediment material into the reservoir. Sediment traps (small containment embankments with lined overflow spillways) will be designed at the outfall locations to slow velocities and drop out sands and gravels being transported during storm events. The sediment traps will be routinely inspected, and periodic cleaning will be required for them to function properly. Runoff resulting from rainfall directly into the quarry footprint and benches will drain to the bottom of the northwest corner of the quarry where a collection pond is proposed to allow possible water quality treatment of runoff prior to release into the reservoir. The pond will require periodic maintenance by removal and proper disposal of sediments and hazardous constituents or residues deposited in the quarry bottom from normal operation activities. Other sediment control measures will include silt fences, straw bales, or straw wattles placed strategically at the toe of disturbed slopes or other recent excavations or fills to prevent erosion and sediment transport. Other best management practices for erosion and sediment control will be evaluated and implemented as needed. A Storm Water Management Plan for all quarry drainage will be prepared as part of the Colorado Dishcharge Permit System-Sormwater Construction Permit.

2.4 Safety

The safety of the workers and the public is the most important focus in all aspects of the Osprey

Point Quarry from the design to the operations. A discussion of the larger safety risks for the quarry operations and the mitigation procedures is presented below.

2.4.1 Worker Safety During Quarry Operations

Prior to any work being performed at the quarry, a comprehensive program-wide Site Safety and Security Plan will be developed. Part of this plan will focus on the safety of quarry operations. Specifically, rock slope safety will be a significant safety risk. To mitigate this risk, several safety measures will be implemented, including:

- A project-specific Drilling and Blasting Plan which includes safety will be developed and reviewed with applicable parties.
- Slopes will be visually inspected regularly for any signs of instability or loose rocks.
- Slopes will be machine-scaled as excavation proceeds.
- Rock stability measures such as rockbolts, mesh, or shotcrete will be implemented as needed depending on conditions.
- Slopes will be periodically inspected by the Engineer of Record (Kiewit Infrastructure and Engineering Group) to confirm design parameters and validate assumptions.

See Appendix A, Production Quarry Design Narrative, Section 4.0 Geotechnical Design Recommendations, for additional details on the evaluation of the slopes prior to, during, and after construction. In addition to rock slope safety, other high safety risk items include excavation and truck hauling operations. For each operation a specific Hazard Analysis will be performed to identify specific risks and mitigation procedures to be reviewed and implemented by the crew performing the work.

2.4.2 Public Safety During Quarry Operations

The Osprey Point Quarry work may pose hazards to the general public. This section will discuss a few of the higher risk items as well as mitigation procedures. The blasting operations present a risk for the public. As part of the Drilling and Blasting Plan, the procedures for the blasting operations as well as the clearing of the blast zones will be established. The pre-blast procedures will include clearing all non-essential personnel from the immediate area of the blast and posting blast-guards in the designated areas as shown in Figure 11. The locations of the blast-guards may vary depending upon many factors such as the actual location of the blast in the quarry. The blast-guards will remain in their designated areas to keep the area cleared until the blaster-in-charge gives the all-clear. If an unauthorized person is observed within the protected area or other potential safety issues are observed, the blast will be postponed. The blaster-in-charge will be the responsible person and will have constant radio contact with the blast-guards. Recreational boaters within the waters near Osprey Point Quarry may potentially enter the blast zone. To mitigate this risk, a floating barrier with warning signs will be installed as shown in Figure 11. This barrier will act as a visual warning and create a physical deterrent for recreational boaters. Additionally, the reservoir will be visually cleared either from the shore or from a boat prior to each blast to ensure no boating recreationists are within the designated blast zone.

After the blast is completed, the blast area will be examined by the blaster-in-charge and crew for any safety concerns. If there are no issues, the blaster-in-charge will give the all-clear signal over the radio to all the blast-guards that it is safe for them to leave their designated location.

Even though this area will be closed to the public, the cut slopes of the quarry may present a fall hazard for the public who may have unintentially entered the site. To mitigate this risk, temporary fencing will be installed along the rim of the quarry and remain in place for the duration of the project to protect people from potential falls down the slopes. In addition to the fencing, signage will be posted on South Boulder Creek Inlet Trail to inform recreationists of construction activity and provide guidance to stay clear.

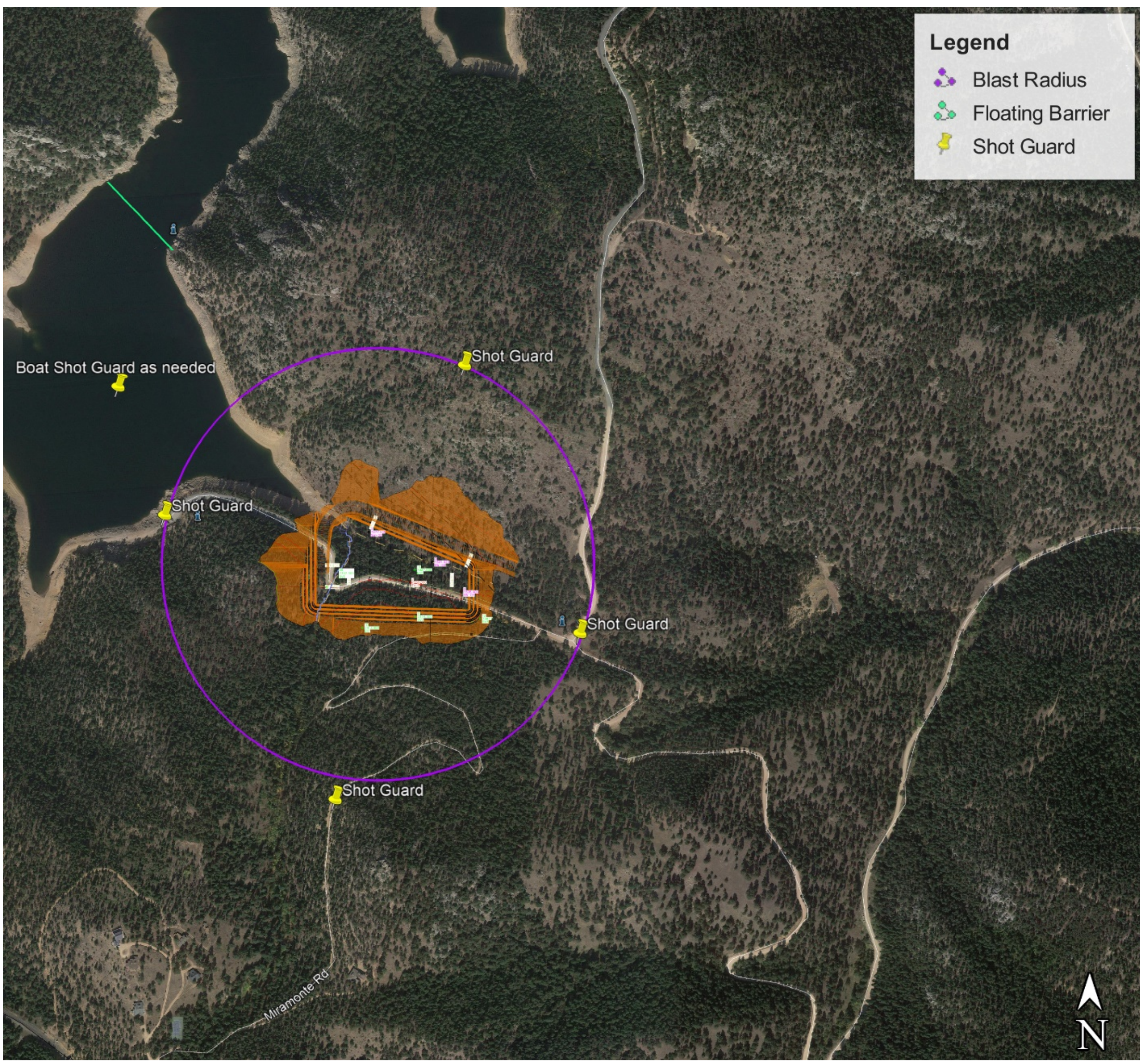


Figure 11: Blast Zone and Floating Barrier

2.5 Osprey Point Quarry Operations Schedule

The following is a summary for the Osprey Point Quarry Operations schedule. Refer to Appendix B, Quarry Operations Schedule, for the Bar Chart Summary Schedule. The quarry development work, which includes the preparatory work and the overburden removal, is planned for 2022 to coincide with the overall project site development work. During the 2023 season, the rock processing equipment will be mobilized to the site and set up for operations, which will include crushing rock for the RCC test fill operations. The 2024 and 2025 seasons will find the quarry operations in full production to support the RCC and CVC work. The rock crushing operations are anticipated to be completed in the 2025 season; the reclamation of the Osprey Point Quarry is anticipated to be completed in the 2026 season. A more detailed review of the Osprey Point Quarry operations schedule is as follows:

The Osprey Point Quarry site preparatory work is planned to start April 1, 2022. The purpose of this work is to ready the quarry site for the overburden excavation operations. The following operations make up this preparatory work:

- The first operations will be to provide survey control and layout for the limits of clearing for the quarry and access road based on the approved quarry design.
- Installation of best management practices for erosion control will be installed based on the approved Erosion Control Plan.
- The next operation will be installation of temporary or permanent fencing at select areas along the top of the quarry limits to protect the public from entering the work operations.
- Clearing of vegetation and topsoil excavation operations will then commence. The clearing debris will be processed onsite and removed as required. The excavated topsoil material will be stockpiled at the location shown on Figure 2. The topsoil stockpile area will also be prepared to accept material during this period.

Once the preparatory work has been completed, excavation of the Osprey Point Quarry overburden will start. This work is planned to start in May 2022 and to continue for about 3 months. Approximately 373,000 CY of overburden excavation will be used to build various site development embankments such as office pads and maintenance pads, but primarily it will be used to build the crusher pad as shown in Figure 2.

The last operations for 2022 season will be to perform test crushing operations. Once enough overburden has been removed and competent rock exposed, a small quantity of rock will be drilled and blasted, excavated, and hauled to select crushing equipment mobilized for test crushing. The purpose of the test crushing is to produce concrete aggregates for further testing and verification of concrete mix designs. The test crush is anticipated to occur as early as possible in summer 2022, because the same crushing equipment will be used for producing the site aggregate for the access roads and pads.

In 2023, the production rock crushing equipment will be mobilized to the site and setup on the crusher pad starting in July with about a 2-month duration. Once the setup is complete, a select quantity of rock from Osprey Point Quarry will be drilled and blasted, excavated, and hauled to the crusher to process concrete aggregate to be used for the RCC test fill. The test fill is a small-scale replication of the RCC embankment to demonstrate the methods to be used for the production RCC operations. The plan is to perform the RCC test fill in 2023 to prove the methods and to allow enough time for any necessary adjustments.

The RCC and CVC operations for the dam raise of the GRE Project is planned for 2024 and 2025 seasons. The Osprey Point Quarry operations will follow this schedule and be in full production during these work seasons. It is anticipated that the quarry operations will occur between the months of April and October each season. The RCC and CVC operations for the dam raise is planned for completion by the end of October 2025, which will also represent the completion of the quarry operations. The remaining aggregate quantities for the 2026 structures work requiring CVC will be evaluated closely to ensure suitable quantities are stockpiled for this work.

Once the quarry operations have been completed in 2025, the final reclamation process can begin. This work is planned to start in early 2026 and to be completed the same year.

Appendix A:
Production Quarry Design Narrative (Including Slope Stability Analysis)

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Gross Reservoir Expansion Project

Draft Final Osprey Point Quarry Design

Prepared By:
Kiewit Engineering Group, Inc
12510 Belford Avenue
Englewood, CO 80112
303-675-2220

Prepared For:
KBJV
1526 Cole Blvd
Lakewood, CO 80401
720-356-5659

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1.0 Introduction

1.1 Scope of Work

This document presents the results of the geotechnical interpretations, analyses, and design recommendations developed by Kiewit Engineering Group, Inc. (Kiewit Engineering) for the proposed Gross Reservoir Expansion (GRE) Project. This report was prepared to provide recommendations for the GRE Exhibit A Scope of Work - Task 9 Osprey Point Quarry Design including geotechnical analysis of soil and rock slopes and evaluation of surface drainage. Kiewit Engineering has prepared these recommendations for Kiewit-Barnard Joint Venture (KBJV).

The Gross Reservoir Expansion Project (GRE Project) is located on the South Boulder Creek in Boulder County, Colorado. The objective of this project is to raise the existing dam by 131 feet to increase the storage capacity of Gross Reservoir. The Osprey Point Quarry (Quarry) will provide concrete aggregate for the GRE Project construction. The proposed location and plan of the Quarry are shown Figure 1 in and Figure 2, respectively.

This document incorporates the results of the following geotechnical investigation reports prepared for the GRE project:

- Geological and Geotechnical Interpretive Report – Production Quarry Volume 1, prepared by Stantec Consulting Services, Inc. dated February 4, 2019.
- Geological and Geotechnical Data Report – Production Quarry Volume 1, prepared by Stantec Consulting Services, Inc. dated February 4, 2019.
- P2-Site Development Geotechnical Design Report, prepared by Stantec Consulting Services, Inc. dated November 5, 2018.

Additional investigation was also performed by Black & Veatch in October 2020, but a report has not been completed at the time of this design. The analysis and recommendations contained in this report are based on the information presented in the documents listed above and draft borings completed by Black & Veatch.

2.0 Project Background

2.1 Existing Site Conditions

Gross Reservoir is located on the South Boulder Creek, roughly 7 miles southwest of Boulder, Colorado in the Arapaho-Roosevelt National Forest. The reservoir is located on Denver Water and National Forest System lands. The reservoir currently has a storage capacity of 42,000 acre-feet. The existing dam is a 340-foot-tall curved concrete gravity structure.

2.2 Proposed Construction

The Quarry will be located to the east of Osprey Point within Denver Water property limits, where it will tie into the reservoir and be mostly inundated upon project completion. The excavation will not extend below Elevation 7250 feet, based on the aggregate quantity needed for construction and rock quantity estimated at this time. The vertical limit of disturbance will be Elevation 7461 feet. During construction, the Gross Reservoir water level will be maintained at or below Elevation 7250 feet. Rock will be excavated using blasting methods following the geometry shown in Figure 2.

2.3 Previous Geotechnical Investigations

Previous investigation was performed by Shannon & Wilson in 2016, Stantec Consulting Services (Stantec), Inc in 2018 and Black & Veatch in 2020. In summary, the geological and geotechnical investigations in the Quarry area consisted of:

- sixteen test borings drilled to depths ranging from 70 to 185 feet below the ground surface,
- ten downhole televiewer surveys,
- eight test pits excavated 6 to 12 feet below the ground surface,
- sixteen seismic refraction tomography (SRT) line surveys, and
- two downhole seismic (DS) surveys.

In addition, the P2-Site Development report provided guidance and recommendations for joint strength that were not reported in the Quarry reports.

3.0 Surface and Subsurface Conditions

3.1 Surface Conditions

The Quarry site topography consists of steep terrain with elevations ranging from approximately 7260 to about 7470 feet. The Quarry site collects existing drainage flows primarily from the north and south with a small basin draining in from the east. Drainage from the hillside north of the Quarry will sheet flow into the Quarry site while a larger drainage feature exists towards the southwestern corner of the Quarry running south to north-towards the reservoir. A road leading to the Osprey Point boat launch also runs through the proposed Quarry location. Vegetation primarily consists of grasses, cacti, and coniferous trees.

3.2 Subsurface Conditions

Surficial deposits include in-situ (residuum), naturally deposited (alluvium / colluvium), or human placed (fill) materials. The majority of surficial deposits originated from decomposed granite (DG) and are generally classified as silty sand based on the ASTM Unified Soil Classification System. The consistency of the silty sand is described as medium dense to very dense. The borings show surficial deposits ranging from 10 to 40-feet deep.

Bedrock was encountered below the surficial deposits. The bedrock primarily consists of medium to coarse-grained granodiorite of the Pre-Cambrian age Boulder Creek Batholith. The granodiorite contains local intrusions of aplite and quartz monzonite dikes less than 5-feet in width. The aplite and quartz monzonite are generally high to very high in strength and more resistant to weathering than the granodiorite. The dikes are more brittle and therefore have a higher fracture frequency than the granodiorite. The greater fracture density may indicate higher permeability within the dikes.

Previous mapping done by Wells (1967) and observations during the 2018 Stantec investigation identified the Roger's Fault Zone (RFZ) near the Gross Reservoir and the planned Quarry. The northwest corner of the Quarry crosses into the RFZ, which consists of southeast to northwest trending faults and shears. One boring was performed within the limits of Roger's Fault and indicates 20 feet of silty sand overburden over 24 feet of highly weathered granodiorite that breaks down into poorly graded sand and gravel. The RFZ was also observed through exposure on the surface near the reservoir, anomalously low compressional wave velocity (V_p) along SRT lines, and a shear zone observed in Test Pit TR-4. Rock excavated in this area may not be suitable for aggregate.

Groundwater was recorded in borings TH-9, TH-10, and TH-11 (refer to Figure 2 for boring locations) during drilling indicating water elevations of 7335, 7414, and 7404 feet, respectively. Though the observed groundwater elevations likely do not represent the normal water table because water was used during drilling, the recorded water elevations in these borings vary following the ground surface topography. A piezometer was installed in boring TH-8 and a reading from September 2018 recorded groundwater at elevation 7377 feet. As the bottom of Quarry elevation is 7250, groundwater inflow to the Quarry should be expected.

4.0 Geotechnical Design Recommendations

4.1 Surficial Soil Parameters

Parameters to describe the strength and behavior of the surficial soils were developed as a basis for evaluating stability of the overburden slopes. Laboratory testing of soil strength was generally not performed in the previous investigations; therefore, strength parameters were derived based on field testing and empirical correlations.

Two standard penetration tests (SPT) were performed on the surficial soils. Hammer efficiency was not reported, so 85% was assumed based on recommended efficiency corrections reported in Rogers, 2006. The friction angle was estimated using an empirical correlation with SPT blow counts from Terzaghi, Peck, and Mesri (1996). Soil unit weight was estimated using correlations in FHWA NHI-06-089. Engineering judgement and previous experience with similar soils further refined the soil design parameters. Previous reports did not provide recommendations for surficial soils. Recommended values for the design of the overburden slopes are summarized in Table 1.

Table 1: Generalized Surficial Soil Design Parameters

	Silty Sand
Total Unit Weight	125 pcf[1]
Friction Angle	35°
Cohesion	0 psf[2]

[1] Pounds per cubic foot
[2] Pounds per square inch

4.2 Rock Parameters

Rock was modeled as granodiorite and broken into two groups based on degree of weathering: (1) moderately weathered to fresh rock and, (2) highly to completely weathered. Rock parameters were developed as a basis for evaluating performance of the rock slopes. These parameters were derived using field testing, laboratory testing, and empirical correlations, and are summarized in Table 2.

The previous investigations provided rock testing results for unit weight and compressive strength as well as geological strength index (GSI) values for various rock core runs. Tests were not performed for joint friction angle in the quarry area. A planar joint friction angle of 34 degrees was used based on published data from Wyllie (1996). The friction angle for rough joints varies depending on the normal stress on the joint. The variation in joint friction angle was evaluated for normal stress corresponding to different depths using the method from Barton and Choubey (1977). A joint roughness coefficient of 6 and uniaxial joint compressive strength of 3,000 pounds per square inch was recommended from previous investigations. The joint roughness presented in the core logs consistently described the joints as slightly rough, which agrees with the recommendation from the previous investigation. Based on this analysis, the joint friction angle ranged from 41 degrees to 45 degrees for the anticipated normal stresses in the quarry. The Hoek-Brown constants m_i and D (disturbance factor) were determined using Hoek (2006).

Due to the lack in testing for joint friction, it is recommended that direct shear tests be performed on rock core samples to verify joint friction angle.

Table 2: Generalized Rock Design Parameters

	Moderately Weathered Rock	Highly Weathered Rock
Total Unit Weight	165 pcf[1]	
Intact Rock Compressive Strength	8,000 psi[2]	
Geologic Strength Index	65	30
Joint Friction Angle	41 to 45°	
Hoek-Brown Constant, m_i	29	
Disturbance Factor	1	
Joint Roughness Coefficient	6	
Joint Compressive Strength	3,000 psi[2]	

[1] Pounds per cubic foot
[2] Pounds per square inch

4.3 Overburden Cut Slopes

Global stability analyses were performed for the soil cut slopes using the two-dimensional limit equilibrium software GeoStudio Slope/W (Version 10). The Morgenstern-Price analysis method was used to determine the appropriate slope geometry for temporary and permanent conditions. A minimum factor of safety of 1.3 was used for the temporary and permanent conditions.

A CAT 773 haul truck surcharge (1,400 psf) with a 10-ft minimum offset from the slope crest was utilized in the analysis to account for construction equipment for the temporary condition. The surcharge pressure was calculated as a shadow pressure below trucks loaded with a 15% overload on the payload. A surcharge was not applied to the permanent condition because significant surcharges are not expected after construction is complete.

The reservoir level was modeled at Elevation 7250 feet during construction. The expanded reservoir water level was modeled at Normal High Water Level (NHWL - Elevation 7406 feet) and Normal Low Water Level (NLWL - Elevation 7380 feet) post construction. Figure 3 presents the average yearly reservoir water level from 2010 to 2018 and the expected new reservoir level after project completion. A rapid drawdown analysis was not performed due to the granular composition of the overburden soil. The overburden soil is expected to have a high enough hydraulic conductivity so it will not retain the porewater pressure if the reservoir level is rapidly dropped. Additionally, based on the data in Figure 3, a rapid drawdown condition is not expected during normal reservoir operation. Table 3 summarizes the results from the stability analyses and the Slope/W outputs are presented in Figure 4 through Figure 10.

Table 3: Slope/W Slope Stability Results

Slope Type[1]		Surcharge	Water Level Elevation	Factor of Safety
Overburden	2H:1V	None	7406 feet (NHWL)	1.4
	1.75H:1V	None	7406 feet (NHWL)	1.3
	2H:1V	None	7380 feet (NLWL)	1.3
	2H:1V	None	7250 feet	1.4
	2H:1V	CAT 773	7250 feet	1.5

[1] Horizontal : Vertical

Based on the analyses results, a 2H:1V slope meets the minimum factor of safety of 1.3 for temporary and permanent soil slopes. A 1.75H:1V soil slope was also analyzed for slopes entirely above the post-construction NHWL to optimize the slope design and reduce the limits of disturbance around the Quarry. The results show that a 1.75H:1V slope above the NHWL also meets the minimum factor of safety for temporary and permanent slopes.

4.4 Rock Cut Slopes

The rock cut slopes recommendations were developed based on geotechnical data from previous site investigations and rock parameters listed in Section 4.2. Kinematic analyses were performed using Rocscience Dips (Version 8) to determine which joint sets are of concern regarding potential failures. A joint friction angle of 41 degrees was used in Dips. Potentially unstable wedges were analyzed using Rocscience Swedge (Version 6). The joint friction in Swedge was modeled using the Barton and Choubey (1977) method. A rockfall analysis was performed using the Colorado Rockfall Simulation Program (CRSP) (Version 4). Global stability of slopes was evaluated using limit equilibrium analyses in GeoStudio Slope/W 2021 and Rocscience Slide 2 (Version 9). The Hoek-Brown failure criteria was used to define the rock strength in Slope/W. An anisotropic analysis was performed on the rock in Slide2. The rock mass strength was defined using Hoek-Brown and the joint strength was approximated using Barton and Choubey (1977).

Five major joint sets were identified in the previous investigations and are listed in Table 4. The major joint sets were plotted on stereonets for each side of the Quarry to identify potentially unstable wedges. The stereonet analysis identified potential wedge sliding in the eastern, southern, and western slopes. The results are presented in Figure 13 through Figure 16.

Table 4: Major Joint Sets

Joint Set	Range of Strike Azimuth	Range of Dip	Range of Dip Azimuth
1	305° - 334°	43° - 56°	35° - 64°
2	280° - 288°	52° - 66°	10° - 18°
3	13° - 33°	38°	103° - 121°
4	312° - 322°	18° - 32°	42° - 52°
5	230°	43°	320°

Small unstable wedges and debris will be scaled during excavation and larger wedges may need to be stabilized by rock bolting. Larger wedges were evaluated using the Barton model for joint strength to determine the factor of safety against sliding into the Quarry. Stability results are presented in Figure 17 through Figure 23. Two cases were considered: (1) dry joint surfaces and, (2) joints 20% filled with water to account for rainfall. Weep holes are recommended 5 feet above each bench to drain the rock mass to meet the design criteria. The weep holes should be 40-feet long and be inclined 5 degrees from horizontal. The joints are expected to be 20% filled with water or less with the proposed weep holes. A pattern rock bolt design was developed for potentially unstable wedges and the results are summarized in Table 5 and Table 6.

Rock bolts were designed to meet a factor of safety of 1.3. A minimum bonded length of 10 feet is required beyond the potential failure plane. Based on the analysis, bolts will be between 30 and 35 feet long. The design will be adjusted based on field observation.

Table 5: Rock Bolting Requirements for Dry Joints

Slope	Joints	Factor of Safety without Reinforcement	Factor of Safety with Reinforcement	Dowel Capacity (kips)
East	J2 & J5	1.4	Not Required	
South	J1 & J2	0.9	1.3	50
	J1 & J5	1.7	Not Required	
	J2 & J5	1.2	1.3	10
West	J1 & J2	1.8	Not Required	

Table 6: Rock Bolting Requirements for Joints 20% Filled with Water

Slope	Joints	Factor of Safety without Reinforcement	Factor of Safety with Reinforcement	Dowel Capacity (kips)
East	J2 & J5	1.4	Not Required	
South	J1 & J2	0.8	1.3	52
	J1 & J5	1.7	Not Required	
	J2 & J5	1.2	1.3	10
West	J1 & J2	1.8	Not Required	

The stereonet analysis indicated that rock toppling may be a possible, however this failure mode is not expected in the granodiorite. Toppling commonly occurs in rocks with columnar features or rocks with regularly spaced parallel fractures, which is not a characteristic of the bedrock at the quarry location. This assumption will be verified through field mapping and observations during construction.

A rockfall analysis was performed for 40-foot high 0.25H:1V slopes with various bench widths. Various rock sizes smaller than 5-feet in diameter were modeled with the assumption that larger rocks will be scaled or rock bolted. The CRSP input and results for a 3-foot sized rock can be found in Figure 24 and Figure 25. It was determined that the 10-foot-wide bench will stop approximately 55% of fallen rocks. Quarry operations should be conducted in such a manner that the exposure to unprotected personnel is minimized.

Local stability of one bench was evaluated using the Hoek-Brown failure criteria for completely to moderately weathered rock slopes. This analysis of completely weathered rock is representative of slopes in the NE corner of the Quarry that intersects Roger's Fault. Results can be found in Figure 8 and Figure 9 and are summarized in Table 7. Based on the results, 0.25H:1V rock slopes with a maximum height of 40 feet and 10-foot benches are appropriate in moderately weathered to fresh rock at the Quarry. Each rock slope shall be inspected and scaled during construction to mitigate rockfall hazards. Where deemed necessary, potential wedges shall be rock bolted. Highly weathered rock can be sloped at a 1H:1V to reduce limits of disturbance around the Quarry.

Global stability of the entire slope (overburden over completely weathered rock over moderately weathered rock) was evaluated using an anisotropic shear strength function. This analysis is based on persistent joints through the slope, which represents a worst-case condition. The impact of pattern rock bolting was also evaluated. Results of this analysis can be found in

Figure 11 and Figure 12. Based on the results, pattern bolting will be needed if joints are persistent. This recommendation will be adjusted based on field conditions and observation of joints.

Table 7: Slope/W Local Bench Slope Stability Results

Slope Type		Surcharge	Water Level Elevation	Factor of Safety
Completely Weathered Rock	0.25H:1V	CAT 773	7250 feet	1.4
Moderately Weathered Rock	0.25H:1V	CAT 773	7250 feet	3.9

Table 8: Slide Global Slope Stability Results

Slope Type	Rock Bolts	Factor of Safety
2H:1V Overburden over 2H:1V Completely Weathered Rock over 0.25H:1V Moderately Weathered Rock	None	0.8
	10' x 10' Rock Bolt Pattern extending 10' beyond failure plane	1.3

5.0 Drainage Recommendations

5.1 Drainage Area Description

Areas draining to the Quarry include approximately 19 acres from the north, 84 acres from the south, and 3 acres from the east. The basins are steep, with slopes ranging from 15 up to about 40 percent. The ground cover consists of grasses, shrub vegetation, and coniferous moderately dense forest. Soils are predominantly Hydrologic Soils Group (HSG) Type D (high runoff potential), with some Type A (free draining with low runoff potential) within the total area draining to the Quarry. A map of the hydrologic soils group in the project area can be found in Figure 28. According to the soil survey computed by the United States Department of Agriculture, the area of interest contains several soil surveys that may have been mapped at different scales, with different land uses in mind, at different times, or at different levels of detail. Due to the level of uncertainty that may exist with these different soil surveys, an assumption was made to use all Type D soils in hydrology calculations in order to remain conservative. All the area currently draining to the Quarry naturally drains into Gross Reservoir. The next section describes the proposed drainage basins in detail.

5.2 Basin Hydrology

Twelve basins, also known as catchments in the calculations, have been delineated for the different design points in and around the Quarry. Figure 26 and Figure 27, the Quarry Basin Map, shows the twelve drainage basins in the project area. Basins Q1 through Q9 consist of offsite and onsite areas that drain towards the Quarry footprint, and basins QAR1 through QAR3 consist of offsite and onsite areas that drain towards or in the Quarry Access Road. Basin Q1 is the largest at 55.9 acres and drains south to north in a defined swale to the southwest corner of the Quarry. Basins Q2 and Q3 are 3.3 and 7.0 acres, respectively and also drain from south to north towards the southern excavation limits of the Quarry as sheet flow. These flows will be intercepted by diversion ditches and conveyed around the grading limits of the Quarry. Basins Q4 (9.1 acres) and Q5 (8.2 ac) drain from north to south as sheet flow and will be intercepted by the proposed Quarry Access Road north-side ditch, draining to the west. Basin Q6 is a 0.5-acre area between the Quarry Access Road and the Crusher Pad that will drain westward in a natural swale. Basins Q7 and Q8 (3.0 acres and 2.7 acres respectively) are the overburden slope areas upstream of the Quarry footprint. These flows will sheet flow down the slope and Quarry benches into the bottom of the Quarry. Basin Q9 is the Quarry footprint itself, which will be graded to drain towards the northwest corner. A large offsite basin, QAR1 (13.6 acres), drains from the south to the northeast and will be intercepted by a road-side ditch on the south side of the Quarry Access Road. Basins QAR2 (1.3 acres) and QAR3 (2.1 acres) are the Quarry Access Road itself, which drains to the north and west towards the Quarry.

Basin hydrology was developed using the Colorado Urban Hydrograph Procedure (CUHP), a synthetic unit hydrograph method calibrated to the Front Range and accepted by Boulder County as an approved hydrology modeling approach. The key model input parameters include basin (or catchment) area, slope, channel length and length to subbasin centroid, and infiltration characteristics for Horton's equation. Table 9 below provides a summary of basin input parameters for the CUHP model, and Table 10 presents the 10-, 25-, 50-, and 100-year 1-hour rainfall depths used in the modeling. The 1-hour rainfall depths were taken from the NOAA Atlas 14 Point Precipitation Frequency Estimates. The full results of the CUHP inputs and NOAA Atlas 14 Precipitation Data can be found in Figure 31 and Figure 30, respectively.

Table 9: CUHP Basin Input Parameters

Sub-basin	Area (ac)	Flowpath Length (ft)	Length to Centroid (ft)	Slope (ft/ft)	Percent Imper-vious (%)	Initial Infiltration Rate (in/hr)	Decay Coeff. (1/sec)	Final Infiltration Rate (in/hr)
Q1	55.9	2609.2	1323.1	0.172	2	3.0	0.0018	0.5
Q2	3.3	1234.0	622.8	0.262	2	3.0	0.0018	0.5
Q3	7.0	1370.4	651.5	0.200	2	3.0	0.0018	0.5
Q4	9.1	1237.7	589.4	0.372	2	3.0	0.0018	0.5
Q5	8.2	1284.5	835.6	0.415	2	3.0	0.0018	0.5
Q6	0.5	346.6	171.0	0.122	2	3.0	0.0018	0.5
Q7	3.0	433.8	185.6	0.500	45	3.0	0.0018	0.5
Q8	2.7	141.4	16.0	0.510	45	3.0	0.0018	0.5
Q9	7.4	785.9	332.4	0.005	90	3.0	0.0018	0.5
QAR1	13.6	2499.4	835.8	0.154	2	3.0	0.0018	0.5
QAR2	1.3	930.9	538.0	0.014	40	3.0	0.0018	0.5
QAR3	2.1	1478.5	775.5	0.100	40	3.0	0.0018	0.5

Table 10: NOAA Atlas 14 1-Hour Rainfall Depths

Storm Event	1-Hour Rainfall Depth (in)
10-yr	1.30
25-yr	1.60
50-yr	1.84
100-yr	2.08

The CUHP model was run using a 1-minute timestep between computations, and the peak discharge results are presented in below. It is recommended that the temporary conveyance and diversion facilities be designed for the 10-year flows. The Quarry is anticipated to be in operation for 4 years and there is a 40-percent chance that a 10-year rainfall event would occur within a 4-year construction window. With the hydrologic results presented in Table 11, the drainage areas and peak discharge rates for each basin were plotted by storm event. As shown in Figure 33, a linear equation can be used to describe the relationship between Drainage Area and Peak Discharge for the 10-year storm event. The linear equation for the 25-year storm is used to calculate the peak discharge rate for any drainage area in Task 11. The full hydrologic results can be found at the end of this report in Figure 32.

Table 11: Peak Discharge Rates for Quarry Subbasins

Subbasin	Area (ac)	Storm Event			
		10-yr	25-yr	50-yr	100-yr
Q1	55.9	13.2	38.5	52.6	69.2
Q2	3.3	0.5	1.6	2.2	3.0
Q3	7.0	1.3	3.9	5.3	7.1
Q4	9.1	2.3	6.7	9.1	11.9
Q5	8.2	1.8	5.2	7.1	9.3
Q6	0.5	0.1	0.3	0.3	0.5
Q7	3.0	4.1	6.5	8.2	9.8
Q8	2.7	4.5	9.2	11.1	12.7
Q9	7.4	5.3	10.0	12.6	15.5
QAR1	13.6	2.2	6.7	9.2	12.4
QAR2	1.3	0.4	0.7	0.9	1.1
QAR3	2.1	0.8	1.4	1.7	2.1

5.3 Drainage Conveyance and Diversion Design

Flows draining towards the Quarry will be handled with diversion ditches, pipes, and various erosion control measures. The primary intent is to intercept drainage before it enters the Quarry working area and divert flows around the excavation limits. Drainage flows generated within the Quarry excavation limits will be collected at the northwest corner and drained to the reservoir through a pipe. This outfall point is anticipated to convey sediment from disturbed areas and will have a sediment basin system upstream of the outlet pipe to prevent excess sediment transport to and deposition within the reservoir. The outlet pipe will have a headgate installed at the outfall of the sediment basin to allow closure in the event of a hydraulic oil leak or fuel spill but would normally be left in the open position. The intent of the design described below is to prevent sediment-producing flows from co-mingling with non-sediment producing flows. The individual basin drainage components are discussed below and can be found in Figure 26 and Figure

27along with the drainage outfall points. On sheet 2 of the Quarry Basin Map, Figure 27, a table summarizes the cumulative discharge rates at each design point.

Calculations for sizing the v-ditches were completed using Bentley's FlowMaster hydraulic toolbox. Inputs to the program include Manning's roughness coefficient, channel slope, side slopes, and discharge. These inputs were taken from the CUHP hydrology results and the proposed grading. A summary of the ditch calculations can be found in Figure 34. Sizing for the proposed pipes and riprap aprons was completed using the Culvert Design spreadsheet created by the Mile High Flood District (MHFD). The calculations for the four proposed pipes and their respective riprap aprons can be found in Figure 35 through Figure 45.

Basin Q1

Basin Q1 will drain to the limits of excavation at the southwest corner of the Quarry. The 10-year flow of 13 cfs will be collected in a 30-inch diameter HDPE pipe (referred to as "SW Outlet Pipe") which will run along the second Quarry bench and along the western 2H:1V excavated slope. Since the pipe will follow the bench and excavated slope, the longitudinal slope of the pipe will vary from 0 percent to 25 percent. The flows will then be conveyed north to a discharge point just south of the original Osprey Point road. A riprap apron will be placed at the pipe end section from which the flows will sheet flow down into the reservoir.

Basin Q2

The 3.3-acre Q2 basin will generate a peak 10-year discharge of about 0.5 cfs. Flows will be intercepted in an east to west 0.5-foot deep v-ditch (Ditch Q2) sloping at a minimum 2.8 percent longitudinal slope with minimum 3H:1V side slopes. The v-ditch will run along the southern cut slope of the Quarry and drain towards the SW Outlet Pipe where the flows will combine with the 13 cfs from basin Q1 and discharge into the reservoir west of the Quarry. A temporary berm will be installed at the upstream end of the pipe to prevent the Q1 and Q2 flows from bypassing the pipe end section.

Basin Q3

Basin Q3 (7.0 acres) will generate a 10-year peak flow of approximately 1.3 cfs. Drainage will generally sheet flow from the south and collect at the south and east ends of the Quarry excavation in Ditch Q3, a 0.5-foot-deep v-ditch that runs along the southern cut slope of the Quarry towards the east. At the northern end of the basin, the flows from basin Q3 will combine with flows from basins Q6, QAR1, and QAR2. The combined 10-yr discharge of 4.0 cfs will be collected in a concrete Type 13 inlet and conveyed in two 10-inch steel pipes with end sections (referred to as "NE Outlet Pipe). The two pipes will cross underneath the Quarry Access Road and outfall into a v-ditch on the north side of the road, also known as Ditch Q4.

Basins Q4 and Q5

The hillside draining toward the Quarry from the north has been divided into basins Q4 and Q5. Runoff from these two basins will sheet flow toward the south and be intercepted by the Quarry Access Road v-ditch (Ditch Q4). Ditch Q4 is sized to convey the combined 10-year runoff from basins Q4 and Q5 as well as the cumulative flows going through the NE Outlet Pipe. These flows total to 8.10 cfs. The v-ditch will have a depth of 1 foot and will follow the access road profile at a longitudinal slope of 10 percent. Due to the grades of the access road cut, it is anticipated that the north side roadway ditch will be excavated in rock.

Basin Q6

Basin Q6 is a small, narrow 0.5-acre drainage area just east of the Quarry Access Road that is bounded by the access road, the Crusher Pad, and the Crusher Pad Access Road. The 10-year runoff from the small basin is about 0.1 cfs. Due to the grading constraints produced by the access driveway connecting the Quarry Access Road and the Crusher Pad, a 12-inch CMP culvert (referred to as “E Outlet Pipe”) is proposed to drain the flows underneath the access road and into basin Q3.

Basins Q7, Q8, and Q9

Basins Q7 and Q8, the overburden cut slopes on the south and west sides of the Quarry footprint produce a combined runoff of 5.6 cfs. These flows sheet down the 2H:1V excavated slopes and down the Quarry benches into the bottom of the Quarry, where it combines with the flows from the Quarry footprint itself and basin QAR3. Basin Q9, which consists of the Quarry bottom and benches, produces a 10-year runoff rate of 5.3 cfs. The bottom of the Quarry will be graded at 0.5% to drain to the NW corner of the Quarry where a sediment basin or similar BMP will collect the flows from Q7, Q8, Q9, and QAR3. The combined 10-year flows are approximately 14.8 cfs. The four subbasins draining to the northwest corner of the Quarry are anticipated to convey sediment that will need to be removed before discharging into the reservoir. From the sediment basin, a 30” CMP (referred to as “Quarry Outfall Pipe”) will convey the combined 14.8 cfs underneath the Quarry Access Road and discharge to the west of the Quarry, from which the flows will sheet flow into the reservoir.

Basins QAR1

Runoff from basin QAR1 will sheet flow from the south to the northeast, producing a 10-year peak discharge of 2.2 cfs. These flows will be collected and conveyed by a 1-foot-deep roadside v-ditch (Ditch QAR1). This ditch will run along the western side of the Quarry Access Road and follow the access road profile with a longitudinal slope ranging from 1.4 percent to 10 percent. Ditch QAR1 will terminate around station 14+50 at a riprap pad, which will slow down the flows and prevent erosion of the existing ground. The runoff will flow towards the west in an existing swale and combine with the Q3 flows at the NE Outlet Pipe.

Basins QAR2

Basin QAR2 consists of the Quarry Access Road surface from the beginning of the road at station 0+00 to approximately station 13+50. The access road cross slope slopes towards the northeast and produces a 10-year peak discharge of 0.4 cfs. This flow is collected and conveyed through a 0.5-foot-deep v-ditch (Ditch QAR2) that follows the access road profile, similar to Ditch QAR1. Just east of this portion of the access road is the Crusher Pad. The Quarry Access Road sits above the Crusher Pad so a safety berm is placed along the edge of the roadway. Ditch QAR2 will be inside this berm right along the edge of the roadway. The ditch will terminate around station 13+00 at which point the 0.4 cfs will sheet flow across the access road into Ditch QAR1.

Basins QAR3

Basin QAR3 contains the Quarry Access Road surface from approximate station 13+50 to the end of the road, station 31+05. The access road runs along the north end of the Quarry, set about 80’ above the Quarry bottom, and leads down into the Quarry bottom terminating at the western edge of the Quarry. This portion of the road is sloped towards the Quarry and generates a 10-year discharge of 0.8 cfs. Similar to the first half of the Quarry Access Road, a safety berm protects drivers along the southern edge of the road. A 0.5-foot-deep v-ditch (Ditch QAR3) will run along the inside of the safety berm on the edge of the access road. Ditch QAR3 will follow the road profile at 10 percent and terminate with the safety berm in the bottom of the Quarry. The flows conveyed in this ditch will sheet flow towards the sediment basin in the northwest corner of the Quarry before being discharged through the Quarry Outlet Pipe.

5.4 Erosion Control Measures

A variety of erosion control measures will be implemented using appropriate BMPs as the design advances toward the 100% submittal. These measures will include the use of turf reinforced matting (TRM) for high velocity flows down steep hillside or embankment slope channels, rock check structures in roadside v-ditches to flatten steep ditch gradients in cases where the ditch is excavated in overburden, riprap aprons at pipe outlets, and strategic placement of silt fences, straw bales, and straw wattles in new disturbance areas. In addition, a sediment basin will be placed in the Quarry bottom to slow runoff velocities sufficiently to drop out sediment and decant the storm flows into the reservoir.

6.0 Quarry Model Development

6.1 Rock Surface Development

The rock surface was developed using available geotechnical information and subsurface data from three previous investigations. Rock described in the borings as moderately weathered to fresh rock with an RQD equal to or greater than 50 was considered quality rock that will be suitable for aggregate. An initial rock surface was created from the elevation of quality rock in the borings. The rock surface was extended using supplemental points from the Seismic Refraction Tomography (SRT) data. Top of quality rock was estimated to be at the elevation corresponding to 6000 ft/s based on comparison of nearby borings to the SRT data. Finally, the surface was further refined based on the geologic setting and topographic data.

6.2 Quarry Design

The Quarry location and slopes developed by KBJV were adjusted to meet the recommended slope design. Slopes in overburden were modeled at 2H:1V with small sections locally steepened to 1.9H:1V to minimize visual impacts and disturbance. A 10-foot bench was included at the intersection of overburden slopes with the rock surface to reduce raveling of overburden into the Quarry and as contingency to account for variations in the actual rock surface. Rock slopes were modeled at 0.25H:1V with 10-foot wide benches every 40 vertical feet. The bottom of the Quarry will be sloped at a minimum 0.5% towards the northwest corner of the Quarry to provide positive drainage.

6.3 Quarry Access Road

The access road into the Quarry was designed for CAT 773 haul trucks with a 115% overload on payload. The minimum road width (46 feet) is 2.5 times the truck width plus a safety berm with a height equal to the rolling radius of the truck tire. The berm will be constructed along all sections of the access road that are adjacent to a slope crest.

7.0 References

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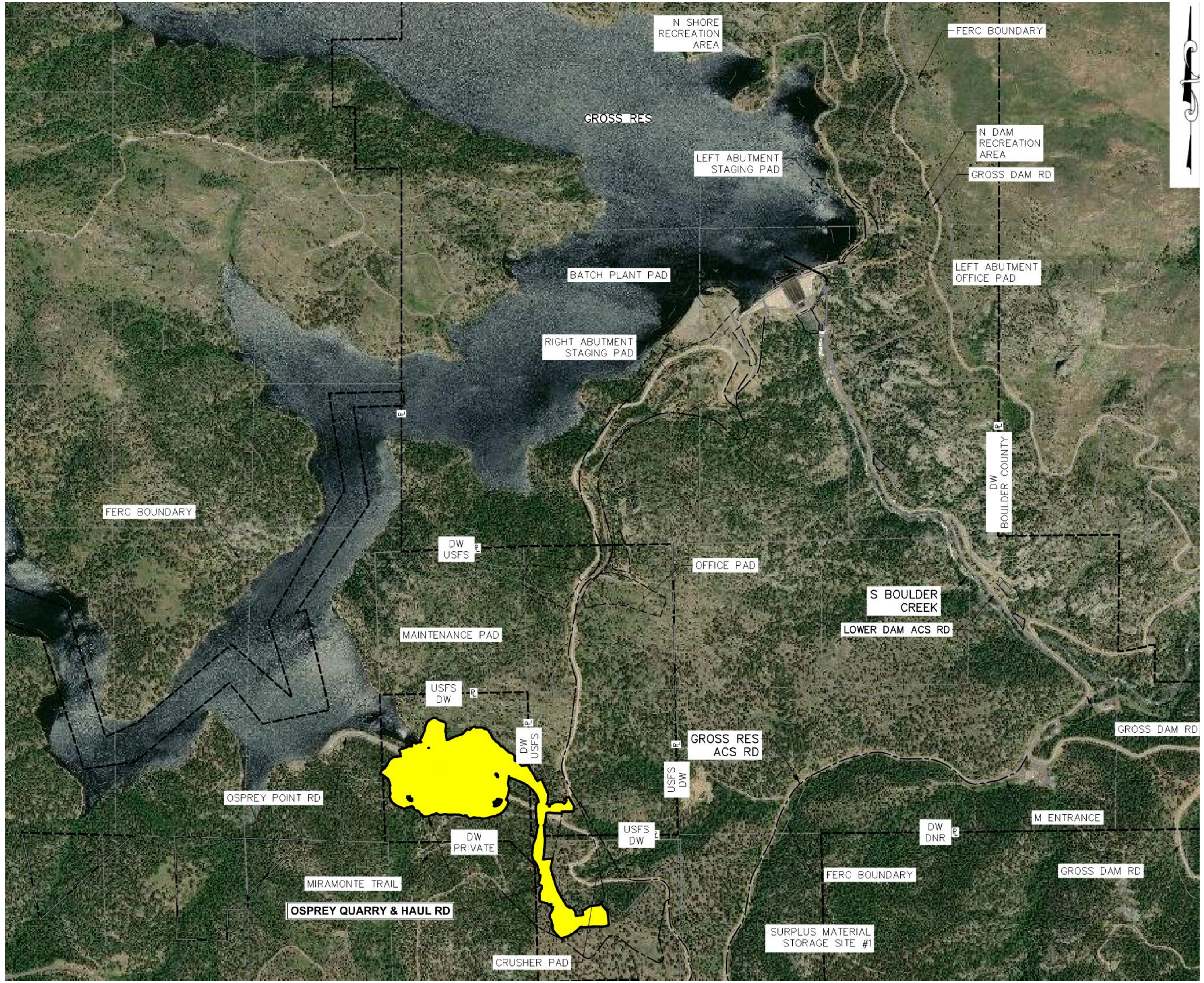


Figure 1: Osprey Point Quarry Location

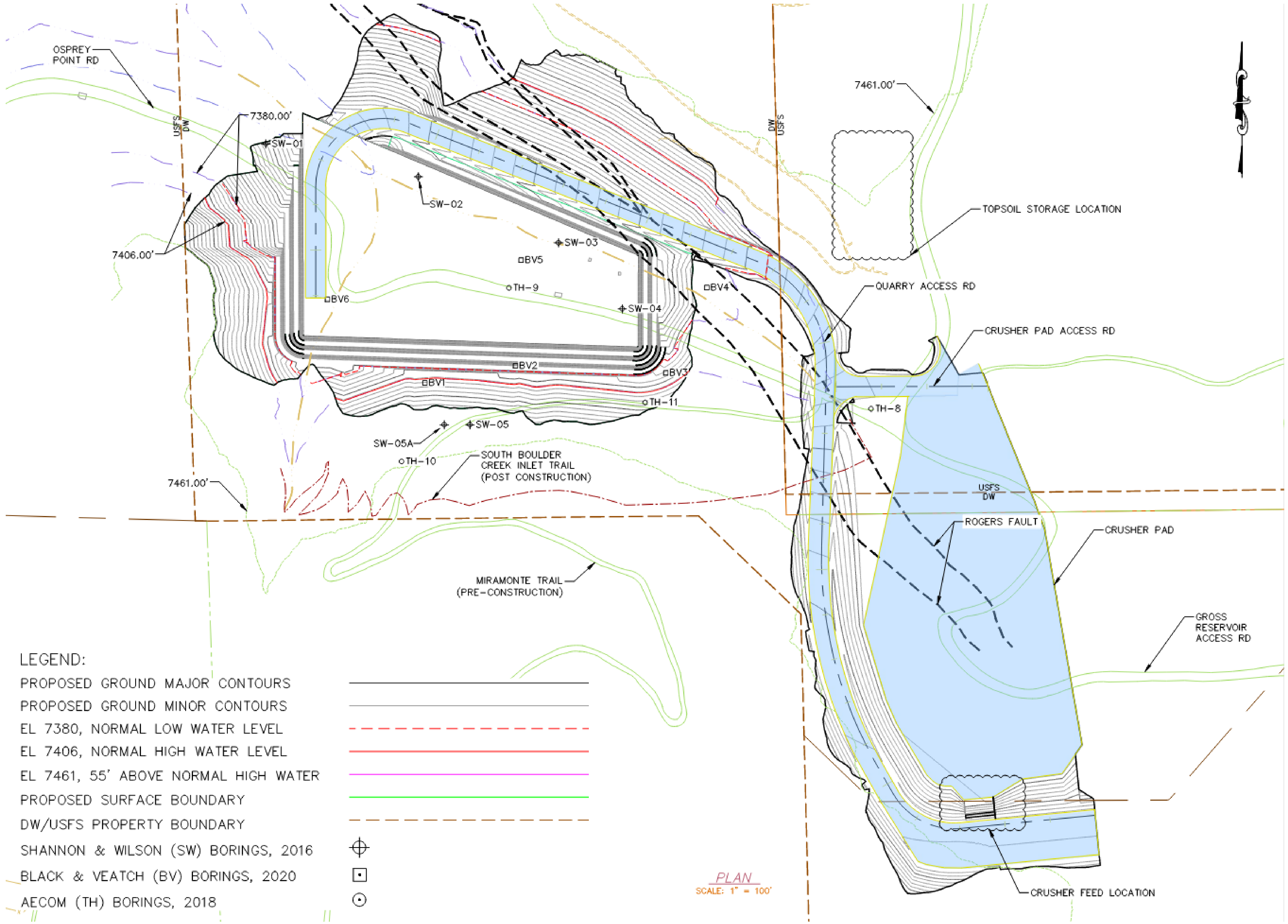


Figure 2: Osprey Point Quarry Geometry

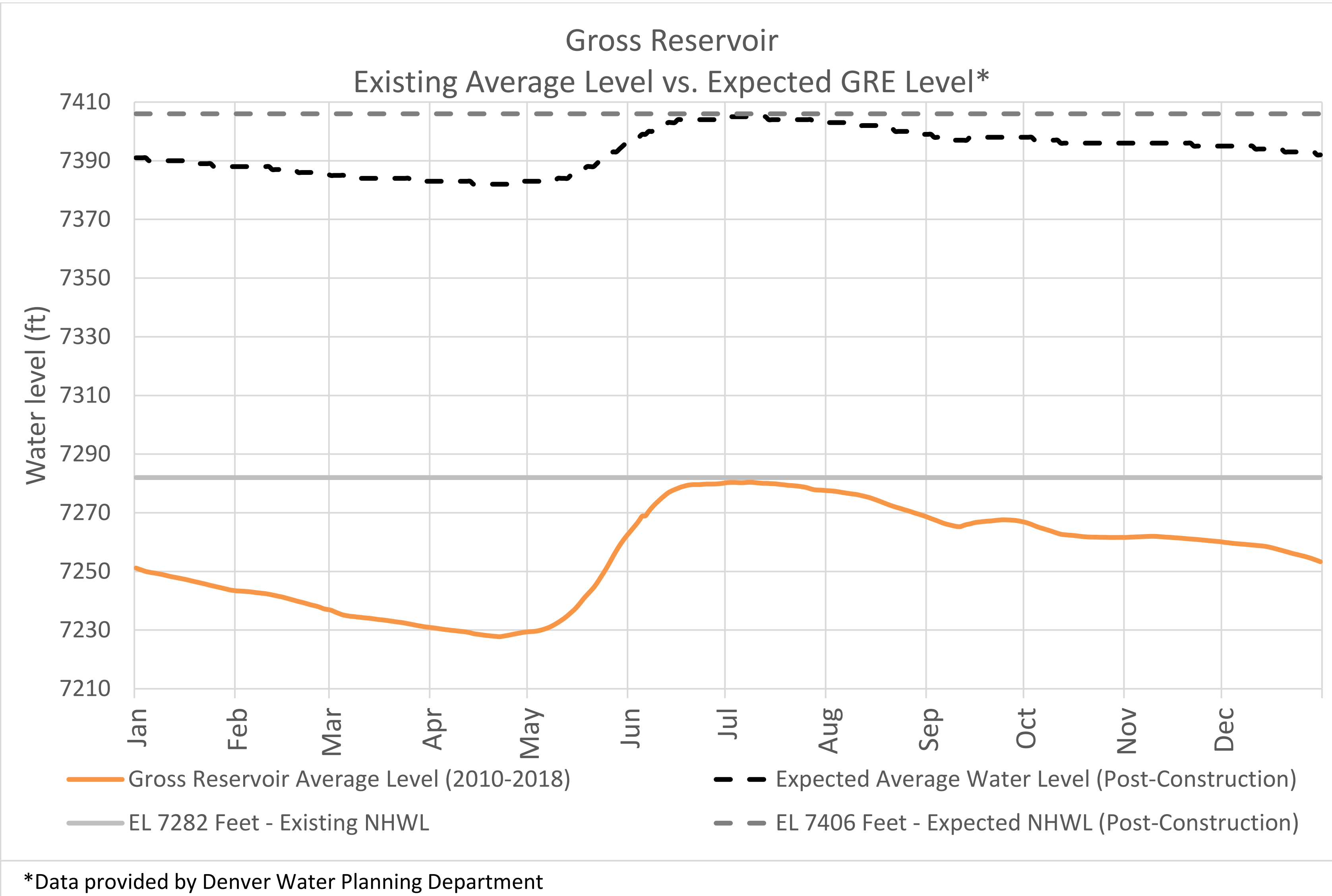


Figure 3: Gross Reservoir Existing and Expected Water Level

Color	Name	Model	Unit Weight	Cohesion'	Phi'	Strength Function	Piezometric Line
	Comp. Weathered Rock	Shear/Normal Fn.	165			Hoek-Brown Function (Comp W)	1
	Dense Silty Sand	Mohr-Coulomb	125	0	35		1
	Mod. Weathered Rock	Shear/Normal Fn.	165			Hoek-Brown Function (Mod W)	1

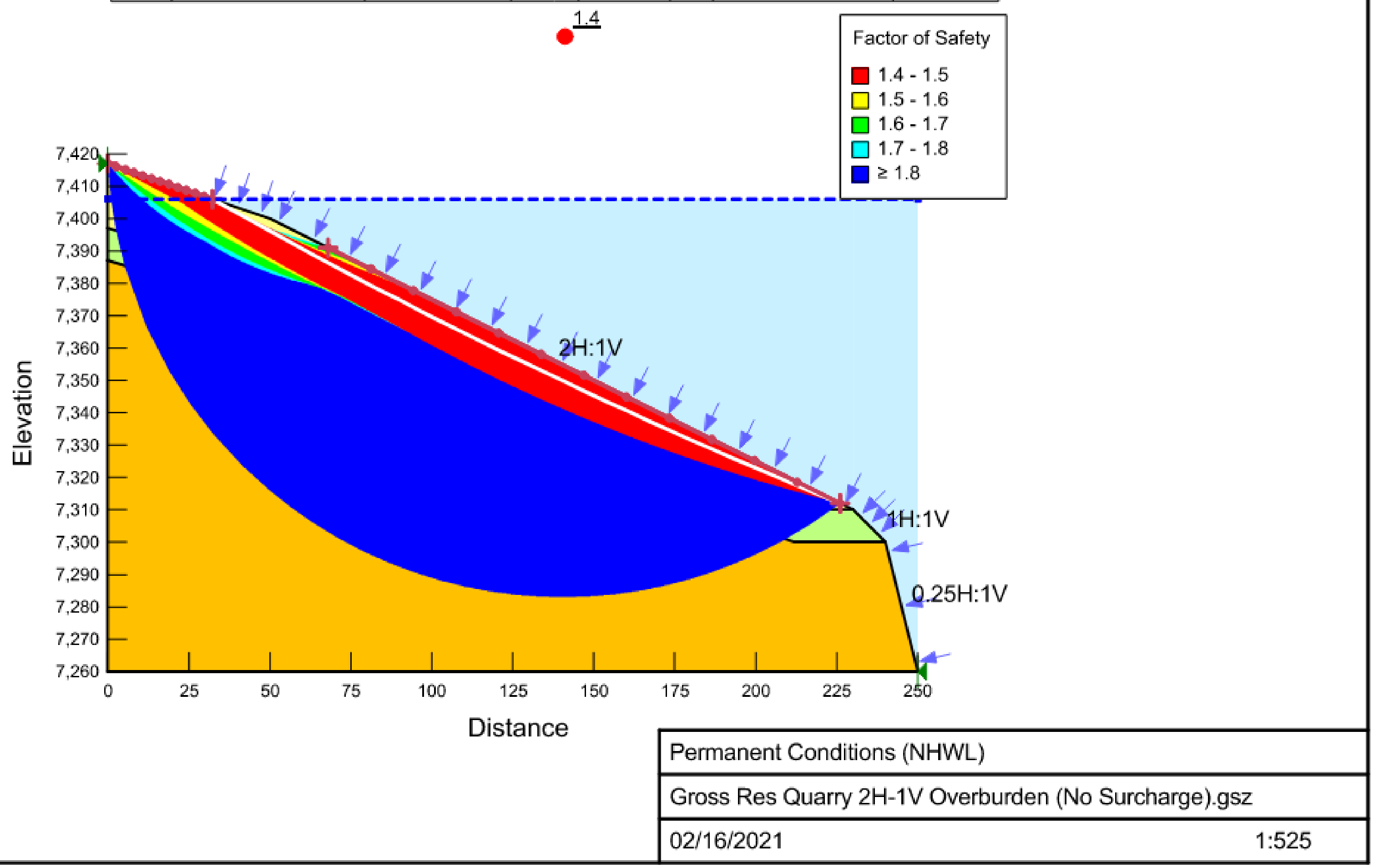


Figure 4: 2H:1V Overburden NHWL Slope/W Results

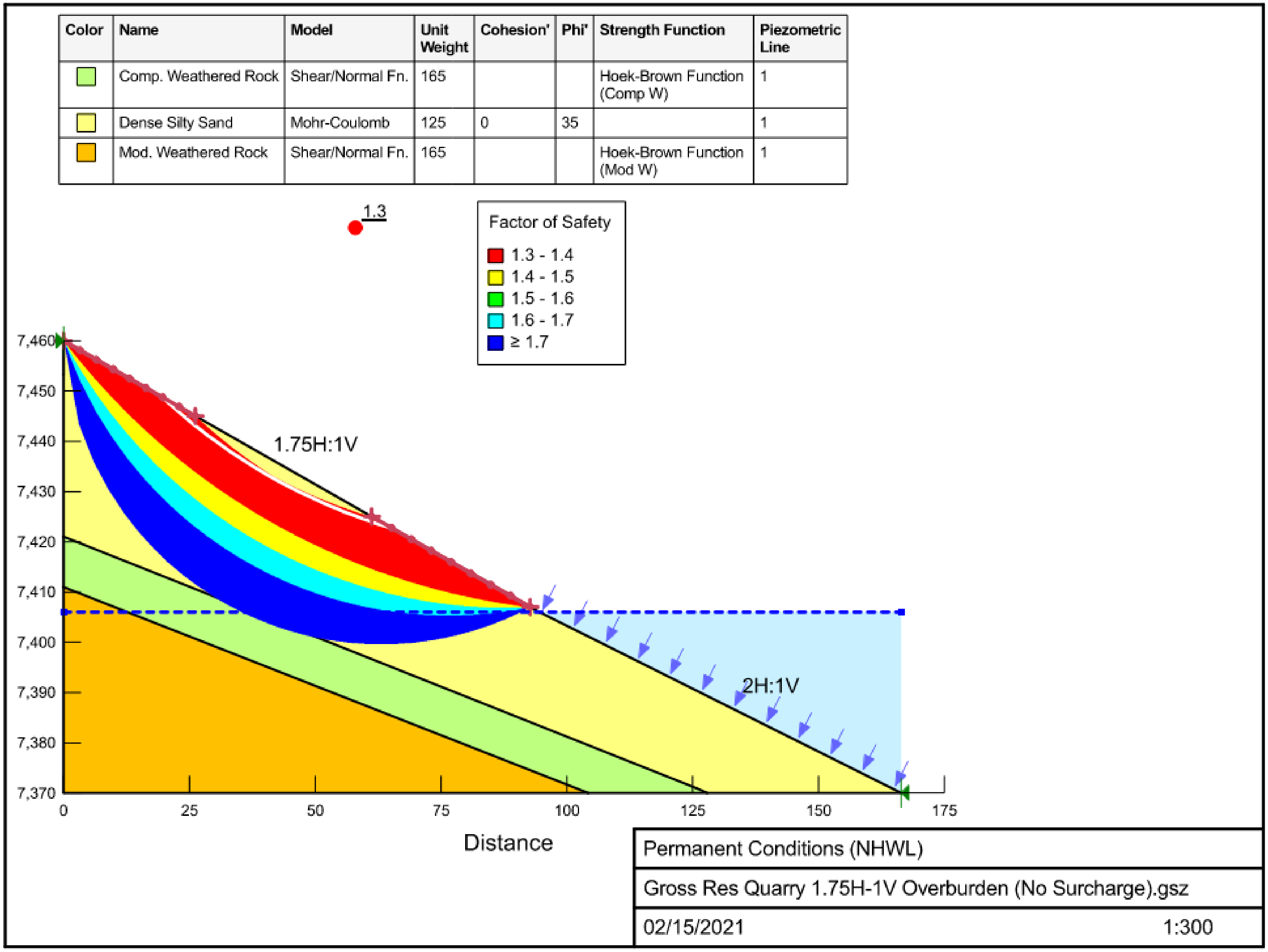
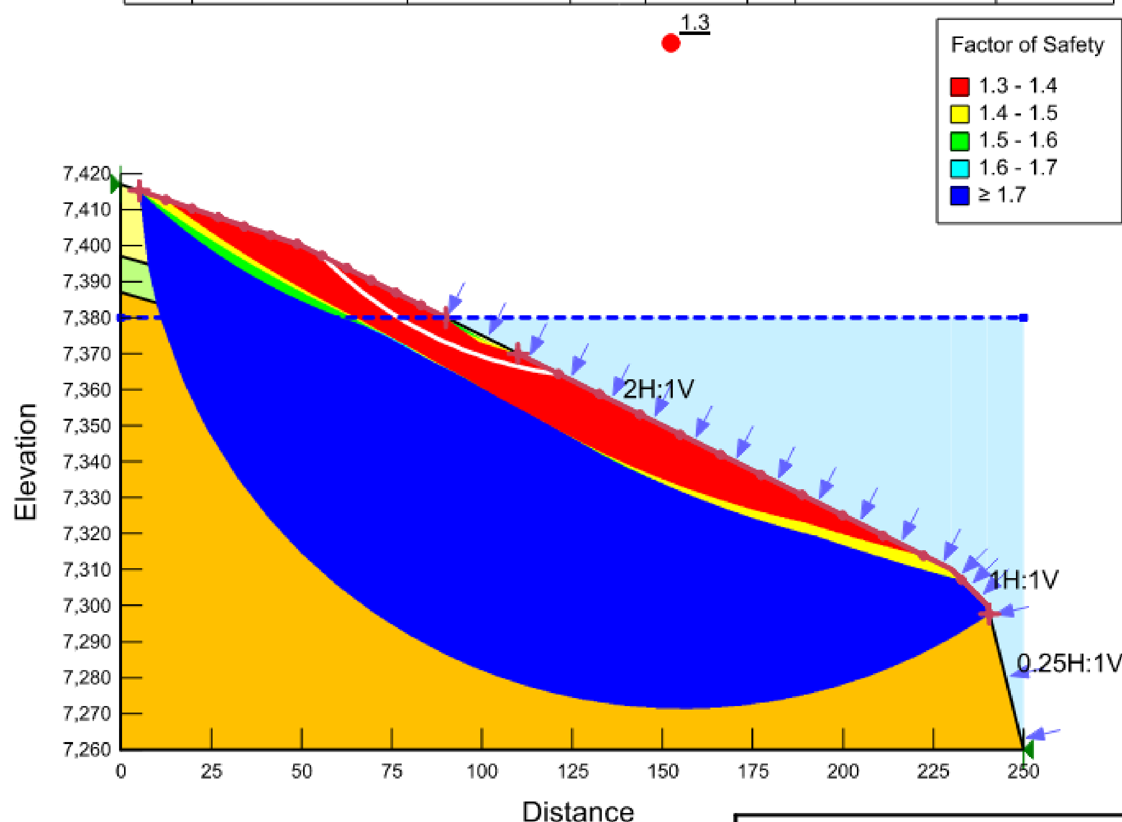


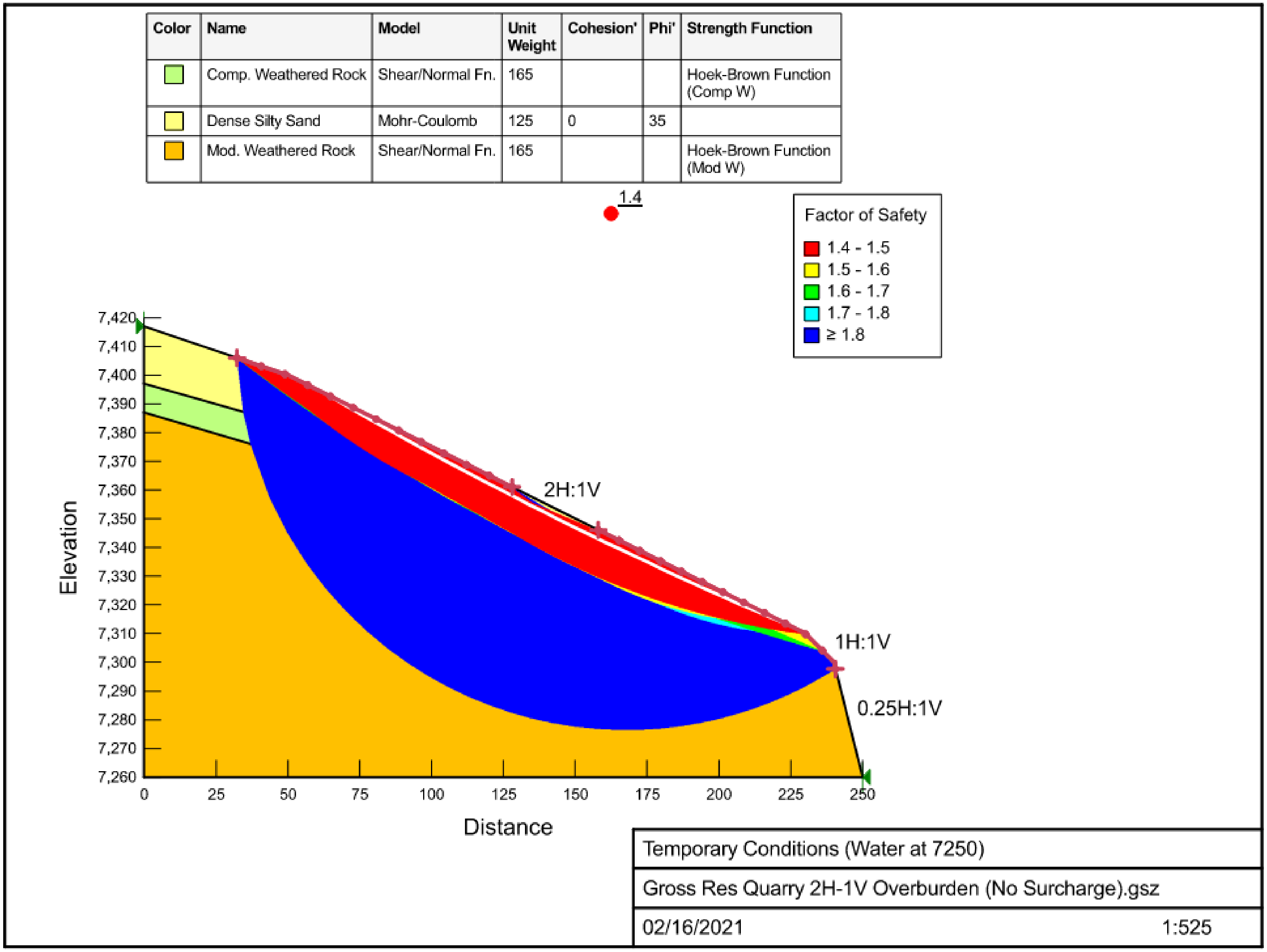
Figure 5: 1.75H:1V Overburden NHWL Slope/W Results

Color	Name	Model	Unit Weight	Cohesion'	Phi'	Strength Function	Piezometric Line
	Comp. Weathered Rock	Shear/Normal Fn.	165			Hoek-Brown Function (Comp W)	1
	Dense Silty Sand	Mohr-Coulomb	125	0	35		1
	Mod. Weathered Rock	Shear/Normal Fn.	165			Hoek-Brown Function (Mod W)	1



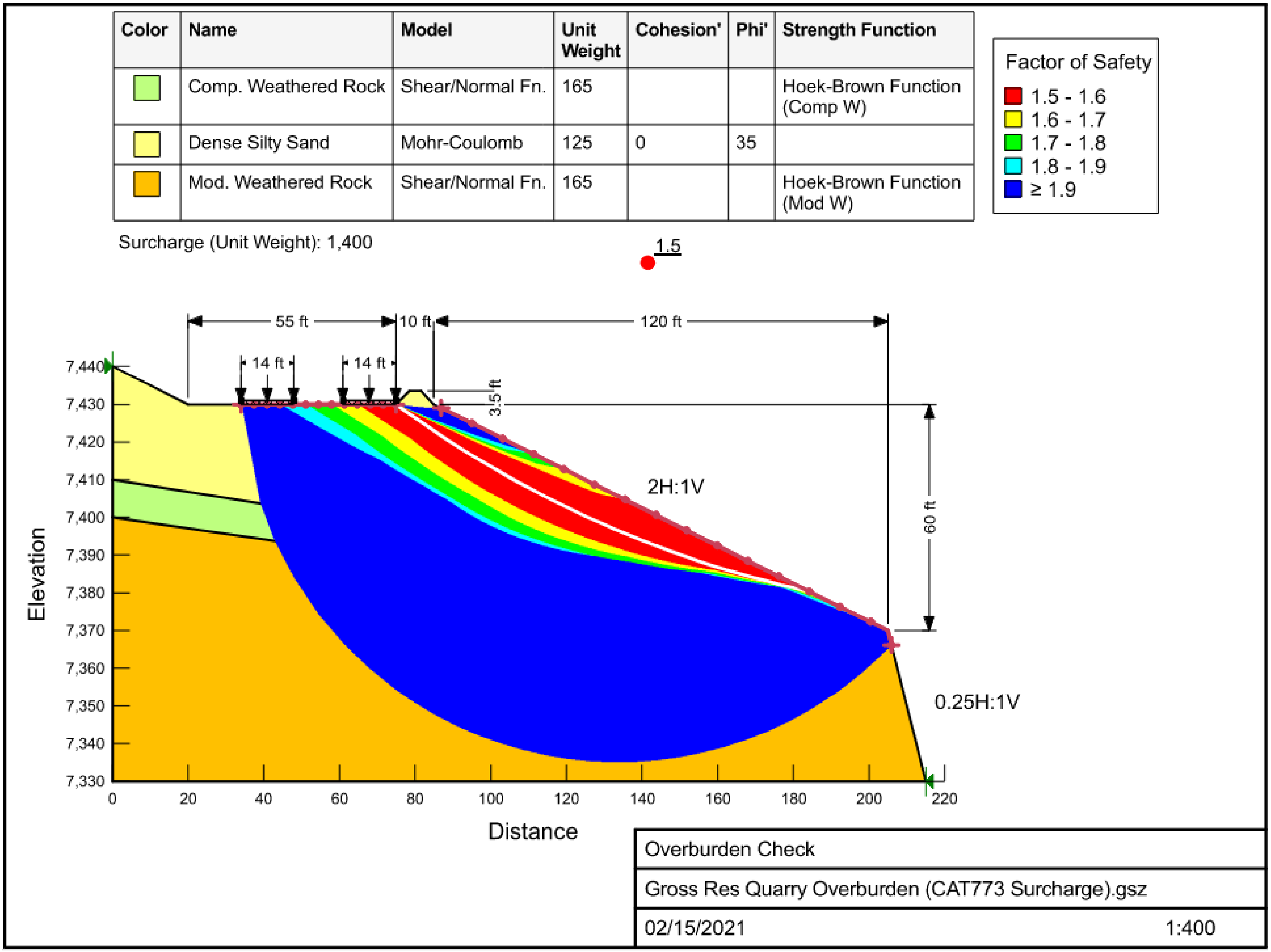
Permanent Conditions (NLWL)
Gross Res Quarry 2H-1V Overburden (No Surcharge).gsz
02/16/2021 1:525

Figure 6: 2H:1V Overburden NLWL Slope/W Results



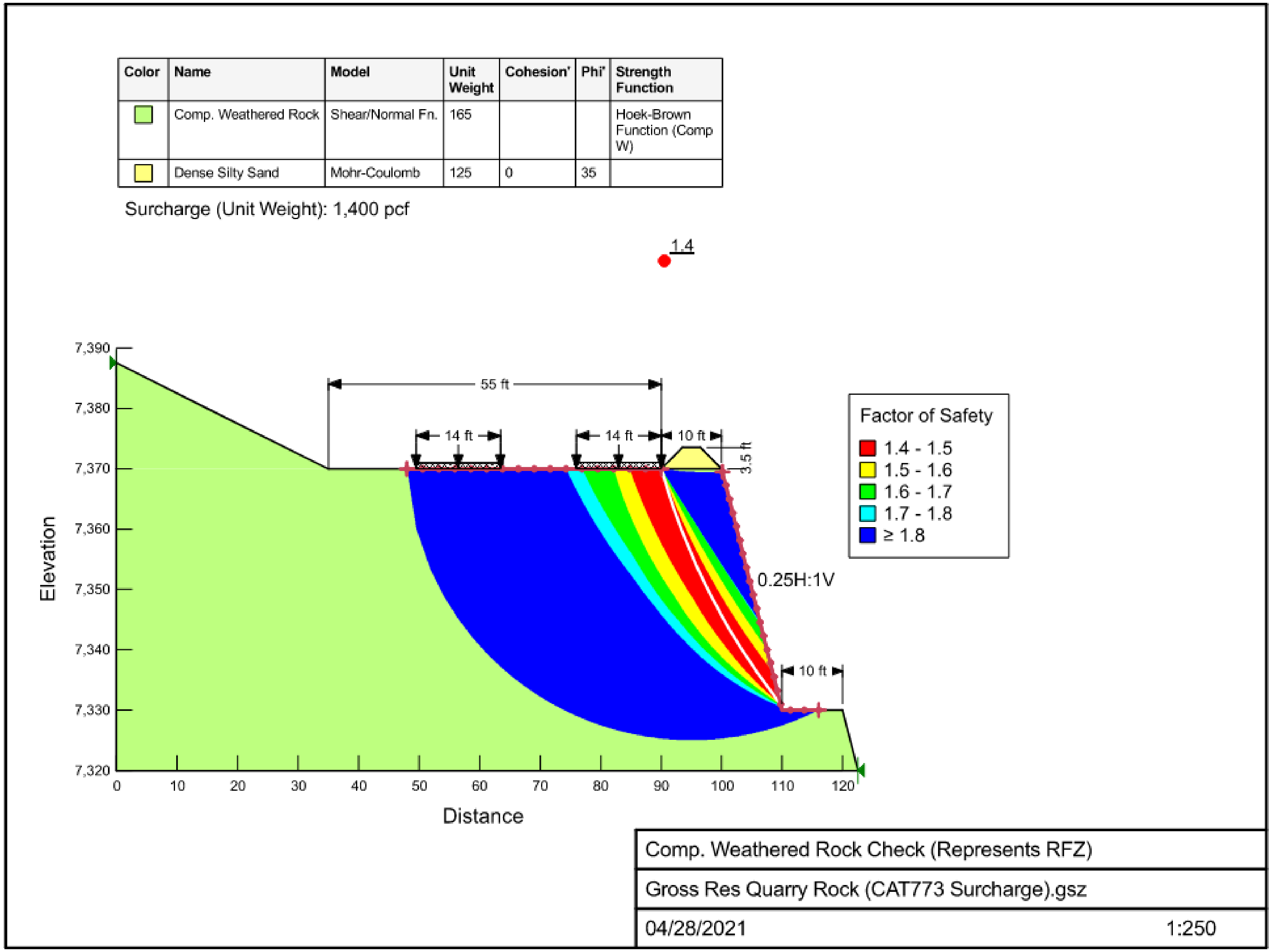
Color	Name	Model	Unit Weight	Cohesion'	Phi'	Strength Function
	Comp. Weathered Rock	Shear/Normal Fn.	165			Hoek-Brown Function (Comp W)
	Dense Silty Sand	Mohr-Coulomb	125	0	35	
	Mod. Weathered Rock	Shear/Normal Fn.	165			Hoek-Brown Function (Mod W)

Figure 7: 2H:1V Overburden Slope/W Results (Temporary Condition)



Color	Name	Model	Unit Weight	Cohesion'	Phi'	Strength Function
(light green)	Comp. Weathered Rock	Shear/Normal Fn.	165			Hoek-Brown Function (Comp W)
(light yellow)	Dense Silty Sand	Mohr-Coulomb	125	0	35	
(orange)	Mod. Weathered Rock	Shear/Normal Fn.	165			Hoek-Brown Function (Mod W)

Figure 8: Quarry Access Road 2H:1V Overburden Slope/W Results (Temporary Condition with Surcharge)



Color	Name	Model	Unit Weight	Cohesion'	Phi'	Strength Function
	Comp. Weathered Rock	Shear/Normal Fn.	165			Hoek-Brown Function (Comp W)
	Dense Silty Sand	Mohr-Coulomb	125	0	35	

Figure 9: Quarry Access Road 0.25H:1V Highly Weathered Rock Slope/W Results

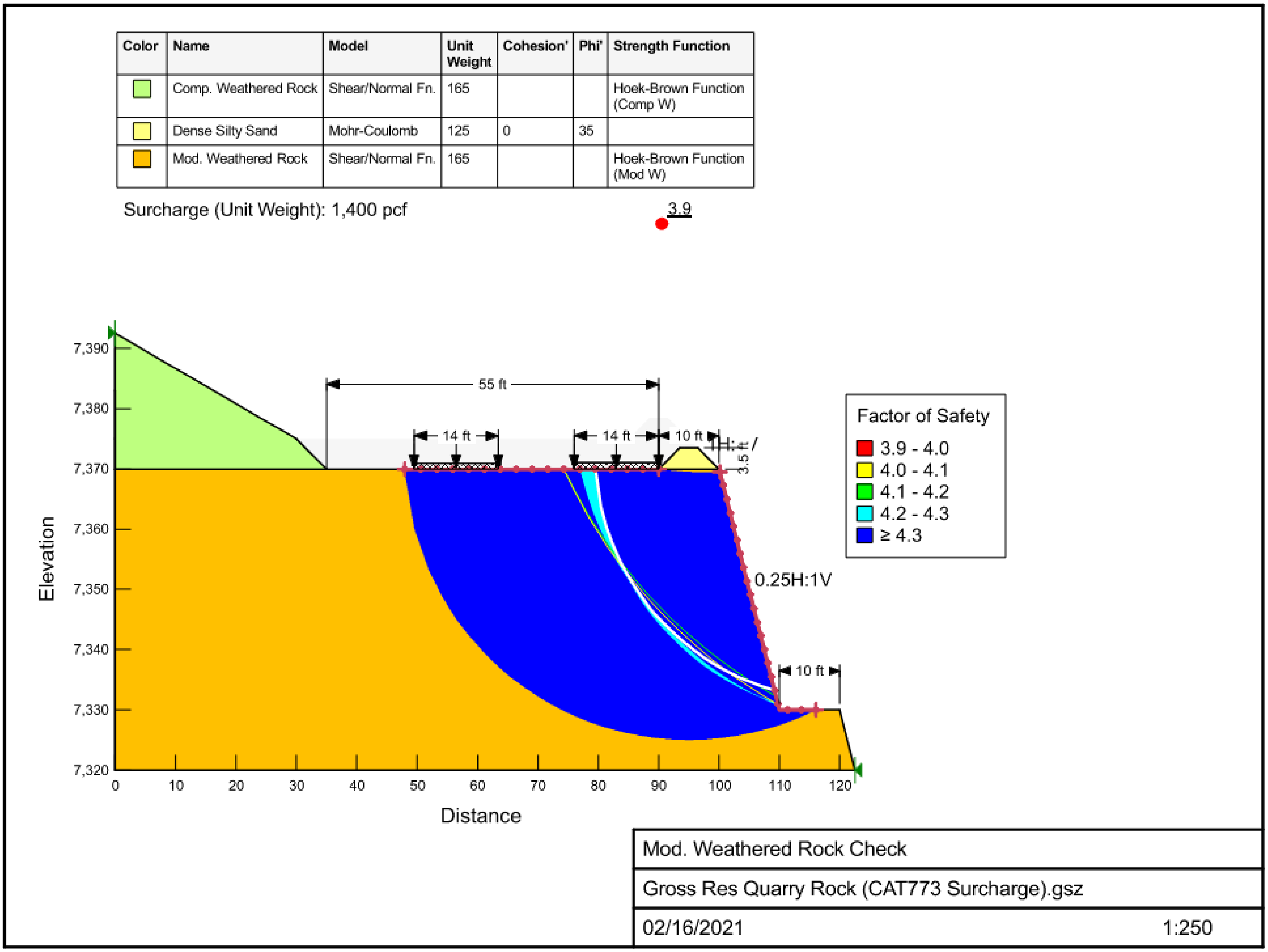
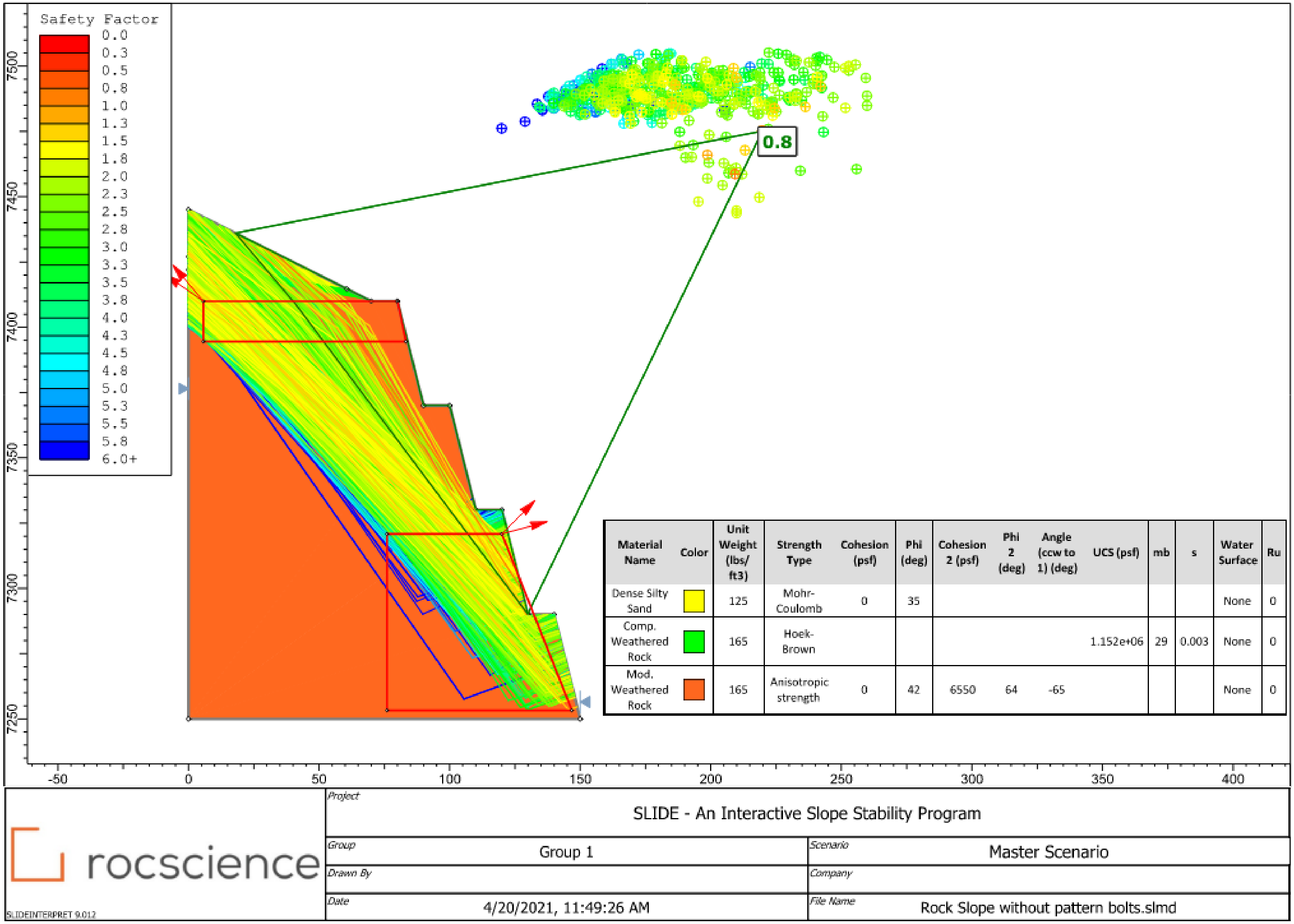
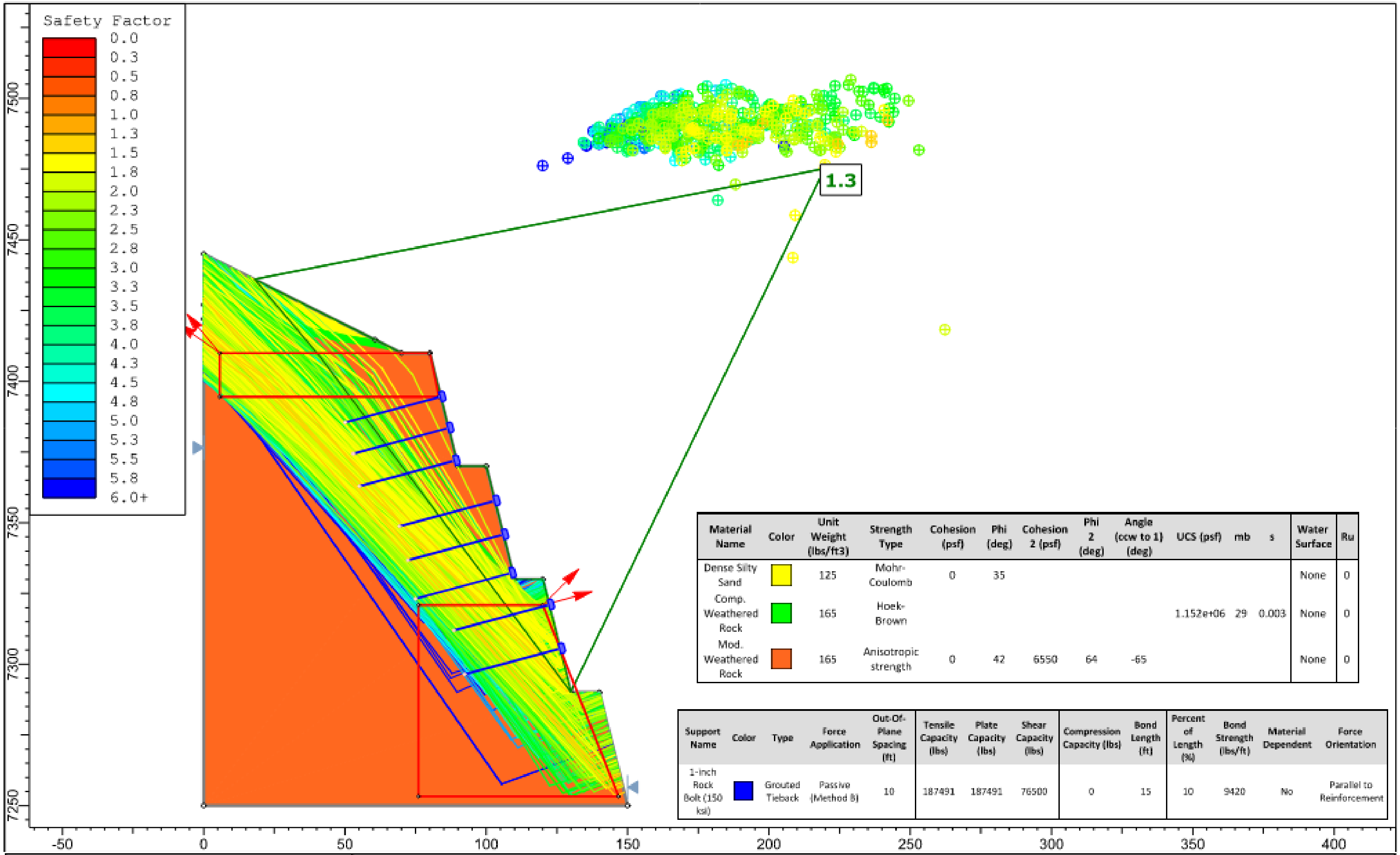


Figure 10: Quarry Access Road 0.25H:1V Moderately Weathered Rock Slope/W Results



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion 2 (psf)	Phi 2 (deg)	Angle (ccw to 1) (deg)	UCS (psf)	mb	s	Water Surface	Ru
Dense Silty Sand		125	Mohr-Coulomb	0	35							None	0
Comp. Weathered Rock		165	Hoek-Brown						1.152e+06	29	0.003	None	0
Mod. Weathered Rock		165	Anisotropic strength	0	42	6550	64	-65				None	0

Figure 11: Global Stability of Quarry Slope without Pattern Rock Bolts



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion 2 (psf)	Phi 2 (deg)	Angle (ccw to 1) (deg)	UCS (psf)	mb	s	Water Surface	Ru
Dense Silty Sand		125	Mohr-Coulomb	0	35							None	0
Comp. Weathered Rock		165	Hoek-Brown						1.152e+06	29	0.003	None	0
Mod. Weathered Rock		165	Anisotropic strength	0	42	6550	64	-65				None	0

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Tensile Capacity (lbs)	Plate Capacity (lbs)	Shear Capacity (lbs)	Compression Capacity (lbs)	Bond Length (ft)	Percent of Length (%)	Bond Strength (lbs/ft)	Material Dependent	Force Orientation
1-inch Rock Bolt (150 ksi)		Grouted Tieback	Passive (Method B)	10	187491	187491	76500	0	15	10	9420	No	Parallel to Reinforcement

rocscience
SLIDEINTERPRET 9.012

Project	SLIDE - An Interactive Slope Stability Program		
Group	Group 1	Scenario	Master Scenario
Drawn By		Company	
Date	4/20/2021, 11:49:26 AM	File Name	Rock Slope with pattern bolts.slmd

Figure 12: Global Stability of Quarry Slope without Pattern Rock Bolts

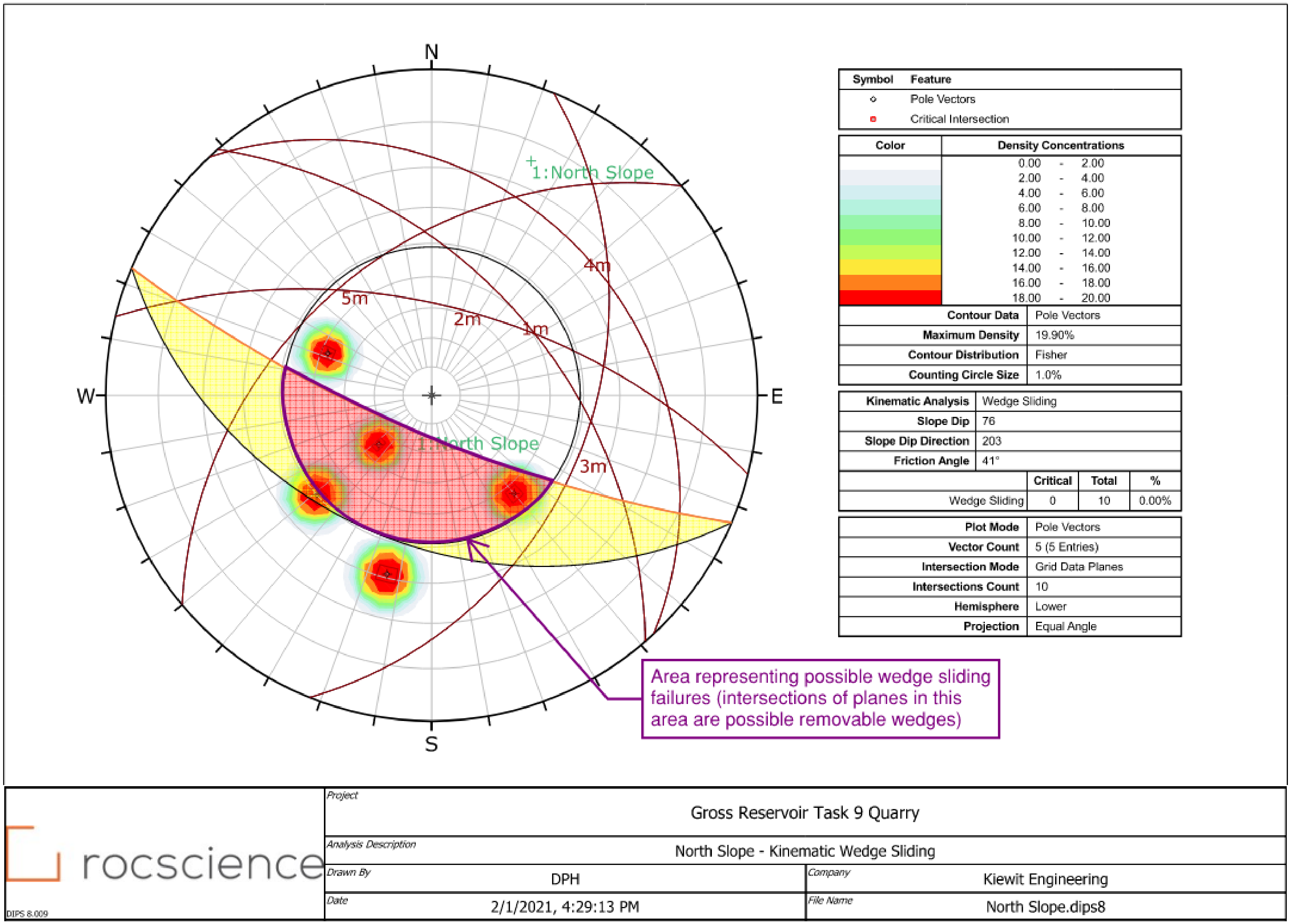


Figure 13: North Slope Kinematic Wedge Sliding Results

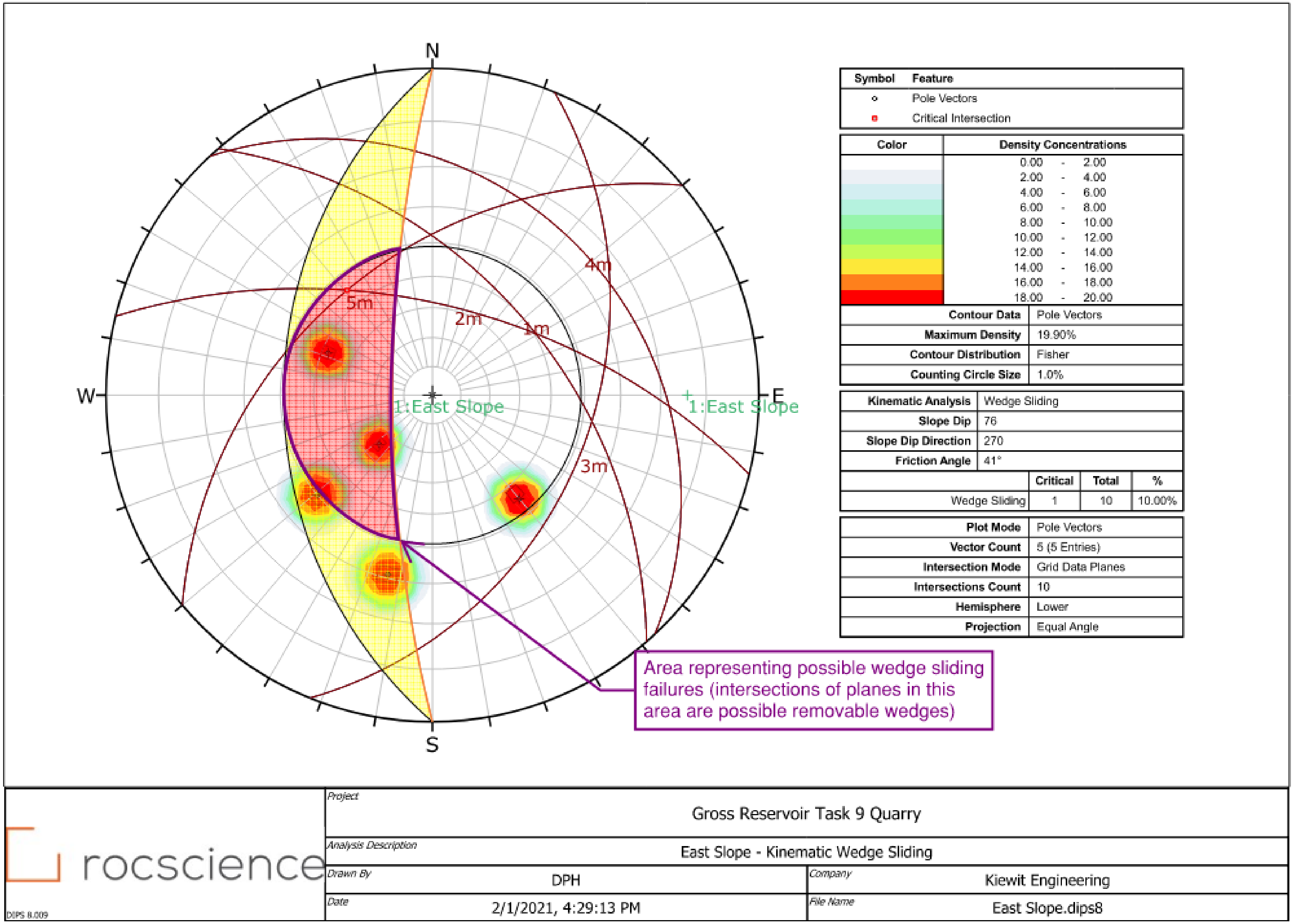
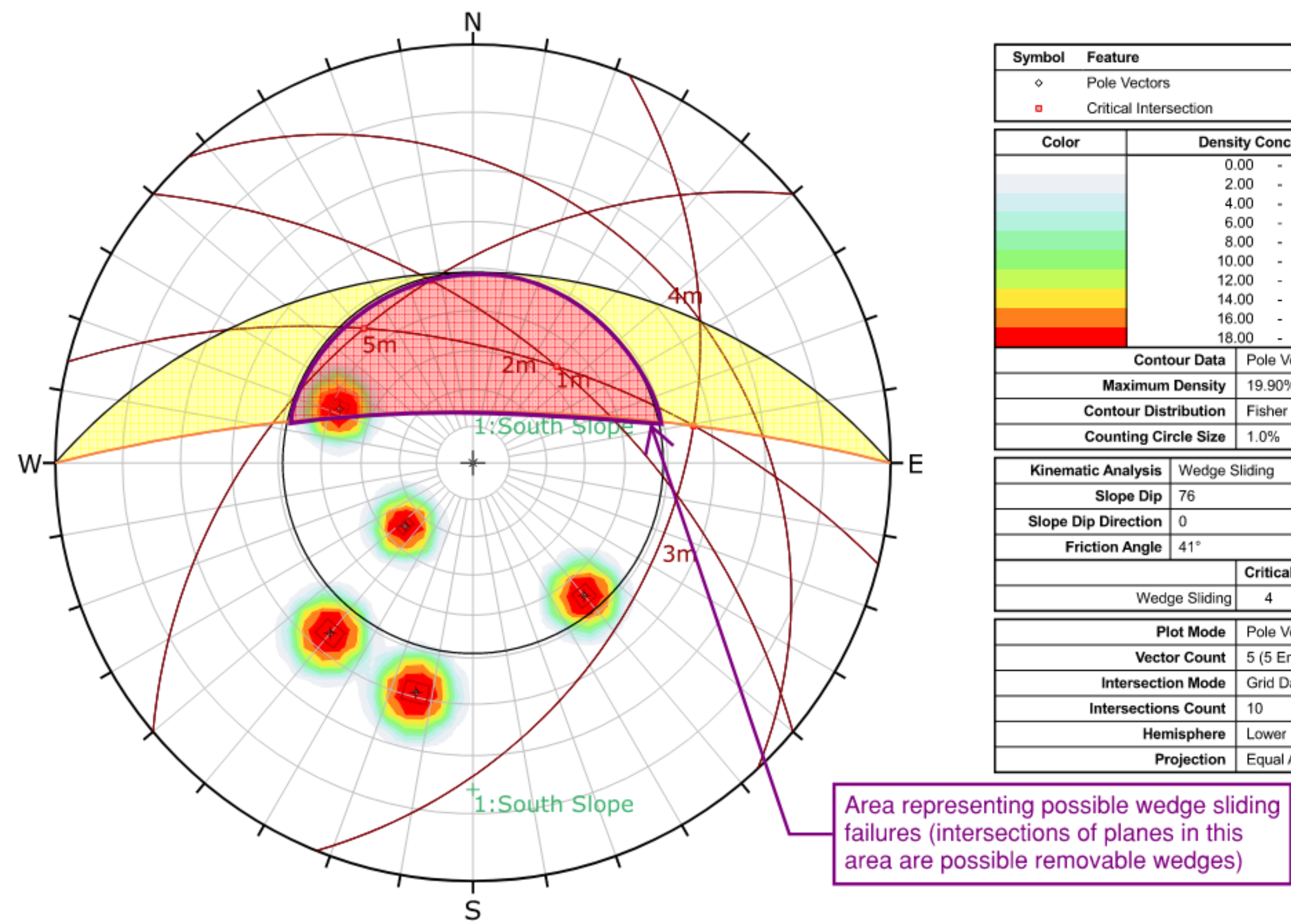


Figure 14: East Slope Kinematic Wedge Sliding Results



Symbol	Feature
◇	Pole Vectors
▫	Critical Intersection

Color	Density Concentrations
	0.00 - 2.00
	2.00 - 4.00
	4.00 - 6.00
	6.00 - 8.00
	8.00 - 10.00
	10.00 - 12.00
	12.00 - 14.00
	14.00 - 16.00
	16.00 - 18.00
	18.00 - 20.00

Contour Data	Pole Vectors
Maximum Density	19.90%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Wedge Sliding		
Slope Dip	76		
Slope Dip Direction	0		
Friction Angle	41°		
	Critical	Total	%
Wedge Sliding	4	10	40.00%

Plot Mode	Pole Vectors
Vector Count	5 (5 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	10
Hemisphere	Lower
Projection	Equal Angle

rocscience	Project: Gross Reservoir Task 9 Quarry		
	Analysis Description: South Slope - Kinematic Wedge Sliding		
	Drawn By: DPH	Company: Kiewit Engineering	
DIPS 8.009	Date: 2/1/2021, 4:29:13 PM	File Name: South Slope.dips8	

Figure 15: South Slope Kinematic Wedge Sliding Results

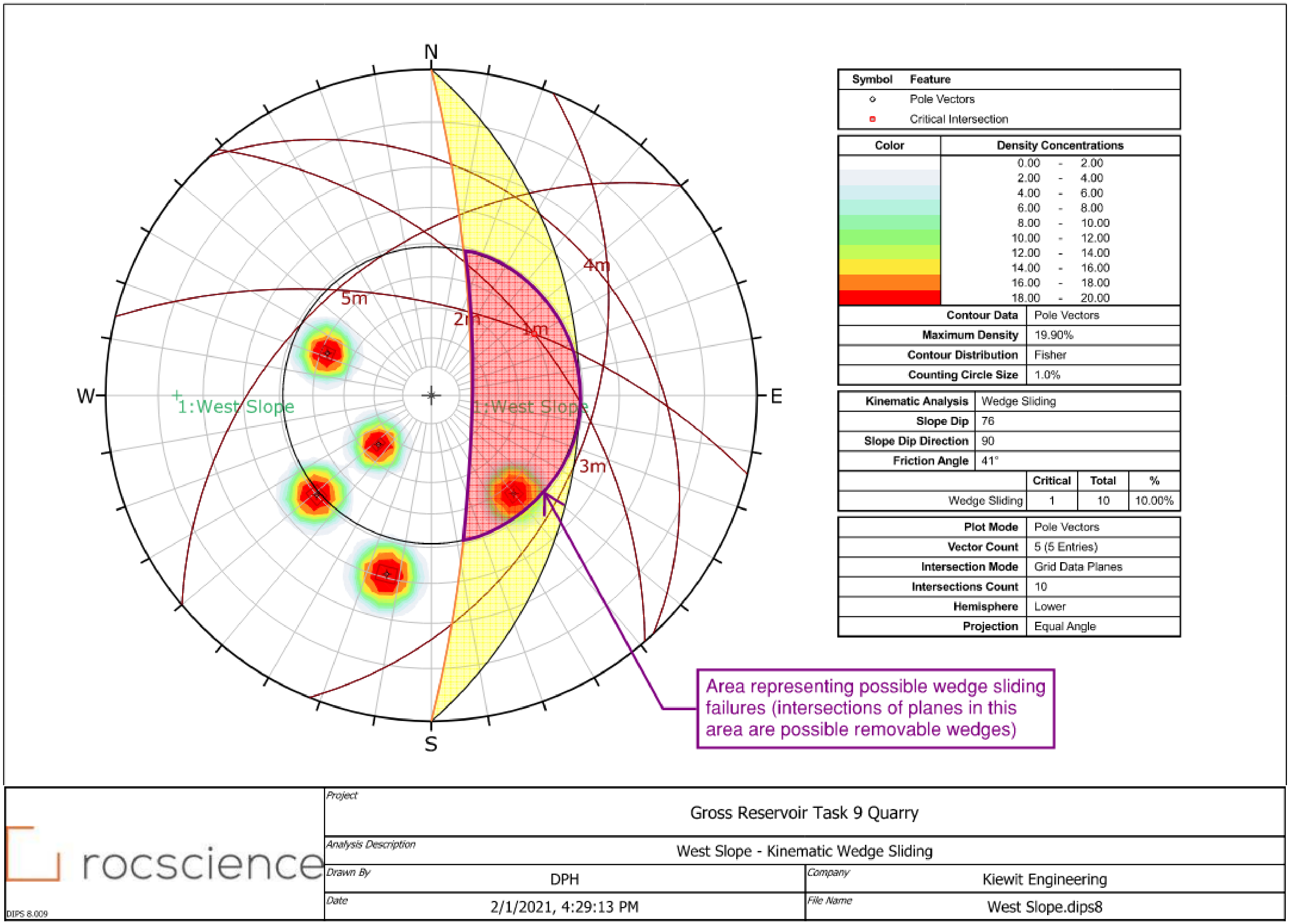


Figure 16: West Slope Kinematic Wedge Sliding Results

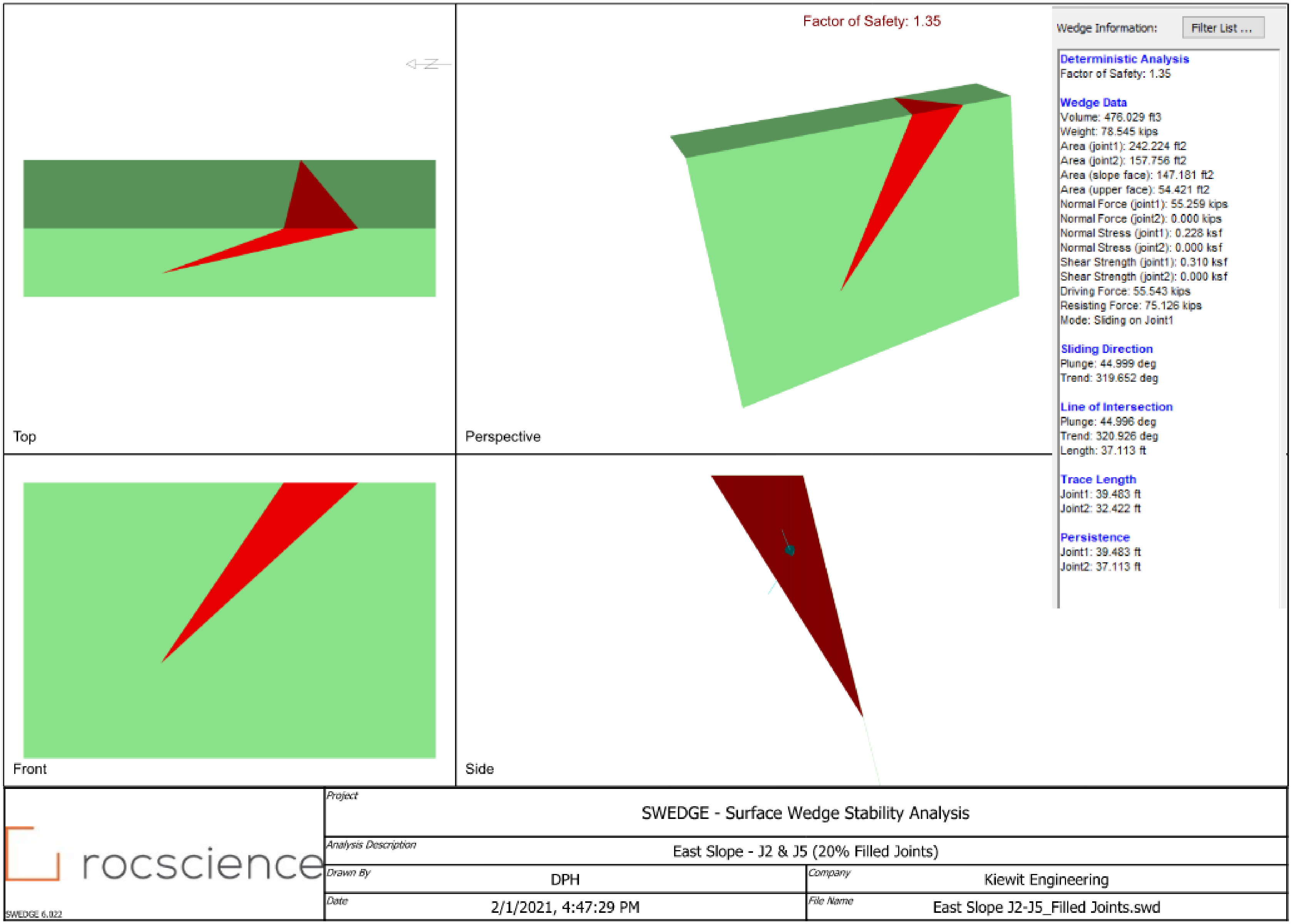


Figure 17: East Slope J2 & J5 Rock Bolting Results (Joints Filled with 20% Water)

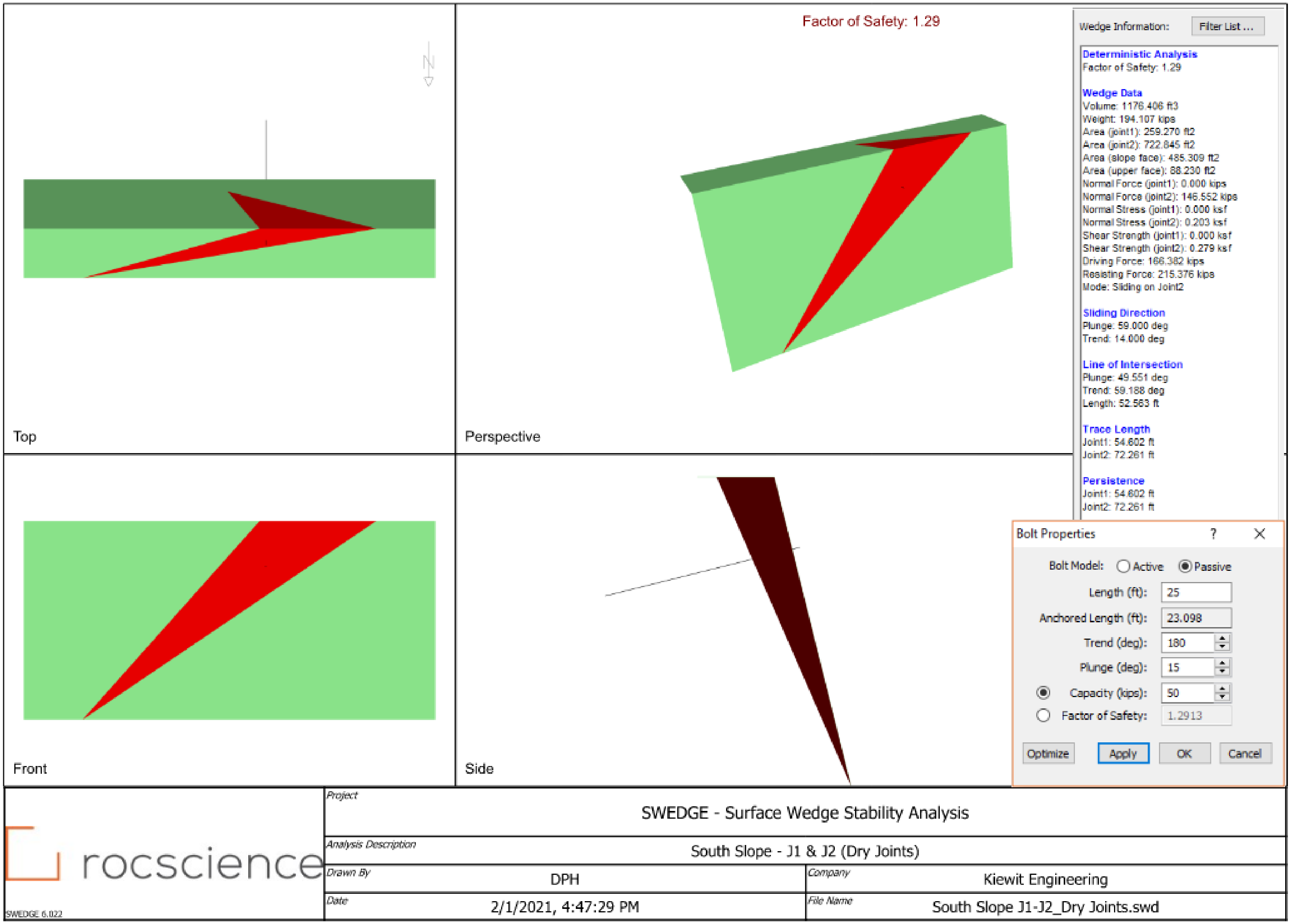


Figure 18: South Slope J1 & J2 Rock Bolting Results (Dry Joints)

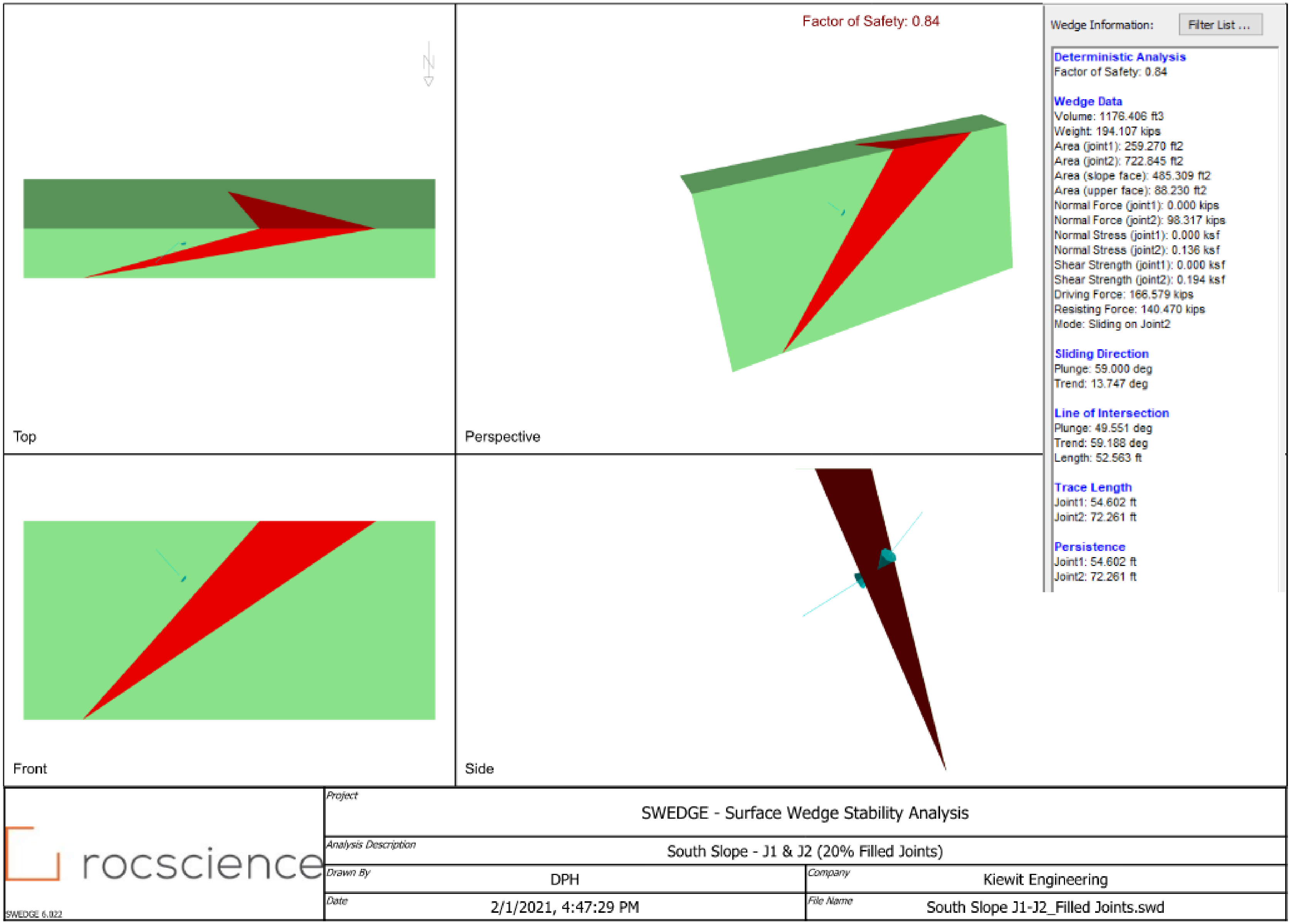


Figure 19: South Slope J1 & J2 Rock Bolting Results (Joints Filled with 20% Water)

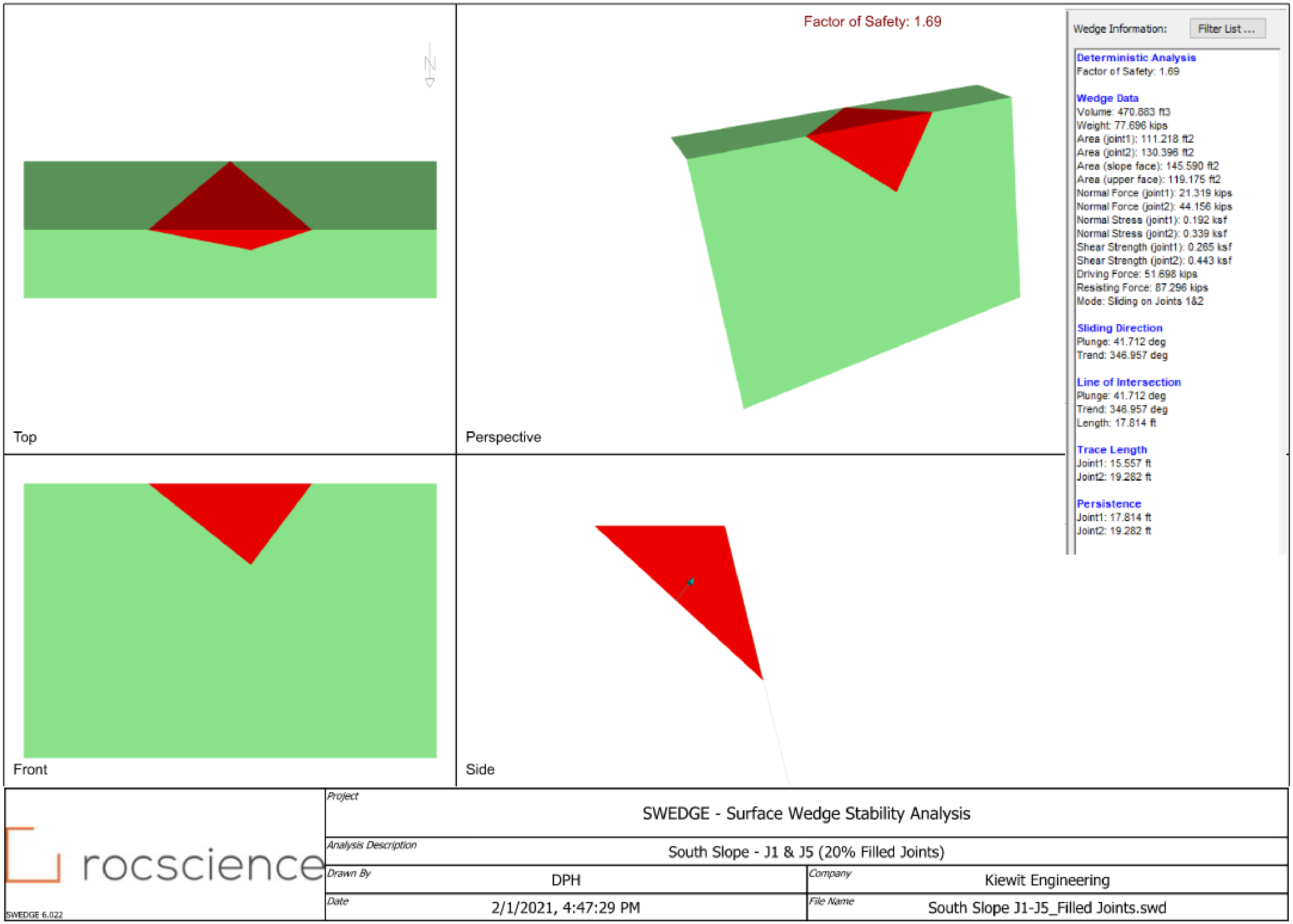


Figure 20: South Slope J1 & J5 Rock Bolting Results (Joints Filled with 20% Water)

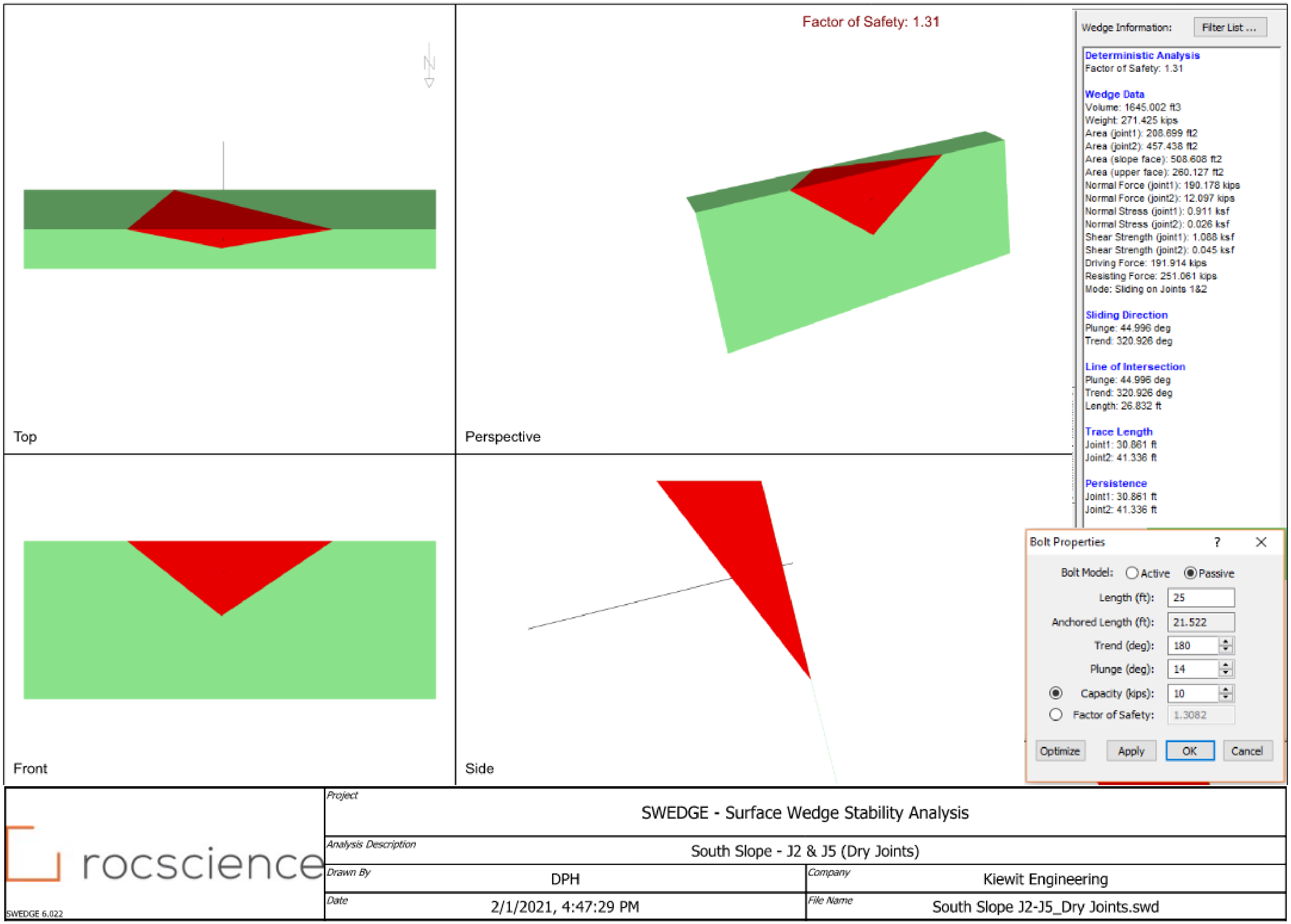


Figure 21: South Slope J2 & J5 Rock Bolting Results (Dry Joints)

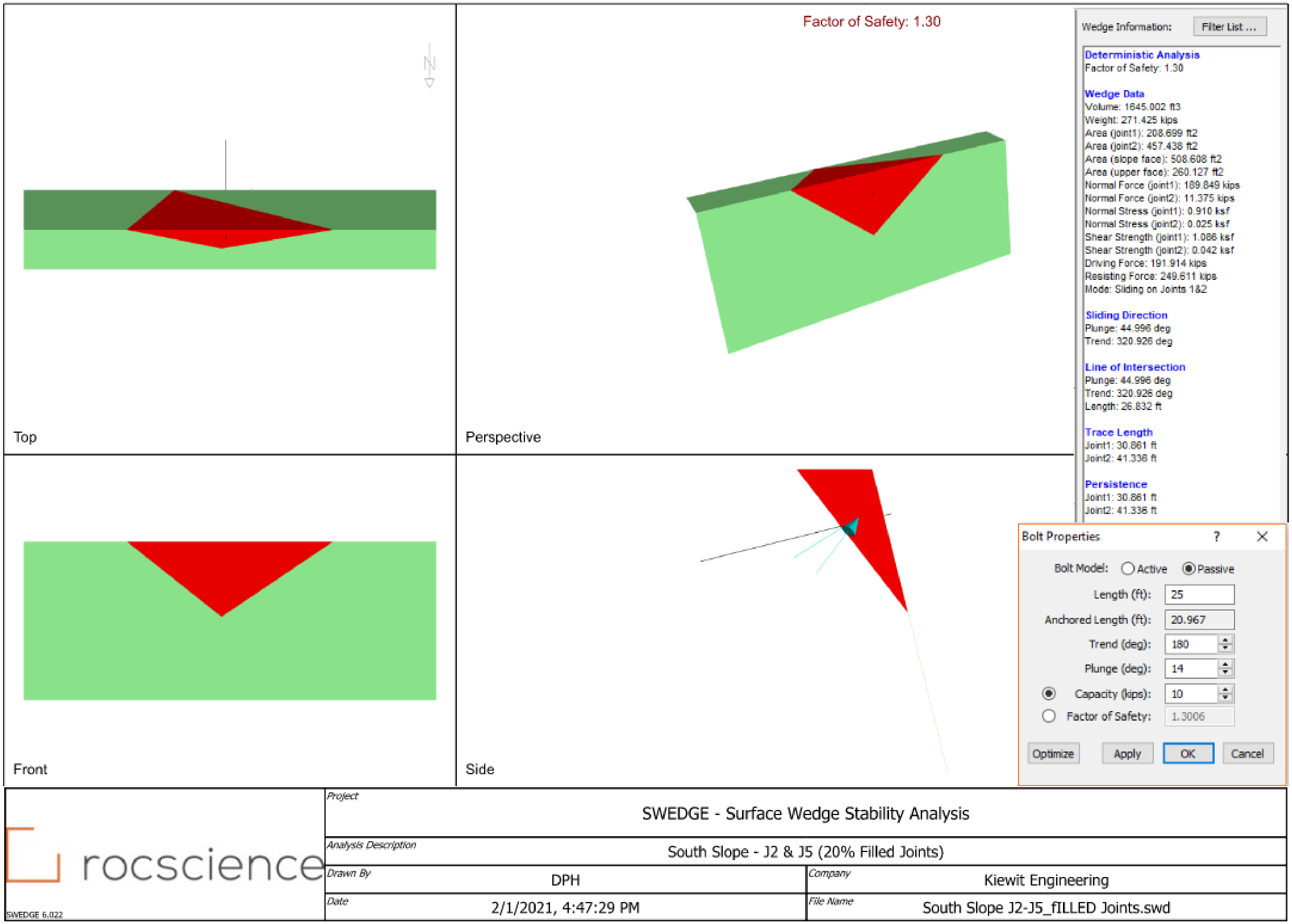


Figure 22: South Slope J2 & J5 Rock Bolting Results (Joints Filled with 20% Water)

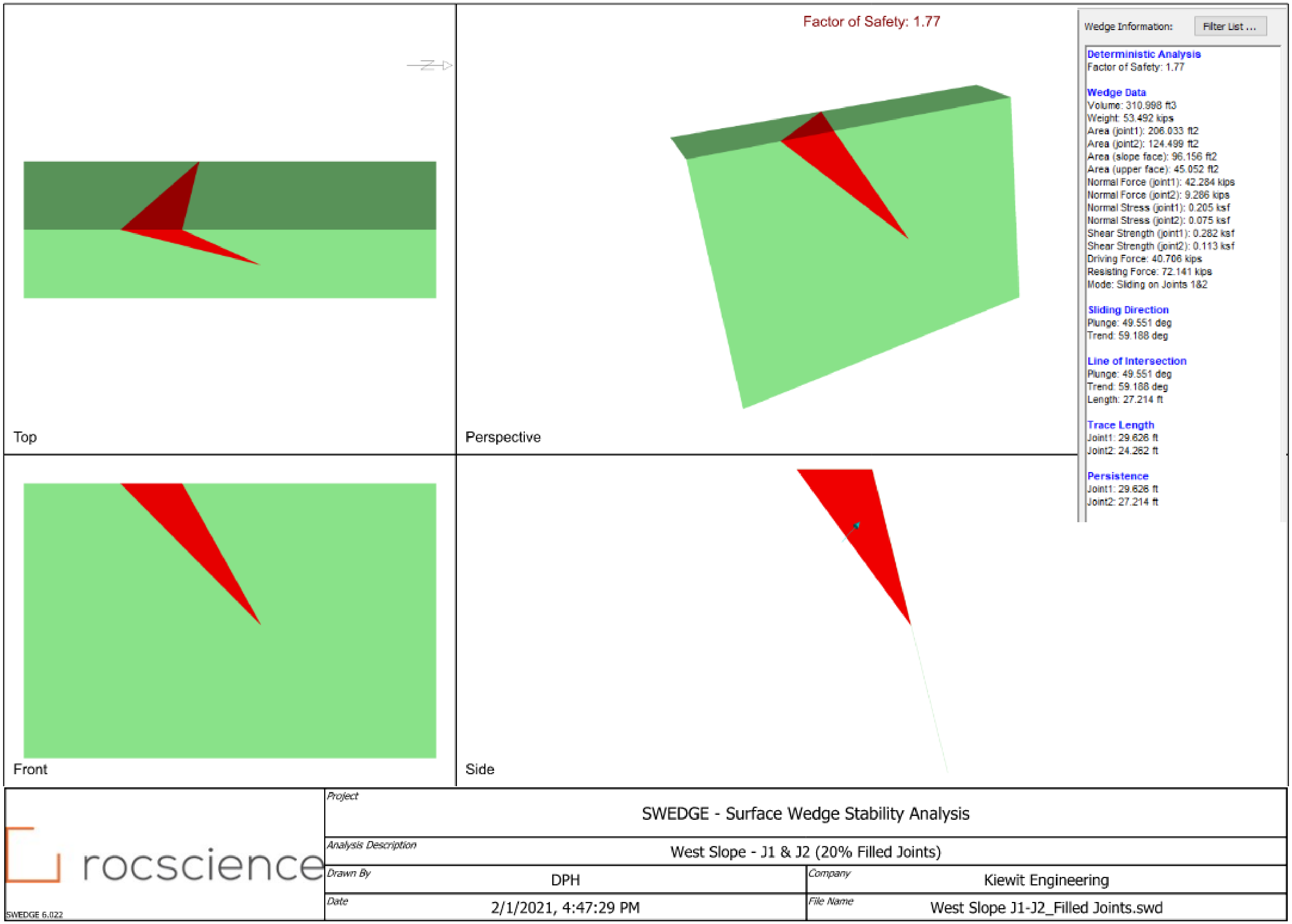


Figure 23: West Slope J1 & J2 Rock Bolting Results (Joints Filled with 20% Water)

Input File Specifications

Units of Measure: U.S.
Total Number of Cells: 10
Analysis Point X-Coordinate 1: 30
Analysis Point X-Coordinate 2: 0
Analysis Point X-Coordinate 3: 0
Initial Y-Top Starting Zone Coordinate: 185
Initial Y-Base Starting Zone Coordinate: 185
Remarks:

Cell Data

Cell No.	Surface R.	Tangent C.	Normal C.	Begin X	Begin Y	End X	End Y
1	.6	.85	.22	0	200	10	160
2	.6	.85	.22	10	160	20	160
3	.6	.85	.22	20	160	30	120
4	.6	.85	.22	30	120	40	120
5	.6	.85	.22	40	120	50	80
6	.6	.85	.22	50	80	60	80
7	.6	.85	.22	60	80	70	40
8	.6	.85	.22	70	40	80	40
9	.6	.85	.22	80	40	90	0
10	.6	.85	.22	90	0	120	0

Figure 24: CRSP Input Specifications for 3-ft diameter rockfall

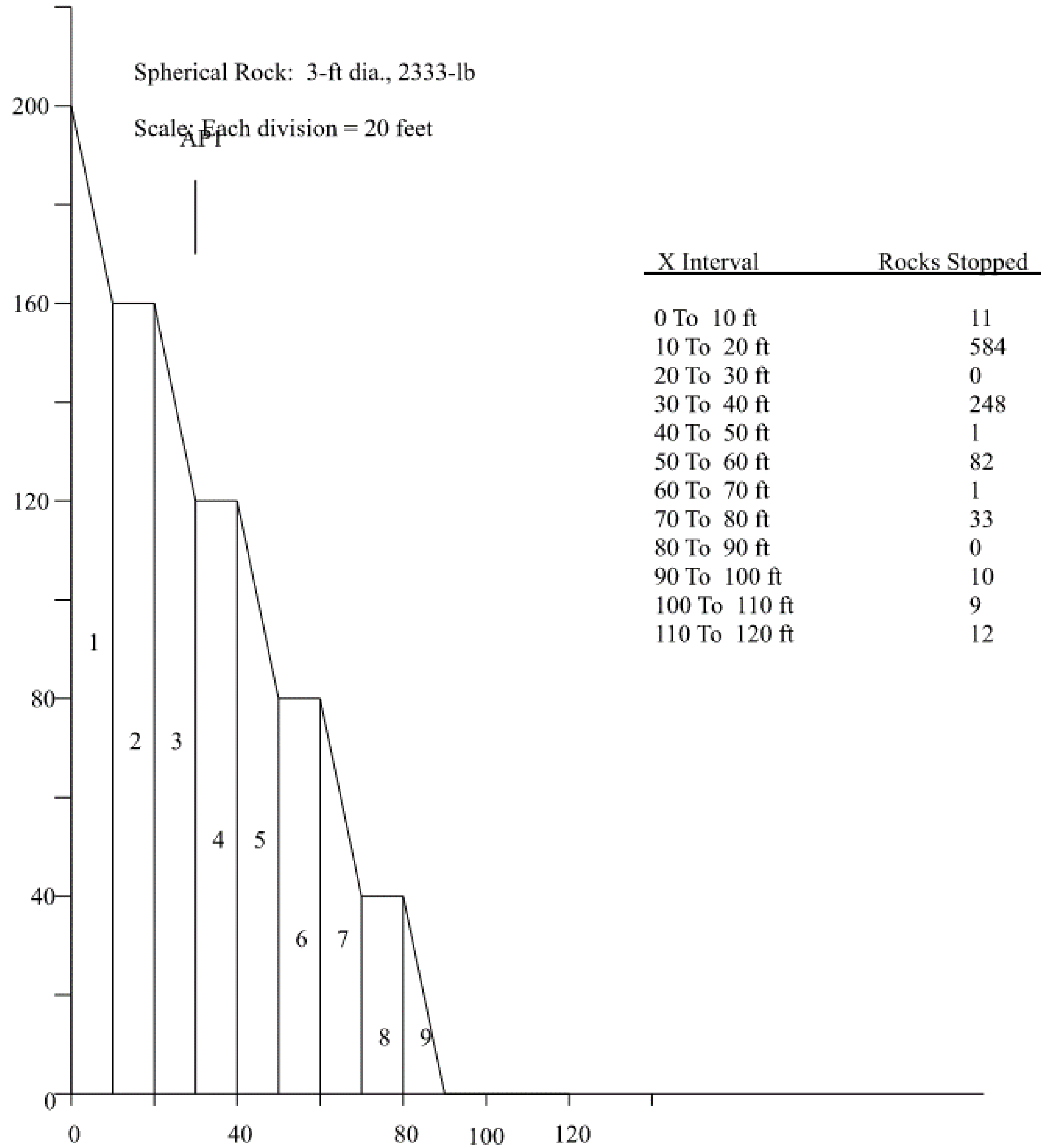


Figure 25: CRSP Results for 3-ft diameter rockfall

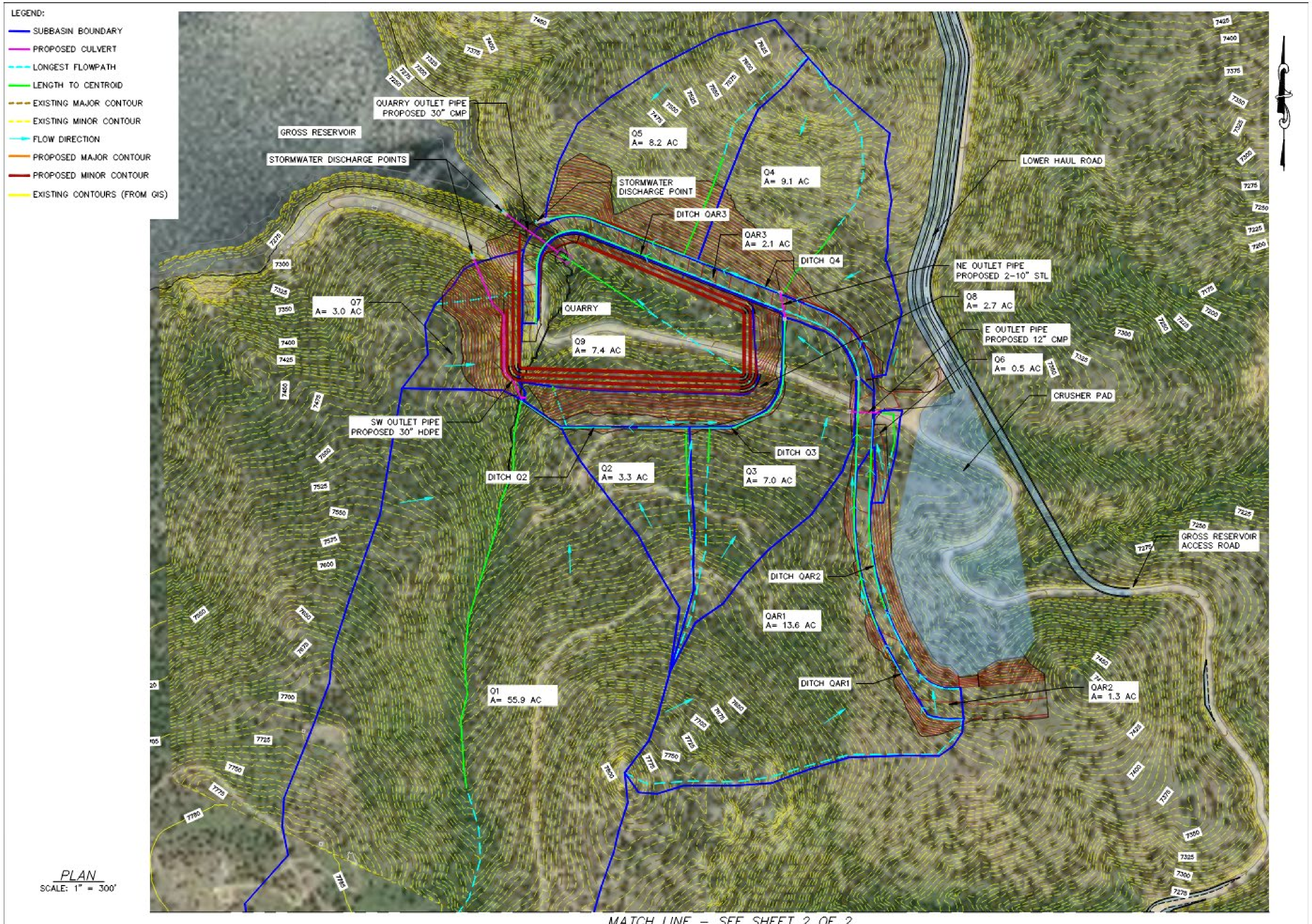
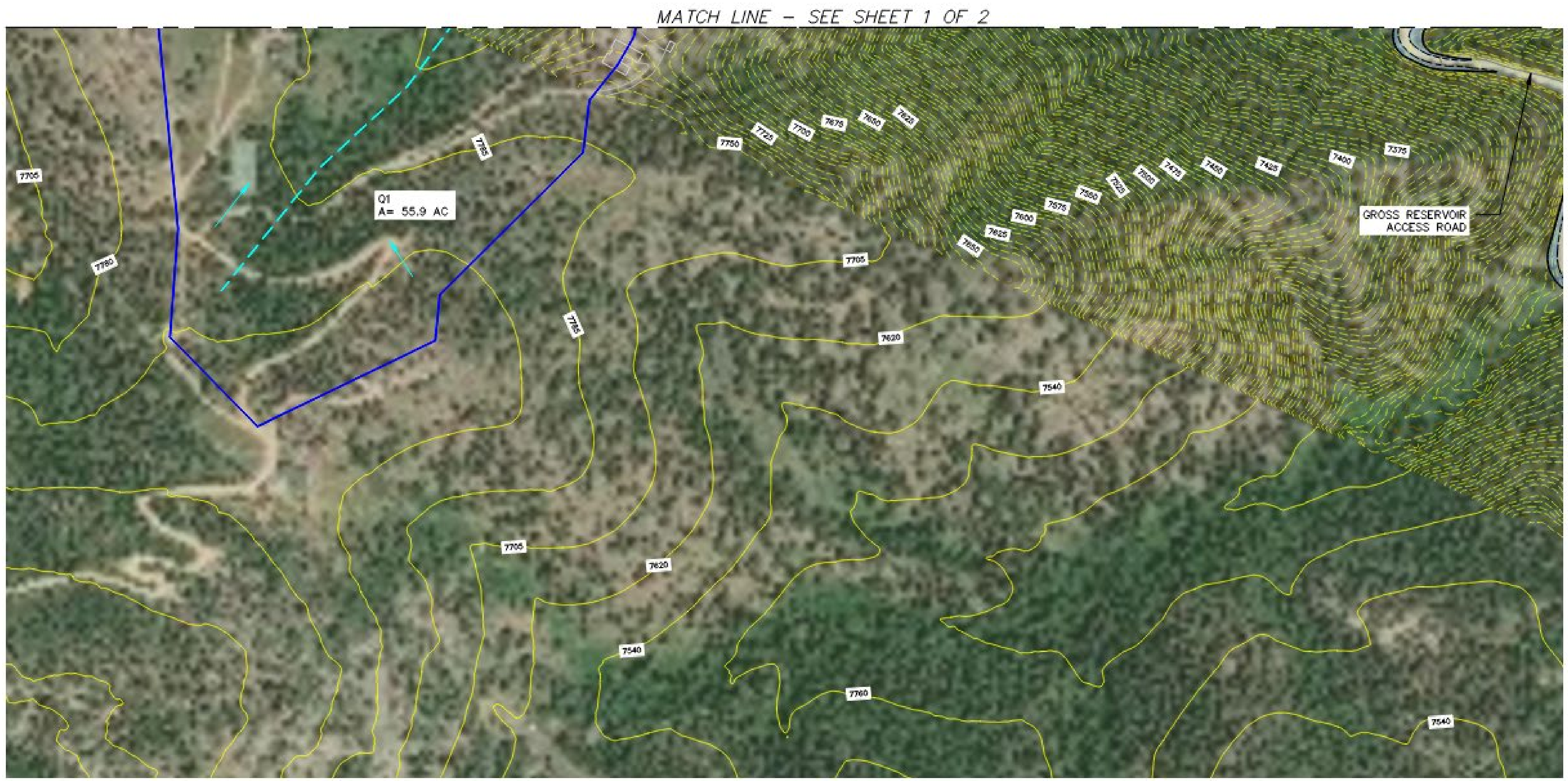


Figure 26: Quarry Basin Map (Sheet 1 of 2)

LEGEND:
- SUBBASIN BOUNDARY
- PROPOSED CULVERT
- LONGEST FLOWPATH
- EXISTING MAJOR CONTOUR
- EXISTING MINOR CONTOUR
- FLOW DIRECTION
- PROPOSED MAJOR CONTOUR
- PROPOSED MINOR CONTOUR
- EXISTING CONTOURS (FROM GIS)

CUMULATIVE FLOW RATES (cfs)

DRAINAGE FEATURE	CONTRIBUTING DRAINAGE AREAS	TOTAL DRAINAGE AREA (AC)	PEAK DISCHARGE Q10 (cfs)
SW OUTLET PIPE	Q1, Q2	59.19	13.73
DITCH Q2	Q2	3.34	0.53
DITCH Q3	Q3	6.95	1.31
NE OUTLET PIPE	Q3, Q6, QAR1, QAR2	22.28	4.02
DITCH Q4	Q3, Q4, Q5, Q6, QAR1, QAR2	39.54	8.10
E OUTLET PIPE	Q6	0.46	0.08
QUARRY OUTLET PIPE	Q7, Q8, Q9, QAR3	15.04	14.78
DITCH QAR1	QAR1	13.58	2.23
DITCH QAR2	QAR2	1.29	0.40
DITCH QAR3	QAR3	2.05	0.80



PLAN
SCALE: 1" = 300'

Figure 27: Quarry Basin Map (Sheet 2 of 2)

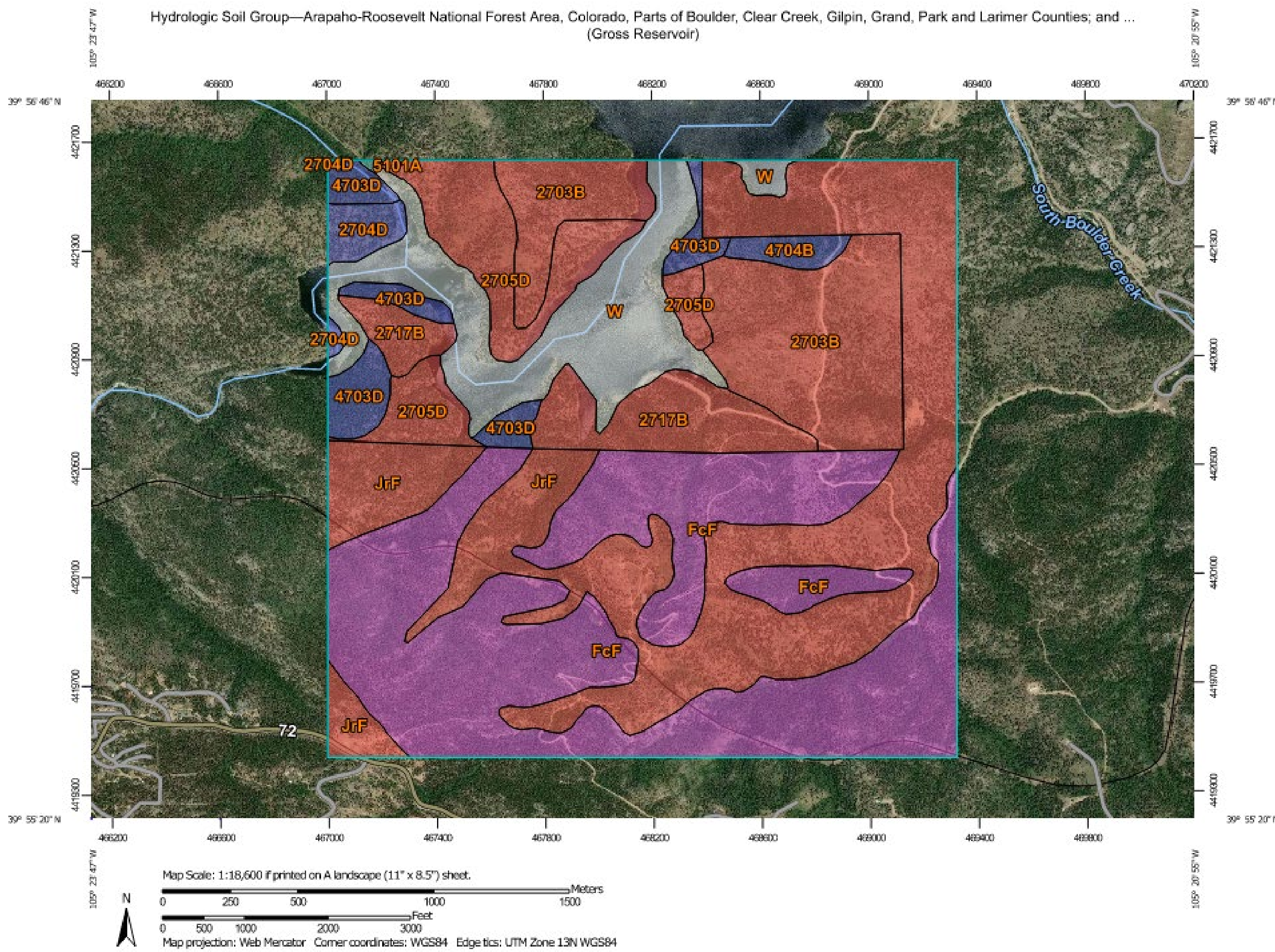


Figure 28: Hydrologic Soil Group Map

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

A

A/D

B

B/D

C

C/D

D

Not rated or not available

Soil Rating Lines

A

A/D

B

B/D

C

C/D

D

Not rated or not available

Soil Rating Points

A

A/D

B

B/D

C

C/D

D

Not rated or not available

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 scales ranging from 1:20,000 to 1:24,000.

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: Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties
Survey Area Data: Version 8, Jul 15, 2020

Soil Survey Area: Boulder County Area, Colorado
Survey Area Data: Version 17, Jun 5, 2020

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

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

Date(s) aerial images were photographed: Sep 20, 2015—Oct 21, 2017

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Figure 29: Hydrologic Soil Group Map Legend

NOAA Atlas 14 Precipitation Data

Comment	10-yr NOAA Atlas 14		
1Hr Depth	1.3	NOAA Atlas 14 Point Precipitation Frequency Estimates: CO (Note: Use 60-minute recurrence interval depth)	
Return Period	10	Years	
Time	Depth	CurveValue	
0:05	0.026		0.02
0:10	0.048		0.037
0:15	0.107		0.082
0:20	0.195		0.15
0:25	0.325		0.25
0:30	0.156		0.12
0:35	0.073		0.056
0:40	0.056		0.043
0:45	0.049		0.038
0:50	0.042		0.032
0:55	0.042		0.032
1:00	0.042		0.032
1:05	0.042		0.032
1:10	0.042		0.032
1:15	0.042		0.032
1:20	0.033		0.025
1:25	0.025		0.019
1:30	0.025		0.019
1:35	0.025		0.019
1:40	0.025		0.019
1:45	0.025		0.019
1:50	0.025		0.019
1:55	0.022		0.017
2:00	0.017		0.013
2:05	0		

Figure 30: NOAA Atlas 14 Precipitation Data

Summary of CUHP Input Parameters (Version 2.0.1)

								Depression Storage		Horton's Infiltration Parameters			DCIA Level and Fractions			
Catchment Name/ID	SWMM Node/ID	Raingage Name/ID	Area (sq.mi.)	Dist. to Centroid (miles)	Length (miles)	Slope (ft./ft.)	Percent Imperv.	Pervious (inches)	Imperv. (inches)	Initial Rate (in./hr.)	Final Rate (in.hr.)	Decay Coeff. (1/sec.)	DCIA Level	Dir. Con't Imperv. Fraction	Receiv. Perv. Fraction	Percent Eff. Imperv.
Q1		10-YR NOAA ATLAS 14 1-HR	0.087	0.251	0.494	0.172	2.0	0.40	0.05	3.00	0.50	0.0018	0.00	0.04	0.02	1.62
Q2		10-YR NOAA ATLAS 14 1-HR	0.005	0.118	0.234	0.262	2.0	0.40	0.05	3.00	0.50	0.0018	0.00	0.00	0.02	1.61
Q3		10-YR NOAA ATLAS 14 1-HR	0.011	0.123	0.260	0.200	2.0	0.40	0.05	3.00	0.50	0.0018	0.00	0.00	0.02	1.61
Q4		10-YR NOAA ATLAS 14 1-HR	0.014	0.112	0.234	0.372	2.0	0.40	0.05	3.00	0.50	0.0018	0.00	0.04	0.02	1.62
Q5		10-YR NOAA ATLAS 14 1-HR	0.013	0.158	0.243	0.415	2.0	0.40	0.05	3.00	0.50	0.0018	0.00	0.04	0.02	1.62
Q6		10-YR NOAA ATLAS 14 1-HR	0.001	0.032	0.066	0.122	2.0	0.40	0.05	3.00	0.50	0.0018	0.00	0.00	0.02	1.61
Q7		10-YR NOAA ATLAS 14 1-HR	0.005	0.035	0.082	0.500	45.0	0.40	0.05	3.00	0.50	0.0018	0.00	0.83	0.22	43.26
Q8		10-YR NOAA ATLAS 14 1-HR	0.004	0.003	0.027	0.510	45.0	0.40	0.05	3.00	0.50	0.0018	0.00	0.83	0.22	43.26
Q9		10-YR NOAA ATLAS 14 1-HR	0.012	0.063	0.149	0.005	90.0	0.40	0.60	3.00	0.50	0.0018	0.00	0.96	0.37	89.29
QAR1		10-YR NOAA ATLAS 14 1-HR	0.021	0.158	0.473	0.154	2.0	0.40	0.05	3.00	0.50	0.0018	0.00	0.04	0.02	1.62
QAR2		10-YR NOAA ATLAS 14 1-HR	0.002	0.102	0.176	0.014	40.0	0.40	0.05	3.00	0.50	0.0018	0.00	0.80	0.20	38.23
QAR3		10-YR NOAA ATLAS 14 1-HR	0.003	0.147	0.280	0.100	40.0	0.40	0.05	3.00	0.50	0.0018	0.00	0.80	0.20	38.23

Figure 31: CUHP Basin Input Parameters

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 2.0.1)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph			
Catchment Name/ID	User Comment for Catchment	CT	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)	Runoff per Unit Area (cfs/acre)
Q1		0.157	0.157	26.3	3.46	13.7	2.45	5.8	100	202,749	0.16	32,996	38.0	13.20	32,993	0.24
Q2		0.157	0.044	41.0	1.69	21.3	1.19	2.8	4	12,124	0.16	1,973	41.0	0.53	1,972	0.16
Q3		0.157	0.061	33.8	1.89	17.6	1.34	3.2	10	25,227	0.16	4,105	40.0	1.31	4,104	0.19
Q4		0.157	0.069	23.5	1.55	12.2	1.09	2.6	18	32,943	0.16	5,361	36.0	2.32	5,360	0.26
Q5		0.157	0.066	28.8	1.76	15.0	1.24	2.9	13	29,691	0.16	4,832	37.0	1.76	4,831	0.22
Q6		0.157	0.018	35.0	0.79	18.2	0.56	1.3	1	1,682	0.16	274	40.0	0.08	273	0.18
Q7		0.092	0.045	6.8	0.54	3.5	0.38	0.9	20	10,701	0.68	7,298	30.0	4.12	7,192	1.40
Q8		0.092	0.043	1.3	0.34	0.7	0.24	0.6	98	9,698	0.68	6,614	25.0	4.52	5,426	1.69
Q9		0.075	0.088	15.1	1.32	7.9	0.93	2.2	23	26,752	0.78	20,910	36.0	5.34	20,912	0.72
QAR1		0.157	0.083	40.1	2.85	20.8	2.02	4.8	16	49,300	0.16	8,023	41.0	2.23	8,023	0.16
QAR2		0.094	0.029	61.5	1.66	32.0	1.18	2.8	1	4,691	0.62	2,907	45.0	0.40	2,907	0.31
QAR3		0.094	0.036	46.5	1.57	24.2	1.11	2.6	2	7,449	0.62	4,617	40.0	0.80	4,616	0.39

Figure 32: CUHP Unit Hydrograph Parameters

Summary of Quarry Basin Hydrology

Peak Flow Rates (cfs)

Drainage Basin	Area (ac)	Storm Event 10-yr	25-yr	50-yr	100-yr
Q1	55.85	13.20	38.51	52.61	69.21
Q2	3.34	0.53	1.61	2.20	2.96
Q3	6.95	1.31	3.88	5.31	7.09
Q4	9.08	2.32	6.68	9.10	11.94
Q5	8.18	1.76	5.17	7.08	9.32
Q6	0.46	0.08	0.25	0.34	0.46
Q7	2.95	4.12	6.52	8.24	9.76
Q8	2.67	4.52	9.22	11.09	12.72
Q9	7.37	5.34	10.02	12.61	15.51
QAR1	13.58	2.23	6.71	9.18	12.35
QAR2	1.29	0.40	0.71	0.88	1.10
QAR3	2.05	0.80	1.39	1.72	2.14

Cumulative Flow Rates (cfs)

Drainage Feature	Contributing Drainage Areas	Total Drainage Area (ac)	Peak Discharge, Q10 (cfs)
SW Outlet Pipe	Q1, Q2	59.19	13.73
Ditch Q2	Q2	3.34	0.53
Ditch Q3	Q3	6.95	1.31
NE Outlet Pipe	Q3, Q6, QAR1, QAR2	22.28	4.02
Ditch Q4	Q3, Q4, Q5, Q6, QAR1, QAR2	39.54	8.10
E Outlet Pipe	Q6	0.46	0.08
Quarry Outlet Pipe	Q7, Q8, Q9, QAR3	15.04	14.78
Ditch QAR1	QAR1	13.58	2.23
Ditch QAR2	QAR2	1.29	0.40
Ditch QAR3	QAR3	2.05	0.80

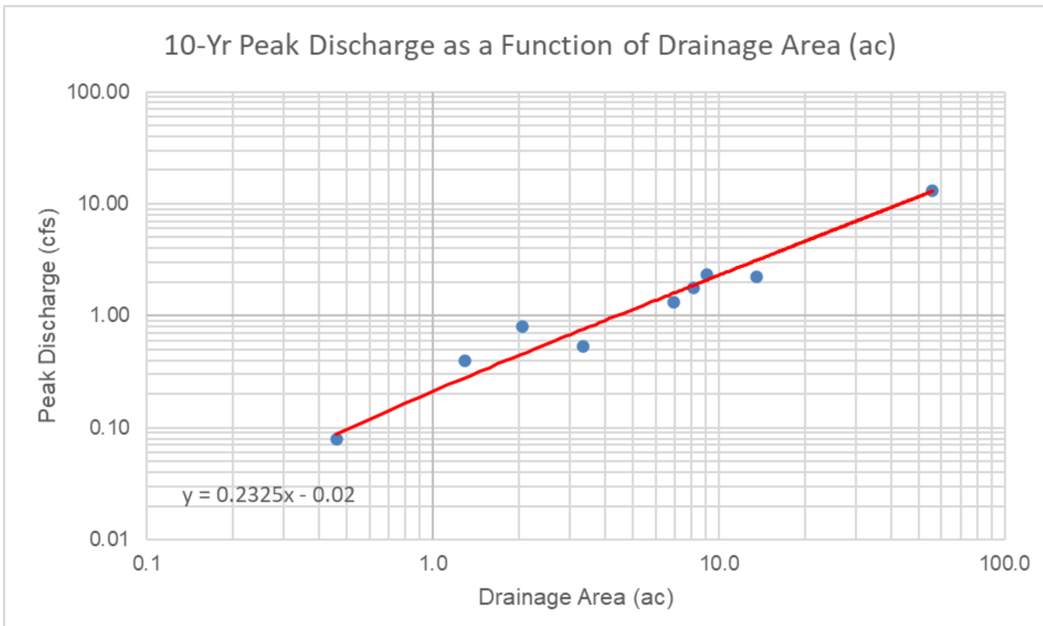


Figure 33: CUHP Peak Discharge Summary

Task 9 Ditch Report

Label	Solve For	Friction Method	Roughness Coefficient
Ditch Q2	Normal Depth	Manning Formula	0.030
Ditch Q3	Normal Depth	Manning Formula	0.030
Ditch Q4	Normal Depth	Manning Formula	0.030
Ditch QAR3	Normal Depth	Manning Formula	0.030
Ditch QAR1	Normal Depth	Manning Formula	0.030
Ditch QAR2	Normal Depth	Manning Formula	0.030

Channel Slope (ft/ft)	Normal Depth (ft)	Left Side Slope (ft/ft (H:V))	Right Side Slope (ft/ft (H:V))
0.02800	0.28	3.00	3.00
0.07200	0.33	3.00	3.00
0.10000	0.62	3.00	3.00
0.10000	0.26	3.00	3.00
0.01420	0.55	3.00	3.00
0.01420	0.29	3.00	3.00

Discharge (ft^3/s)	Flow Area (ft^2)	Wetted Perimeter (ft)	Hydraulic Radius (ft)
0.53	0.24	1.80	0.13
1.31	0.34	2.12	0.16
8.10	1.17	3.94	0.30
0.80	0.21	1.65	0.12
2.23	0.92	3.51	0.26
0.40	0.25	1.84	0.14

Top Width (ft)	Critical Depth (ft)	Critical Slope (ft/ft)	Velocity (ft/s)
1.71	0.29	0.02688	2.18
2.01	0.41	0.02382	3.90
3.74	0.85	0.01869	6.95
1.57	0.34	0.02544	3.90
3.33	0.51	0.02219	2.42
1.75	0.26	0.02791	1.58

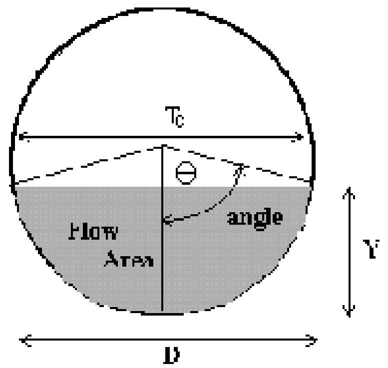
Velocity Head (ft)	Specific Energy (ft)	Froude Number	Flow Type
0.07	0.36	1.02	Supercritical
0.24	0.57	1.68	Supercritical
0.75	1.37	2.20	Supercritical
0.24	0.50	1.90	Supercritical
0.09	0.65	0.81	Subcritical
0.04	0.33	0.73	Subcritical

Figure 34: FlowMaster Ditch Calculations

CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

Project: **Blue cells are for user data entry**
Pipe ID: **Green cells are calculated values**

Clear all cells



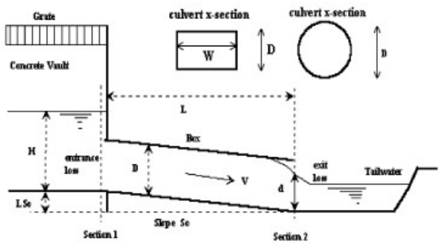
Design Information (Input)			
Pipe Invert Slope	So =	0.0950	ft/ft
Pipe Manning's n-value	n =	0.0240	*
Pipe Diameter	D =	12.00	inches
Design discharge	**Q =**	**0.08**	**cfs**
Full-flow Capacity (Calculated)			
Full-flow area	Af =	0.79	sq ft
Full-flow wetted perimeter	Pf =	3.14	ft
Half Central Angle	Theta =	3.14	radians
Full-flow capacity	Qf =	5.96	cfs
Calculation of Normal Flow Condition			
Half Central Angle (0<Theta<3.14)	Theta =	0.58	radians
Flow area	An =	0.03	sq ft
Top width	Tn =	0.55	ft
Wetted perimeter	Pn =	0.58	ft
Flow depth	Yn =	0.08	ft
Flow velocity	Vn =	2.66	fps
Discharge	Qn =	0.08	cfs
Percent Full Flow	Flow =	1.3%	of full flow
Normal Depth Froude Number	Fr_n =	2.00	supercritical
Calculation of Critical Flow Condition			
Half Central Angle (0<Theta-c<3.14)	Theta-c =	0.69	radians
Critical flow area	Ac =	0.05	sq ft
Critical top width	Tc =	0.64	ft
Critical flow depth	Yc =	0.12	ft
Critical flow velocity	Vc =	1.59	fps
Critical Depth Froude Number	Fr_c =	1.00	

*** Unexpected value for Manning's n**

Figure 35: E Outlet Pipe Conduit Sizing

CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

Project: **Blue cells are for user data entry**
Basin ID: **Green cells are calculated values**
Status:



Clear Worksheet

Clear Results

Calculate

Design Information (Input):

Circular Culvert:	Barrel Diameter in Inches	D =	12	inches
	Inlet Edge Type (choose from pull-down list)		1.5 : 1 Beveled Edge	1.5 : 1 Beveled Edge
OR:				
Box Culvert:	Barrel Height (Rise) in Feet	Height (Rise) =		ft.
	Barrel Width (Span) in Feet	Width (Span) =		ft.
	Inlet Edge Type (choose from pull-down list)		Square Edge w/ 30-78 deg. Flared Wingwall	Square Edge w/ 30-78 deg. Flared Wingwa
	Number of Barrels	No =	1	
	Inlet Elevation at Culvert Invert	Inlet Elev =	7409.8	ft. elev.
	Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.)	Slope =	0.095	ft vert. / ft horiz.
	Culvert Length in Feet	L =	99	ft.
	Manning's Roughness	n =	0.024	
	Bend Loss Coefficient	K_b =	0	
	Exit Loss Coefficient	K_x =	1	

Design Information (calculated):

Entrance Loss Coefficient	K_e =	0.20
Friction Loss Coefficient	K_f =	10.05
Sum of All Loss Coefficients	K_s =	11.25
Orifice Inlet Condition Coefficient	C_d =	1.04
Minimum Energy Condition Coefficient	KE_{low} =	-0.0898

Calculations of Culvert Capacity (output):

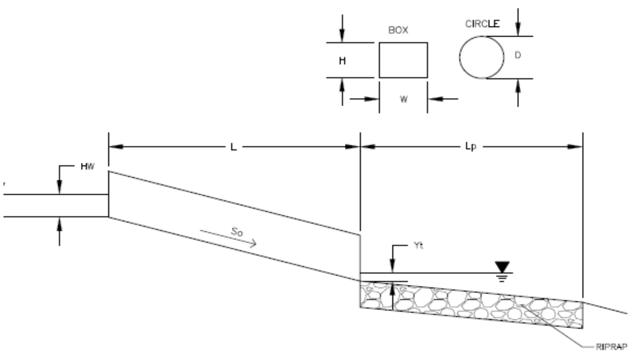
Recalculate

Water Surface Elevation Enter HW Elev **(ft., linked)**	**Tailwater Surface Elevation ft**	**Culvert Inlet-Control Flowrate cfs**	**Culvert Outlet-Control Flowrate cfs**	**Controlling Culvert Flowrate cfs (output)**	**Inlet Equation Used:**	**Flow Control Used**
7409.81		0.00	0.00	**0.00**	No Flow (WS < inlet)	N/A
7410.01		0.20	1.64	**0.20**	Min. Energy. Eqn.	INLET
7410.21		0.60	1.73	**0.60**	Min. Energy. Eqn.	INLET
7410.41		1.10	1.81	**1.10**	Regression Eqn.	INLET
7410.61		1.80	1.91	**1.80**	Regression Eqn.	INLET
7410.81		2.50	1.99	**1.99**	Regression Eqn.	OUTLET
7411.01		3.30	2.14	**2.14**	Regression Eqn.	OUTLET
7411.21		3.90	2.31	**2.31**	Regression Eqn.	OUTLET
7411.41		4.40	2.45	**2.45**	Regression Eqn.	OUTLET
7411.61		4.90	2.59	**2.59**	Regression Eqn.	OUTLET
7411.81		5.40	2.72	**2.72**	Regression Eqn.	OUTLET
7412.01		5.80	2.84	**2.84**	Regression Eqn.	OUTLET
7412.21		6.20	2.97	**2.97**	Regression Eqn.	OUTLET
7412.41		6.60	3.08	**3.08**	Regression Eqn.	OUTLET
7412.61		7.00	3.19	**3.19**	Regression Eqn.	OUTLET
7412.81		7.30	3.31	**3.31**	Regression Eqn.	OUTLET
7413.01		7.60	3.41	**3.41**	Orifice Eqn.	OUTLET
7413.21		7.90	3.51	**3.51**	Orifice Eqn.	OUTLET
7413.41		8.20	3.61	**3.61**	Orifice Eqn.	OUTLET
7413.61		8.40	3.71	**3.71**	Orifice Eqn.	OUTLET
7413.81		8.70	3.80	**3.80**	Orifice Eqn.	OUTLET
7414.01		8.90	3.89	**3.89**	Orifice Eqn.	OUTLET
7414.21		9.20	3.99	**3.99**	Orifice Eqn.	OUTLET
7414.41		9.40	4.07	**4.07**	Orifice Eqn.	OUTLET
7414.61		9.60	4.15	**4.15**	Orifice Eqn.	OUTLET
7414.81		9.80	4.24	**4.24**	Orifice Eqn.	OUTLET
7415.01		10.10	4.33	**4.33**	Orifice Eqn.	OUTLET
7415.21		10.30	4.40	**4.40**	Orifice Eqn.	OUTLET
7415.41		10.50	4.48	**4.48**	Orifice Eqn.	OUTLET
7415.61		10.70	4.56	**4.56**	Orifice Eqn.	OUTLET

Figure 36: E Outlet Pipe Stage-Discharge Sizing

Determination of Culvert Headwater and Outlet Protection

Project: Blue cells are for user data entry
Basin ID: Green cells are calculated values



Clear Worksheet
Clear Results
Calculate

Soil Type:
Choose One:
○ Sandy
◉ Non-Sandy

Design Information (Input):

Design Discharge	Q =	0.08	cfs
Circular Culvert:			
Barrel Diameter in Inches	D =	12	inches
Inlet Edge Type (Choose from pull-down list)		1.5 : 1 Beveled Edge	
Box Culvert:		**OR**	
Barrel Height (Rise) in Feet	Height (Rise) =		ft
Barrel Width (Span) in Feet	Width (Span) =		ft
Inlet Edge Type (Choose from pull-down list)			
Number of Barrels	No =	1	
Inlet Elevation	Elev IN =	7409.8	ft
Outlet Elevation OR Slope	So =	0.095	ft/ft
Culvert Length	L =	99	ft
Manning's Roughness	n =	0.024	
Bend Loss Coefficient	k_b =	0	
Exit Loss Coefficient	k_x =	1	
Tailwater Surface Elevation	Elev Y_t =		ft
Max Allowable Channel Velocity	V =	7	ft/s

Required Protection (Output):

Tailwater Surface Height	Y_t =	0.40	ft
Flow Area at Max Channel Velocity	A_t =	0.01	ft^2
Culvert Cross Sectional Area Available	A =	0.79	ft^2
Entrance Loss Coefficient	k_e =	0.20	
Friction Loss Coefficient	k_f =	9.44	
Sum of All Losses Coefficients	k_s =	10.64	ft
Culvert Normal Depth	Y_n =	0.13	ft
Culvert Critical Depth	Y_c =	0.12	ft
Tailwater Depth for Design	d =	0.56	ft
Adjusted Diameter OR Adjusted Rise	D_a =	-	ft
Expansion Factor	1/(2*tan(Θ)) =	6.70	
Flow/Diameter$^{2.5}$ OR Flow/(Span * Rise$^{1.5}$)	Q/D^2.5 =	0.08	$ft^{0.5}/s$
Froude Number	Fr =	0.76	
Tailwater/Adjusted Diameter OR Tailwater/Adjusted Rise	Yt/D =	0.40	
Inlet Control Headwater	HW_I =	0.18	ft
Outlet Control Headwater	HW_O =	-0.52	
Design Headwater Elevation	**HW =**	**7,409.99**	**ft**
Headwater/Diameter OR Headwater/Rise Ratio	**HW/D =**	**0.18**	
Minimum Theoretical Riprap Size	d_{50} =	0	in
Nominal Riprap Size	d_{50} =	6	in
UDFCD Riprap Type	**Type =**	**VL**	
Length of Protection	**L_p =**	**3**	**ft**
Width of Protection	**T =**	**2**	**ft**

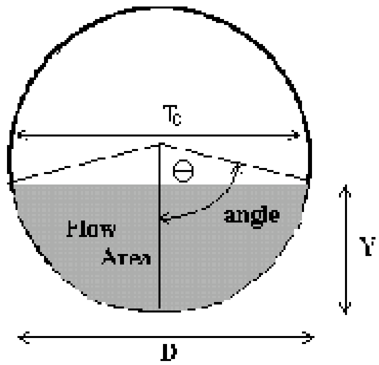
Figure 37: E Outlet Pipe Outfall Protection

CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

Project: **Blue cells are for user data entry**

Pipe ID: **Green cells are calculated values**

Clear all cells



Design Information (Input)			
Pipe Invert Slope	So =	0.0120	ft/ft
Pipe Manning's n-value	n =	0.0240	*
Pipe Diameter	D =	30.00	inches
Design discharge	**Q =**	**14.78**	**cfs**
Full-flow Capacity (Calculated)			
Full-flow area	Af =	4.91	sq ft
Full-flow wetted perimeter	Pf =	7.85	ft
Half Central Angle	Theta =	3.14	radians
Full-flow capacity	Qf =	24.40	cfs
Calculation of Normal Flow Condition			
Half Central Angle (0<Theta<3.14)	Theta =	1.69	radians
Flow area	An =	2.84	sq ft
Top width	Tn =	2.48	ft
Wetted perimeter	Pn =	4.24	ft
Flow depth	Yn =	1.40	ft
Flow velocity	Vn =	5.21	fps
Discharge	Qn =	14.78	cfs
Percent Full Flow	Flow =	60.6%	of full flow
Normal Depth Froude Number	Fr_n =	0.86	subcritical
Calculation of Critical Flow Condition			
Half Central Angle (0<Theta-c<3.14)	Theta-c =	1.61	radians
Critical flow area	Ac =	2.57	sq ft
Critical top width	Tc =	2.50	ft
Critical flow depth	Yc =	1.30	ft
Critical flow velocity	Vc =	5.75	fps
Critical Depth Froude Number	Fr_c =	1.00	

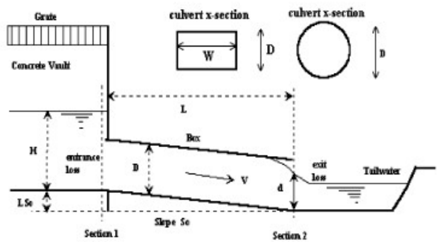
*** Unexpected value for Manning's n**

Figure 38: Quarry Outlet Pipe Conduit Sizing

CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

Project: **Blue cells are for user data entry**
Basin ID: **Green cells are calculated values**
Status:

Clear Worksheet
Clear Results
Calculate



Design Information (Input):

Circular Culvert:	Barrel Diameter in Inches	D =	30	inches
	Inlet Edge Type (choose from pull-down list)		1.5 : 1 Beveled Edge	1.5 : 1 Beveled Edge
OR:				
Box Culvert:	Barrel Height (Rise) in Feet	Height (Rise) =		ft.
	Barrel Width (Span) in Feet	Width (Span) =		ft.
	Inlet Edge Type (choose from pull-down list)		Square Edge w/ 30-78 deg. Flared Wingwall	Square Edge w/ 30-78 deg. Flared Wingwa
	Number of Barrels	No =	1	
	Inlet Elevation at Culvert Invert	Inlet Elev =	7250	ft. elev.
	Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.)	Slope =	0.012	ft vert. / ft horiz.
	Culvert Length in Feet	L =	210.8	ft.
	Manning's Roughness	n =	0.024	
	Bend Loss Coefficient	K_b =	0	
	Exit Loss Coefficient	K_x =	1	

Design Information (calculated):

Entrance Loss Coefficient	K_e =	0.20
Friction Loss Coefficient	K_f =	6.59
Sum of All Loss Coefficients	K_s =	7.79
Orifice Inlet Condition Coefficient	C_d =	1.03
Minimum Energy Condition Coefficient	KE_{low} =	-0.0877

Calculations of Culvert Capacity (output):

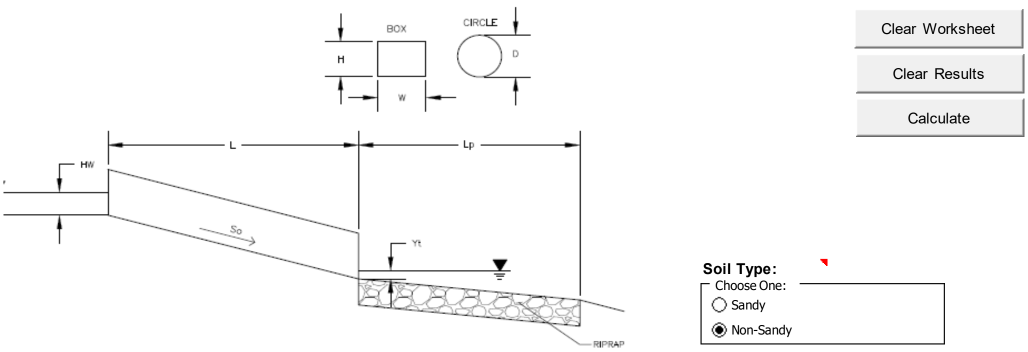
Recalculate

Water Surface Elevation (Enter HW Elev) (ft., linked)	Tailwater Surface Elevation ft	Culvert Inlet-Control Flowrate cfs	Culvert Outlet-Control Flowrate cfs	Controlling Culvert Flowrate cfs (output)	Inlet Equation Used:	Flow Control Used
7250.00		0.00	0.00	**0.00**	No Flow (WS < inlet)	N/A
7250.20		0.20	17.40	**0.20**	Min. Energy. Eqn.	INLET
7250.40		0.80	17.88	**0.80**	Min. Energy. Eqn.	INLET
7250.60		2.00	18.35	**2.00**	Min. Energy. Eqn.	INLET
7250.80		3.50	18.83	**3.50**	Min. Energy. Eqn.	INLET
7251.00		5.30	19.29	**5.30**	Min. Energy. Eqn.	INLET
7251.20		7.40	19.76	**7.40**	Min. Energy. Eqn.	INLET
7251.40		9.40	20.23	**9.40**	Regression Eqn.	INLET
7251.60		11.70	20.68	**11.70**	Regression Eqn.	INLET
7251.80		14.30	21.13	**14.30**	Regression Eqn.	INLET
7252.00		17.10	21.56	**17.10**	Regression Eqn.	INLET
7252.20		20.10	22.01	**20.10**	Regression Eqn.	INLET
7252.40		23.10	22.44	**22.44**	Regression Eqn.	OUTLET
7252.60		26.10	23.07	**23.07**	Regression Eqn.	OUTLET
7252.80		29.00	23.90	**23.90**	Regression Eqn.	OUTLET
7253.00		31.80	24.70	**24.70**	Regression Eqn.	OUTLET
7253.20		34.40	25.48	**25.48**	Regression Eqn.	OUTLET
7253.40		36.80	26.24	**26.24**	Regression Eqn.	OUTLET
7253.60		39.10	26.98	**26.98**	Regression Eqn.	OUTLET
7253.80		41.40	27.70	**27.70**	Regression Eqn.	OUTLET
7254.00		43.50	28.40	**28.40**	Regression Eqn.	OUTLET
7254.20		45.50	29.08	**29.08**	Regression Eqn.	OUTLET
7254.40		47.50	29.77	**29.77**	Regression Eqn.	OUTLET
7254.60		49.40	30.42	**30.42**	Regression Eqn.	OUTLET
7254.80		51.20	31.03	**31.03**	Regression Eqn.	OUTLET
7255.00		53.00	31.66	**31.66**	Regression Eqn.	OUTLET
7255.20		54.70	32.28	**32.28**	Regression Eqn.	OUTLET
7255.40		56.40	32.89	**32.89**	Regression Eqn.	OUTLET
7255.60		58.10	33.50	**33.50**	Regression Eqn.	OUTLET
7255.80		59.70	34.09	**34.09**	Regression Eqn.	OUTLET

Figure 39: Quarry Outlet Pipe Stage-Discharge Sizing

Determination of Culvert Headwater and Outlet Protection

Project: Blue cells are for user data entry
Basin ID: Green cells are calculated values



Design Information (Input):

	Design Discharge	Q =	14.78	cfs
Circular Culvert:				
	Barrel Diameter in Inches	D =	30	inches
	Inlet Edge Type (Choose from pull-down list)	1.5 : 1 Beveled Edge		
Box Culvert:			**OR**	
	Barrel Height (Rise) in Feet	Height (Rise) =		ft
	Barrel Width (Span) in Feet	Width (Span) =		ft
	Inlet Edge Type (Choose from pull-down list)			
	Number of Barrels	No =	1	
	Inlet Elevation	Elev IN =	7250.00	ft
	Outlet Elevation **OR** Slope	So =	1.20%	ft/ft
	Culvert Length	L =	210.8	ft
	Manning's Roughness	n =	0.024	
	Bend Loss Coefficient	k_b =	0	
	Exit Loss Coefficient	k_x =	1	
	Tailwater Surface Elevation	Elev Y_t =		ft
	Max Allowable Channel Velocity	V =	7	ft/s

Required Protection (Output):

Tailwater Surface Height	Y_t =	1.00	ft
Flow Area at Max Channel Velocity	A_t =	2.11	ft^2
Culvert Cross Sectional Area Available	A =	4.91	ft^2
Entrance Loss Coefficient	k_e =	0.20	
Friction Loss Coefficient	k_f =	6.59	
Sum of All Losses Coefficients	k_s =	7.79	ft
Culvert Normal Depth	Y_n =	1.40	ft
Culvert Critical Depth	Y_c =	1.30	ft
Tailwater Depth for Design	d =	1.90	ft
Adjusted Diameter **OR** Adjusted Rise	D_a =	-	ft
Expansion Factor	1/(2*tan(Θ)) =	6.24	
Flow/Diameter$^{2.5}$ **OR** Flow/(Span * Rise$^{1.5}$)	Q/D^2.5 =	1.50	$ft^{0.5}/s$
Froude Number	Fr =	0.86	
Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise	Yt/D =	0.40	
Inlet Control Headwater	HW_I =	1.84	ft
Outlet Control Headwater	HW_O =	0.47	
Design Headwater Elevation	**HW =**	**7,251.84**	**ft**
Headwater/Diameter OR Headwater/Rise Ratio	**HW/D =**	**0.74**	
Minimum Theoretical Riprap Size	d_{50} =	3	in
Nominal Riprap Size	d_{50} =	6	in
UDFCD Riprap Type	**Type =**	**VL**	
Length of Protection	L_p =	**8**	**ft**
Width of Protection	**T =**	**4**	**ft**

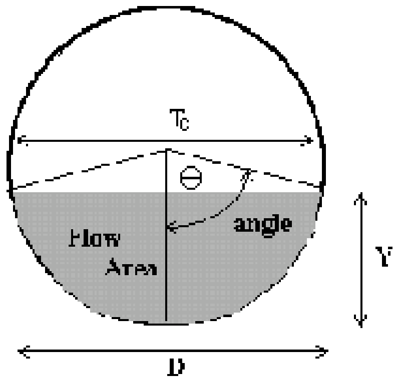
Figure 40: Quarry Outlet Pipe Outfall Protection

CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

Project: **Blue cells are for user data entry**

Pipe ID: **Green cells are calculated values**

Clear all cells



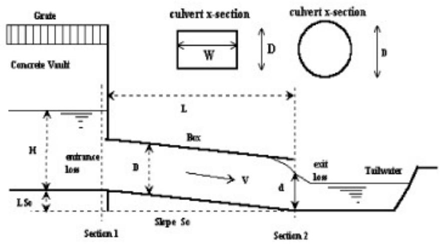
Design Information (Input)			
Pipe Invert Slope	So =	0.0110	ft/ft
Pipe Manning's n-value	n =	0.0120	
Pipe Diameter	D =	30.00	inches
Design discharge	**Q =**	**13.73**	**cfs**
Full-flow Capacity (Calculated)			
Full-flow area	Af =	4.91	sq ft
Full-flow wetted perimeter	Pf =	7.85	ft
Half Central Angle	Theta =	3.14	radians
Full-flow capacity	Qf =	46.73	cfs
Calculation of Normal Flow Condition			
Half Central Angle (0<Theta<3.14)	Theta =	1.31	radians
Flow area	An =	1.66	sq ft
Top width	Tn =	2.42	ft
Wetted perimeter	Pn =	3.28	ft
Flow depth	Yn =	0.93	ft
Flow velocity	Vn =	8.27	fps
Discharge	Qn =	13.73	cfs
Percent Full Flow	Flow =	29.4%	of full flow
Normal Depth Froude Number	Fr_n =	1.76	supercritical
Calculation of Critical Flow Condition			
Half Central Angle (0<Theta-c<3.14)	Theta-c =	1.57	radians
Critical flow area	Ac =	2.45	sq ft
Critical top width	Tc =	2.50	ft
Critical flow depth	Yc =	1.25	ft
Critical flow velocity	Vc =	5.61	fps
Critical Depth Froude Number	Fr_c =	1.00	

Figure 41: SW Outlet Pipe Conduit Sizing

CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

Project: **Blue cells are for user data entry**
Basin ID: **Green cells are calculated values**
Status:

Clear Worksheet
Clear Results
Calculate



Design Information (Input):

Circular Culvert:	Barrel Diameter in Inches	D =	30	inches
	Inlet Edge Type (choose from pull-down list)		1.5 : 1 Beveled Edge	1.5 : 1 Beveled Edge
OR:				
Box Culvert:	Barrel Height (Rise) in Feet	Height (Rise) =		ft.
	Barrel Width (Span) in Feet	Width (Span) =		ft.
	Inlet Edge Type (choose from pull-down list)		Square Edge w/ 30-78 deg. Flared Wingwall	Square Edge w/ 30-78 deg. Flared Wingwa
	Number of Barrels	No =	1	
	Inlet Elevation at Culvert Invert	Inlet Elev =	7360.41	ft. elev.
	Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.)	Slope =	0.011	ft vert. / ft horiz.
	Culvert Length in Feet	L =	183	ft.
	Manning's Roughness	n =	0.012	
	Bend Loss Coefficient	K_b =	0	
	Exit Loss Coefficient	K_x =	1	

Design Information (calculated):

Entrance Loss Coefficient	K_e =	0.20
Friction Loss Coefficient	K_f =	4.08
Sum of All Loss Coefficients	K_s =	5.28
Orifice Inlet Condition Coefficient	C_d =	1.03
Minimum Energy Condition Coefficient	KE_{low} =	-0.0877

Calculations of Culvert Capacity (output):

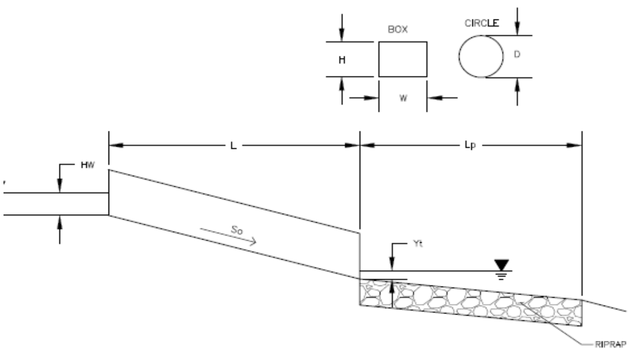
Recalculate

Water Surface Elevation (Enter HW Elev) (ft., linked)	Tailwater Surface Elevation ft	Culvert Inlet-Control Flowrate cfs	Culvert Outlet-Control Flowrate cfs	Controlling Culvert Flowrate cfs (output)	Inlet Equation Used:	Flow Control Used
7374.80		0.00	0.00	**0.00**	No Flow (WS < inlet)	N/A
7375.00		0.20	45.60	**0.20**	Min. Energy. Eqn.	INLET
7375.20		0.80	45.91	**0.80**	Min. Energy. Eqn.	INLET
7375.40		2.00	46.24	**2.00**	Min. Energy. Eqn.	INLET
7375.60		3.50	46.55	**3.50**	Min. Energy. Eqn.	INLET
7375.80		5.30	46.86	**5.30**	Min. Energy. Eqn.	INLET
7376.00		7.40	47.19	**7.40**	Min. Energy. Eqn.	INLET
7376.20		9.50	47.50	**9.50**	Regression Eqn.	INLET
7376.40		11.80	47.80	**11.80**	Regression Eqn.	INLET
7376.60		14.30	48.11	**14.30**	Regression Eqn.	INLET
7376.80		17.10	48.42	**17.10**	Regression Eqn.	INLET
7377.00		20.10	48.72	**20.10**	Regression Eqn.	INLET
7377.20		23.20	49.00	**23.20**	Regression Eqn.	INLET
7377.40		26.20	49.45	**26.20**	Regression Eqn.	INLET
7377.60		29.10	50.06	**29.10**	Regression Eqn.	INLET
7377.80		31.80	50.65	**31.80**	Regression Eqn.	INLET
7378.00		34.40	51.21	**34.40**	Regression Eqn.	INLET
7378.20		36.90	51.79	**36.90**	Regression Eqn.	INLET
7378.40		39.20	52.35	**39.20**	Regression Eqn.	INLET
7378.60		41.40	52.91	**41.40**	Regression Eqn.	INLET
7378.80		43.50	53.46	**43.50**	Regression Eqn.	INLET
7379.00		45.60	54.02	**45.60**	Regression Eqn.	INLET
7379.20		47.50	54.55	**47.50**	Regression Eqn.	INLET
7379.40		49.40	55.08	**49.40**	Regression Eqn.	INLET
7379.60		51.30	55.61	**51.30**	Regression Eqn.	INLET
7379.80		53.00	56.14	**53.00**	Regression Eqn.	INLET
7380.00		54.80	56.67	**54.80**	Regression Eqn.	INLET
7380.20		56.50	57.17	**56.50**	Regression Eqn.	INLET
7380.40		58.10	57.70	**57.70**	Regression Eqn.	OUTLET
7380.60		59.70	58.20	**58.20**	Regression Eqn.	OUTLET

Figure 42: SW Outlet Pipe Stage-Discharge Sizing

Determination of Culvert Headwater and Outlet Protection

Project: Blue cells are for user data entry
Basin ID: Green cells are calculated values



Clear Worksheet

Clear Results

Calculate

Soil Type:
Choose One:
○ Sandy
◉ Non-Sandy

Supercritical Flow! Using Da to calculate protection type.

Design Information (Input):

	Design Discharge	Q =	13.73	cfs
Circular Culvert:				
	Barrel Diameter in Inches	D =	30	inches
	Inlet Edge Type (Choose from pull-down list)	1.5 : 1 Beveled Edge		
Box Culvert:			**OR**	
	Barrel Height (Rise) in Feet	Height (Rise) =		ft
	Barrel Width (Span) in Feet	Width (Span) =		ft
	Inlet Edge Type (Choose from pull-down list)			
	Number of Barrels	No =	1	
	Inlet Elevation	Elev IN =	7360.41	ft
	Outlet Elevation **OR** Slope	So =	0.011	ft/ft
	Culvert Length	L =	183	ft
	Manning's Roughness	n =	0.012	
	Bend Loss Coefficient	k_b =	0	
	Exit Loss Coefficient	k_x =	1	
	Tailwater Surface Elevation	Elev Y_t =		ft
	Max Allowable Channel Velocity	V =	7	ft/s

Required Protection (Output):

Tailwater Surface Height	Y_t =	1.00	ft
Flow Area at Max Channel Velocity	A_t =	1.96	ft^2
Culvert Cross Sectional Area Available	A =	4.91	ft^2
Entrance Loss Coefficient	k_e =	0.20	
Friction Loss Coefficient	k_f =	4.08	
Sum of All Losses Coefficients	k_s =	5.28	ft
Culvert Normal Depth	Y_n =	0.84	ft
Culvert Critical Depth	Y_c =	1.25	ft
Tailwater Depth for Design	d =	1.87	ft
Adjusted Diameter **OR** Adjusted Rise	D_a =	1.67	ft
Expansion Factor	1/(2*tan(Θ)) =	6.70	
Flow/Diameter$^{2.5}$ **OR** Flow/(Span * Rise$^{1.5}$)	Q/D^2.5 =	1.39	ft$^{0.5}$/s
Froude Number	Fr =	2.11	**Supercritical!**
Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise	Yt/D =	0.60	
Inlet Control Headwater	HW_I =	1.76	ft
Outlet Control Headwater	HW_O =	-5.70	
Design Headwater Elevation	**HW =**	**7,376.56**	**ft**
Headwater/Diameter OR Headwater/Rise Ratio	**HW/D =**	**0.70**	
Minimum Theoretical Riprap Size	d_{50} =	3	in
Nominal Riprap Size	d_{50} =	6	in
UDFCD Riprap Type	**Type =**	**VL**	
Length of Protection	**L_p =**	**8**	**ft**
Width of Protection	**T =**	**4**	**ft**

Figure 43: SW Outlet Pipe Outfall Protection

Worksheet for NE Outlet Pipe*

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.013	
Channel Slope	0.01600	ft/ft
Diameter	0.83	ft
Discharge	2.01	ft³/s

Results

Normal Depth	0.53	ft
Flow Area	0.36	ft²
Wetted Perimeter	1.53	ft
Hydraulic Radius	0.24	ft
Top Width	0.80	ft
Critical Depth	0.64	ft
Percent Full	63.6	%
Critical Slope	0.00984	ft/ft
Velocity	5.53	ft/s
Velocity Head	0.48	ft
Specific Energy	1.00	ft
Froude Number	1.45	
Maximum Discharge	2.95	ft³/s
Discharge Full	2.74	ft³/s
Slope Full	0.00860	ft/ft
Flow Type	SuperCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

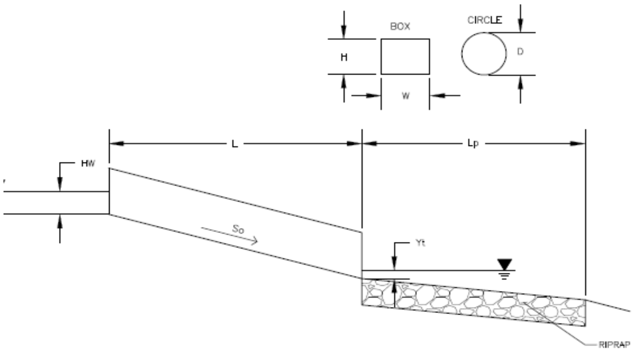
Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	63.62	%
Downstream Velocity	Infinity	ft/s

*This calculation is for one of the two NE Outlet Pipes. An assumption was made that each pipe would convey 50% of the total 4.02 cfs going to the pipes.

Figure 44: NE Outlet Pipe FlowMaster Conduit Sizing

Determination of Culvert Headwater and Outlet Protection

Project: Blue cells are for user data entry
Basin ID: Green cells are calculated values



Clear Worksheet
Clear Results
Calculate

Soil Type:
Choose One:
○ Sandy
◉ Non-Sandy

Supercritical Flow! Using Da to calculate protection type.

Design Information (Input):

	Design Discharge	Q =	4.02	cfs
Circular Culvert:				
	Barrel Diameter in Inches	D =	20	inches
	Inlet Edge Type (Choose from pull-down list)	1.5 : 1 Beveled Edge		
Box Culvert:			**OR**	
	Barrel Height (Rise) in Feet	Height (Rise) =		ft
	Barrel Width (Span) in Feet	Width (Span) =		ft
	Inlet Edge Type (Choose from pull-down list)			
	Number of Barrels	No =	1	
	Inlet Elevation	Elev IN =	7362.08	ft
	Outlet Elevation **OR** Slope	So =	0.016	ft/ft
	Culvert Length	L =	79.43	ft
	Manning's Roughness	n =	0.013	
	Bend Loss Coefficient	k_b =	0	
	Exit Loss Coefficient	k_x =	1	
	Tailwater Surface Elevation	Elev Y_t =		ft
	Max Allowable Channel Velocity	V =	7	ft/s

Required Protection (Output):

Tailwater Surface Height	Y_t =	0.67	ft
Flow Area at Max Channel Velocity	A_t =	0.57	ft^2
Culvert Cross Sectional Area Available	A =	2.18	ft^2
Entrance Loss Coefficient	k_e =	0.20	
Friction Loss Coefficient	k_f =	1.25	
Sum of All Losses Coefficients	k_s =	2.45	ft
Culvert Normal Depth	Y_n =	0.54	ft
Culvert Critical Depth	Y_c =	0.74	ft
Tailwater Depth for Design	d =	1.20	ft
Adjusted Diameter **OR** Adjusted Rise	D_a =	1.10	ft
Expansion Factor	1/(2*tan(Θ)) =	6.70	
Flow/Diameter$^{2.5}$ **OR** Flow/(Span * Rise$^{1.5}$)	Q/D^2.5 =	1.12	$ft^{0.5}/s$
Froude Number	Fr =	1.84	Supercritical!
Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise	Yt/D =	0.60	
Inlet Control Headwater	HW_I =	1.03	ft
Outlet Control Headwater	HW_O =	0.06	
Design Headwater Elevation	**HW =**	**7,363.11**	**ft**
Headwater/Diameter OR Headwater/Rise Ratio	**HW/D =**	**0.62**	
Minimum Theoretical Riprap Size	d_{50} =	2	in
Nominal Riprap Size	d_{50} =	6	in
UDFCD Riprap Type	**Type =**	**VL**	
Length of Protection	L_p =	**5**	**ft**
Width of Protection	**T =**	**3**	**ft**

Figure 45: NE Outlet Pipe Outfall Protection

Appendix B:
Quarry Operations Schedule

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Gross Reservoir Expansion Project

Osprey Quarry Operations Schedule

			2022								2023								2024								2025								2026							
Description	Qty	UoM	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov
Survey (3 Days)			■																																							
Install BMP's (5 Days)			■																																							
Install Temp Fence (5 Days)			■																																							
Clear and Grub (12 Days)	23	AC	■	■																																						
Strip Topsoil (12 Days)	17,000	CY		■																																						
Overburden Exc to Emb	356,000	CY		■	■	■																																				
Crusher Mobe / Set-up														■	■																											
Test Crush (Mix Design Verification)						■																																				
RCC Test Fill	925	CY														■																										
Drill/Shoot Quarry	727,000	CY																	■	■	■	■	■	■	■		■	■	■	■	■	■	■									
Quarry Excavation to Crusher	727,000	CY																	■	■	■	■	■	■	■		■	■	■	■	■	■	■									
Quarry Reclamation																																			■	■	■	■	■	■	■	

Appendix C:
Quarry Design PDF Files

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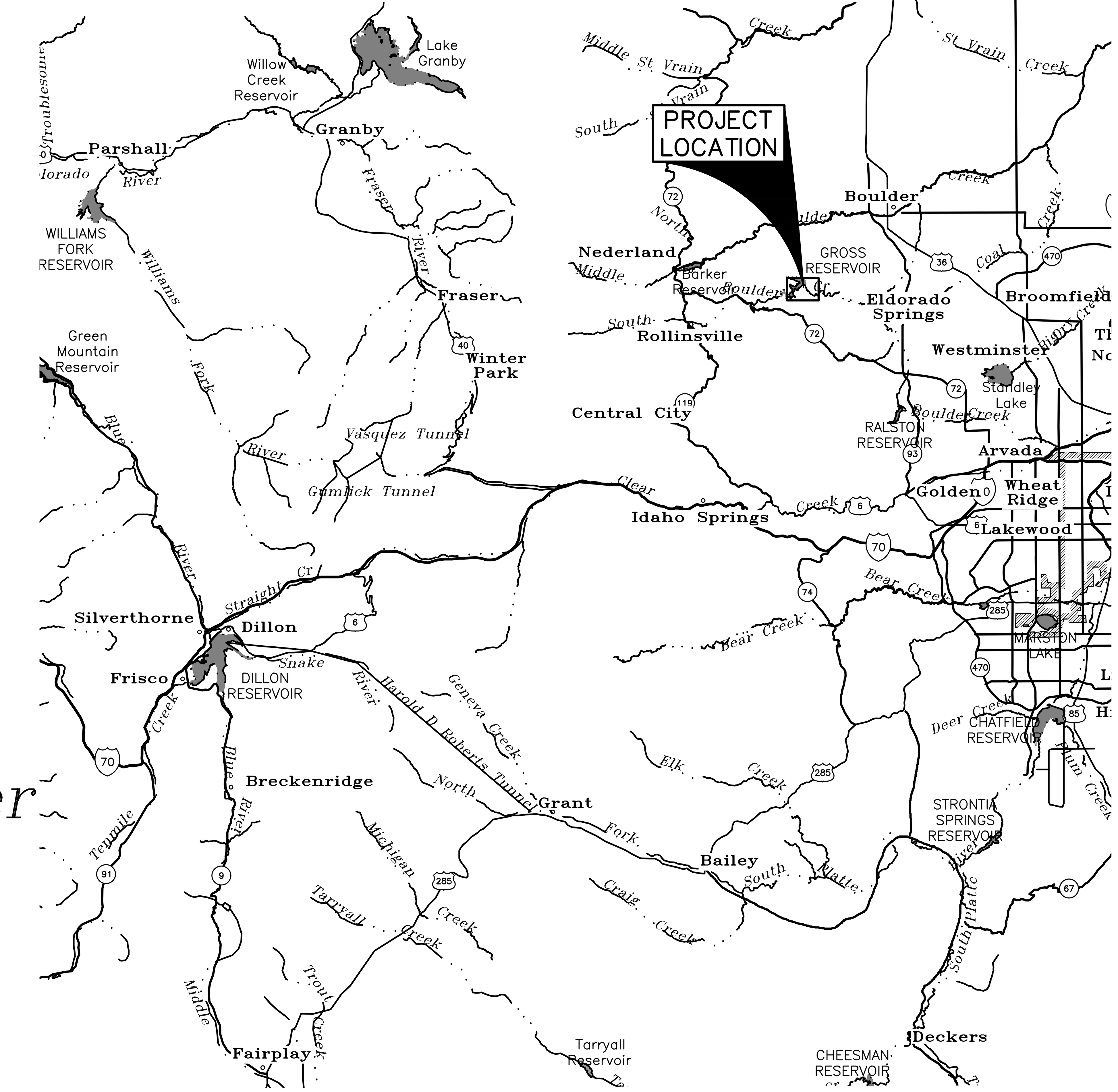
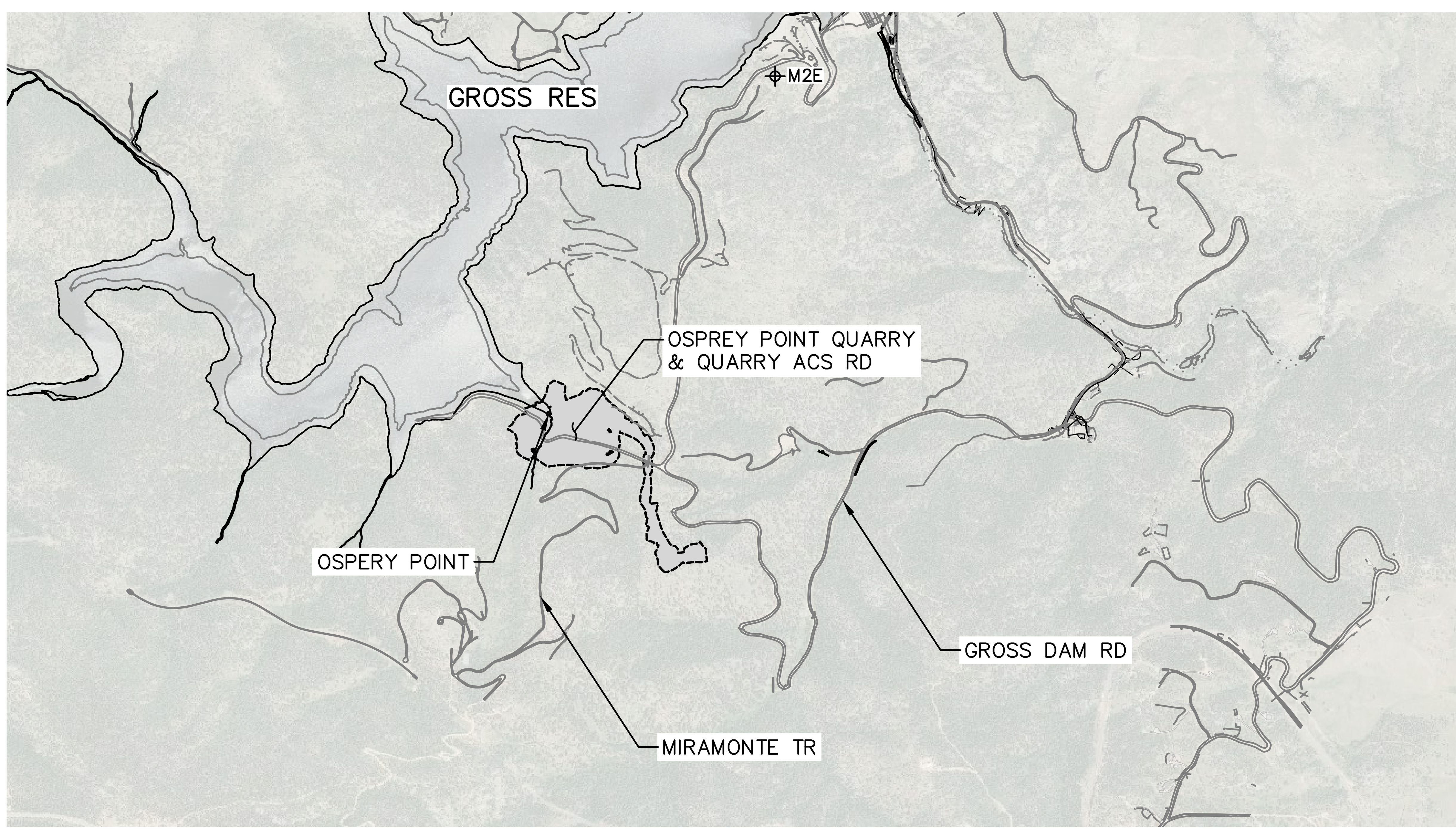
DENVER WATER
DENVER, COLORADO
GROSS RESERVOIR EXPANSION
OSPREY POINT QUARRY DEVELOPMENT

BOARD OF WATER COMMISSIONERS
DENVER, COLORADO
Gary M. Reiff – President
James S. Lochhead – CEO/Manager
Robert J. Mahoney – Chief Engineering Officer

OSPREY QUARRY OPERATIONS PLAN APPENDIX C



LOCATION MAP
SCALE: 1" = 6 Miles



VICINITY MAP
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DRAWING INDEX

DWG NO	DWG TITLE
G.01	OSPREY POINT QUARRY COVER SHEET
G.02	GENERAL NOTES, LEGEND & ABBREVIATIONS
C.01	QUARRY ACCESS ROAD GEOMETRIC CONTROL PLAN
C.02	QUARRY SITE PLAN
C.03	QUARRY ACCESS ROAD PLAN & PROFILE
C.04	QUARRY ACCESS ROAD PLAN & PROFILE
C.05	QUARRY ACCESS ROAD PLAN & PROFILE
C.06	QUARRY SECTIONS 1 & 2
C.07	QUARRY SECTIONS 3 & 4
C.08	QUARRY SECTION 5
C.09	QUARRY ACCESS ROAD TYPICAL SECTIONS
C.10	QUARRY TYPICAL DETAILS
C.11	CDOT METAL PIPE DETAIL
C.12	CDOT METAL PIPE DETAIL
C.13	CDOT METAL PIPE END SECTION DETAIL
C.14	CDOT METAL PIPE END SECTION DETAIL
C.15	RIPRAP APRON DETAIL
C.16	DRAINAGE PIPE PROFILES
C.17	CONCRETE INLET TYPE 13 DETAIL

PROJECT DIRECTORY

OWNER:
DENVER WATER
1600 W 12TH AVE
DENVER, CO 80204
303-628-6000

CONTACT:
PROGRAM MANAGER
JEFF MARTIN, PE, PMP
303-628-6508
jeff.martin@denverwater.org

DENVER WATER
1600 West 12th Ave
Denver, Colorado 80204-3412
T: 303.628.6000
F: 303.628.6851
denverwater.org

CONSULTANT
Kiewit

GROSS RESERVOIR EXPANSION

OSPREY POINT QUARRY DEVELOPMENT

REFERENCE:
CAPITAL PROJECTS CONSTRUCTION STANDARDS 3rd Edition
ENGINEERING STANDARDS FIFTEENTH EDITION 2018
THIS DRAWING IS BASED ON THE DW_GROSS_GRID COORDINATE SYSTEM

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△	4/16/21	DRAFT FINAL REVIEW
△	2/15/21	DRAFT REVIEW

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OSPREY POINT QUARRY COVER SHEET

G.01

P:\KIE-Gross Reservoir\3-DES\05 GEO\CAD\Sheets\1952 C.01 QUARRY COVER SHEET.dwg #### DESIGN 4/30/2021 12:52 PM

GENERAL NOTES

1. THE CONTRACTOR SHALL VERIFY AND CHECK ALL DIMENSIONS, LOCATIONS, ELEVATIONS, AND DETAILS SHOWN ON THESE DRAWINGS PRIOR TO THE START OF CONSTRUCTION. AND UNCERTAINTIES AND DISCREPANCIES SHALL BE IMMEDIATELY REPORTED TO THE ENGINEER OF RECORD FOR CLARIFICATION.
2. IN THE CASE OF DISCREPANCY BETWEEN THE SPECIFICATIONS AND CONSTRUCTION DRAWINGS, THE MORE STRINGENT SHALL APPLY.
3. THE CONTRACTOR/OWNER SHALL BE RESPONSIBLE FOR OBTAINING ALL REQUIRED PERMITS FROM ALL APPLICABLE AGENCIES PRIOR TO COMMENCEMENT OF CONSTRUCTION.
4. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE COMPLIANCE AND ENFORCEMENT OF ALL APPLICABLE SAFETY REGULATIONS.
5. THE CONTRACTOR SHALL BE RESPONSIBLE TO PROVIDE MEASURES TO PROTECT PUBLIC AND WILDLIFE FROM EDGE OF SLOPES.
6. THE CONTRACTOR SHALL ALWAYS HAVE ONSITE A SIGNED COPY OF THE APPROVED PLANS, A COPY OF THE APPLICABLE STANDARDS AND SPECIFICATIONS, AND A COPY OF ANY PERMITS REQUIRED FOR THE PROJECT.
7. ALL DIMENSIONS IN FEET UNLESS OTHERWISE INDICATED. DIMENSIONS FOR LAYOUT AND CONSTRUCTION SHALL NOT BE SCALED FROM ANY DRAWING. IF PERTINENT DIMENSIONS ARE NOT SHOWN, CONTACT THE ENGINEER FOR CLARIFICATION AND ANNOTATE THE DIMENSION ON THE RECORD DRAWINGS.
8. ALL COORDINATES IN FEET IN TERMS OF THE DENVER WATER GROSS GRID COORDINATE SYSTEM.
9. ALL STATIONING IS BASED ON THE CENTERLINE OF PROJECT FEATURES UNLESS OTHERWISE NOTED.
10. ACTUAL DIMENSIONS AND ELEVATIONS MAY DIFFER FROM THOSE SHOWN ON THE DRAWINGS. THE CONTRACTOR SHALL BE RESPONSIBLE FOR VERIFYING ALL DIMENSIONS AND ELEVATIONS IN THE FIELD.
11. CONTRACTOR SHALL LOCATE ALL UNDERGROUND UTILITIES WITHIN THE PROJECT FOOTPRINT PRIOR TO COMMENCING NEW CONSTRUCTION. COORDINATE ALL GRADING, EXCAVATION, AND DRAINAGE ACTIVITIES WITH UTILITIES AND ELECTRICAL WORK PRIOR TO COMMENCING CONSTRUCTION.

CLEARING AND GRUBBING

1. THE CONTRACTOR SHALL NOT DISTURB OUTSIDE DENVER WATER PROPERTY LINE WITHOUT APPROVALS FROM LANDOWNERS.
2. VEGETATION AND TREES SHALL ONLY BE REMOVED WITHIN THE LIMITS OF CONSTRUCTION AS REQUIRED FOR QUARRY AND QUARRY ACCESS ROAD CONSTRUCTION.
3. VEGETATION, TOPSOIL, AND DELETERIOUS MATERIAL SHOULD NOT BE DISPOSED OF IN EARTH FILLS.

EXCAVATION

1. ROCK SLOPES SHALL BE INSPECTED AFTER EACH BLAST AND MECHANICALLY SCALED PRIOR TO COMMENCING WORK BENEATH THE SLOPES. THIS SHOULD BE A HOLD POINT UNTIL THE SLOPE IS INSPECTED AND APPROVED.
2. CONTRACTOR SHALL BE PREPARED TO INSTALL ROCK BOLTS AND/OR ROCK MESH TO STABILIZE WEDGES AS DIRECTED BY THE ENGINEER.
3. EXCAVATION SHALL BE INSPECTED BY THE ENGINEER TO VALIDATE SOIL AND ROCK PROPERTIES.
4. WEEP HOLES WILL BE REQUIRED IN ROCK CUTS. WEEP HOLES SHALL BE 40-FEET LONG AND INSTALLED 5 FEET ABOVE EACH BENCH WITH A SPACING OF 40-FEET AND 5 DEGREE INCLINATION. ADDITIONAL HOLES WILL BE ADDED IF CRITICAL WEDGES ARE ENCOUNTERED IN THE FIELD.

DRAINAGE

1. DITCHES IN OVERBURDEN SUBJECT TO VELOCITIES OVER 4 FT/S SHALL BE LINED WITH TURF REINFORCED MATTING (TRM) OR OTHER APPROVED METHODS AS IDENTIFIED IN PLAN.
2. CONTRACTOR SHALL MAINTAIN POSITIVE DRAINAGE DURING DIFFERENT PHASES OF CONSTRUCTION. THE DRAINAGE DESIGN SUBMITTED IS BASED UPON THE ULTIMATE GRADING OF THE QUARRY SITE.
3. TEMPORARY BERMS SHALL HAVE A MINIMUM HEIGHT OF 18 INCHES FROM THE FLOWLINE OF THE DITCH, SIDE SLOPES OF 3H:1V OR FLATTER AND A MINIMUM BASE WIDTH OF 4.5 FEET. REFER TO CDOT-208-1 (SHEET 7 OF 11) FOR THE STANDARD DETAIL.

EROSION CONTROL

1. CONTRACTOR SHALL USE CONTROL MEASURES FOR EROSION AND SEDIMENT CONTROL THAT WILL OCCUR ON DISTURBED AREAS UNTIL THE SITE IS FULLY STABILIZED PER CDOT STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION, SECTIONS 208 AND 216. ALL EROSION AND SEDIMENT CONTROL PRACTICES AND OTHER PROTECTIVE MEASURES MUST ALWAYS BE MAINTAINED IN EFFECTIVE OPERATING CONDITION.
2. THE CONTRACTOR SHALL ENSURE THAT ALL POTENTIAL POLLUTANTS GENERATED DURING CONSTRUCTION WORK ASSOCIATED WITH THIS PROJECT BE PREVENTED FROM DISCHARGE TO STORMWATER CONVEYANCE AND THE RESERVOIR.
3. ALL BMP'S SHALL BE IN ACCORDANCE WITH BOULDER COUNTY STORMWATER QUALITY PERMITS.
4. ALL PIPE OUTFALL OR DITCH DISCHARGE POINTS SHALL HAVE EROSION PROTECTION MEASURES INSTALLED CONSISTING OF TRM OR RIPRAP FROM THE PIPE OR DITCH OUTLET EXTENDING TO THE LIMITS AS SHOWN ON THE RIPRAP APRON DETAIL (SHEET C.14).
5. THE OUTFALL DRAINING INSIDE THE QUARRY FOOTPRINT SHALL HAVE A SEDIMENT BASIN INSTALLED AT THE OUTFALL LOCATION WITHIN THE QUARRY FOOTPRINT.

DESIGN PARAMETERS

1. THE FOLLOWING GEOTECHNICAL REPORTS BY OTHERS WERE REFERENCES FOR DESIGN:
   a. "GEOLOGICAL AND GEOTECHNICAL INTERPRETIVE REPORT – PRODUCTION QUARRY – VOLUME 1", STANTEC, FEBRUARY 2019
   b. "GEOLOGICAL AND GEOTECHNICAL DATA REPORT – PRODUCTION QUARRY – VOLUME 1", STANTEC, FEBRUARY 4, 2019
   c. "P2-SITE DEVELOPMENT GEOTECHNICAL DESIGN REPORT", AECOM, NOVEMBER 5, 2018
2. DESIGN LOADS:
   a. CAT 773 LOADED HAUL TRUCK WITH 15% OVERLOAD ON PAYLOAD: 1400 PSF
   b. CAT 390 EXCAVATOR: 980 PSF
3. SOIL AND ROCK PROPERTIES:
   a. OVERBURDEN FRICTION ANGLE: 35 DEGREES
   b. OVERBURDEN COHESION: 0 PSF
   c. OVERBURDEN UNIT WEIGHT: 125 PCF
   d. INTACT ROCK COMPRESSIVE STRENGTH: 8,000 PSI
   e. INTACT ROCK UNIT WEIGHT: 165 PCF
4. DESIGN STORM EVENT: 10 YEAR

ABBREVIATIONS

BVCS	BEGINNING VERTICAL CURVE STATION
BVCE	BEGINNING VERTICAL CURVE ELEVATION
CORR	CORRUGATED
CVC	CONVENTIONALLY-VIBRATED CONCRETE
E	EASTING
EVCS	ENDING VERTICAL CURVE STATION
EVCE	ENDING VERTICAL CURVE ELEVATION
FERC	FEDERAL ENERGY REGULATORY COMMISSION
N	NORTHING
NHWL	NORMAL HIGH WATER LINE
NLWL	NORMAL LOW WATER LINE
OFF	OFFSET
OR	OWNER'S REPRESENTATIVE
RCC	ROLLER-COMPACTED CONCRETE
TRM	TURF REINFORCED MATTING
USFS	UNITED STATES FOREST SERVICES

LEGEND– CIVIL

BH	BOREHOLE
	FERC BOUNDARY
	MATCHLINE
	LIMITS DISTURBANCE/CONSTRUCTION
	NHWL (NORMAL HIGH WATER LINE)
UF	BLOCKS
	FLOW DIRECTION
	DITCH FLOWLINE
	SUBBASE/AGGREGATE
	ROCK

DENVER WATER
1600 West 12th Ave
Denver, Colorado 80204-3412
T: 303.628.6000
F: 303.628.6851
denverwater.org

CONSULTANT

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GROSS RESERVOIR EXPANSION

OSPREY POINT QUARRY DEVELOPMENT

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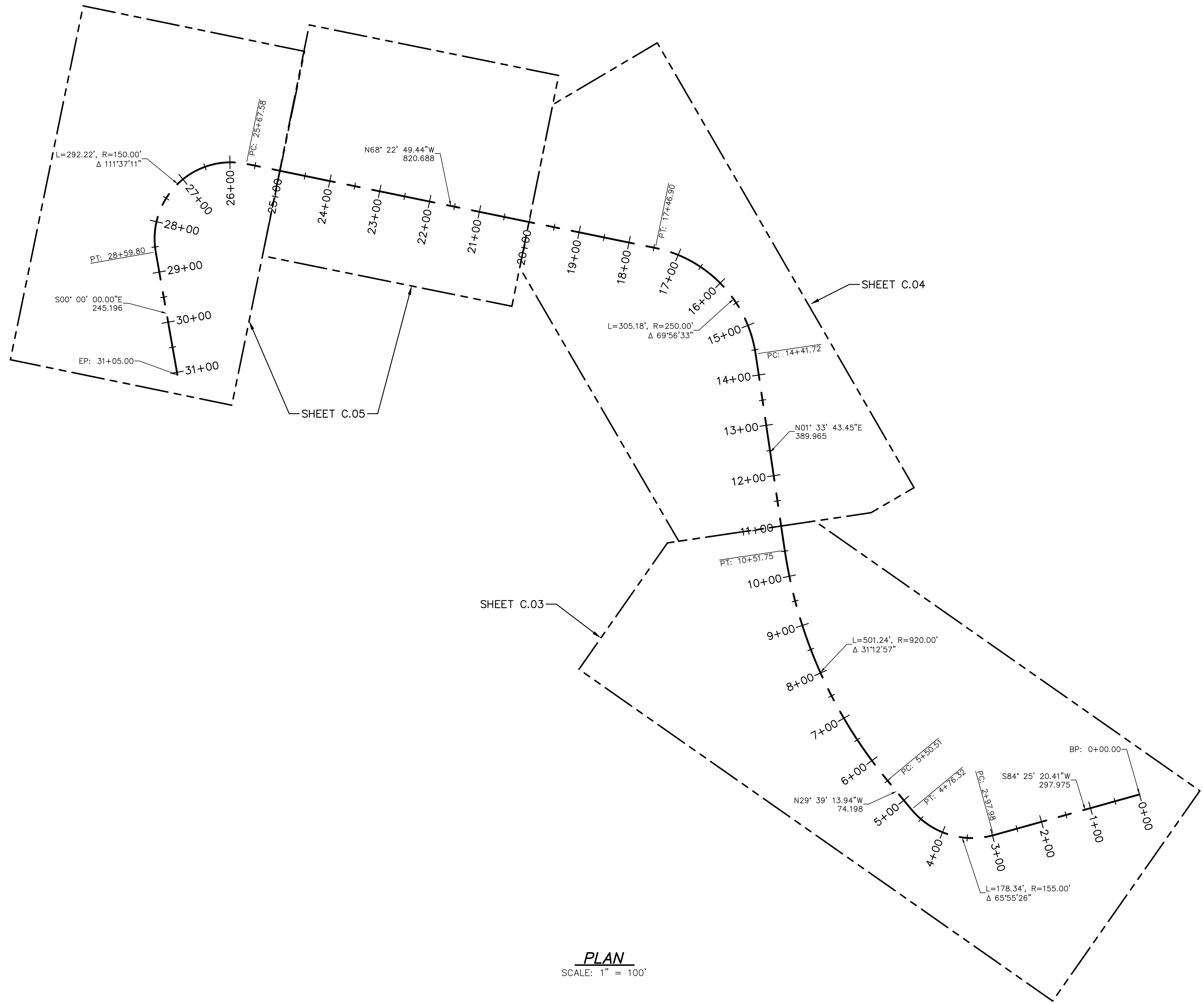
GENERAL NOTES, LEGEND & ABBREVIATIONS

G.02



PLAN
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DENVER WATER
1600 West 12th Ave
Denver, Colorado 80204-3412
T: 303.628.6000
F: 303.628.6851
denverwater.org

CONSULTANT
Kiewit

GROSS RESERVOIR EXPANSION

OSPREY POINT QUARRY DEVELOPMENT

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CHKD BY: *FLEMING/*
CHKD BY: *ZHAO/*
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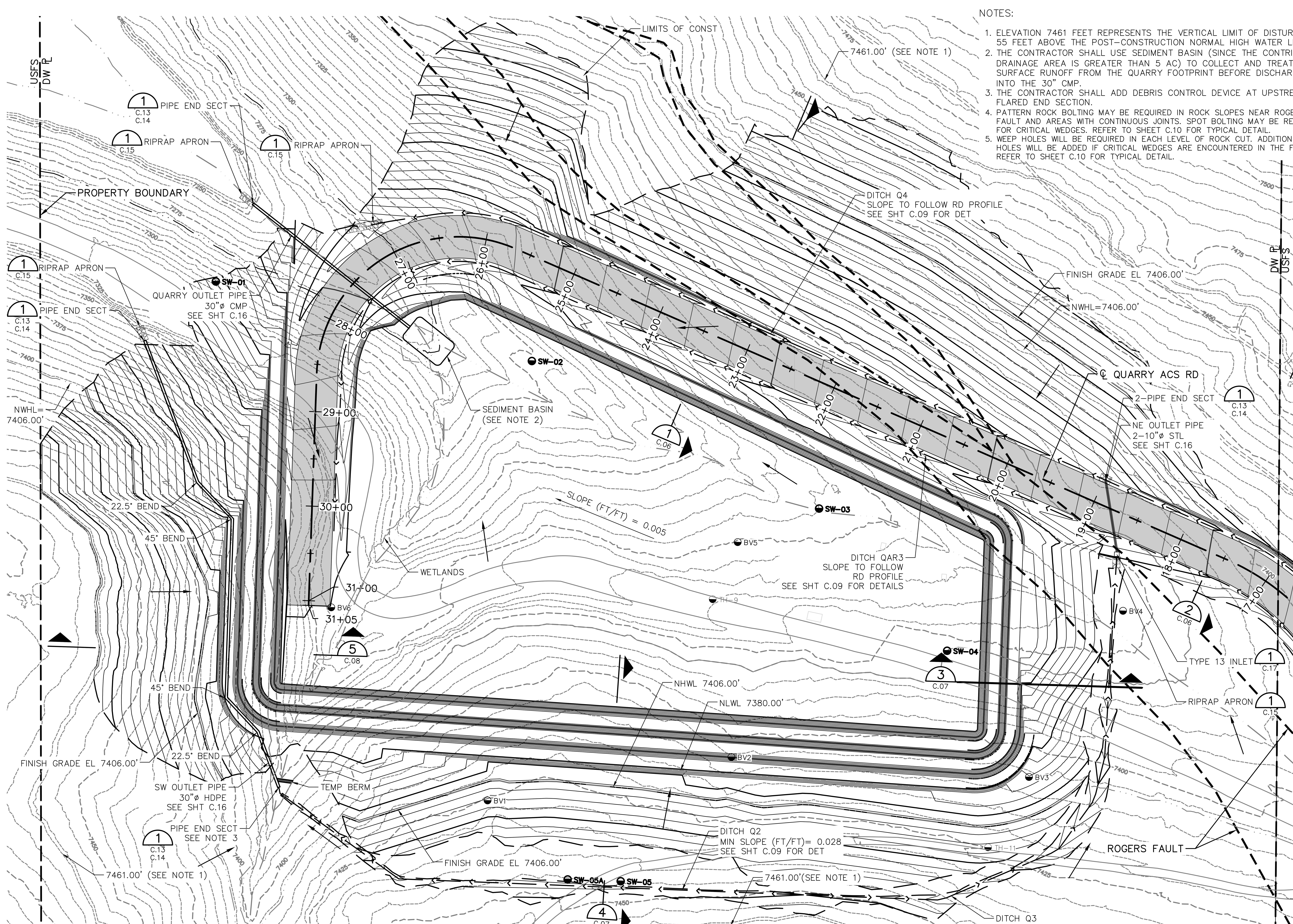
QUARRY ACCESS ROAD GEOMETRIC CONTROL PLAN

C.01

P:\KIE-Gross Reservoir\3-DES\05 GEO\CAD\Sheets\19152 QUARRY ACCESS RD GEOM CONTROL PLAN.dwg #### PNP SCALE 40 4/30/2021 12:52 PM

NOTES:

1. ELEVATION 7461 FEET REPRESENTS THE VERTICAL LIMIT OF DISTURBANCE, 55 FEET ABOVE THE POST-CONSTRUCTION NORMAL HIGH WATER LINE.
2. THE CONTRACTOR SHALL USE SEDIMENT BASIN (SINCE THE CONTRIBUTING DRAINAGE AREA IS GREATER THAN 5 AC) TO COLLECT AND TREAT SURFACE RUNOFF FROM THE QUARRY FOOTPRINT BEFORE DISCHARGING INTO THE 30" CMP.
3. THE CONTRACTOR SHALL ADD DEBRIS CONTROL DEVICE AT UPSTREAM FLARED END SECTION.
4. PATTERN ROCK BOLTING MAY BE REQUIRED IN ROCK SLOPES NEAR ROGER'S FAULT AND AREAS WITH CONTINUOUS JOINTS. SPOT BOLTING MAY BE REQUIRED FOR CRITICAL WEDGES. REFER TO SHEET C.10 FOR TYPICAL DETAIL.
5. WEEP HOLES WILL BE REQUIRED IN EACH LEVEL OF ROCK CUT. ADDITIONAL HOLES WILL BE ADDED IF CRITICAL WEDGES ARE ENCOUNTERED IN THE FIELD. REFER TO SHEET C.10 FOR TYPICAL DETAIL.



PLAN

SCALE: 1" = 50

CI: 5 FT

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GROSS RESERVOIR EXPANSION

OSPREY POINT QUARRY DEVELOPMENT

REFERENCE:
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REVISIONS

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QUARRY SITE PLAN

C.02

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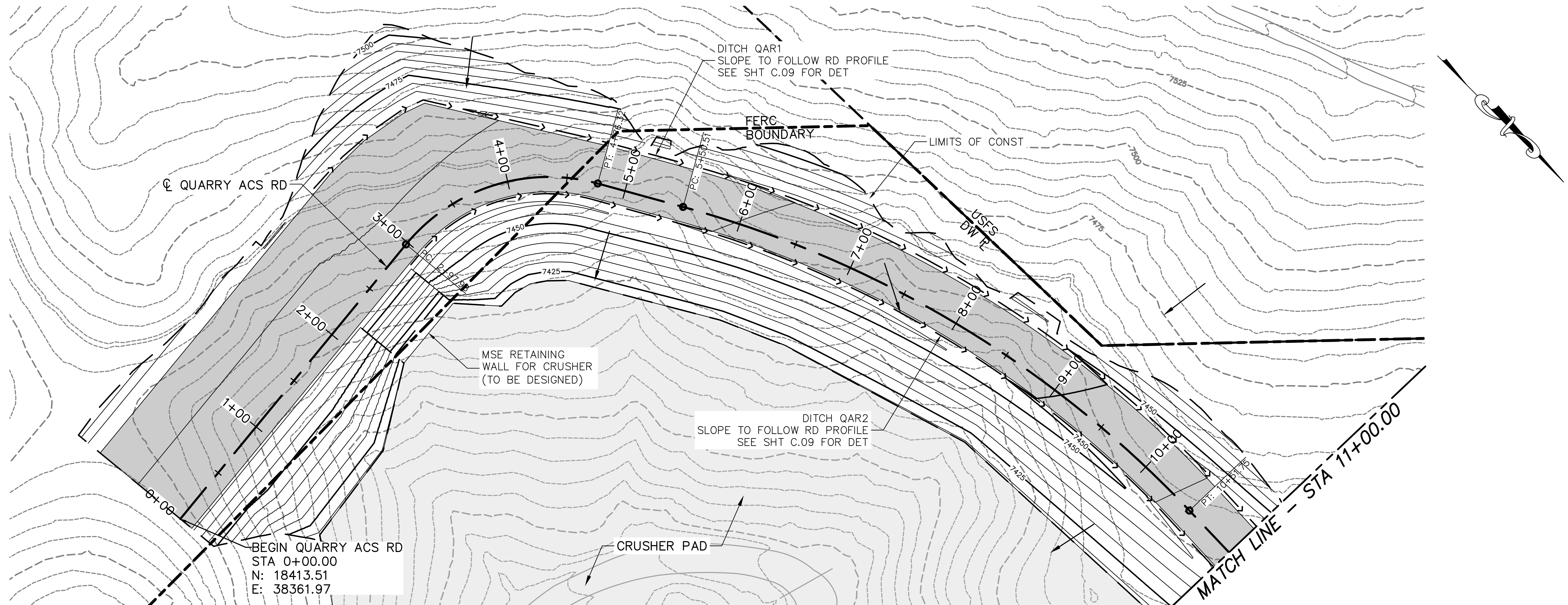
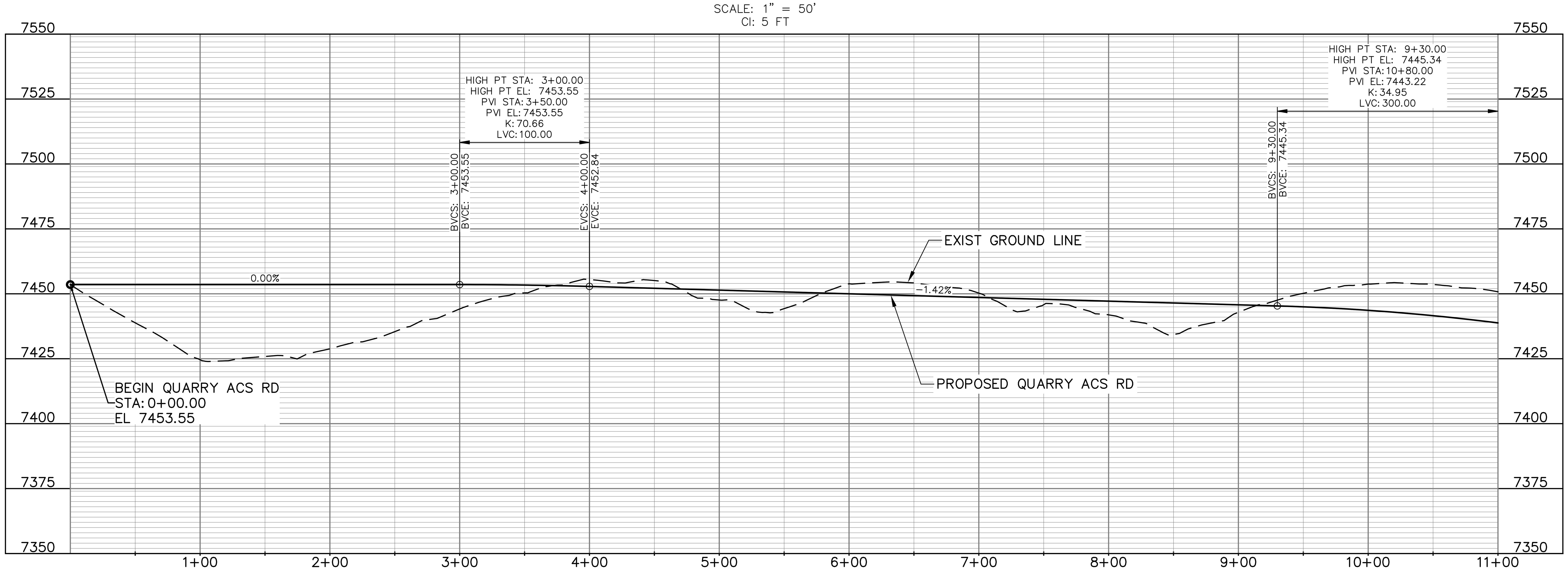


PLAN

SCALE: 1" = 50'
CI: 5 FT



PROFILE

SCALE: 1" = 50' HORIZ
1" = 25' VERT

P:\KIE-Gross Reservoir\3-DES\05 GEO\CAD\Sheets\1952 C.03 QUARRY ACCESS ROAD P&P.dwg #### PLAN & PROFILE_01 4/30/2021 12:52 PM

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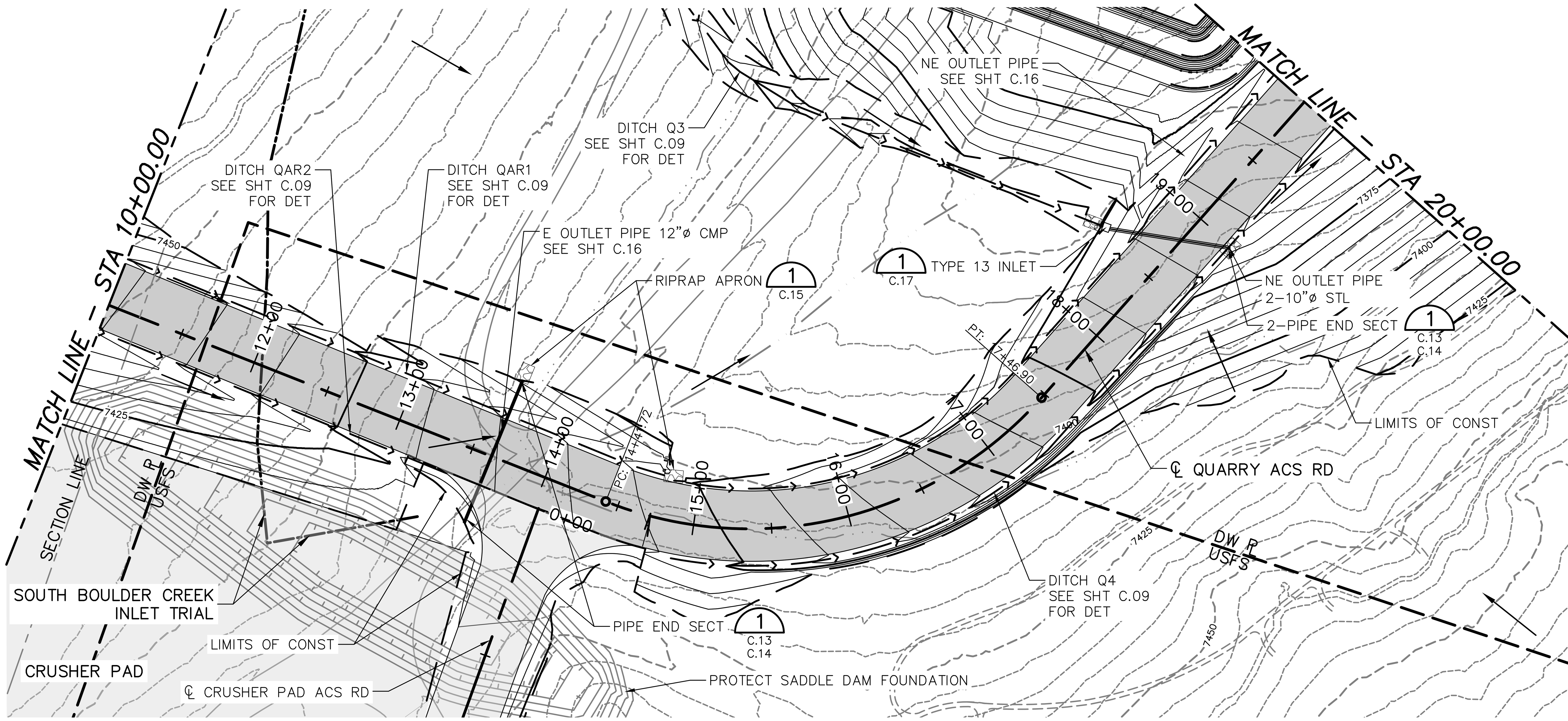
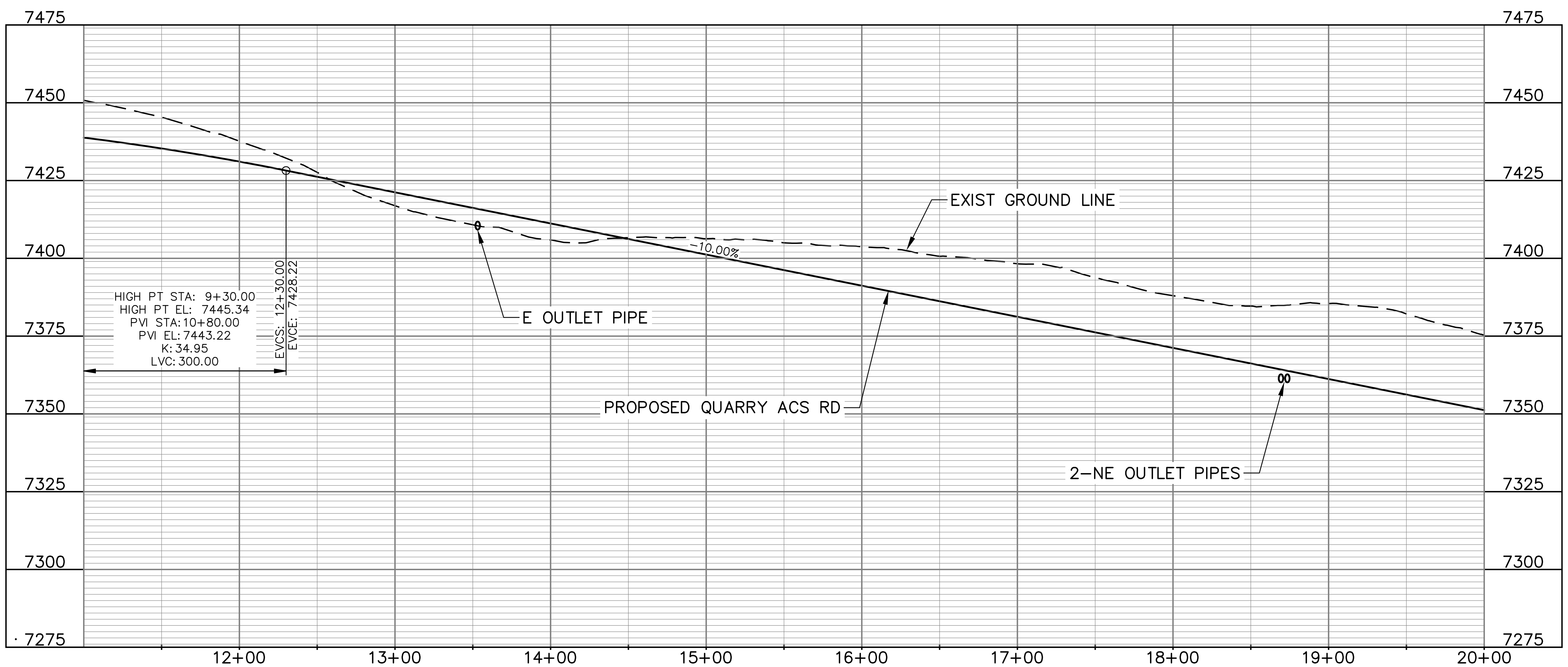
QUARRY ACCESS ROAD PLAN & PROFILE

C.03



PLAN

SCALE: 1" = 50'
CI: 5 FT



PROFILE

SCALE: 1" = 50' HORIZ
1" = 25' VERT

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OSPREY POINT QUARRY DEVELOPMENT

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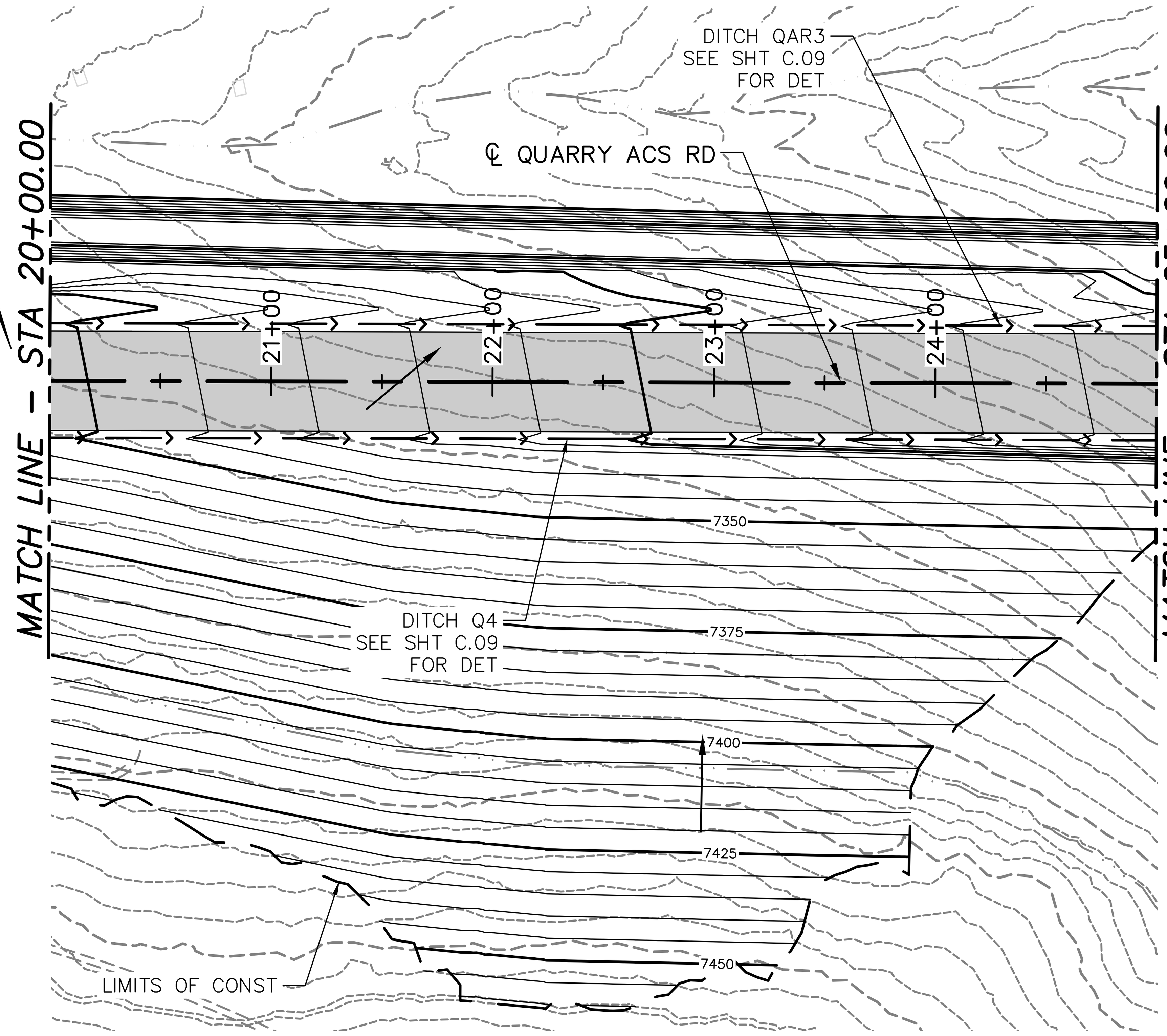
QUARRY ACCESS ROAD PLAN & PROFILE

C.04



PLAN

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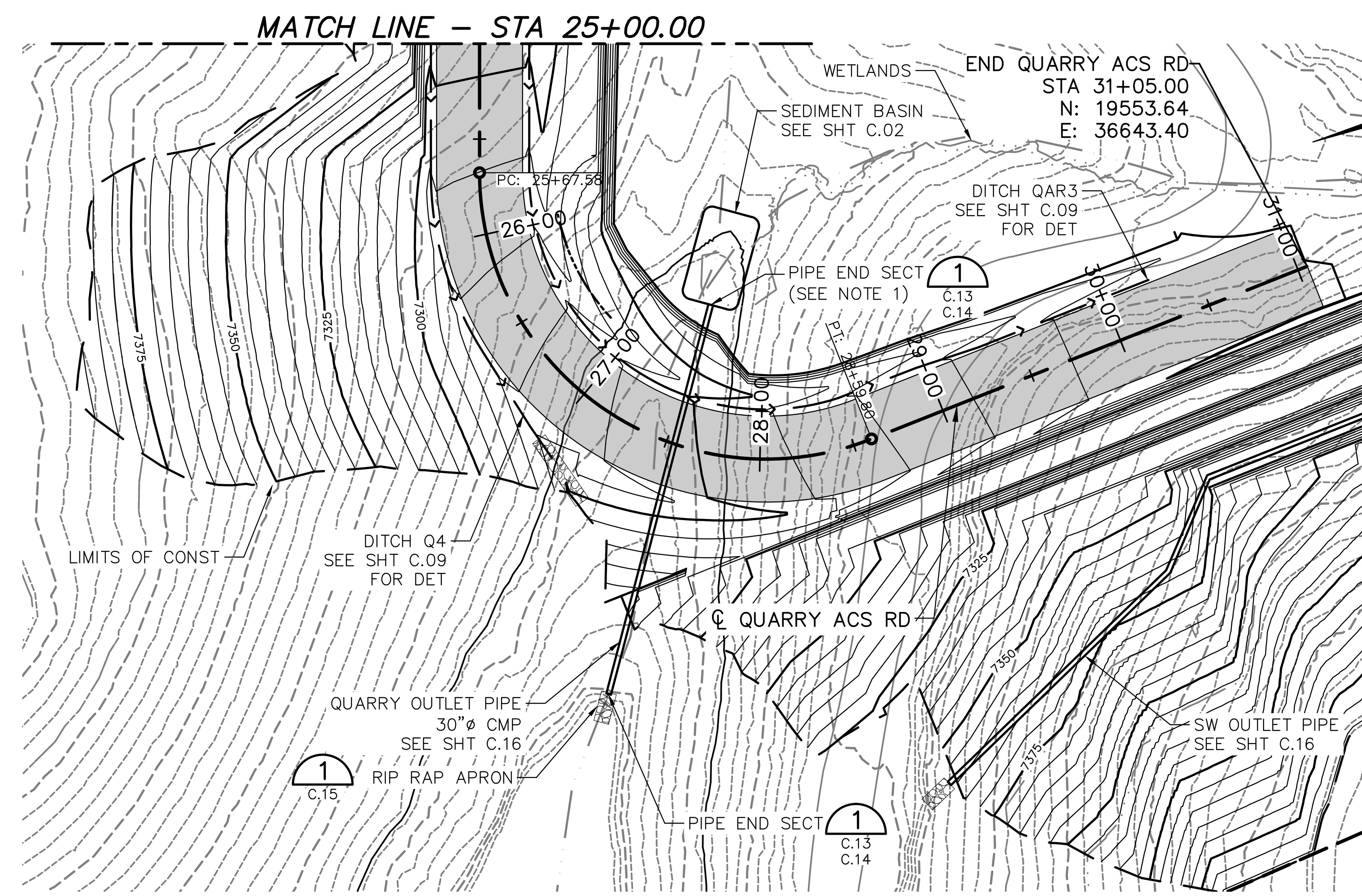
CI: 5 FT

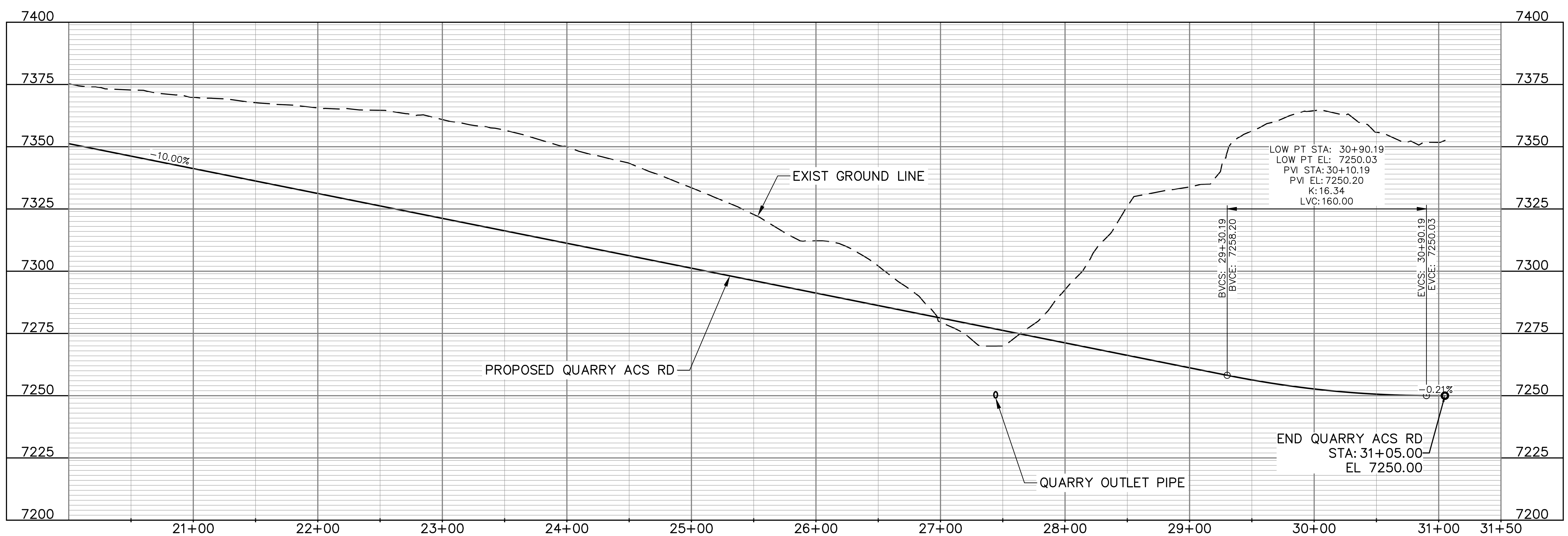


PLAN

SCALE: 1" = 50'
CI: 5 FT

NOTE:

1. CONTRACTOR SHALL INSTALL HEADGATE AT OUTFALL OF SEDIMENT BASIN.



PROFILE

SCALE: 1" = 50' HORIZ
1" = 25' VERT

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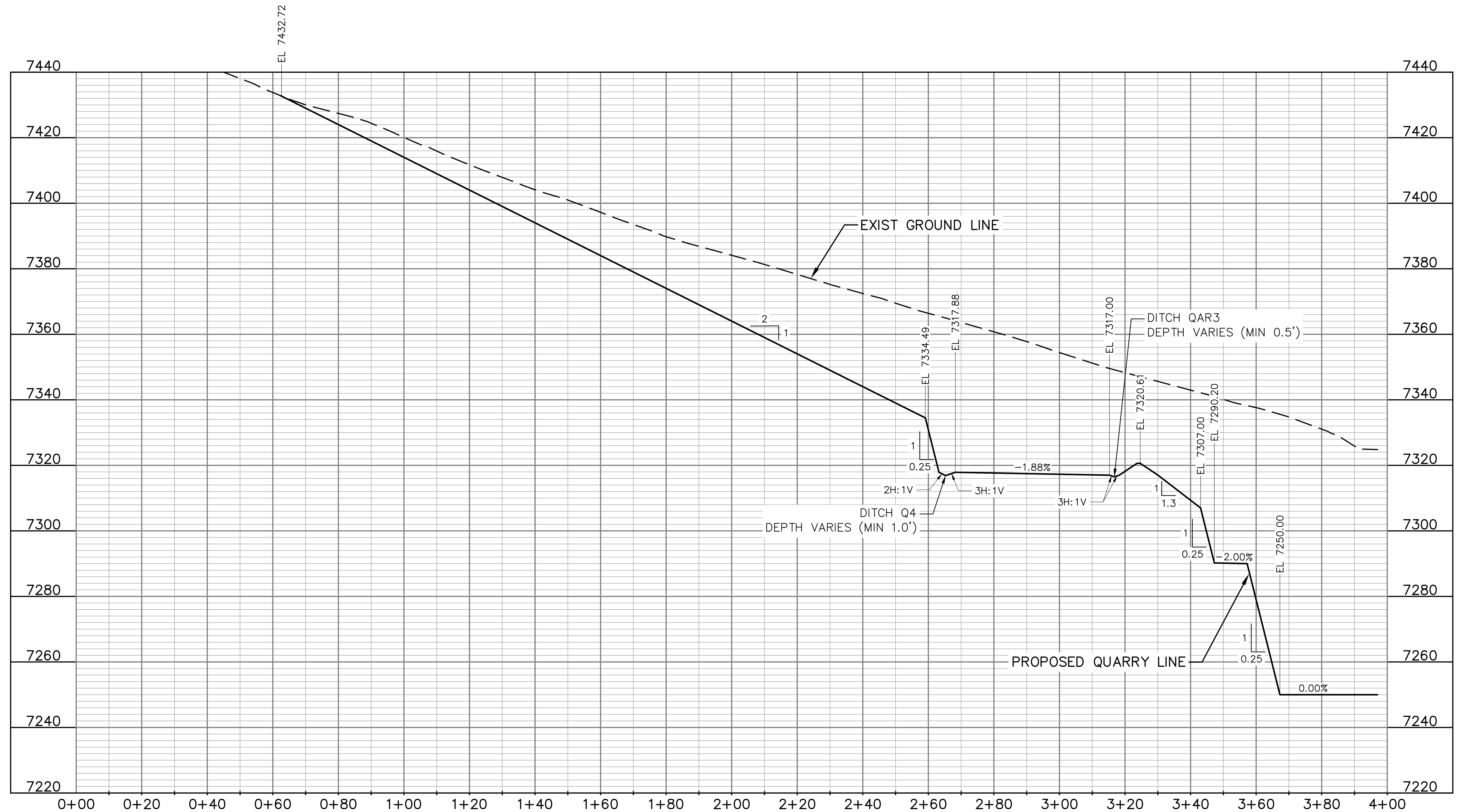
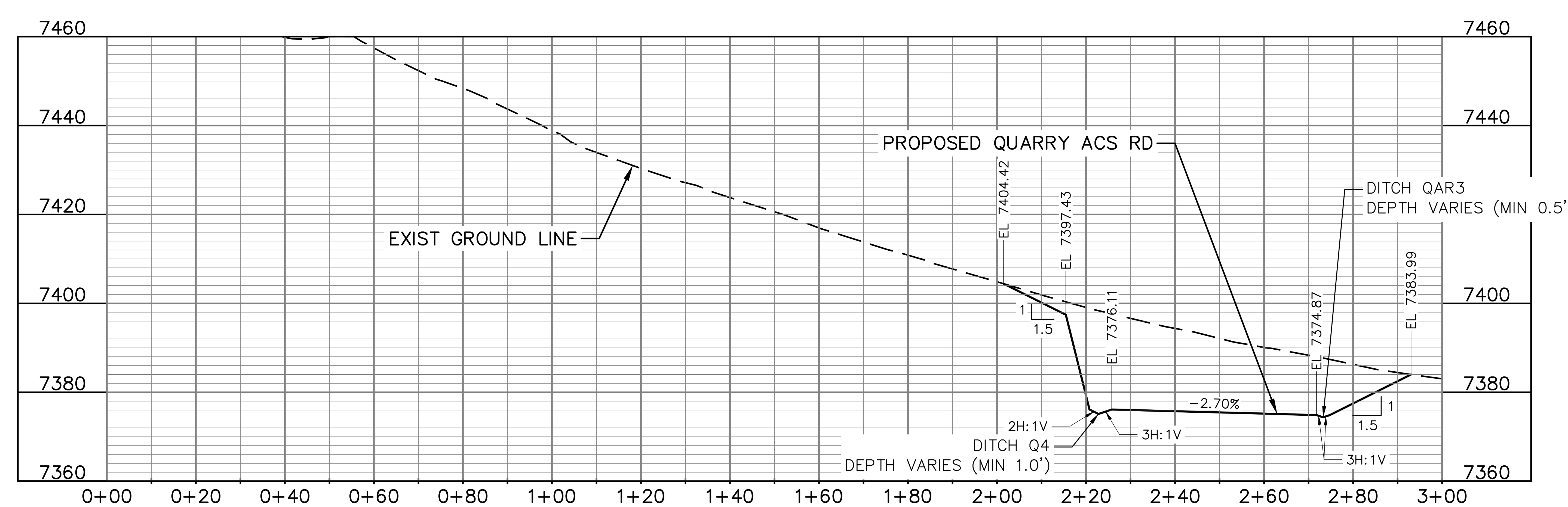
QUARRY ACCESS ROAD PLAN & PROFILE

C.05



SECTION 1 C.02

SCALE: 1" = 20' HORIZ
SCALE: 1" = 20' VERT



SECTION 2 C.02

SCALE: 1" = 20' HORIZ
SCALE: 1" = 20' VERT

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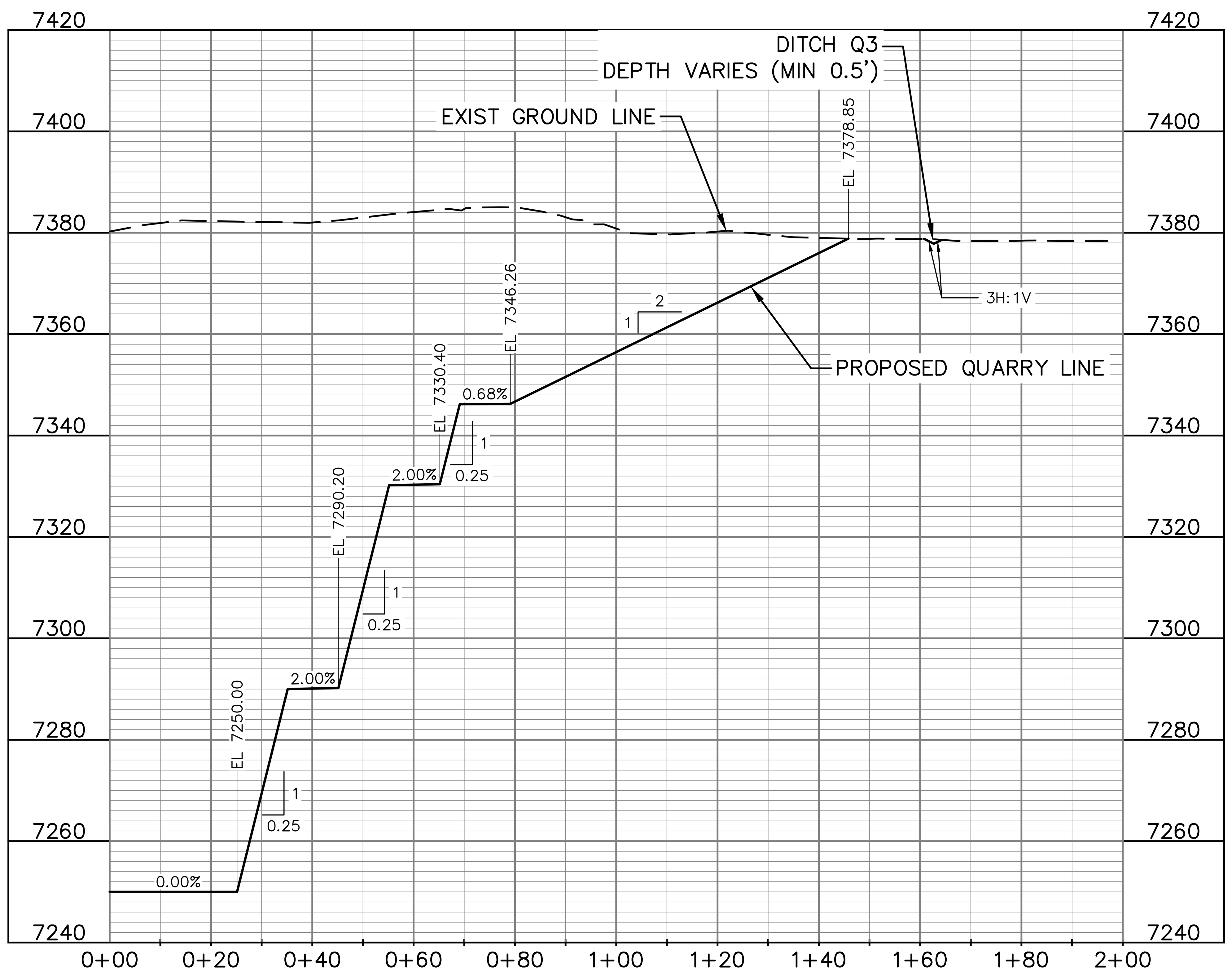
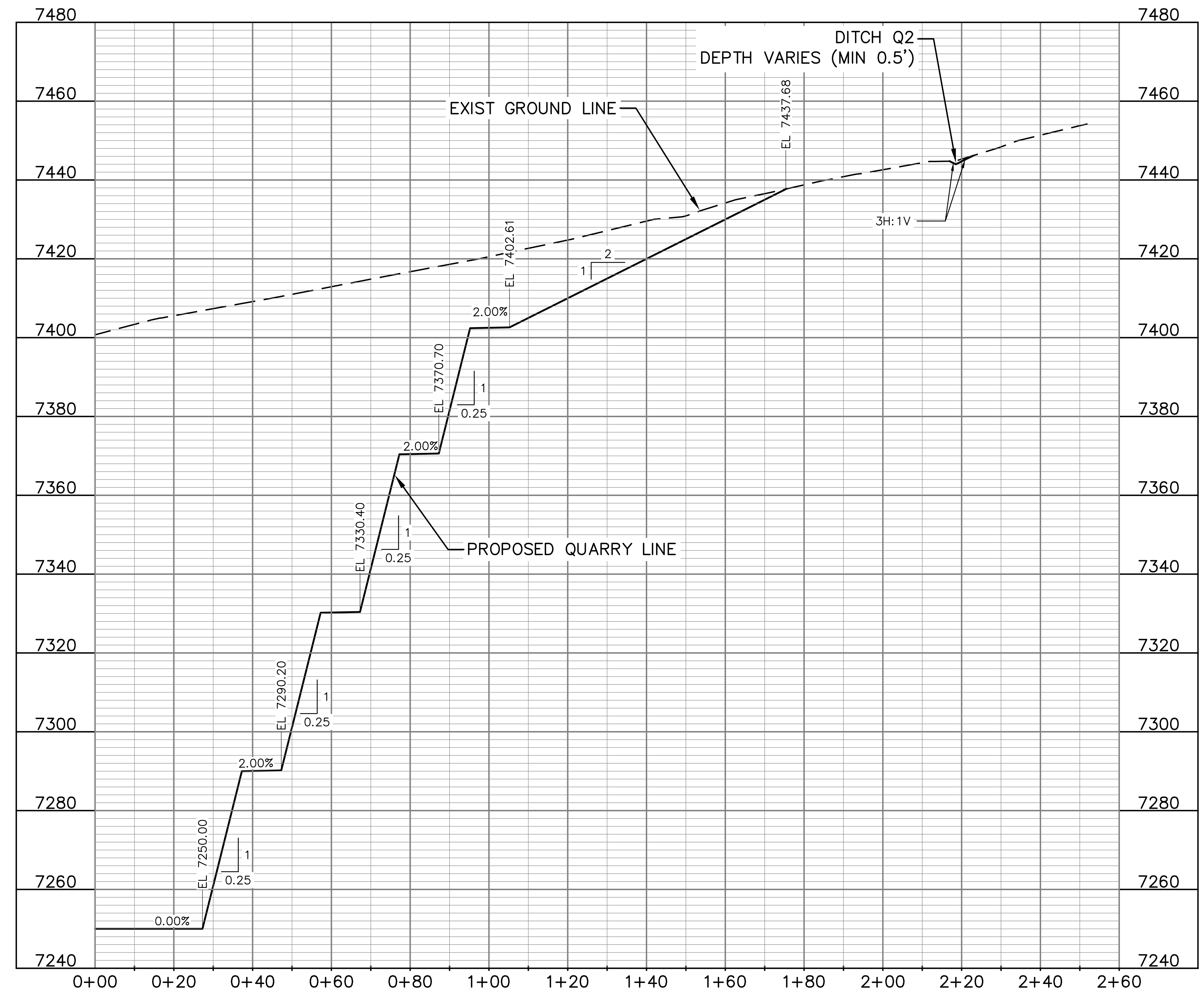
QUARRY SECTIONS 1 & 2

C.06



SECTION 3 (C.02)
SCALE: 1" = 20' HORIZ
SCALE: 1" = 20' VERT



SECTION 4 (C.02)
SCALE: 1" = 20' HORIZ
SCALE: 1" = 20' VERT

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QUARRY SECTIONS 3 & 4

C.07

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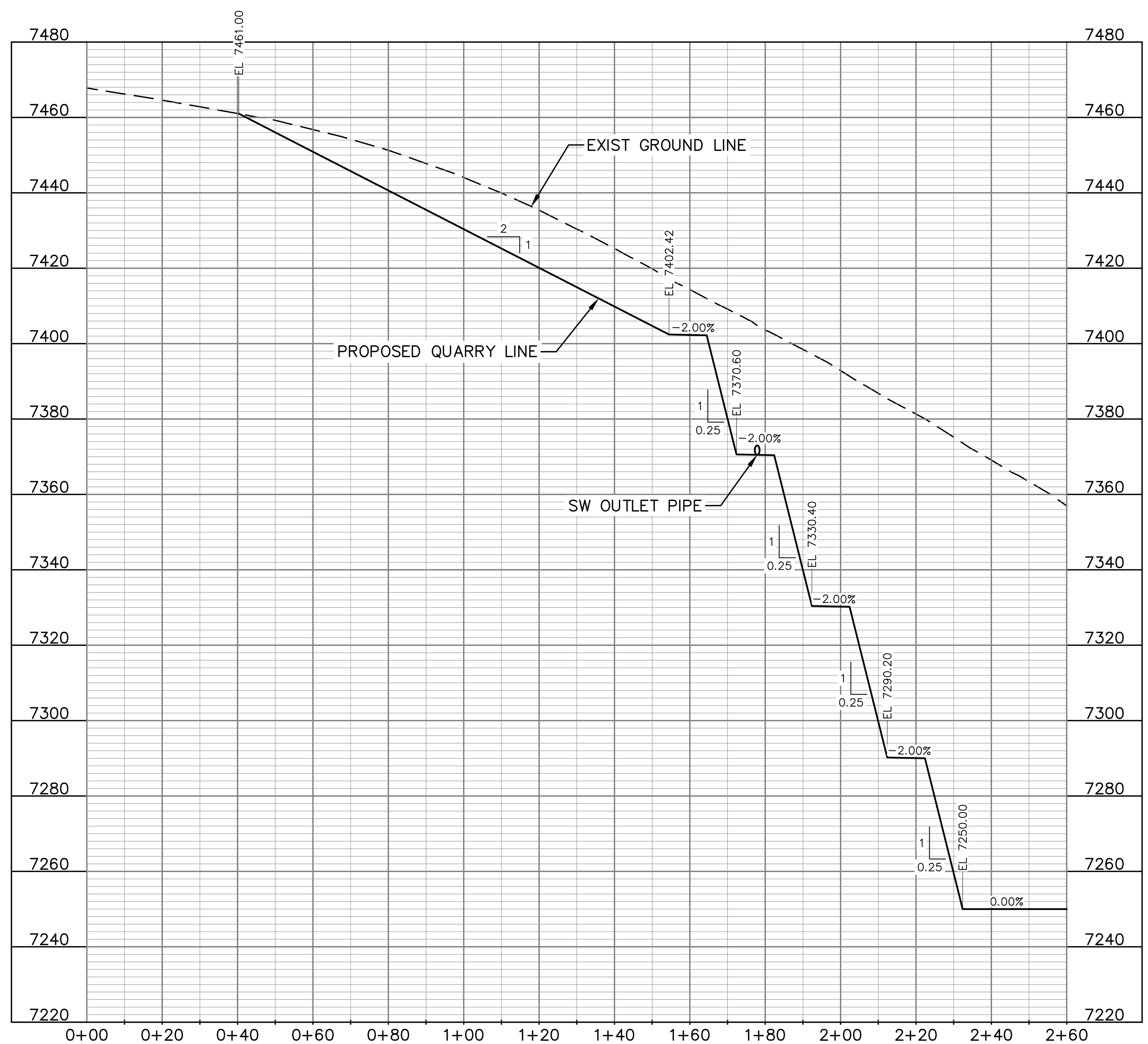

SECTION 5 C.02

SCALE: 1" = 20' HORIZ
SCALE: 1" = 20' VERT

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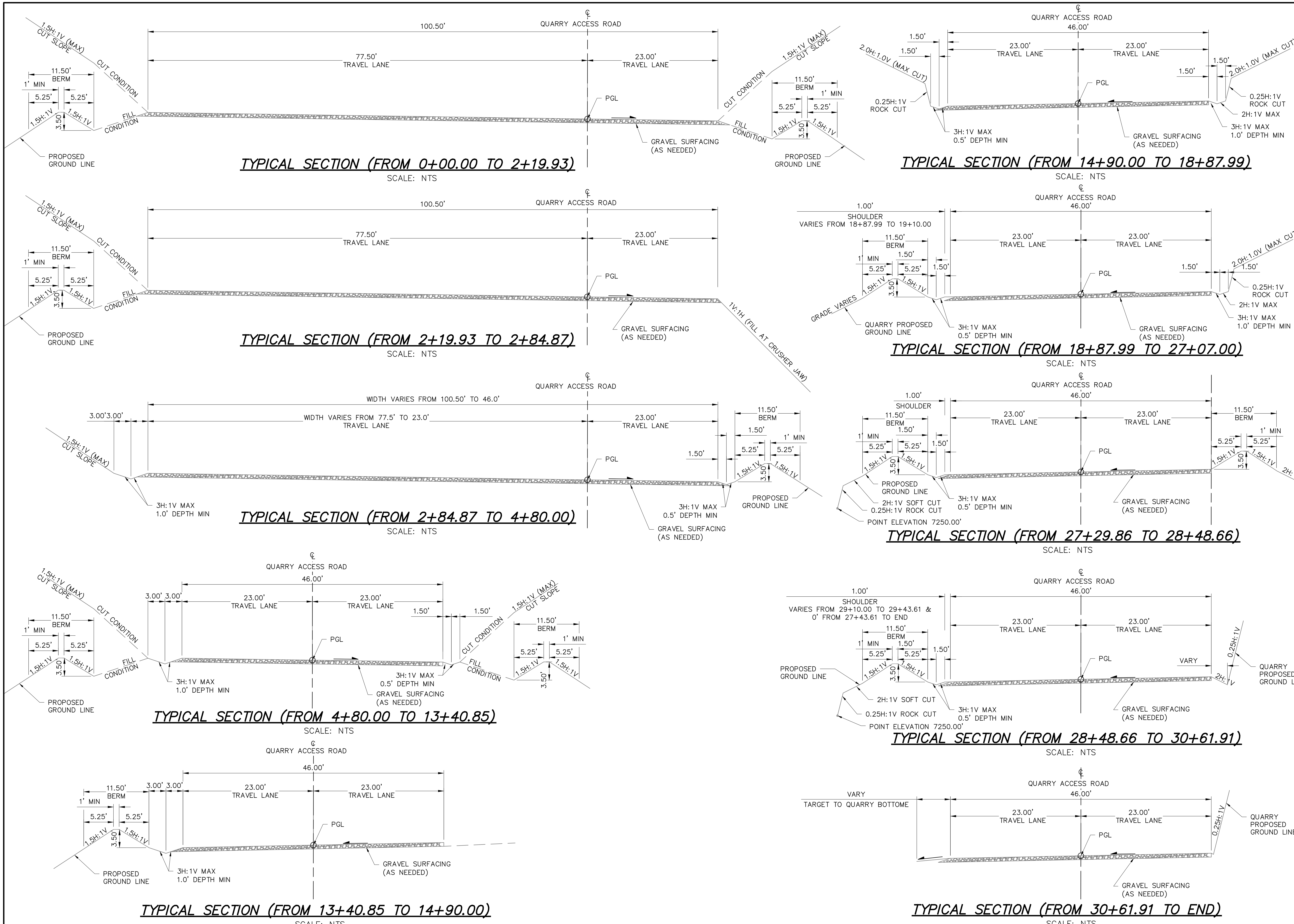
QUARRY SECTION 5

C.08



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QUARRY ACCESS ROAD TYPICAL SECTIONS

C.09

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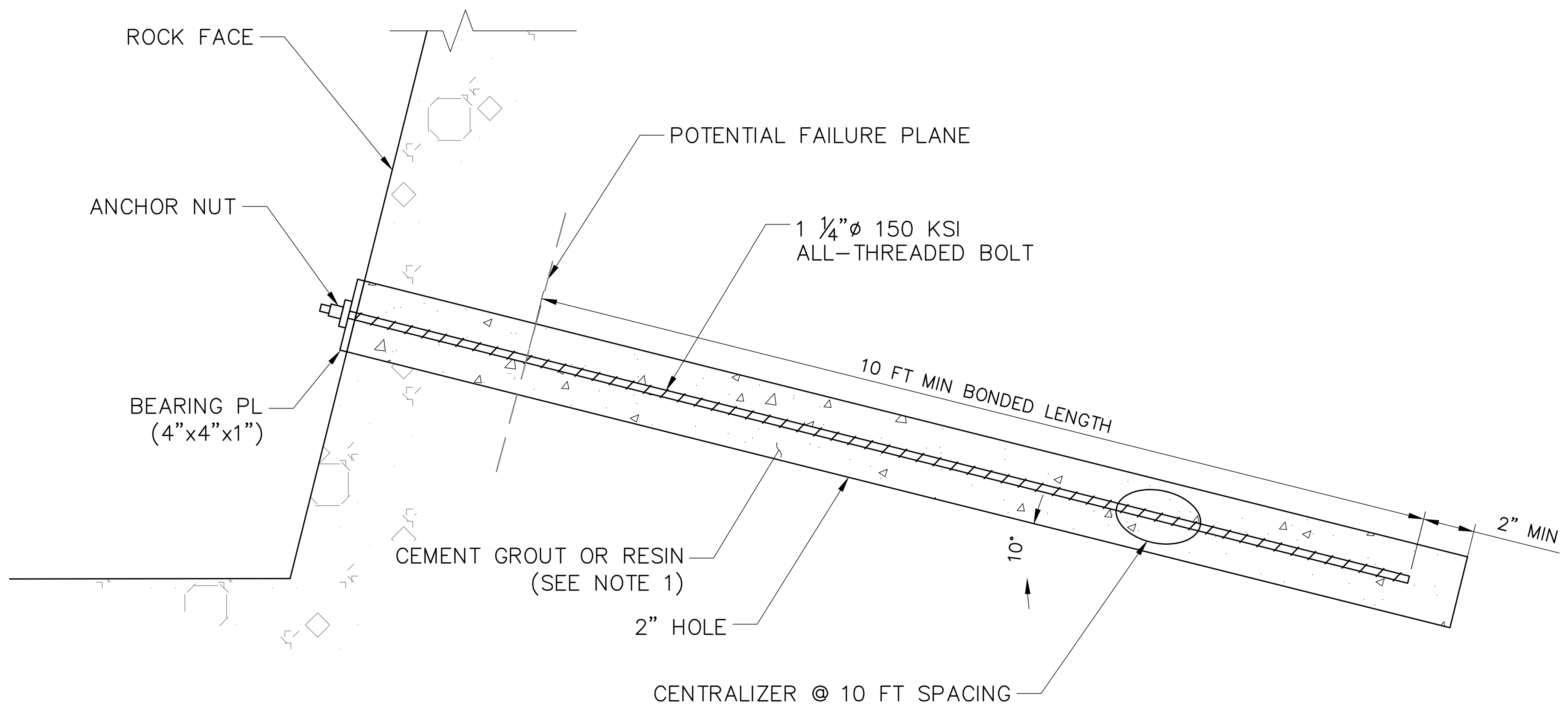
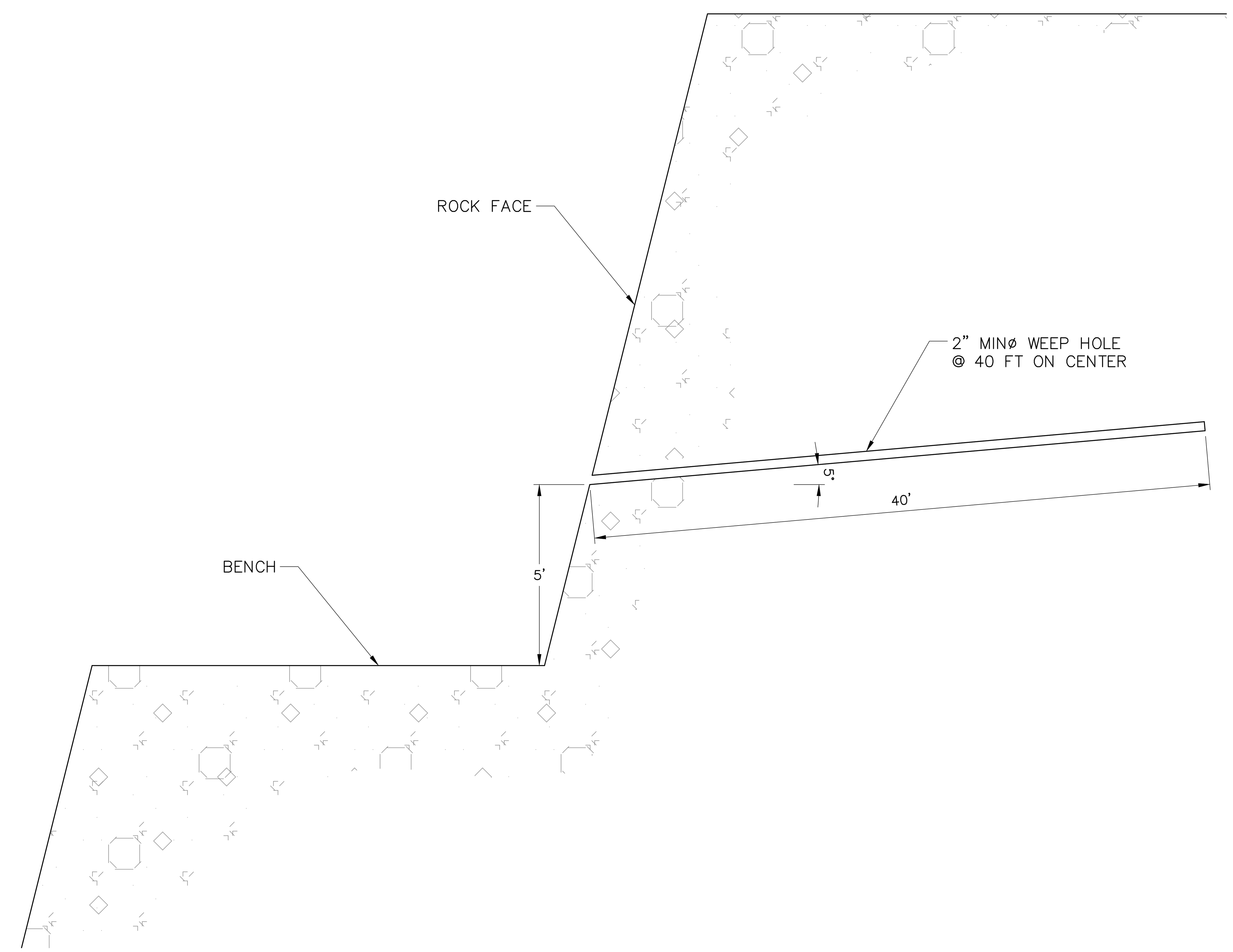


ROCK BOLT TYPICAL DETAIL

SCALE: 1" = 1'



WEEP HOLE TYPICAL DETAIL

SCALE: 1" = 1'

NOTE:

1. GROUT OR RESIN TO BE DESIGNED FOR FINAL SUBMITTAL.

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QUARRY TYPICAL DETAILS

C.10

2 2/3"x1/2' CORRUGATIONS
ROUND STEEL PIPE

PIPE DIA. (IN)	HEIGHT OF COVER LIMITS, H(FT) + * ∅				
	WALL THICKNESS (IN)				
	0.064	0.079	0.109	0.138	0.168
12	92	100	100	100	100
15	74	80	100	100	100
18	61	67	86	90	94
21	53	57	74	77	81
24	46	50	65	68	71
27	41	44	57	60	63
30	37	40	52	54	56
36	30	33	43	45	47
42	34	47	74	77	81
48	30	41	65	68	71
54		36	57	60	63
60			52	54	57
66				49	51
72				45	47
78					43
84					40

* 12" MIN. COVER

3"x1" CORRUGATIONS
ROUND STEEL PIPE

PIPE DIA. (IN)	+ MIN. COVER	HEIGHT OF COVER LIMITS, H(FT) ∅				
		WALL THICKNESS (IN)				
		0.064	0.079	0.109	0.138	0.168
36	12	53	66	98	100	100
42	12	45	56	84	100	100
48	12	39	49	73	88	98
54	12	35	44	65	78	87
60	12	31	39	58	70	78
66	12	28	36	53	64	71
72	12	26	33	49	58	65
78	12	24	30	45	54	60
84	12	22	28	42	50	56
90	12	21	26	39	47	52
96	12		24	36	44	49
102	18		23	34	41	46
108	18			32	39	43
114	18			30	37	41
120	18			29	35	39

5"x1" CORRUGATIONS
ROUND STEEL PIPE

PIPE DIA. (IN)	+ MIN. COVER	HEIGHT OF COVER LIMITS, H(FT) ∅				
		WALL THICKNESS (IN)				
		0.064	0.079	0.109	0.138	0.168
48	12	39	49	73	88	98
54	12	35	44	65	78	87
60	12	31	39	58	70	78
66	12	28	36	53	64	71
72	12	26	33	49	58	65
78	12	24	30	45	54	60
84	12	22	28	42	50	56
90	12	21	26	39	47	52
96	12		24	36	44	49
102	18		23	34	41	46
108	18			32	39	43
114	18			30	37	41
120	18			29	35	39

PLASTIC PIPE

TYPE AND MATERIAL	SIZES AVAILABLE (IN)	HEIGHT OF COVER LIMITS H (FT) +*
CORRUGATED POLYETHYLENE (HDPE)	12 TO 48	30
RIBBED POLYETHYLENE (HDPE)	18 TO 96	20
RIBBED POLYVINYL CHLORIDE (PVC)	18 TO 48	25

FILL HEIGHT REQUIREMENTS GREATER THAN THE HEIGHT OF COVER LIMITS LISTED, WILL REQUIRE SPECIAL DESIGN.

* 12" MIN. COVER OR PER MANUFACTURE'S RECOMMENDATION, WHICHEVER IS GREATER.

NOTES:

1. ADEQUATE COVER SHALL BE PROVIDED DURING CONSTRUCTION TO PROTECT THE STRUCTURE FROM DAMAGE.
2. PIPE SHALL BE PLACED WITH LONGITUDINAL SEAMS AT THE SIDES OR QUARTER POINTS BUT NOT ALONG TOP OF VERTICAL AXIS.
3. STRUCTURAL PLATE PIPES OF EQUAL OR GREATER DIAMETER, CONFORMING TO SECTION 510 OF CDOT'S 2019 STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION, MAY BE SUBSTITUTED FOR THE PIPES ON THESE SHEETS AT NO ADDITIONAL COST TO THE PROJECT.
4. WHEN A CULVERT IS TO BE EXTENDED WITH PIPE OF A DIFFERENT MATERIAL, THE CONNECTION SHALL CONFORM TO THE DETAILS ON THE PLANS OR BE APPROVED.

\+ MINIMUM COVER FOR METAL OR PLASTIC PIPE IS THE DISTANCE FROM THE TOP OF THE PIPE TO THE TOP OF SUBGRADE.

∅ COVER GREATER THAN 90 FT. SHALL BE USED ONLY AFTER THOROUGH INVESTIGATION OF FOUNDATION MATERIAL.

METAL PIPE DETAIL 1
C.02
C.04
C.05

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OSPREY POINT QUARRY DEVELOPMENT

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DRAWING TITLE

CDOT METAIL PIPE

C.11

2 ⅔"x½' CORRUGATIONS
ROUND ALUMINUM PIPE ∅

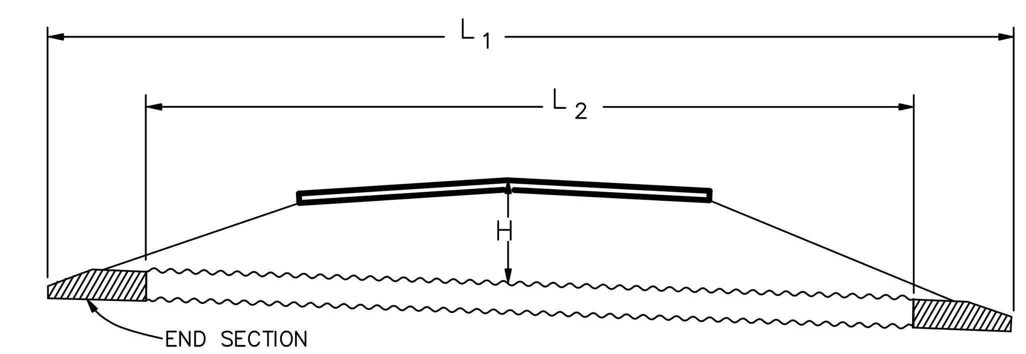
PIPE DIA.	+ MIN. COVER	HEIGHT OF COVER LIMITS, H(FT)				
		WALL THICKNESS (INCHES)				
(INCHES)		0.060	0.075	0.105	0.135	0.164
12	12	50	50	86	90	93
15	12	40	40	69	72	74
18	12	33	33	57	60	62
21	12	28	28	49	51	53
24	12	25	25	43	45	46
27	12	22	22	38	40	41
30	12		20	34	36	37
36	12		16	28	30	31
42	12			44	52	53
48	12			38	45	47
54	18			34	40	41
60	18				36	37
66	18				33	34
72	18					31

3"x1" CORRUGATIONS
ROUND ALUMINUM PIPE ∅

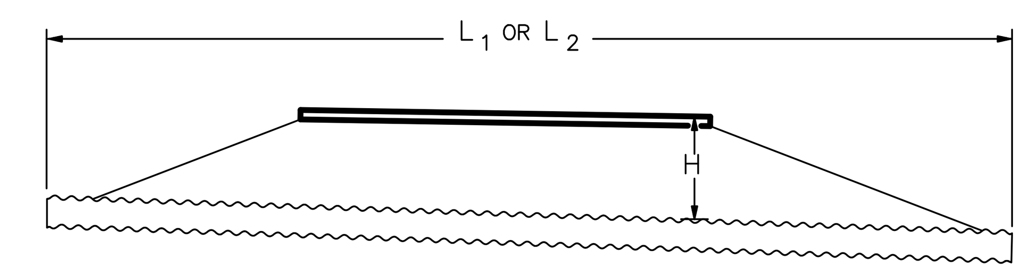
PIPE DIA.	+ MIN. COVER	HEIGHT OF COVER LIMITS, H(FT)				
		WALL THICKNESS (INCHES)				
(INCHES)		0.060	0.075	0.105	0.135	0.164
30	12	36	45	62	93	100
36	12	30	37	51	77	100
42	12	26	32	44	66	86
48	12	22	28	38	58	72
54	18	20	25	34	51	63
60	18	18	22	31	46	57
66	18		20	28	42	51
72	18		18	25	38	47
78	24			23	35	43
84	24			22	32	40
90	24			20	30	37
96	24			19	28	34
102	24				26	32
108	24				24	30
114	24					28
120	24					27

6"x1" CORRUGATIONS
ROUND ALUMINUM PIPE

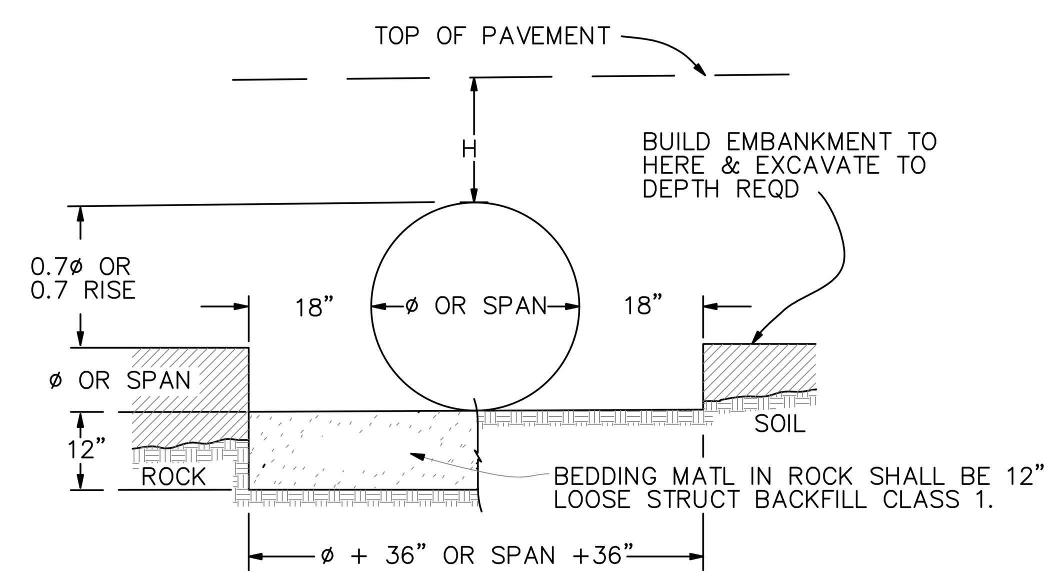
PIPE DIA.	+ MIN. COVER	HEIGHT OF COVER LIMITS, H(FT)				
		WALL THICKNESS (INCHES)				
(INCHES)		0.060	0.075	0.105	0.135	0.164
36	12	26	36	51	66	80
42	12	23	31	44	56	69
48	12	20	27	38	49	60
54	18	18	23	34	44	53
60	18	17	21	30	39	48
66	18		19	27	36	43
72	18		17	25	33	40
78	24			23	30	37
84	24			21	28	34
90	24				25	32
96	24				24	29
102	24				23	28
108	24					26
114	24					24



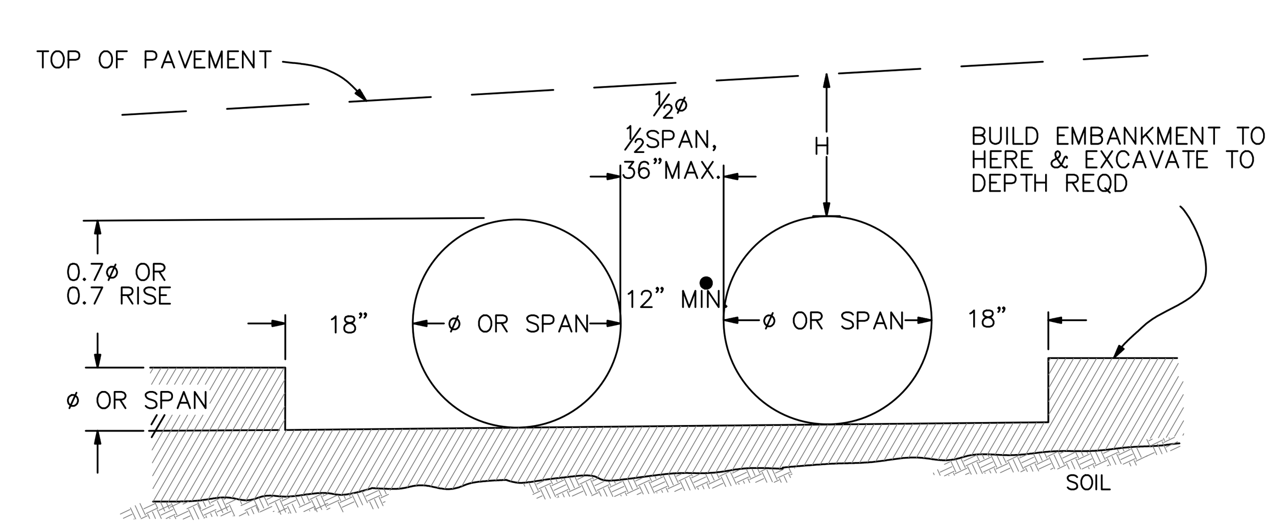
METAL OR PLASTIC CULVERT WITH END SECTIONS
SCALE: NTS



METAL OR PLASTIC CULVERT WITHOUT END SECTIONS
SCALE: NTS



INSTALLATION OF METAL OR PLASTIC CULVERT PIPE
SCALE: NTS



INSTALLATION OF MULTIPLE METAL OR PLASTIC CULVERT PIPE
SCALE: NTS

LEGEND

H = HEIGHT OF COVER LIMIT, MAXIMUM HEIGHT OF FILL OVER TOP OF CULVERT, INCLUDING PAVEMENT.

L_1 = LENGTH OF CULVERT TO BE MEASURED WHEN PLACED IN ACCORDANCE WITH SECTION 617 OR 624.

L_2 = LENGTH OF CULVERT TO BE MEASURED WHEN PLACED IN ACCORDANCE WITH SECTION 603.

• MINIMUM SPACING BETWEEN OUTSIDE WALLS OF PIPE OR END SECTION.

METAL PIPE DETAIL (1)
C.02
C.04
C.05

NOTES:

+ MINIMUM COVER FOR METAL AND PLASTIC PIPE IS THE DISTANCE FROM THE TOP OF THE PIPE TO THE TOP OF RIGID PAVEMENT OR TO THE TOP OF SUBGRADE FOR FLEXIBLE PAVEMENT.

∅ COVER GREATER THAN 90 FT. SHALL BE USED ONLY AFTER THOROUGH INVESTIGATION OF FOUNDATION MATERIAL.

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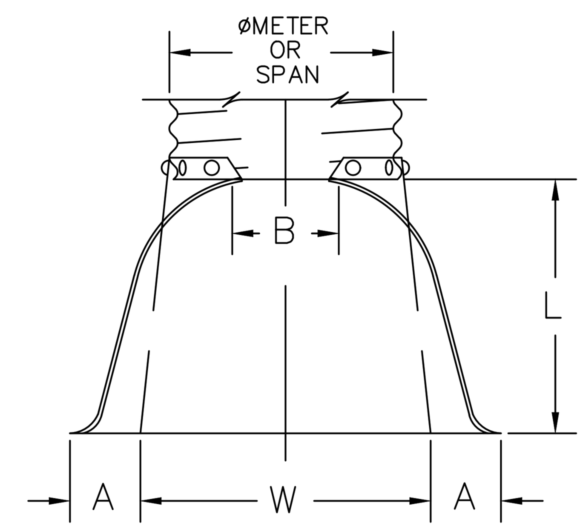
CDOT METAIL PIPE

C.12

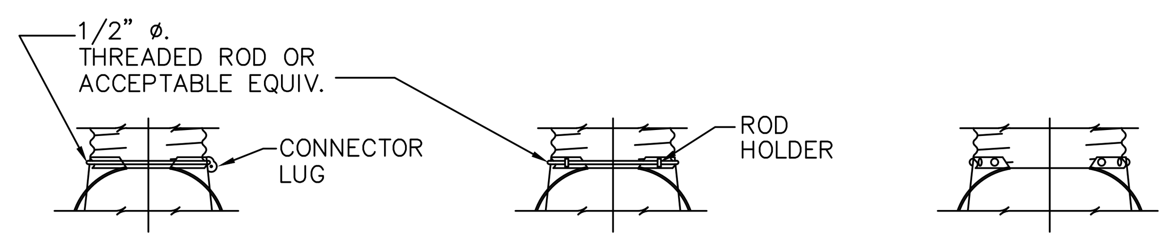
P:\KIE-Gross Reservoir\3-DES\05 GEO\CAD\Sheets\19152 C.10-C.11 METAL PIPE DETAIL.dwg #### C.12 4/30/2021 12:53 PM

THIN-WALL ROUND PIPE

PIPE ø.	THICKNESS	DIMENSIONS					
		A	B	H	L	W	T
		(inches)					
12	0.064	6	6	6	21	24	34
18	0.064	8	10	6	31	36	46
21	0.064	9	12	6	36	42	52
24	0.064	10	13	6	41	48	58
30	0.079	12	16	8	51	60	70
36	0.079	14	19	9	60	72	94
42	0.109	16	22	11	69	84	106
48	0.109	18	27	12	78	90	112
54	0.109	18	30	12	84	102	124
60	0.109	18	33	12	87	114	136
66	0.109	18	36	12	87	120	142
72	0.109	18	39	12	87	126	148
78	0.109	18	42	12	87	132	154
84	0.109	18	45	12	87	138	160



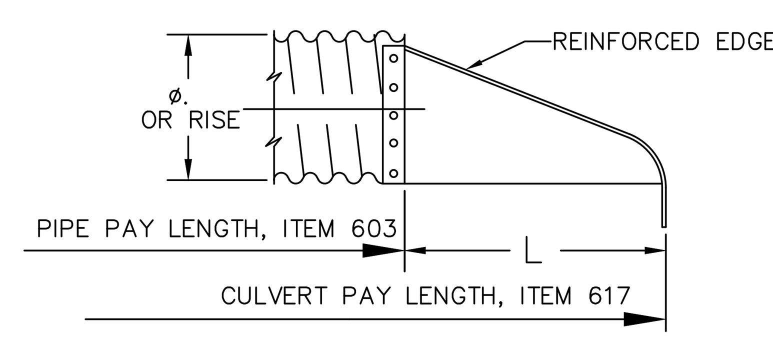
PLAN



TYPE 1
FOR 18 IN. THRU 24 IN. ROUND PIPE WITH ANNULAR CORRUGATIONS. NOT TO BE USED ON HELICALLY-FORMED PIPE UNLESS RECORRUGATED.

TYPE 2
FOR 30 IN. THRU 36 IN. ROUND PIPE WITH ANNULAR CORRUGATIONS. NOT TO BE USED ON HELICALLY-FORMED PIPE UNLESS RECORRUGATED.

TYPE 3
FOR 42 IN.THRU 84 IN. ROUND PIPE WITH ANNULAR CORRUGATIONS AND ALL SIZES WITH HELICAL CORRUGATIONS AND FOR ALL METAL PIPE ARCH CULVERTS. SHOP ATTACH A 24 IN. MIN. LENGTH OF ANNULAR PIPE WITH GALV. RIVETS OR BOLTS, SPOT WELDS, OR 2 IN. LONG SKIP WELDS ON 8 IN. CTRS. REPAIR BURNT GALV. PER SPECS.



TYPICAL CONNECTIONS

END SECTION AND CONNECTION DETAILS FOR ROUND CORRUGATED METAL PIPE CULVERTS
SCALE: NTS

METAL PIPE END SECTION DETAIL 1
C.02
C.04
C.05

NOTES:

1. DIMENSIONS OF END SECTIONS MAY VARY SLIGHTLY FROM THOSE SHOWN ON THE TABLES DUE TO DIFFERENT MANUFACTURER'S VARIATIONS.
2. CONCRETE END SECTIONS ARE TO BE FURNISHED WITH TONGUE OR GROOVE AS REQUIRED.
3. DESIGN LENGTH OF CULVERT OR SIDE DRAIN IS BASED ON LENGTH OF END SECTION SHOWN IN TABLE. ANY ADDITIONAL PIPE REQUIRED TO PROVIDE THE DESIGN LENGTH SHALL BE FURNISHED BY AND AT THE EXPENSE OF THE CONTRACTOR.
4. INSIDE CONFIGURATION AND JOINT OF CONCRETE END SECTION END PIPE SHALL MATCH.
5. GALVANIZED TOE PLATE AS SHOWN, WILL BE REQUIRED ON END SECTIONS FOR CORRUGATED STEEL PIPE AND SHALL BE THE SAME THICKNESS AS END SECTIONS. TOE PLATE SHALL BE FIELD-BOLTED TO END SECTION WITH 3/8" GALVANIZED BOLTS, NUTS AND WASHERS.
6. GALVANIZED STEEL SHALL BE IN CONFORMANCE WITH AASHTO M 111, M 218 OR M 232.
7. FOR TYPE SD END SECTIONS, BARS SHALL BE FABRICATED FROM NPS-3 GALVANIZED STEEL SCHEDULE 40 PIPE WHICH SHALL BE IN CONFORMANCE WITH ASTM A 53.
8. FOR A TYPE SD END SECTION, THE INSTALLATION OF ALTERNATIVE 1 OR ALTERNATIVE 2 END SECTION SHALL BE THE CONTRACTOR'S OPTION.
9. CONCRETE PIPE JOINT FASTENERS, WHERE SHOWN ON PLANS, SHALL BE INSTALLED SO THAT A MINIMUM OF 15 LINEAR FEET OF THE OUTLET END OF THE PIPE ARE MECHANICALLY LOCKED TOGETHER. END SECTION LENGTHS, WHEN USED, WILL BE INCLUDED IN THE 15 LF REQUIREMENT.
10. CONNECTIONS OF METAL END SECTIONS TO PLASTIC PIPE SHALL BE APPROVED BY THE ENGINEER.

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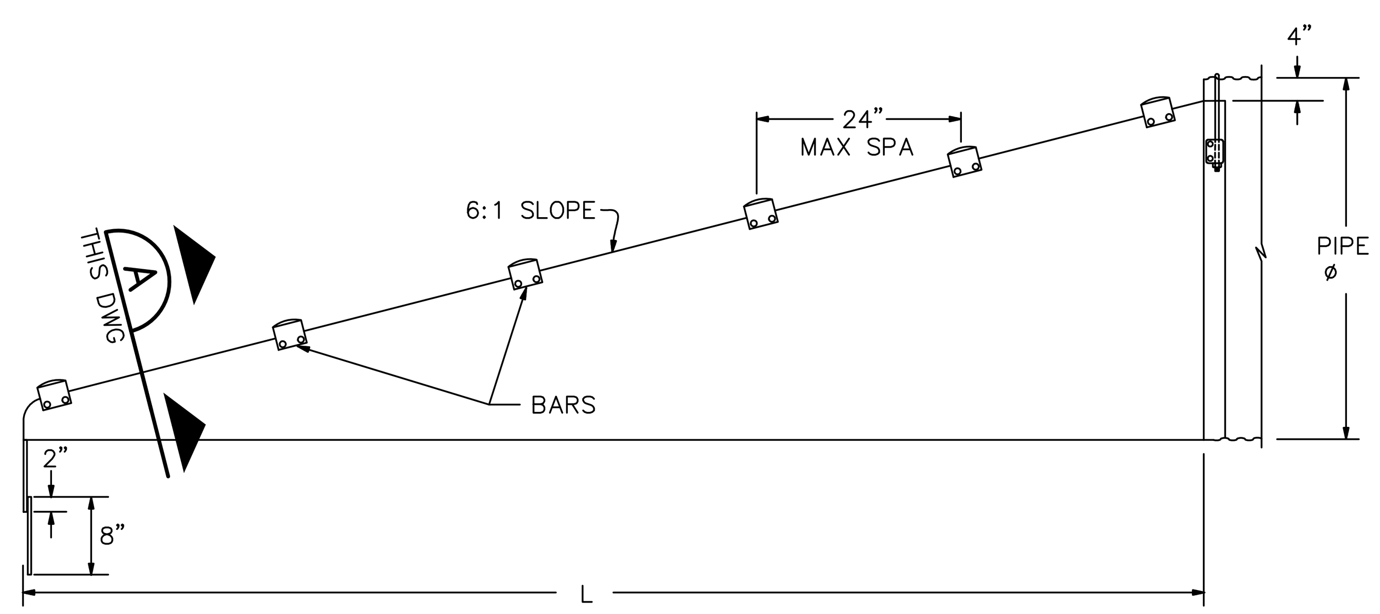
CDOT METAL PIPE END SECTION DETAILS

C.13

NOTE:

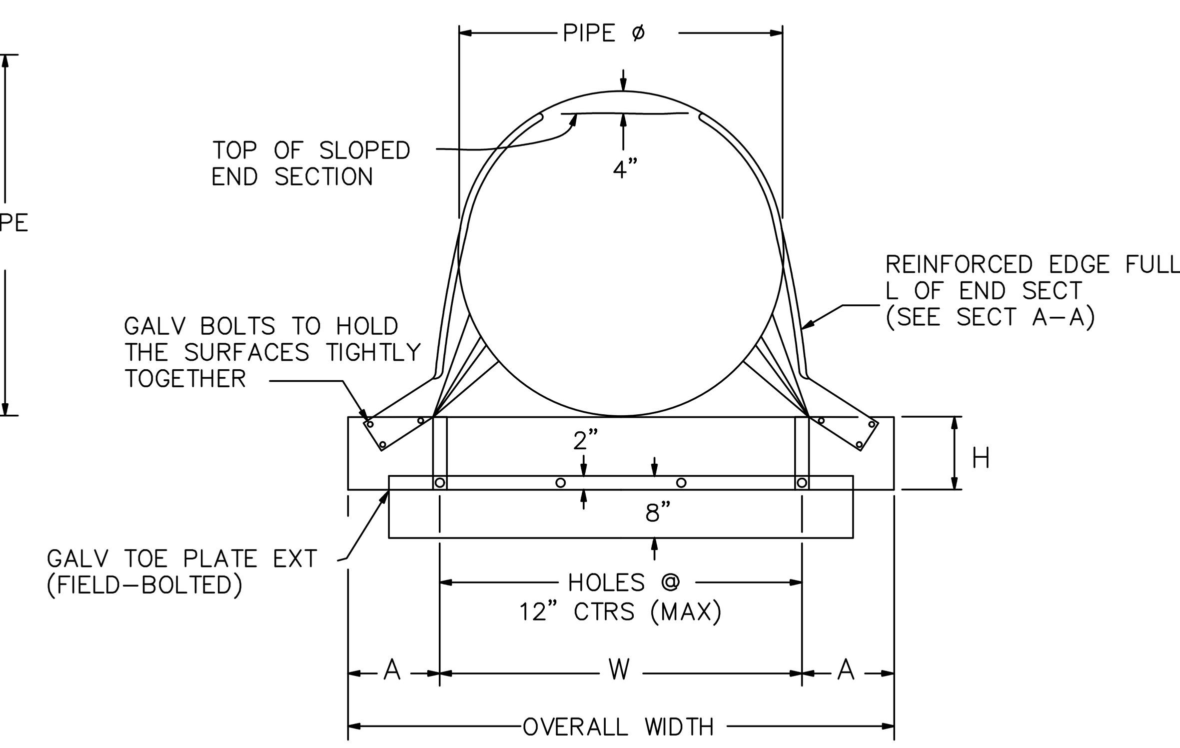
ALL CUT AND/OR WELDED SURFACES TO BE PROTECTED WITH ONE FULL BRUSH COAT OF ZINC RICH PAINT PER CDOT'S 2019 STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION, SECTION 707.09.



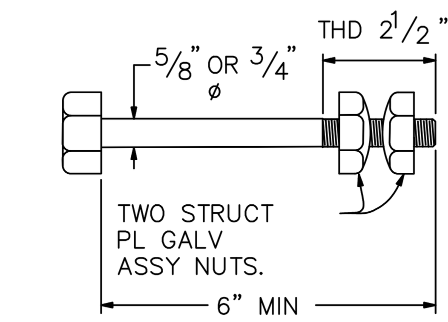
SIDE VIEW OF END SECTION – ALTERNATIVE 1
SCALE: NTS

END SECTIONS FOR CIRCULAR PIPES

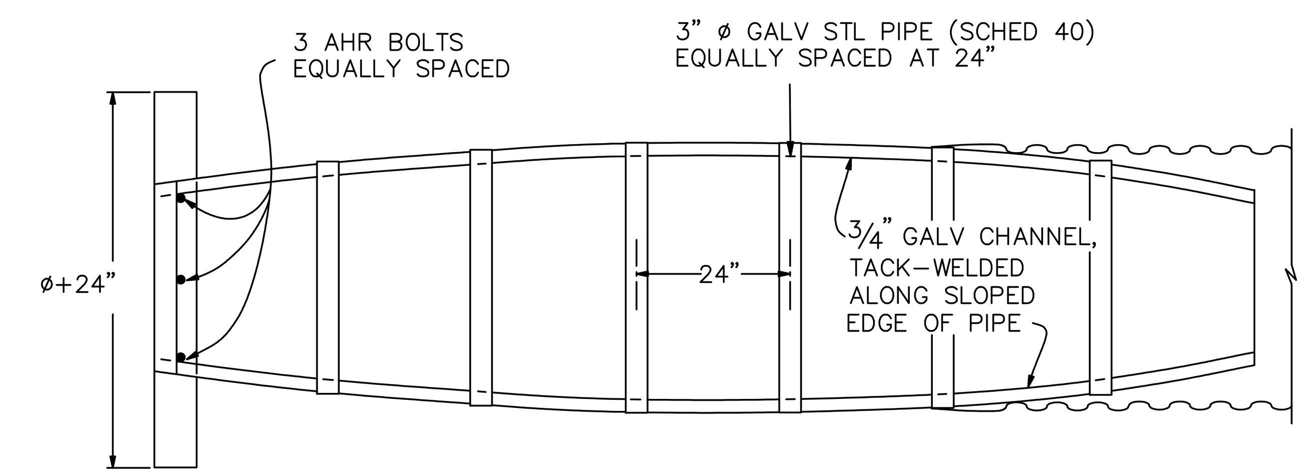
PIPE ø. (in.)	MIN. THICK (in.)	A	H	W	OVERALL WIDTH	SLOPE	LENGTH L
		DIMENSION (INCHES)					
15	.064	8	6	21	37	6:1	30
18	.064	8	6	24	40	6:1	48
21	.064	8	6	27	43	6:1	66
24	.079	8	6	30	46	6:1	84
30	.079	12	9	36	60	6:1	120
36	.109	12	9	42	66	6:1	156



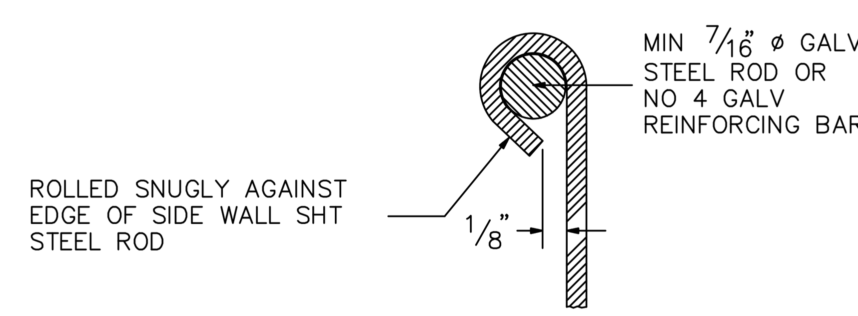
FRONT VIEW – ALTERNATIVE 1
(BAR NOT SHOWN)
SCALE: NTS



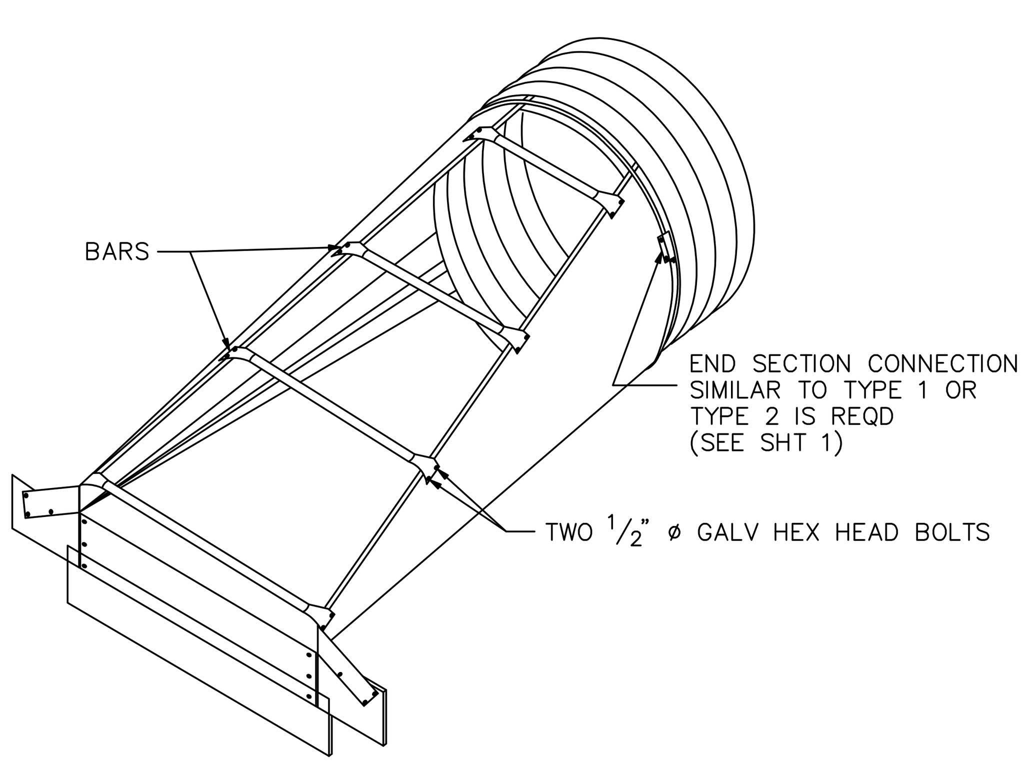
TYPICAL ANCHOR BOLT
(GALVANIZED)
SCALE: NTS



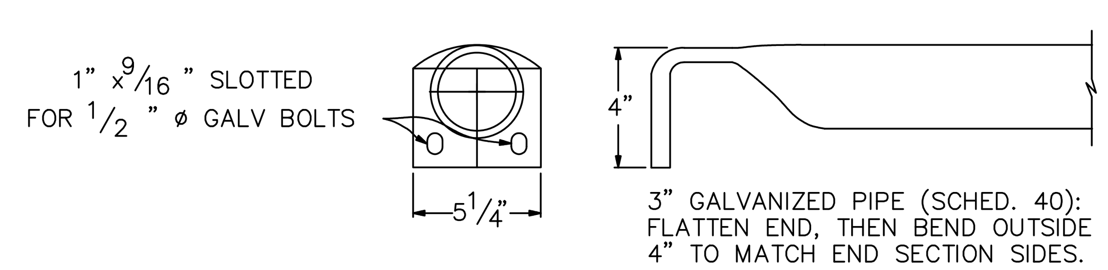
TOP VIEW – ALTERNATIVE 2
SCALE: NTS



SECTION A

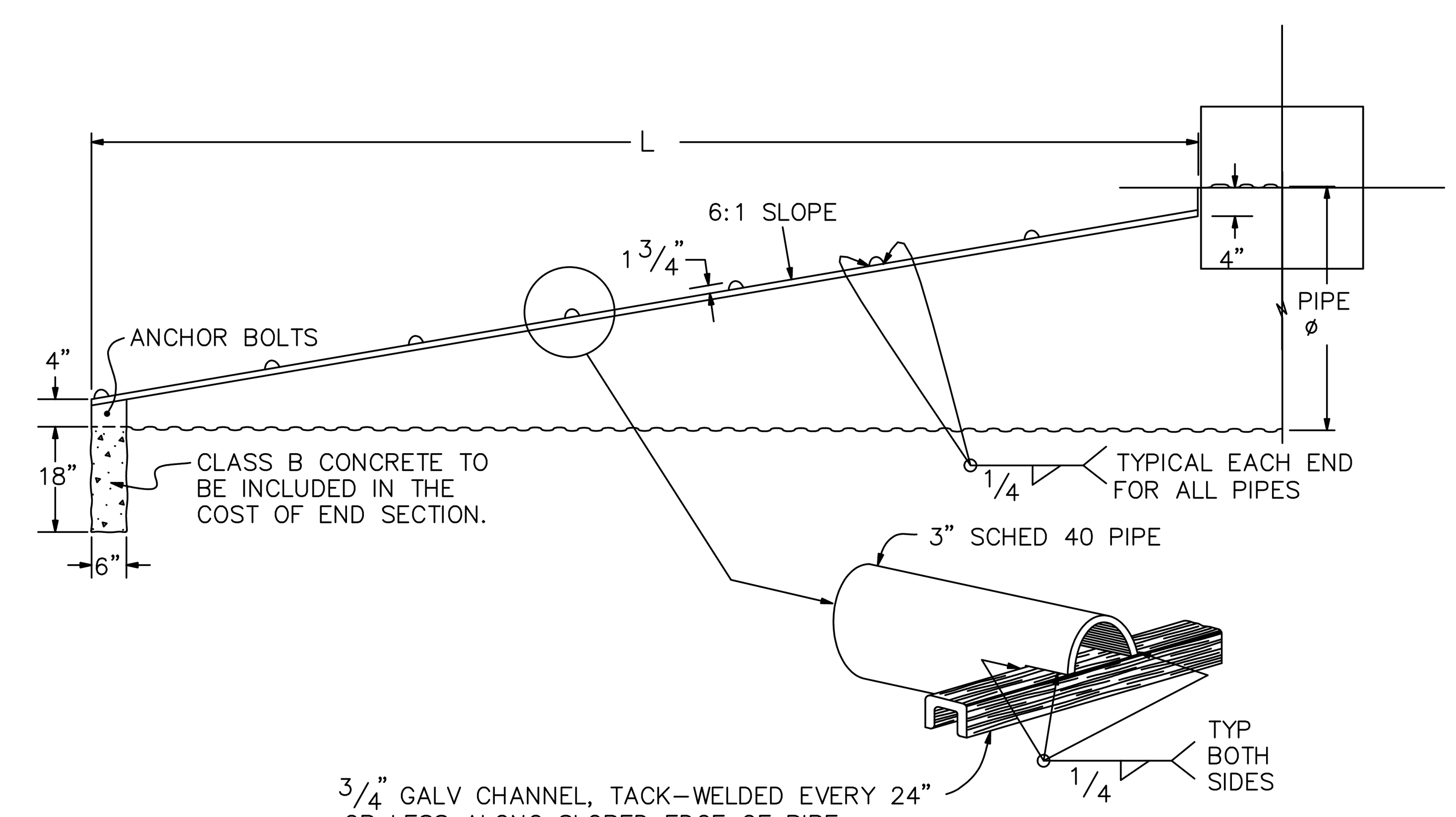


ALTERNATIVE 1



BAR END DETAIL
(FOR ALTERNATIVE 1)

TYPE SD END SECTIONS FOR SIDE DRAIN
SCALE: NTS



BAR END DETAIL
(FOR ALTERNATIVE 2)

SIDE VIEW OF END SECTION – ALTERNATIVE 2
SCALE: NTS

METAL PIPE END SECTION DETAIL 1
C.02
C.04
C.05

P:\KIE–Gross Reservoir\3–DES\05 GEO\CAD\Sheets\19152 C.12–C.13 METAL PIPE END SECTION DETAIL.dwg #### C.14 4/30/2021 12:53 PM

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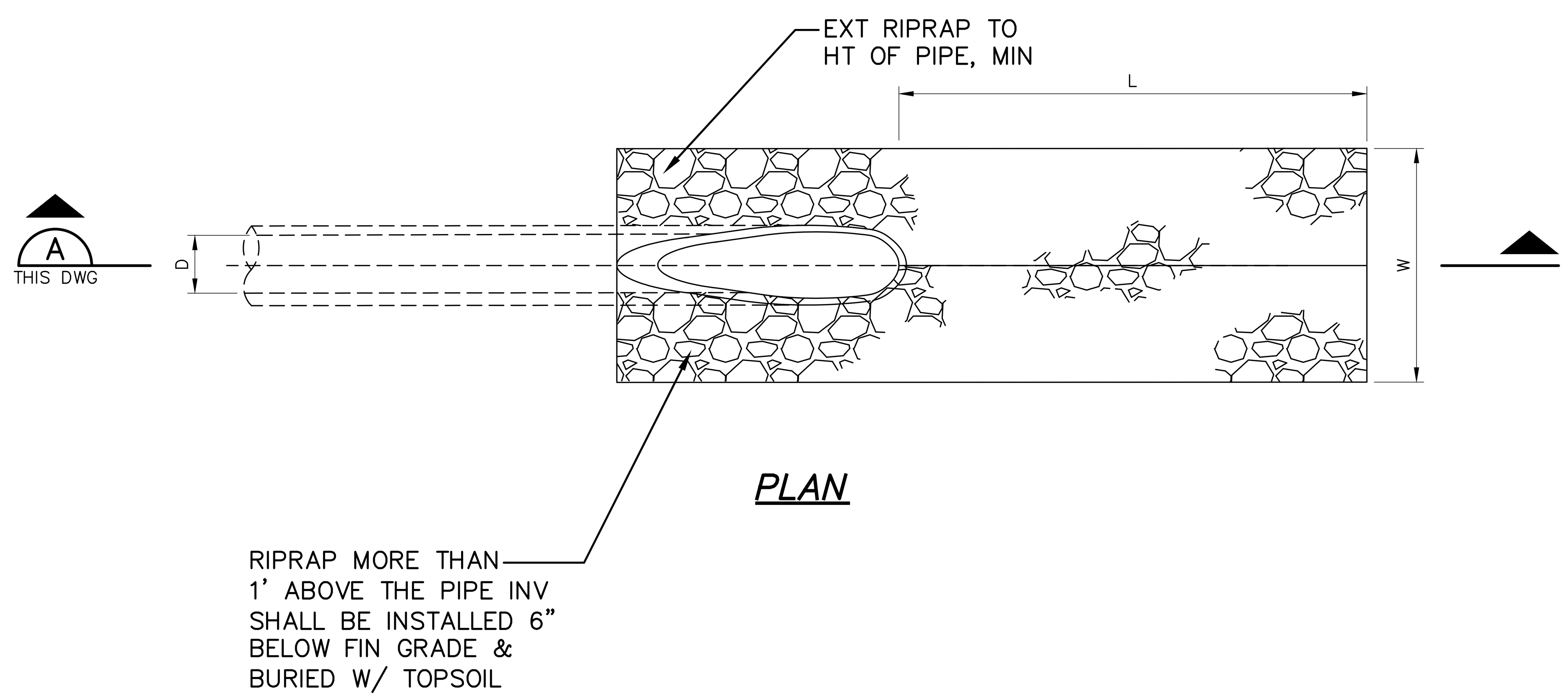
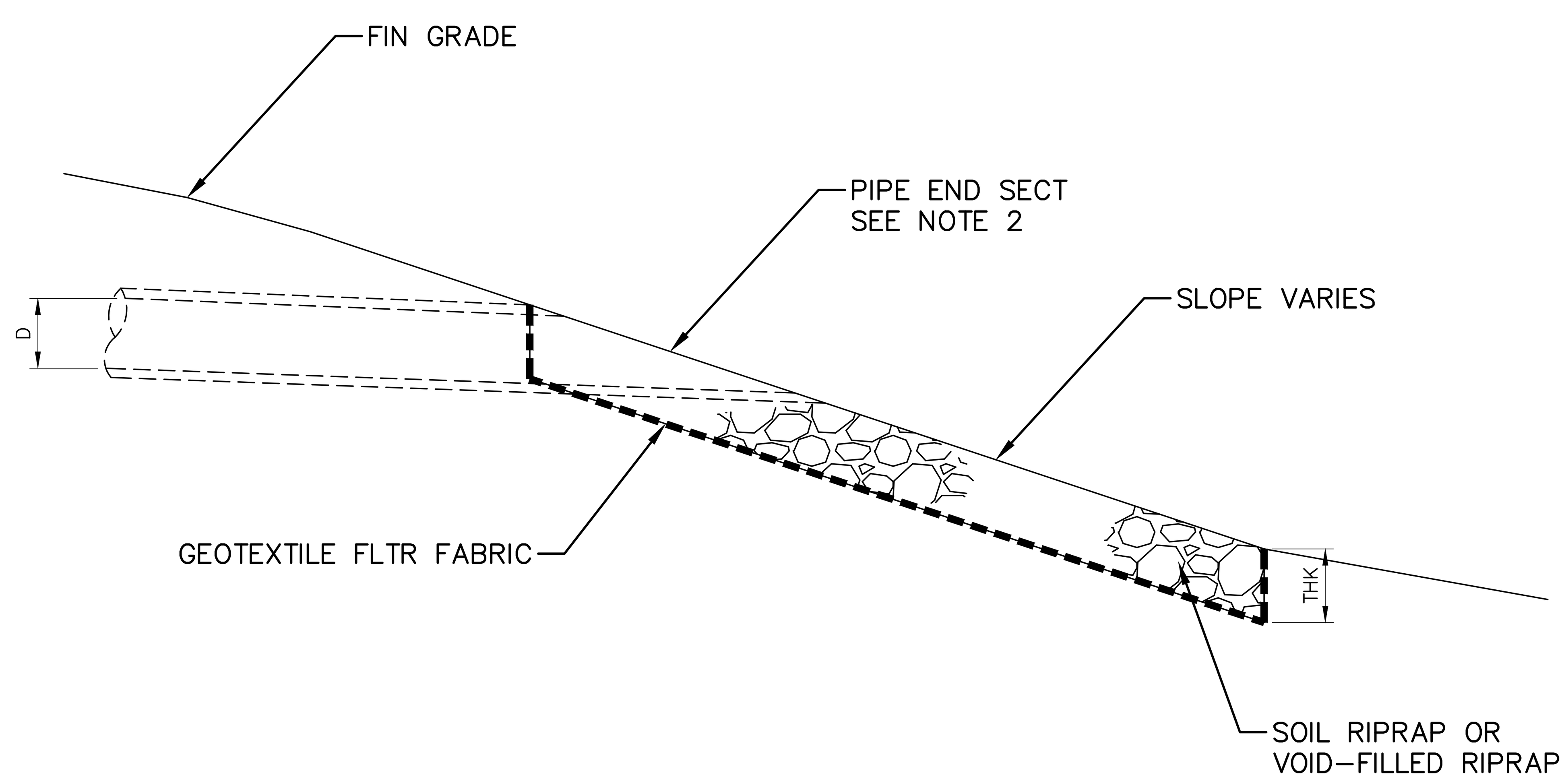
CDOT METAL PIPE END SECTION DETAILS

C.14



PLAN



SECTION A

RIPRAP APRON DETAIL 1 C.02 C.04 C.05

RIPRAP APRON DIMENSIONS						
PIPE ID	Q10 (CFS)	PIPE DIA. (D)	LENGTH (L)	WIDTH (W)	THICKNESS (THK)	D50
E OUTLET PIPE	0.1	12"	3'-0"	2'-0"	1'-0"	6"
NE OUTLET PIPE	4.0	2-10"	5'-0"	3'-0"	1'-0"	6"
QUARRY OUTLET PIPE	14.8	30"	8'-0"	4'-0"	1'-0"	6"
SW OUTLET PIPE	13.7	30"	8'-0"	4'-0"	1'-0"	6"
DITCH Q3 OUTFALL	1.3	N/A	6'-0"	3'-0"	1'-0"	6"
DITCH QAR1 OUTFALL	2.2	N/A	6'-0"	3'-0"	1'-0"	6"
DITCH Q4 OUTFALL	8.10	N/A	8'-0"	4'-0"	1'-0"	6"

NOTES:

1. FOR SIZE AND LOCATION OF PIPES, SEE THE PLANS
2. RIPRAP PROTECTION MAY BE FOR A DITCH OUTFALL OR A PIPE OUTFALL.

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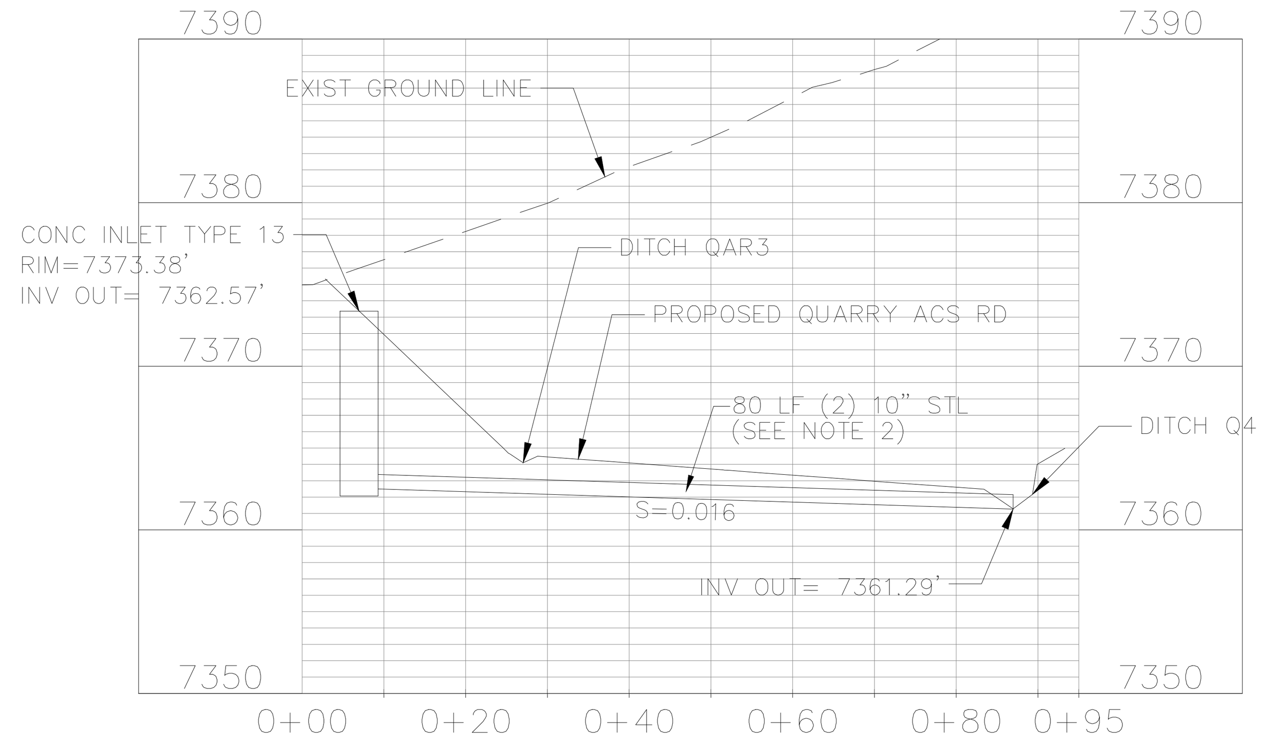
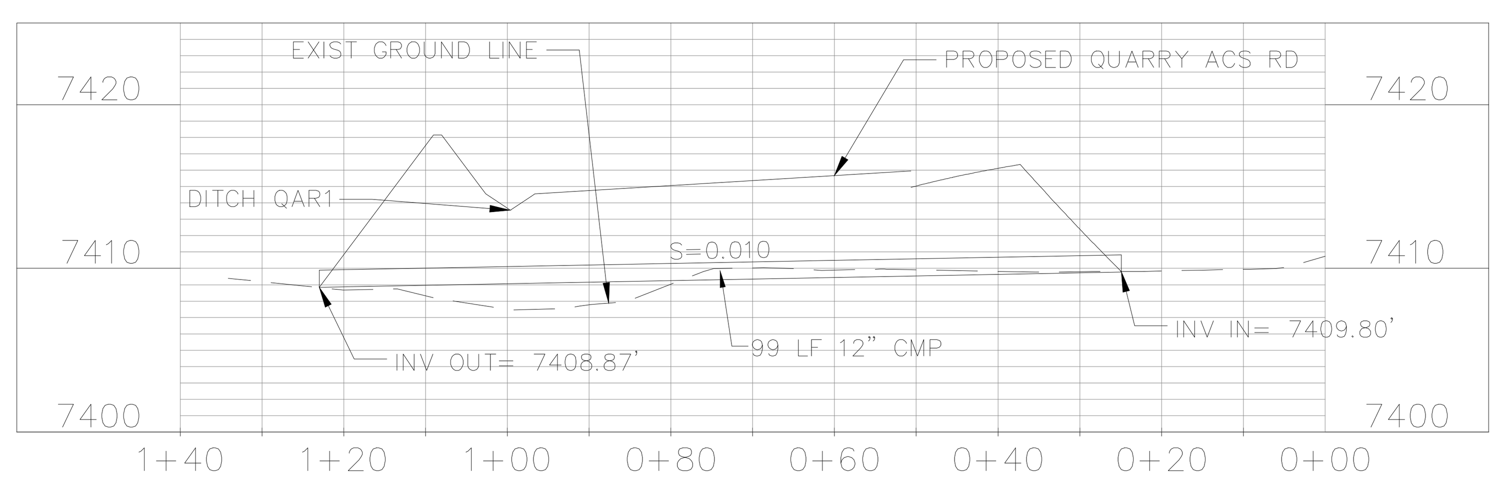
RIPRAP APRON DETAIL

C.15



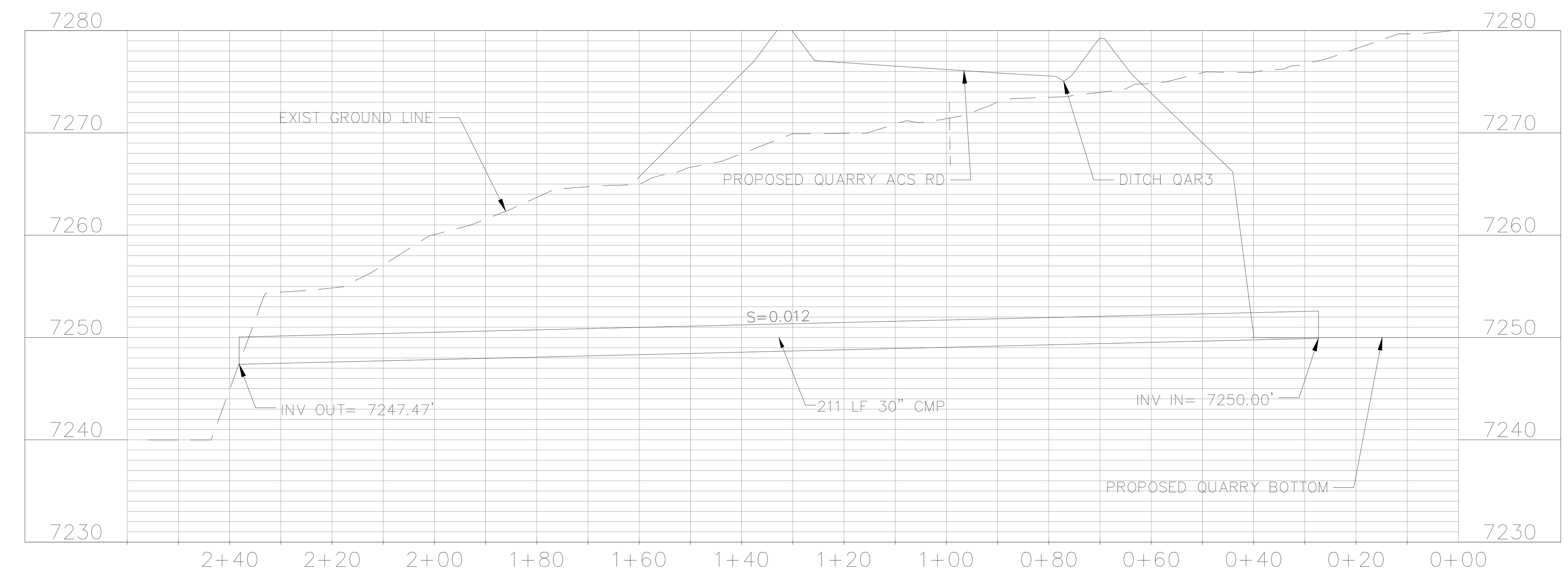
NE OUTLET PIPE PROFILE

SCALE: 1" = 20' HORIZ
1" = 10' VERT



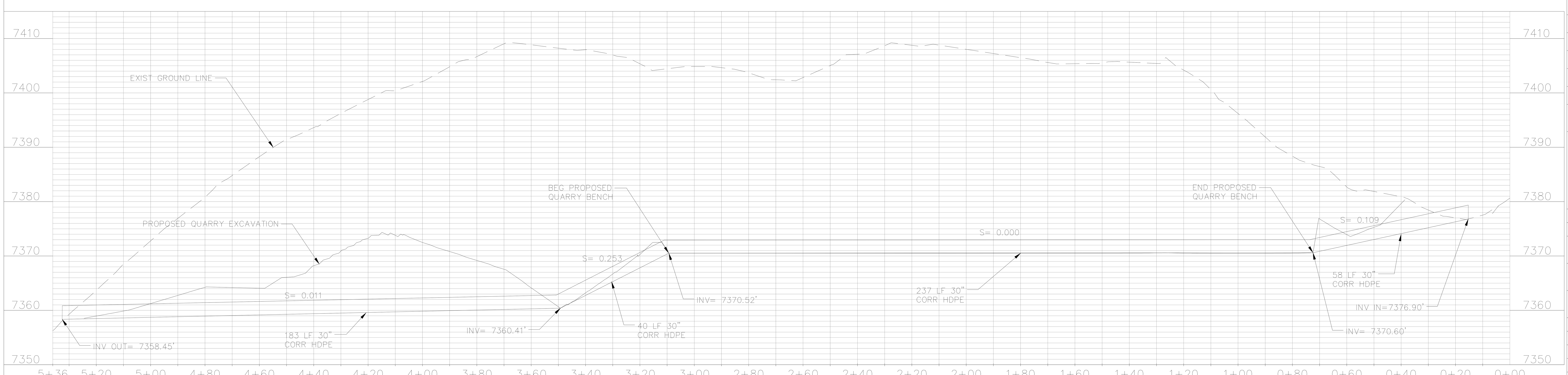
E OUTLET PIPE PROFILE

SCALE: 1" = 20' HORIZ
1" = 10' VERT



QUARRY OUTLET PIPE PROFILE

SCALE: 1" = 20' HORIZ
1" = 10' VERT



NOTE:

1. PIPE SHALL BE ANCHORED TO SURFACE WHERE IT IS NOT BURRIED UNDERNEATH FINISHED GRADE OR EXISTING GROUND.
2. ENCASE PIPE FOR LIMITS UNDERNEATH QUARRY ACCESS ROAD.

SW OUTLET PIPE PROFILE

SCALE: 1" = 20' HORIZ
1" = 10' VERT

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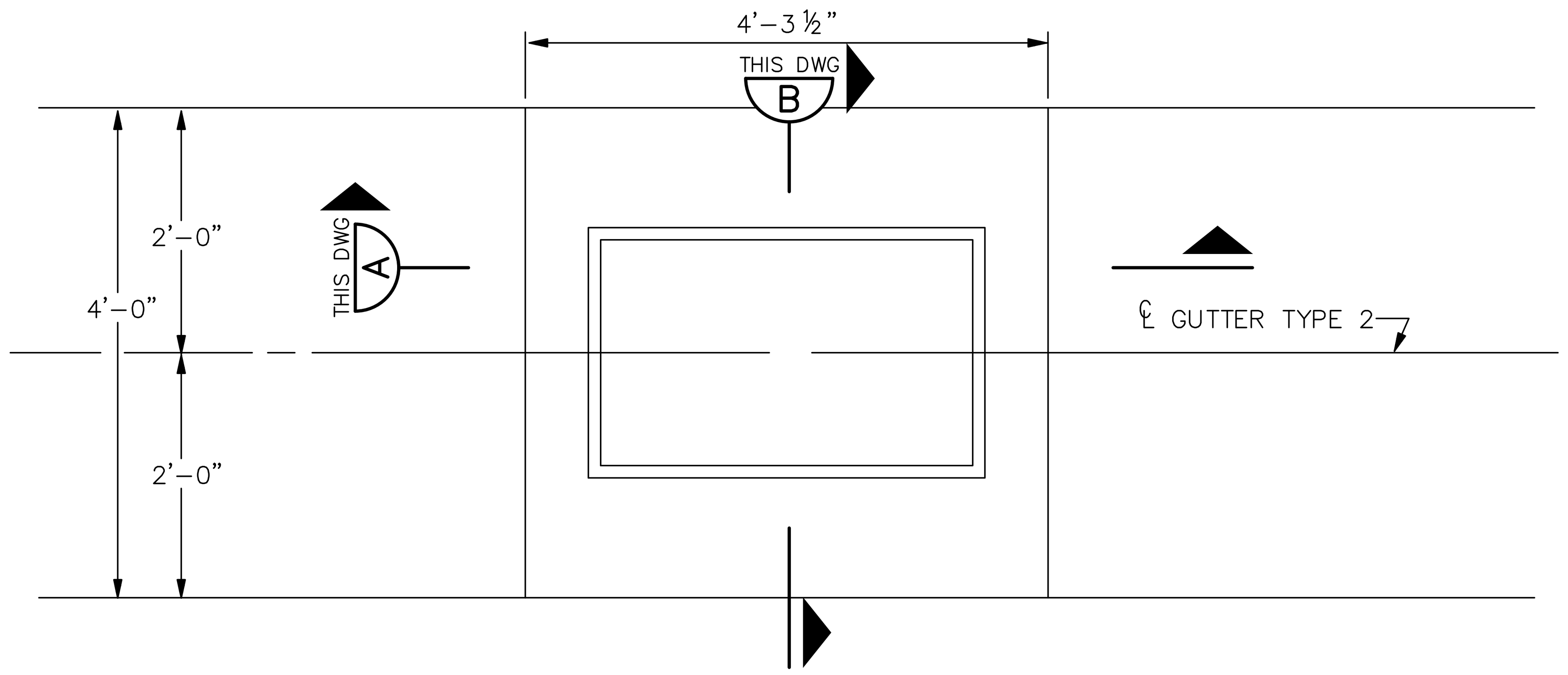
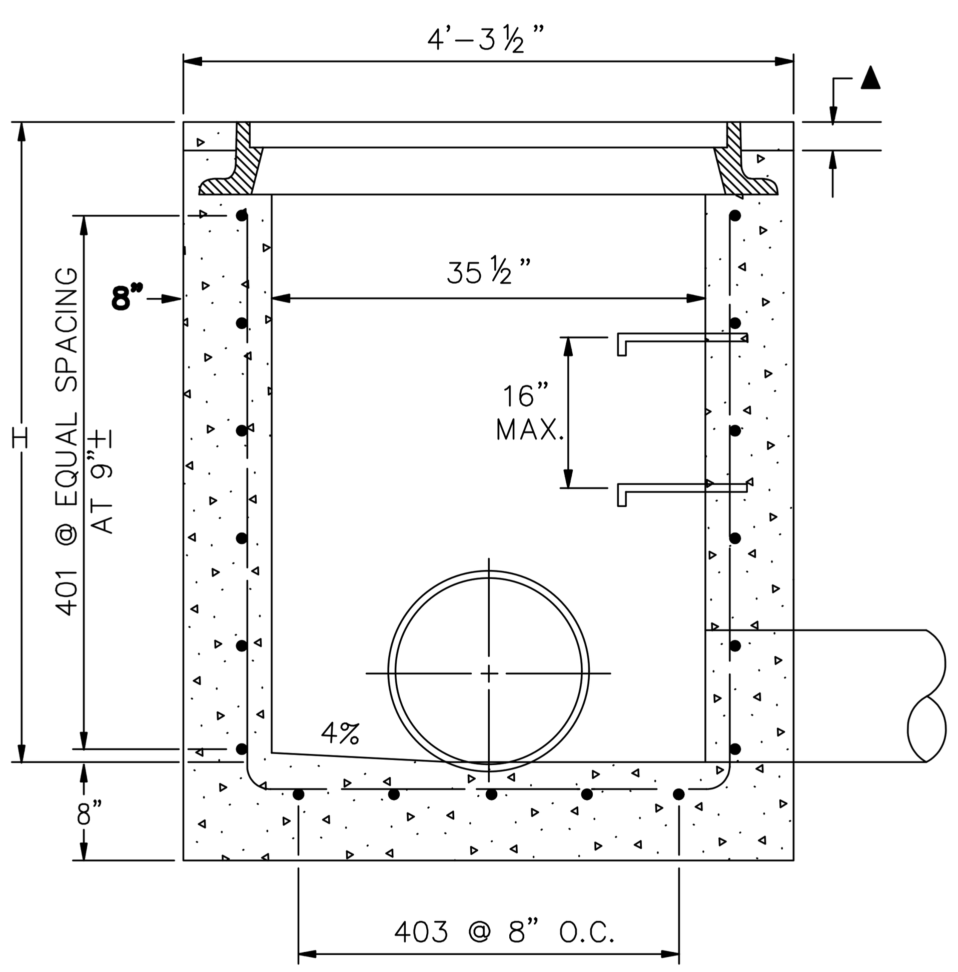
DRAINAGE PIPE PROFILES

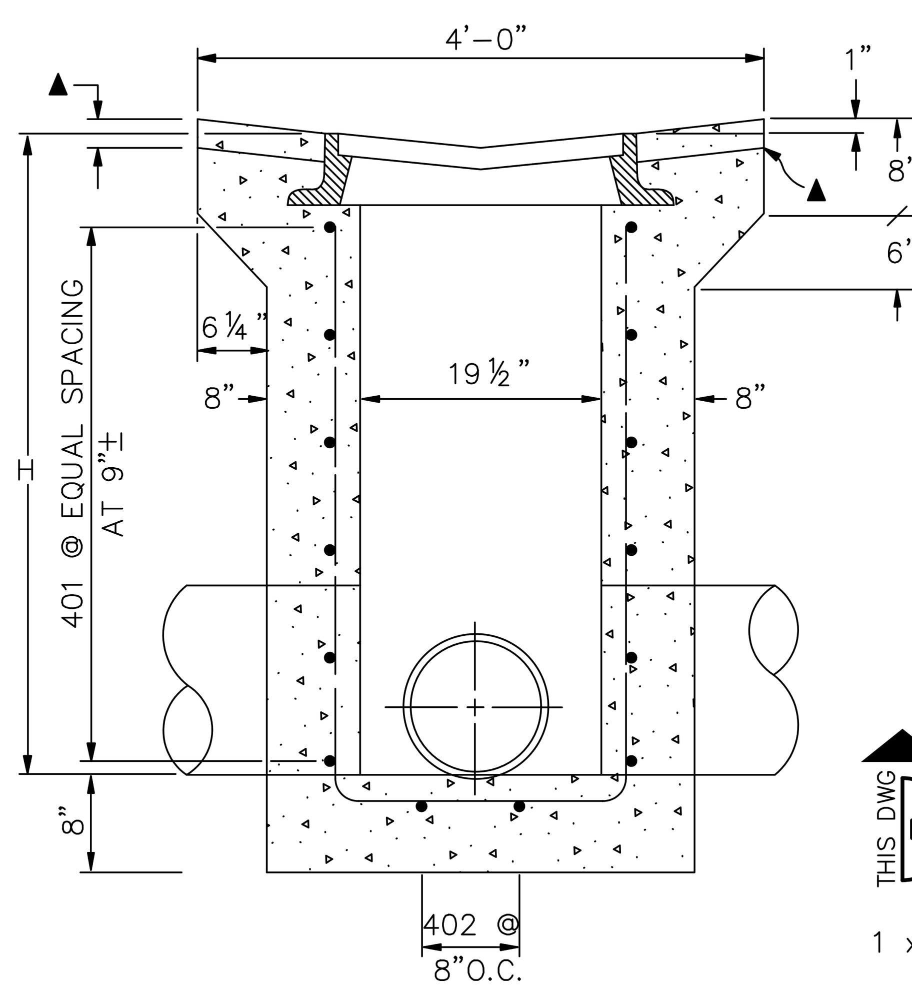
C.16



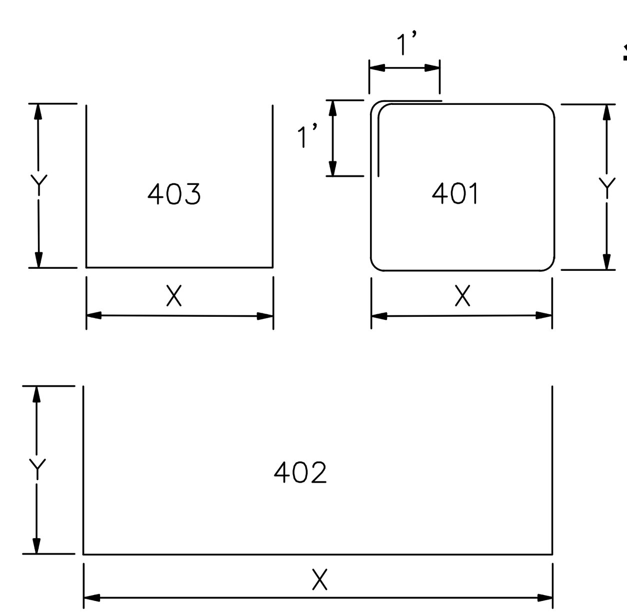
PLAN OF TYPE 13 INLET



SECTION A–A

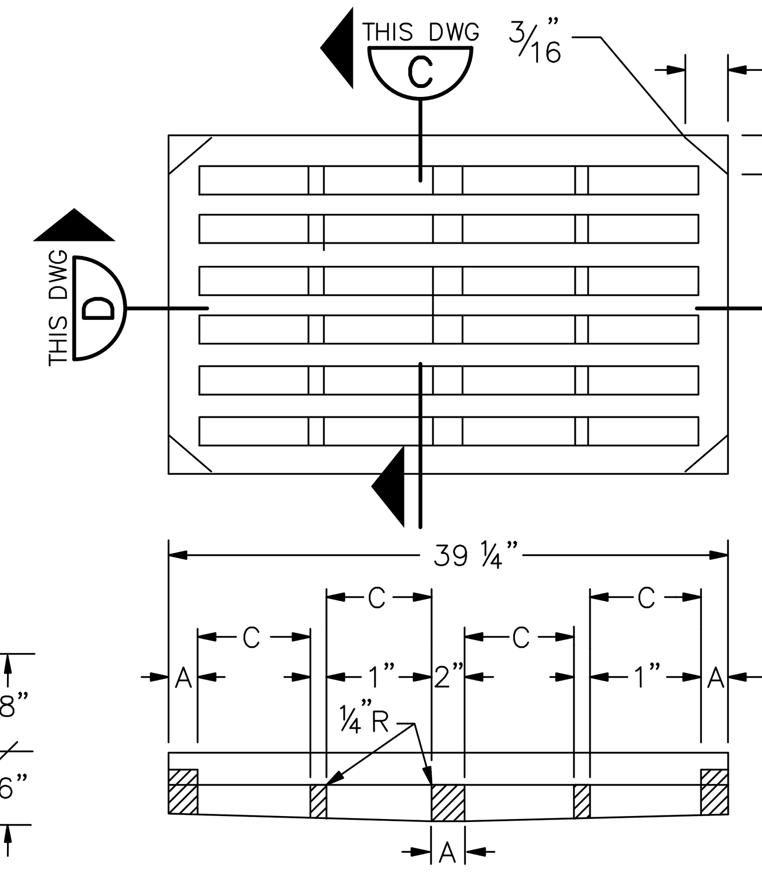


SECTION B–B



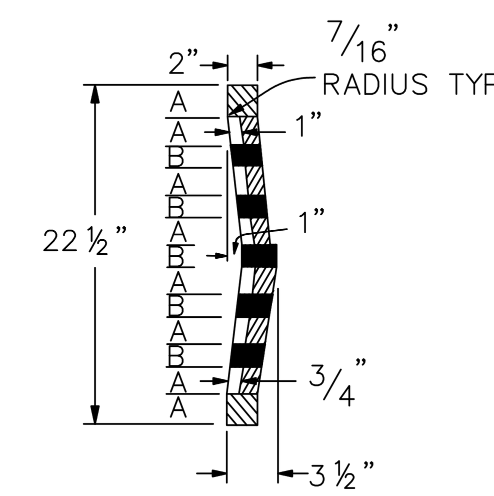
ALL DIMENSIONS ARE OUT–TO–OUT OF BAR.

BENDING DIAGRAM



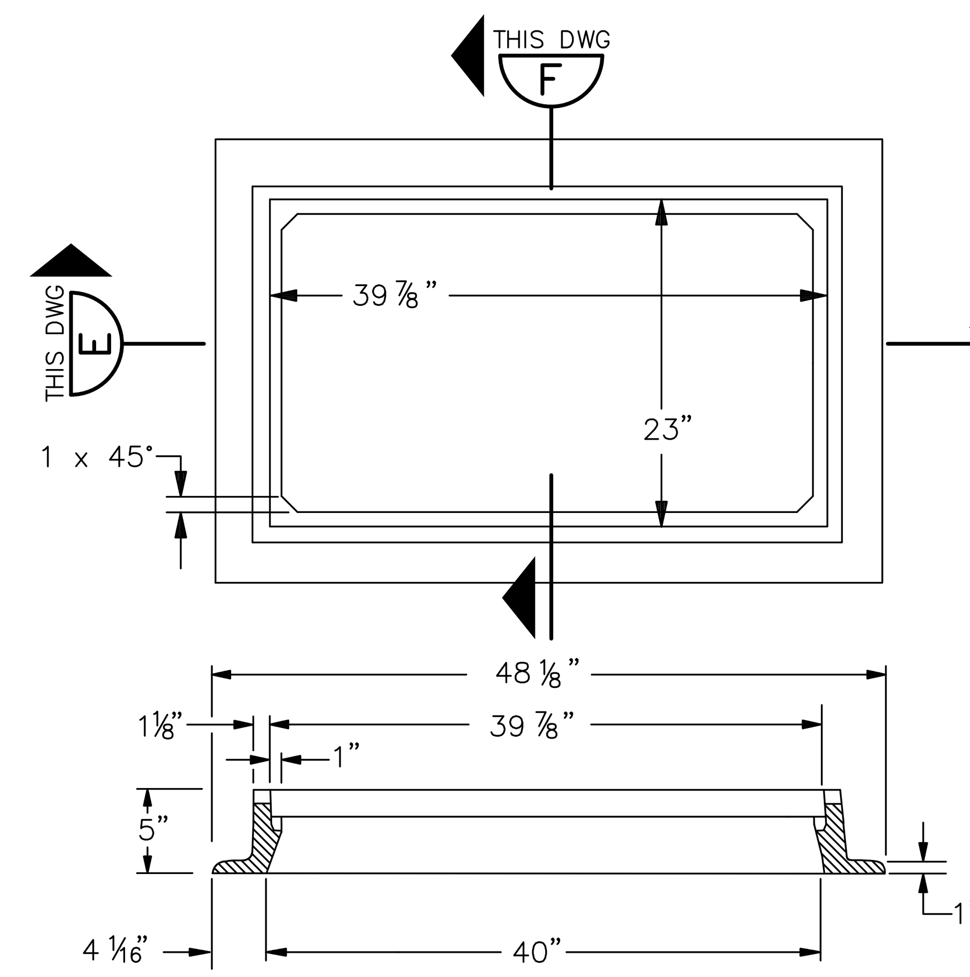
SECTION D–D

NO. 13 GRATE



SECTION C–C

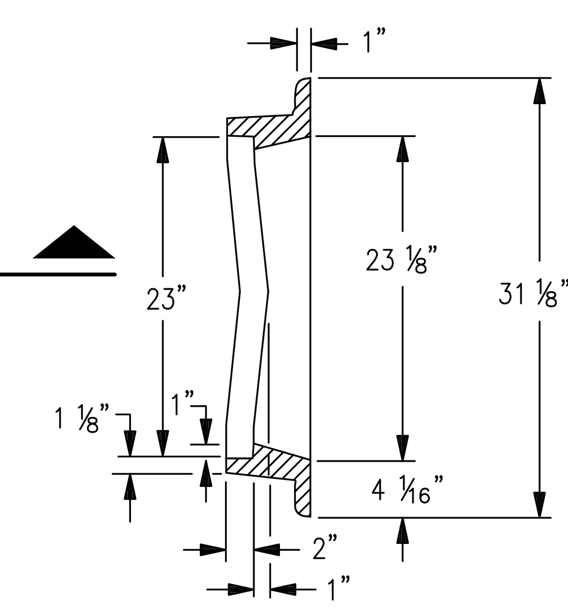
A = 1¾"
B = 11 1/16"
C = 7 15/16"



SECTION E–E

NO. 13 GRATING & FRAMES

APPROX. WEIGHT 590 LBS.



SECTION F–F

NOTES:

1. SEE PLAN DETAILS FOR LOCATION AND SIZE OF PIPE.
2. WHEN BITUMINOUS MATERIAL IS TO EXTEND TO THE EDGE OF THE GRATING FRAME, CONCRETE MAY BE DEPRESSED.
3. CONCRETE SHALL BE CLASS B. INLET MAY BE CAST–IN–PLACE OR PRECAST.
4. CAST–IN–PLACE CONCRETE WALLS SHALL BE FORMED ON BOTH SIDES.
5. EXPOSED CONCRETE CORNERS SHALL BE CHAMFERED ¾ IN.
6. REINFORCING BARS SHALL BE DEFORMED AND SHALL HAVE A 2 IN. MINIMUM CLEARANCE. ALL REINFORCING BARS SHALL BE EPOXY COATED.
7. STEPS SHALL BE PROVIDED WHEN INLET DIMENSION *H* EXCEEDS 3 FT.–6 IN. AND SHALL BE IN ACCORDANCE WITH AASHTO M 199.
8. ALL GRATES AND FRAMES SHALL BE GRAY OR DUCTILE CAST IRON CONFORMING TO CDOT'S 2019 STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION, SECTION 712.06. GRATES AND FRAMES SHALL BE DESIGNED TO WITHSTAND HS 20 LOADING.

QUANTITIES

H	CONCRETE CU YD	REINFORCING STEEL θ LB	NO OF 401 BARS REQD
3'–0"	1.3	72	4
3'–6"	1.5	76	4
4'–0"	1.6	90	5
4'–6"	1.8	104	6
5'–0"	1.9	109	6
5'–6"	2.1	122	7
6'–0"	2.2	136	8
6'–6"	2.4	141	8
7'–0"	2.5	154	9
7'–6"	2.7	168	10
8'–0"	2.8	173	10
8'–6"	3.0	187	11
9'–0"	3.1	200	12
9'–6"	3.3	205	12
10'–0"	3.4	219	13

θ INCLUDES 1% FOR OVERRUN.
NOTE: CONCRETE QUANTITIES INCLUDE VOLUME OCCUPIED BY PIPE.

BAR LIST FOR H=3'–0"

MARK	NO REQD	DIMENSIONS X	DIMENSIONS Y	LENGTH
401	4	3'–6"	2'–2"	13'–4"
402	2	3'–4 ½"	*2'–6 ½"	8'–5 ½"
403	5	2'– ½"	*2'–7"	7'–2 ½"

*ADD 6 IN TO THIS DIMENSION FOR EACH 6 IN INCREASE OF "H" OVER 3 FT–0 IN

CONCRETE INLET TYPE 13 DETAIL (1 / C.02)

NTS

DENVER WATER
1600 West 12th Ave
Denver, Colorado 80204–3412
T: 303.628.6000
F: 303.628.6851
denverwater.org

CONSULTANT

Kiewit

GROSS RESERVOIR EXPANSION

OSPREY POINT QUARRY DEVELOPMENT

REFERENCE:
CAPITAL PROJECTS CONSTRUCTION STANDARDS 3rd Edition

THIS DRAWING IS BASED ON THE DW_GROSS_GRID COORDINATE SYSTEM

No	Date	Description
△		
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△	4/30/21	DRAFT FINAL REVIEW
△	4/16/21	DRAFT FINAL REVIEW
△	2/15/21	DRAFT REVIEW

REVISIONS

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING
0 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

PT NO: 19152
DRAWN BY: PHILIPPI
CHKD BY: FLEMING/
CHKD BY: ZHAO/
APPD BY:
DATE: FEBRUARY 2021
CONTRACT:
AS–BUILT DATE:
AS–BUILT BY:

DRAWING TITLE

CONCRETE INLET TYPE 13 DETAIL

C.17

Appendix D:
Final Quarry Location Report

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September 13, 2016

Final Quarry Location Report: Impact Minimization and Avoidance Measures Moffat Collection System Project

Introduction

Denver Water is in the process of obtaining a Section 404 Permit from the U.S. Army Corps of Engineers (Corps) for the Moffat Collection System Project (Project). The NEPA and Section 404 evaluation processes are nearing completion and the issuance of a Record of Decision by the Corps is expected in 2016. Pursuant to the Corps' mitigation policy at 33 CFR Part 320, Denver Water is seeking the Corps' consideration of Project modifications to minimize adverse Project impacts identified in the Corps' 2014 Final Environmental Impact Statement (FEIS) for the Project, and in response to comments received by the Corps on the FEIS. The purpose of this *Quarry Location Report: Impact Minimization and Avoidance Measures* (Report) is to provide a summary of the findings from the preliminary engineering evaluations completed by Denver Water, which would considerably reduce the quarry and trucking impacts identified in the FEIS.

In response to stakeholder input received during the FEIS process, the Federal Energy Regulatory Commission (FERC) license amendment process, and voluntary public outreach sessions, Denver Water evaluated:

1) the feasibility of producing all aggregate on-site as an alternative to trucking in these materials from an off-site location, and
2) the feasibility of changing the primary quarry location.

The purpose of these feasibility evaluations was to reduce:

1) impacts to National Forest System (NFS) lands,
2) number of surface acres requiring mitigation or reclamation,
3) visual impacts to the viewshed of residences and recreationists, and
4) impacts associated with trucking in aggregates.

This Report provides information on the findings gained from Denver Water's recent preliminary engineering evaluations, specifically concerning:

1) the ability to process both fine (sand) and coarse (gravel) aggregate on-site (thereby reducing the number of truck trips necessary to haul these materials from an off-site location to make concrete),
2) a site comparison of the FEIS Quarry located partially on NFS lands versus an alternative quarry located entirely on Denver Water property and within the new reservoir, and
3) additional activities Denver Water intends to pursue to avoid and minimize Project impacts.

I. Project Background

The existing Gross Dam is an on-stream facility located on South Boulder Creek in Boulder County, Colorado. Gross Reservoir occupies both Denver Water and NFS lands within the Roosevelt National Forest. The dam is owned and operated by Denver Water and provides raw water storage from both west slope transcontinental diversions and from the South Boulder Creek watershed upstream of Gross Dam. The dam structure is a 340-foot tall curved concrete gravity dam with a crest length of 1,050 feet (including the spillway section).

As stated in the FEIS, Denver Water proposes to raise Gross Dam by 131 feet to a final height of 471 feet, increasing storage volume from 41,811 acre-feet to approximately 119,000 acre-feet (Proposed Action). The dam raise would require approximately 930,000 cubic yards of concrete (Corps 2014), which Denver Water estimates would consist of approximately 90 percent sand and gravel aggregate and 10 percent of cement and flyash materials. Section 2.3.2 of the FEIS states "fine aggregates (sand-sized fraction) may be difficult to produce on-site; therefore, supplemental material may be needed from alternative off-site sources." Furthermore, "the majority of the aggregate required to construct the raised dam would be excavated and processed on site" and "alternative quarry sites may be considered, if needed, based on core drilling and laboratory testing, which would be conducted during the design phase." Therefore, the FEIS recognized the need for additional studies to determine if alternate off-site (aggregate) sources would be required to develop the final siting of the primary quarry, and it addressed the possibility of alternative quarry sites at Gross Reservoir.

A. Previous Studies

The FEIS analyzed an on-site hard rock (granite) quarry to supply the needed aggregate for the Project (hereinafter, "FEIS Quarry"). The FEIS Quarry is located north of the existing boat ramp area within the FERC Project Boundary, and occurs on Denver Water property and NFS lands. The FEIS Quarry site would occupy a total area of approximately 29 acres.

Based on a geological reconnaissance by MWH Americas (2006), the Proposed Action assumed the FEIS Quarry would be used to obtain the gravel aggregate; whereas, the sand aggregate would either be produced from this quarry or imported on trucks from a commercial quarry near Longmont, Colorado. No site-specific geotechnical evaluations were completed on the FEIS Quarry to assess the potential to create sand aggregate from the native granite during the development of the FEIS. Therefore, the FEIS' impacts analysis assumed that for traffic, noise, and air quality impacts, all of the sand aggregate would be imported to the site.

B. Recent Studies

Denver Water began advancing the design of the FEIS Quarry in 2013 and has completed several studies to 1) evaluate the potential of the local granite to produce aggregate for concrete, and 2) to evaluate other quarry sites that would minimize site disturbance.

The following four studies, completed between 2015 and 2016, were considered in the development of this Report:

- Geotechnical Report – Gross Reservoir Enlargement (Shannon and Wilson 2015)
- Gross Dam Test Quarry Report (ASI 2015)
- Draft Gross Dam Raise Quarry Evaluation (MWH 2015)
- Geotechnical Data Report – Gross Reservoir Field Investigations (Shannon and Wilson 2016)

The study results were positive, and based on the results, Denver Water proposes to modify the Project to minimize impacts by: 1) producing all of the aggregate material (both sand and gravel) from an on-site quarry, and 2) relocating the quarry site to a location on Denver Water property within the new reservoir inundation area such that all or nearly all of the quarry would be submerged during normal high-water operations.

II. Project Modification to Minimize Impacts

A. Produce All Aggregate On-Site

1. Sand and Gravel Aggregate Can Be Produced On-site

Denver Water developed a small test quarry in 2013 to evaluate the bedrock as a parent source for sand and gravel aggregate. The test quarry evaluation produced positive results in regards to: 1) the ability to make sand aggregate with standard crushing equipment described in the FEIS Quarry operations, 2) good physical properties of the produced sand and gravel aggregate, 3) capability to create both the sand and gravel aggregate on-site, and 4) capability to create concrete with sufficient strength for the new dam raise (ASI 2015). Based on these results, Denver Water intends to design the dam using an on-site quarry to produce both the sand and gravel aggregate.

The FEIS assumed that 60 percent of the material required to make the concrete would be found on-site and 40 percent of the remaining necessary materials (sand aggregate, flyash, and cement) would be hauled from an off-site location (Section 2.8.5; Corps 2014). Instead, by producing all aggregate materials on-site, approximately 90 percent of the materials needed to make the 930,000 cubic yards of total concrete for the dam construction would come from the site and only 10 percent of the remaining materials (cement and flyash) needed to make concrete would need to be hauled from off-site.

2. On-site Production of Aggregate Minimizes Truck Traffic Impacts

By producing all aggregate on-site, this new approach eliminates from the roads those trucks that were estimated for delivering sand aggregate. Effectively, Denver Water estimates that the number of truck trips would be reduced by approximately 72 percent by producing sand aggregate on-site. The FEIS assumed that an average of 22 truck trips per day would be required to haul the 40 percent of remaining components, which included sand aggregate, flyash and cement, required for dam construction from an off-site supply (Section 2.8.5; Corps 2014). The FEIS provides estimates of construction-related traffic impacts, which would occur over a total 4.1 year period for approximately 260 days per year (Section 5.12; Corps 2014). Using these FEIS estimates, for the life of the project (4.1 years), there would be approximately 23,452 trucks in total required to haul the sand aggregate, cement, and flyash (i.e. 22 x 4.1 x 260 = 23,452).

Although the hauling of sand aggregate would be removed from this estimate, the flyash and cement would still require hauling from an off-site supply. Based on the mixed design data in the ASI (2015) report, approximately 163,800 tons of cement and flyash would be needed to make the total concrete. Assuming a 25-ton or 15-cubic yard truck capacity, as analyzed in the FEIS, this equates to approximately 6,552 one way truck trips to import the cement and flyash. Therefore, by producing all of the sand aggregate on-site, approximately 16,900 truck trips (72 percent) would be eliminated from the roads (i.e. 23,452 – 6,552 = 16,900).

3. On-site Production of Aggregate Reduces the Amount of Spoil Material

The ASI (2015) study found that the on-site granodiorite material could be crushed down to aggregate very efficiently with very little reject or material not meeting aggregate specifications. Based on these findings, if only gravel aggregate were to be developed from the parent granodiorite, a large amount of spoil would be created and would require disposal on-site. Fortunately, however, the spoil meets the graduation requirements of the sand aggregate required for concrete production. By using this material on-site rather than disposing it as spoil (ASI 2015), Denver Water estimates that this reduces the amount of spoil material needed to be disposed of on-site.

4. Activities Associated With Producing All Aggregate On-site Are the Same or Similar to the Activities Analyzed in the FEIS to Produce 60 Percent of the Aggregate On-site

a. Blasting

In order to produce all aggregate on-site, a quarry located in granodiorite bedrock would be developed. Development of the quarry would require blasting to break the bedrock into boulder sized particles. As stated in the FEIS, "typically the frequency of blasting would be every 3 to 4 days due to the time it takes to drill the blast holes" (Section 2.3.2.1; Corps 2014). However, Denver Water estimates that blasting could occur on average up to once a day during the quarry operations to accommodate the on-site aggregate production. The boulder-sized rock particles produced from the blast would be loaded into haul trucks and hauled a short distance (1/16 to 1/4 mile) to the rock crushing site, which would either be located within the quarry or just adjacent to the quarry.

b. Processing

The boulder-sized rock particles would be processed with the rock crushing equipment described in the FEIS to produce the sand- and gravel-sized aggregate. The aggregate study completed by ASI (2015) confirmed that sand and gravel sized particles could be created on-site using a tertiary crushing system. Similarly, the FEIS assumed a tertiary crushing process would be used to produce the material needed for the concrete on-site (Appendix I: Rock Crushing/Screening Proposed Action Alt. 1a, Corps 2014). The FEIS analysis was conservative in estimating the processing equipment, processing time, and generator power plant for producing the gravel aggregate.

Consistent with the FEIS, which assumed that three processes would be required to make the gravel aggregate, by using this new approach to produce 100 percent of the aggregate on-site, Denver Water estimates that no additional processing time, equipment, or diesel power would be required. Similar to the FEIS, different material sizes would be sorted between processes to produce aggregate stockpiles consisting of sand aggregate less than 1/8-inch, 1/2-inch, 3/4-inch, and 1 1/2 –inch.

The FEIS states that "the majority of material would be produced prior to the start of construction; therefore, relatively large stockpile areas would be necessary for processing and temporary storage" (Section 2.3.2, Corps 2014). Processing would occur primarily during the day; however, extended operations, up to 24 hours a day, could be possible during the heaviest production periods, which is consistent with the FEIS. In total, about 24 months of rock quarrying and processing would be required to create the required sand and gravel aggregate on-site. Consistent with the FEIS, rock and aggregate crushing equipment would be powered by a series of six to seven 125 to 150 horsepower diesel engines and engine-generator sets with run times similar to what was presented in the FEIS. Thus, Denver

Water estimates that no additional generators would be needed to support processing of both the sand and gravel aggregate on-site.

Denver Water is evaluating opportunities to power this equipment with temporary electrical service from the existing hydropower plant, which would result in reduced emissions and noise. Aggregate production would likely precede concrete production with aggregate stockpiled for several months before use. This would allow aggregate production to occur primarily during the day; however, extended operations, up to 24 hours per day, could possibly be required at times. In total, Denver Water estimates that approximately 796,000 cubic yards of finished aggregate would be developed from the on-site quarry.

c. Stockpiles

Relatively large stockpile areas would be necessary for processing and temporary storage. As shown on Figure 2-3 in the FEIS, two tentative stockpile areas have been identified on-site: one is adjacent to the FEIS Quarry site and the second is located west of the dam (Corps 2014). The FEIS states that the exact size and location of the stockpile areas would be identified during final design and by the construction contractor, whereby wetland and riparian areas and other sensitive ecological resources would be avoided (Section 2.0; Corps 2014).

Based on the recent engineering evaluations, Denver Water estimates that there would be four to five different stockpiles each with specified particle sizes. However, Denver Water estimates that the size of the stockpile areas would not increase from the acreage footprints for the two stockpiles analyzed in the FEIS. Consistent with the FEIS, Denver Water intends to develop the exact size and location of the stockpile areas during the final design, avoiding wetland/riparian areas and other sensitive ecological resource areas.

d. Transport of Aggregate Material to the Dam Site

From the stockpile area locations, the aggregate material would then be transported to the dam construction site along a temporary haul road with haul trucks or along the haul road via a conveyor system, consistent with the FEIS. This temporary haul road would be a gravel road up to approximately 50 feet wide (Appendix I, Corps 2014), but might be able to be reduced to a maximum of 40 feet wide depending on the size of the haul trucks (MWH 2015). Based on the FEIS analysis, there are no known sensitive habitats or cultural resources in the vicinity of the proposed haul road (Corps 2014). The portions of the temporary haul road and stockpile areas that are located above the new high water line would be reclaimed or restored to their approximate original condition or incorporated into the final facility improvements necessary for dam operation. Denver Water continues to evaluate opportunities to minimize stockpile and haul road impacts and will define the final extents of stockpiles during the final engineering design phase.

5. Summary

Regardless of the quarry location, to produce 100 percent aggregate on-site truck trips on CO HWY 72 and Gross Dam Road would be reduced by approximately 72 percent. Blasting frequency, as described in the FEIS as "typically occurring every 3-4 days" might be more frequent and occur daily at times. And, the volume of produced aggregate would increase by approximately 370,000 cubic yards, as compared to the 426,000 cubic yards included in the FEIS analysis, for a total of 796,000 cubic yards of site-produced aggregate. There would be no change to processing, equipment type, diesel power usage, total stockpile acreage or proposed haul roads.

B. Relocate Quarry to Osprey Point

Denver Water completed geotechnical drilling in 2014 and 2015 at two potential quarry sites: the FEIS Quarry site and at a site along the existing access road to Osprey Point (also known as the Haul Road Recreation Area) (hereinafter, "Osprey Point Quarry"). The results from both investigations were positive and indicate that there is sufficient quality and quantity of bedrock to make the required sand and gravel aggregate for the dam construction from either site. Based on these results, the Osprey Point Quarry is the preferred quarry site because it provides several advantages over the FEIS Quarry. The most notable advantage is that the majority of this quarry is located within the expanded reservoir footprint that would be inundated and covered when the reservoir is filled (MWH 2015).

The Osprey Point area was first identified as a possible quarry location during the FEIS development; however, this site was not considered a reliable quarry alternative at the time owing to the fact that a documented fault was identified in this area, and without the completion of a full geotechnical evaluation, the effects of the fault on the quality of the local granite material were unknown. In response to stakeholder concerns and comments received on the FEIS in regards to the impacts to NFS land and visual impacts from the FEIS Quarry, Denver Water has completed several geotechnical evaluations on the Osprey Point Quarry site to date, which conclude that the site is suitable for producing aggregate for the Project. Thus, by utilizing the Osprey Point Quarry Denver Water is able to relocate the quarry to Denver Water land to avoid NFS resource impacts and to a location that would occur below the new high water line (i.e. in an area that was already analyzed as being impacted), which has the added benefit of avoiding the visual impacts and land disturbance associated with the FEIS Quarry.

Although initial investigations concluded that the Osprey Point Quarry would be adequate to supply the material needed for the dam construction, it is the industry standard to have a back-up or alternate quarry site identified and proved prior to starting a dam construction project where borrow aggregate is the primary source for building material. As such, the FEIS Quarry location would only be utilized in the event that the material encountered in the Osprey Point Quarry is not suitable for dam construction.

1. Osprey Point Quarry - Site and Configuration

As shown in **Attachment 1**, the Osprey Point Quarry site is located at the Osprey Point boat launch west of the proposed auxiliary spillway/saddle dam, whereas the FEIS Quarry is located to the north of the Osprey Point Quarry within the extent shown in the FEIS along a rock knob. The Osprey Point Quarry is located adjacent to the FEIS Quarry, yet it has many advantages over the FEIS Quarry. It was designed so that the quarry pit would occur below the new high water line of Gross Reservoir once the reservoir is raised (MWH 2015). In addition, the Osprey Point Quarry configuration results in exposure of a much lower highwall than the FEIS Quarry, which eliminates or greatly minimizes visual impacts. Also, it is located entirely on Denver Water property and eliminates quarry impacts on NFS lands. Additionally, it requires significantly less site disturbance to develop, reclaim, and retire post-construction since most (if not all) of the quarry pit would be inundated.

As shown in **Figures 1** and **2**, renderings of the post-construction conditions of the Osprey Point Quarry as compared to the FEIS Quarry illustrate the substantial benefits of this new quarry location as the preferred quarry for reducing impacts to visual resources in the viewshed of residences and recreationists at Gross Reservoir and for eliminating such impacts on NFS lands.

a. Osprey Point Quarry Minimizes Ground Disturbance Impacts

As stated in the FEIS, the FEIS Quarry "is sized to produce at least twice the volume of aggregate required for construction" (Section 2.3.2, Corps 2014). Similarly, the Osprey Point quarry would be sized to produce at least twice the volume of aggregate required for construction. However, to achieve the same amount of volume, the footprint of the Osprey Point Quarry would be smaller at approximately 14 to 16 acres (MWH 2015) as compared to the 29-acre extent identified and analyzed for the FEIS Quarry. Therefore, because the Osprey Point Quarry would have a smaller footprint and since the location of the quarry would allow for it to be optimally designed to be entirely submerged below the new high water line, this quarry site minimizes ground disturbance impacts as compared to the impacts analyzed for the FEIS Quarry.

The Osprey Point Quarry would be developed in two phases. In the first phase, the west end of the quarry would be mined first and the overburden would be placed in the east end of the quarry to create a working pad for material processing and stockpiling. The first phase would be able to generate approximately 1.6 million tons (approximately 1 million cubic yards) of finished aggregate material. If additional material is required, the working pad and additional overburden would be removed from the east end of the quarry to access an additional 1.6 million tons of finished aggregate material.

b. Osprey Point Quarry Eliminates or Greatly Minimizes Visual Impacts

During construction, at full build-out the Osprey Point Quarry highwall would be approximately 150-160 feet in height (MWH 2015). Post-construction, the area of the highwall remaining above the new high water line could range from fully submerged up to approximately 3 acres. Any remaining portions of the exposed highwall would be benched with 40-foot vertical walls and 20-foot horizontal benches (MWH 2015). Two quarry layouts have been developed for this quarry site by MWH Americas (2015), the most optimistic quarry layout would result in a quarry completely submerged below the new reservoir, while a more conservative layout would result in approximately 55 vertical feet of highwall exposed above the new high water level. Both layouts present a significant opportunity to minimize upland disturbance to the site as compared to the FEIS Quarry location. By comparison, the extent of the FEIS Quarry would include up to approximately 29 acres as shown in the FEIS. Post-construction for the FEIS Quarry, the remaining benched areas exposed above the new high water line would require mitigation treatments to the rock slopes. Preliminary analyses by MWH Americas (2015) estimate that for the FEIS Quarry approximately 250 feet would remain above the water surface revealing an exposed rock face with benches approximately 13 acres in size. Therefore, the Osprey Point Quarry would eliminate or greatly minimize visual impacts as compared to those analyzed in the FEIS for the FEIS Quarry (refer to **Figures 1** and **2**).

c. Osprey Point Quarry Site to be Located within the FEIS Spoil Area

As shown in Figure 2-3 in the FEIS, the Osprey Point Quarry site would be located in the spoil area identified for Project spoils. This spoil area was designed to be submerged below the new high water line of the reservoir.

2. Osprey Point Quarry Operations - Similar To the FEIS Quarry Operations

Regardless of the quarry location, as stated in the FEIS during construction quarry excavation below the normal water line would occur as the reservoir is lowered during normal operation. The final quarry configuration would be developed during final design and in coordination with the FERC Division of Dam Safety and Inspections and the independent Board of Consultants. As described in the FEIS, Denver Water intends to operate the reservoir in accordance with normal operating procedures during construction.

a. Blasting

Regardless of the quarry location, the description of blasting operations in paragraph II(A)(4)(a) above would apply for dam construction.

b. Processing

Regardless of the quarry location, the description above in paragraph II(A)(4)(b) for material processing would apply for the dam construction.

c. Stockpiles

Stockpile areas for the Osprey Point Quarry would be at the quarry, dam, or along the existing road connecting the quarry to the dam site. Preliminary evaluations show enough stockpile area exists in or adjacent to these areas. Other stockpile areas include those shown in the FEIS for the FEIS Quarry; although, Denver Water's impact minimization method is to minimize the number of stockpiles by also utilizing the Osprey Point Quarry and dam sites for stockpiling. Therefore, impacts associated with the stockpiles for the Osprey Point Quarry would be similar to those analyzed for the FEIS Quarry.

Regardless of the quarry location, the description above in paragraph II(A)(4)(c) for stockpiles would apply.

d. Transporting Materials

Specifically for the Osprey Point Quarry, the existing Gross Dam road and the Osprey Point boat launch road provide access to the site. The existing Gross Dam road crosses Denver Water and NFS lands and would serve as the main haul route to transport finished aggregate material to the concrete batch plant at the dam site. As described above, a haul road approximately 50 feet wide to transport materials to the dam site was analyzed in the FEIS. This existing road would need to be temporarily widened to accommodate off-road haul traffic and normal construction traffic. Post-construction, the road would be reclaimed to its original condition. Alternatively, as described in the FEIS, a conveyor system may be an economical solution to move the material from the quarry to the dam site.

Regardless of the quarry location, the description of material transport in paragraph II(A)(4)(d) above would apply for the dam construction.

e. Post Quarry Operations and Construction Reclamation

1. FEIS Quarry

The quarry configuration presented in the FEIS shows that the east half of the FEIS Quarry would be mined using benched slope construction and the west half would be an un-benched quarry excavation; whereas, the un-benched quarry areas would be designed to be completely submerged below the new high water line of the reservoir (FEIS Figure 2-3, Corps 2014). During construction, the extent of the FEIS Quarry would include up to approximately 29 acres as shown in the FEIS. Post-construction, the remaining benched areas exposed above the new high water line would require mitigation treatments to the rock slopes. Preliminary analyses by MWH Americas (2015) estimate that approximately 250 feet would remain above the water surface revealing an exposed rock face with benches up to 13 acres in size.

Post-construction, a portion of the FEIS Quarry would be exposed bedrock in a benched slope formation. For planning purposes, the FEIS indicated that the exposed rock would consist of a cut slope at approximately 20% grade with a series of horizontal benches cut across the face of the slope (Corps 2014). Since a portion of the FEIS Quarry is located on NFS land, a U.S. Forest Service (USFS) condition under the FERC License would require Denver Water to acquire a mineral materials permit and provide a reclamation plan to USFS for its approval prior to ground-disturbing actions on NFS land. As described in the FEIS, mitigation of the FEIS Quarry would consider a range of mitigation, reclamation alternatives and techniques, such as benching, rock sculpting (shaping the exposed rock to mimic a natural rock face), and selective planting to break up the scale of the exposed area and soften the contrasts with adjacent areas. The use of rock staining would also be considered, provided that its application would not create any water quality concerns.

2. Osprey Point Quarry

In contrast, post-construction mitigation and reclamation activities would be minimal for the Osprey Point Quarry since most or all of the quarry site would be inundated by the new reservoir. Regardless, the uppermost benches would be regraded to reduce vertical walls and cliffs along the reservoir edge. The quarry would also be rough graded to drain back towards the reservoir as part of the site decommissioning. If the final configuration results in a portion of the quarry highwall exposed above the new water level, mitigation activities similar to those described in the FEIS would be used on the exposed rock slopes. However, Denver Water is optimistic that the layout of the Osprey Point Quarry would allow for the entire quarry to be inundated by the new reservoir. Therefore, Denver Water would only mine above the new high water line if required by material characteristics or quantities criteria.

As described in the FEIS and applicable to the preferred Osprey Point Quarry, quarry mitigation for any remaining exposed highwall would consider a range of reclamation alternatives and techniques, such as benching, rock sculpting (shaping the exposed rock to mimic a natural rock face), and selective planting to break up the scale of the exposed area and soften the contrasts with adjacent areas. The use of rock staining would also be considered, provided that its application would not create any water quality concerns.

Table 1 below highlights the minimization of impacts afforded by the Osprey Point Quarry site as compared to the FEIS Quarry. **Figures 1 and 2** demonstrate the difference in visual impacts

TABLE 1: COMPARISON OF OSPREY POINT QUARRY AND FEIS QUARRY

	Estimated disturbance area of pit development during construction[1,2]	Total estimated disturbance area of pit development and related activities[2] (i.e. quarry access road, spoil areas, stockpile areas)	Height of highwall during construction[1]	**POST-CONSTRUCTION Height of highwall exposed above the new high water line[1]**	**POST-CONSTRUCTION Area of highwall exposed above the new high water line[1,2]**
Osprey Point Quarry *(Primary site)*	14-16 ac	41-43 ac	150-160 ft	**0-55 ft**	**0-3 ac**
FEIS Quarry *(Backup site)*	29 ac	56 ac	375 ft	**250 ft**	**13 ac**

Notes: ft = feet, ac = acre
Sources:
[1]MWH 2015. MWH considered two design options for the quarry footprint of the Osprey Point Quarry to meet the objective of reducing quarry impacts.
[2]Corps 2014. Final Environmental Impact Statement for the Moffat Collection System Project.

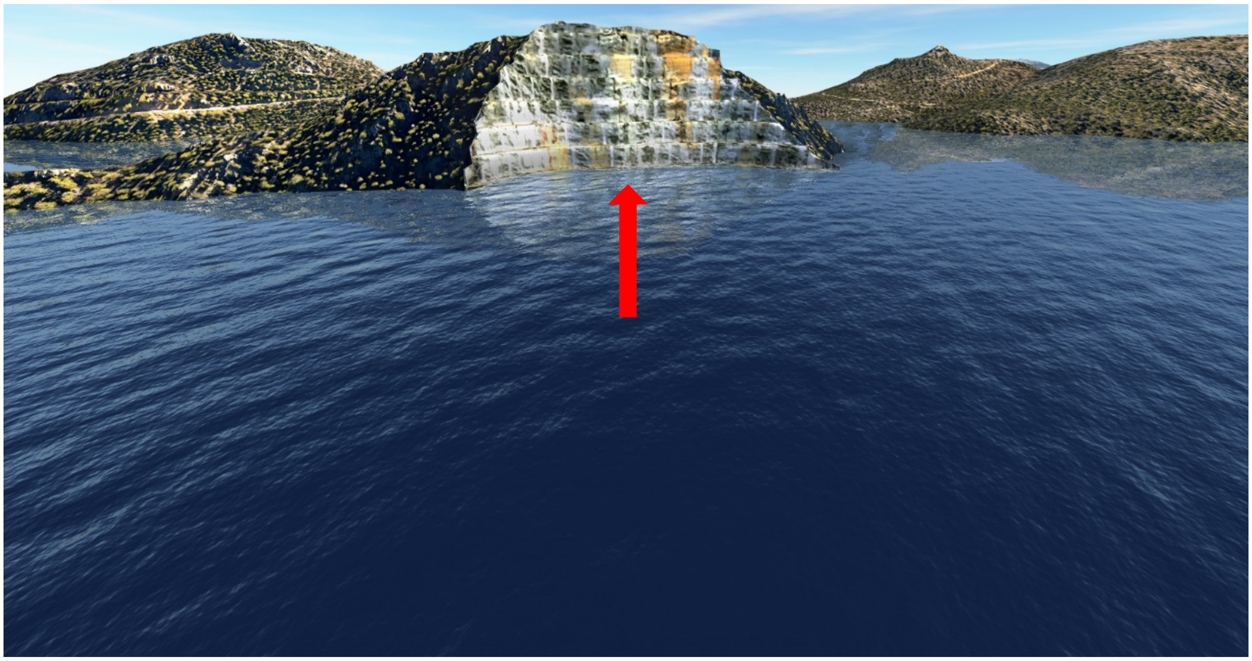


Figure 1 - FEIS Quarry Highwall - Rendering at new High Water Level

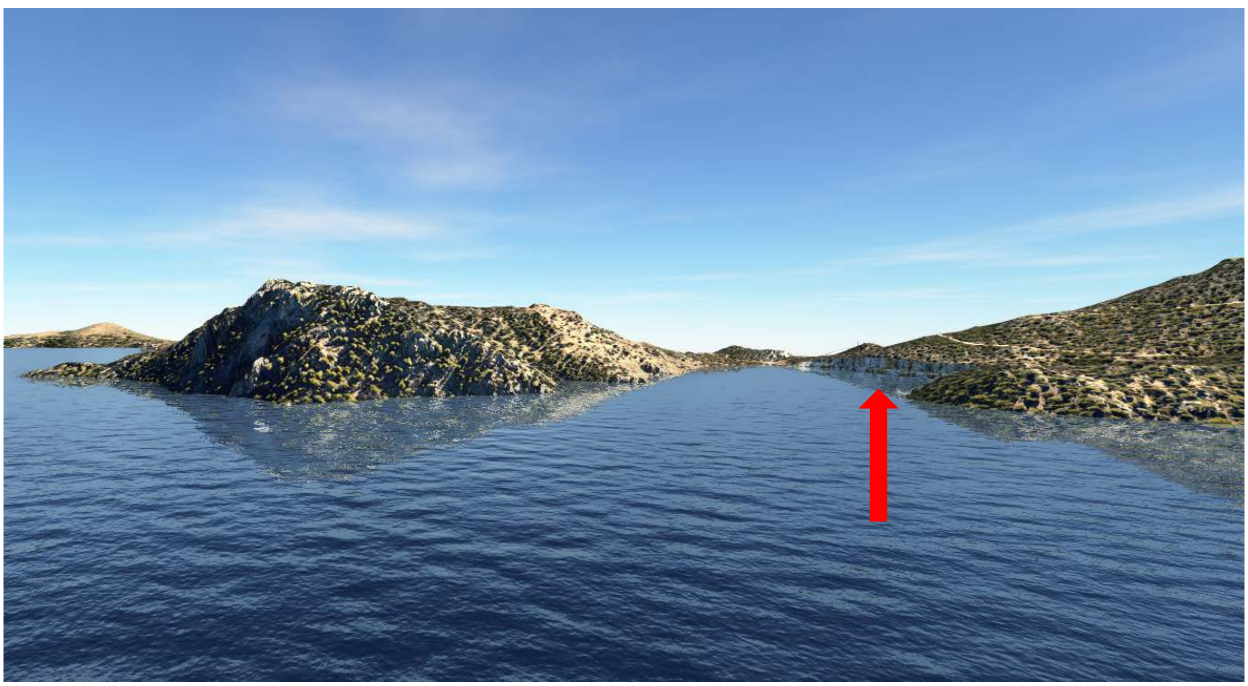


Figure 2 - Osprey Point Quarry Highwall – Rendering at new High Water Level

3. Comparison of Resource Impacts of FEIS Quarry and Osprey Point Quarry

The following analysis shows that ***for each resource category***, even though Denver Water proposes a change in the quarry location, the impacts of the quarry activities to be conducted at the Osprey Point Quarry site will either ***be similar to*** or ***less than*** those impacts analyzed for the FEIS Quarry.

Surface Water

Proposed Action Effects. ***No permanent or temporary impacts*** to surface water are anticipated from the FEIS Quarry site or the proposed spoil area shown at Osprey Point (Section 5.1, Corps 2014). The quarry activities to be conducted at the Osprey Point Quarry site would be similar to those analyzed for the FEIS Quarry site under the Proposed Action. The change in quarry location does not change surface water hydrology (stream flows, reservoir volumes, surface area and levels, and floodplains). Therefore, ***no permanent or temporary impacts*** to surface water are anticipated from implementation of the Osprey Point Quarry site.

Cumulative (Total Environment) Effects. ***No cumulative effects*** to surface water were identified related to the FEIS Quarry site (Section 4.6.1, Corps 2014). Since the quarry activities to be conducted at the Osprey Point Quarry site would be similar to those analyzed for the FEIS Quarry site, ***no cumulative effects*** to surface water are anticipated from the change in location or implementation of the Osprey Point Quarry site.

Water Quality

Proposed Action Effects. ***No permanent or temporary impacts*** to water quality are anticipated from the FEIS Quarry site or the proposed spoil area shown at Osprey Point (Section 5.2, Corps 2014). The quarry activities to be conducted at the Osprey Point Quarry site would be similar to those analyzed for the FEIS Quarry site under the Proposed Action. The change in location does not change reservoir water quality. The geotechnical studies completed for both sites show consistent granodiorite and quartz monzonite that would be exposed with no indication of adverse water quality characteristics such as heavy metals or acid generating rock. Therefore, ***no permanent or temporary impacts*** to water quality are anticipated from implementation of the Osprey Point Quarry site.

Cumulative (Total Environmental) Effects. ***No cumulative effects*** to water quality were identified related to the FEIS Quarry site (Section 4.6.2, Corps 2014). Since the quarry activities to be conducted at the Osprey Point Quarry site would be similar to those analyzed for the FEIS Quarry site, ***no cumulative effects*** to water quality are anticipated from implementation of the Osprey Point Quarry site.

Channel Morphology

Proposed Action Effects. ***No permanent or temporary impacts*** to channel morphology are anticipated from either the FEIS Quarry site or the Osprey Point Quarry site (Section 5.3, Corps 2014). As stated in the FEIS, channel morphology would not be impacted by construction activities at Gross Reservoir. Project impacts to channel morphology are associated with flow changes and not the location of the quarry. Thus, this section is not applicable.

Groundwater

Proposed Action Effects. ***No permanent or temporary impacts*** to groundwater are anticipated from the FEIS Quarry site or the proposed spoil area (Section 5.4, Corps 2014). The quarry activities to be conducted at the Osprey Point Quarry site would be similar to those analyzed for the FEIS Quarry site under the Proposed Action. The change in quarry location does not affect groundwater. Therefore, ***no permanent or temporary impacts*** to groundwater are anticipated from implementation of the Osprey Point Quarry site.

Cumulative (Total Environmental) Effects. ***No cumulative effects*** to groundwater were identified related to the FEIS Quarry site (Section 4.6.4, Corps 2014). Since the quarry activities to be conducted at the Osprey Point Quarry site would be similar to those analyzed for the FEIS Quarry site, ***no cumulative effects*** to ground water are anticipated from implementation of the Osprey Point Quarry site.

Geology

Proposed Action Effects. Under the Proposed Action (including the FEIS Quarry site) there would be an unavoidable loss of geologic resources (i.e., bedrock, sand, and gravel deposits) and alteration of topography associated with the use of borrow materials, which would be a ***permanent impact***. Overall, the Proposed Action (including the FEIS Quarry site) would result in the ***unavoidable adverse impact*** of loss of geologic resources and alteration of topography associated with the use of borrow materials (Section 5.5, Corps 2014). ***Regardless of the quarry location***, the results of the recent technical studies confirmed the geologic resources are similar and confirmed the feasibility of mining 100 percent of the aggregate on-site. The volume of geologic resources lost would increase from an estimated 426,000 cubic yards of finished aggregate (Corps 2014) to 796,000 cubic yards; however, the surface area to be disturbed would be less.

Other potential issues identified in the FEIS relate to the Proposed Action's impacts to geologic resources include seismicity and landslides. The analysis conducted in the Corps' FEIS does not indicate whether the potential for seismic events or landslides appreciably increases in the areas outside of the FEIS Quarry footprint. However, the findings of recent technical studies provide reasonable assurance based on field tests that in comparison to the FEIS Quarry subsurface conditions at the Osprey Point Quarry Site are generally similar in character to those at the FEIS Quarry site (Olson Engineering 2015; Appendix A in Shannon and Wilson 2016; Shannon and Wilson 2015). Olson Engineering (2015) performed a geophysical survey of the Osprey Point Quarry area with the goal of identifying the subsurface expression of the Rogers Fault. Seismic refraction tomography (SRT) was used to acquire the geophysical data. Olson Engineering (2015) concluded that "the Rogers Fault is either non-existent in the Osprey Point valley area, or has not significantly altered the adjacent bedrock in the areas investigated in such a way as to appreciably degrade aggregate resource quality" and "if there is a fault in this area, it is likely a discrete, narrow feature." Therefore, based on this analysis Denver Water believes that landslide or seismicity issues would not compromise dam safety or other quarry construction-safety issues due to the siting of the quarry at Osprey Point rather than at the FEIS Quarry site.

Regardless of the quarry location, Denver Water and the selected contractor would follow all reasonable and prudent measures to ensure the safety of the quarry site and dam construction site. Compliance with the FERC Division of Dam Safety and Inspection would require Denver Water to develop site and dam safety plans for the construction activities including a potential failure modes analysis and an emergency action plan. The FEIS states that potential issues related to geologic resources would be addressed through geotechnical and seismic studies in the design and construction phases, which Denver Water would conduct prior to construction ***regardless of the quarry location***. The approach for the Osprey Point Quarry would remain unchanged from the FEIS, whereby intermittent blasting by explosives such as ANFO (Ammonium Nitrate Fuel Oil) would occur during the early phases of construction as aggregate supplies are needed for dam construction.

Cumulative (Total Environmental) Effects. The Proposed Action (including the FEIS Quarry site) and reasonably foreseeable future actions (RFFAs) would contribute to the removal and use of sand and gravel deposits for dam construction at Gross Reservoir. Other current and projected land development activities would result in demands for sand and gravel resources in the general area, creating a ***minor cumulative effect*** to geological resources under the Proposed Action (including the FEIS Quarry site)(Section 4.6.5, Corps 2014). Cumulative impacts to geologic resources associated with the Osprey Point Quarry site are anticipated ***to be the same as or slightly less than*** those for the FEIS Quarry site.

Soils

Proposed Action Effects. Expansion of the dam, reservoir and related facilities would cause ***permanent impacts*** to soils under the Proposed Action (including the FEIS Quarry site and proposed spoil area shown at Osprey Point). Best management practices (BMPs), environmental protection, and erosion control measures would be implemented as mitigation for impacts to soils. Overall, under the Proposed Action (including the FEIS Quarry site and proposed spoil area) there would be ***some unavoidable adverse impacts*** to soils, such as soil losses, even with the use of appropriate erosion control measures on account of the high erosive potential of some soils (Section 5.6, Corps 2014). According to the NRCS soil survey, the FEIS Quarry is located on units 2705D and 4703D (Table F-1, Corps 2014). The Osprey Point Quarry is located on units 2703B and 2717B. All the units were evaluated in the FEIS, are very similar in nature, and do not consist of Prime Farmland or Soils of Statewide Importance. Additionally, the units located beneath the FEIS Quarry have identified potential limitation of severe water erosion hazard while the units located beneath the Osprey Point Quarry were identified as moderate to severe water erosion hazard. In summary, the soil units are of such similar characteristics that no discernable difference in impacts could be made by switching the quarry site. By comparison, the Osprey Point Quarry site is less susceptible to erosion than the FEIS Quarry site. This is due to the steeper slopes of the FEIS Quarry site. Additionally, because a smaller area would be disturbed from the Osprey Point Quarry and the area needing reclamation would be reduced or eliminated, there would be a reduced potential for long-term soil erosion issues as compared to the FEIS Quarry. For these reasons, impacts to soils associated with the up to 16-acre Osprey Point Quarry site ***would be less than*** those for the 29-acre FEIS Quarry site.

Cumulative (Total Environmental) Effects. Expansion of the dam, reservoir and related facilities would cause impacts to soils under the Proposed Action (including the FEIS Quarry site and proposed spoil area) with RFFAs. These impacts would be minimized during construction by implementing BMPs. Overall, ***minimal cumulative effects*** to soils are anticipated within the Gross Reservoir area under the Proposed Action (FEIS Quarry site)(Section 4.6.6, Corps 2014). Cumulative impacts to soils associated with the up to 16-acre Osprey Point Quarry site are anticipated ***to be less than*** those for the 29-acre FEIS Quarry site.

Vegetation

Proposed Action Effects. Under the Proposed Action ***temporary impacts*** would occur from the dam enlargement, construction of the auxiliary spillway and channel, operation of the quarry, and use of spoil and stockpile areas. ***No permanent impacts*** are anticipated since Denver Water would coordinate with the USFS to ensure appropriate reclamation of the FEIS Quarry site on NFS land. Overall, the FEIS

Quarry site under the Proposed Action would result in ***unavoidable adverse impacts*** due to the loss of vegetated acres and the creation of favorable conditions for the establishment of noxious weeds as a result of construction and operation (Section 5.7, Corps 2014). The Osprey Point Quarry location has the same vegetation type as the FEIS Quarry; coniferous forest land with Ponderosa pine and Douglas fir communities, talus slopes and rock outcrops. Impacts to vegetation associated with the 16-acre Osprey Point Quarry site ***would be less than*** those associated with the 29-acre FEIS Quarry site; however, the Osprey Point Quarry site would occur entirely on Denver Water property thereby ***eliminating unavoidable adverse impacts*** to vegetation on NFS lands caused by the FEIS Quarry site.

If the Osprey Point Quarry on Denver Water land is used, in part to minimize impacts, Denver Water would develop a Quarry Reclamation Plan for areas above the new high water line, if any. Depending on the final configuration of the Osprey Point Quarry, the majority or optimally the entirety of the quarry pit and highwall would be submerged by the new reservoir water level (MWH 2015); therefore, minimal reclamation is anticipated. If portions of the Osprey Point Quarry remain exposed above the new high water line, than the mitigation and reclamation techniques to be applied would be the same as those discussed in the FEIS for the FEIS Quarry (Section 5.17; Corps 2014). Denver Water would consult with the Corps, Boulder County, and Colorado Division of Reclamation and Mine Safety to develop reclamation measures for Denver Water land. Denver Water would submit a draft Quarry Reclamation Plan to FERC and the Corps, if required, prior to any land disturbance and a final plan within one year after quarry activities are complete.

Cumulative (Total Environmental) Effects. ***No cumulative effects*** to vegetation were identified related to the FEIS Quarry site (Section 4.6.7, Corps 2014). Since the quarry activities to be conducted at the 16-acre Osprey Point Quarry site would be similar to and would cover a reduced impact area than those analyzed for the 29-acre FEIS Quarry site, ***no cumulative effects*** to vegetation are anticipated from implementation of the Osprey Point Quarry site.

Riparian and Wetland Areas

Proposed Action Effects. The entire footprint of the Proposed Action, as described in the FEIS, would result in ***permanent impacts*** to 1.95 acres of wetlands, ***temporary impacts*** to 0.12 acres of wetlands, ***permanent impacts*** to 3.53 acres of Other Waters of the U.S., ***temporary impacts*** to 0.49 acres of Other Waters of the U.S., and ***permanent impacts*** to 4.1 acres of riparian habitat from construction of the dam and subsequent inundation from filling the expanded reservoir (Section 5.8, Corps 2014). The FEIS states that all impacted wetlands and Other Waters of the U.S. features would be mitigated in accordance with the Corps' mitigation policies in the conditions of the Section 404 Permit for the Project (Section 5.8, Corps 2014).

Figure 3.8.1 in the FEIS shows that there are no wetland, riparian, or Other Waters of the U.S. features identified within the footprint of the FEIS Quarry (Section 3.0; Corps 2014). In comparison, this same figure shows one Palustrine Scrub-Shrub (PSS) wetland feature (approximately 0.02 acres; GR14-1) occurring near the shoreline of the existing reservoir water level in the area proposed for the Osprey Point Quarry footprint. However, this one PSS wetland feature is located within the proposed spoil area and inundation area of the new high water line. As the FEIS concludes "the majority of impacts [to wetlands] would be associated with the 77,000 AF reservoir enlargement, including tree removal" (Section 5.8; Corps 2014). So, ***regardless of the quarry location***, this PSS wetland feature would be impacted by the proposed spoil area and inundated by the dam raise under the Proposed Action.

Figure 3.8.1 also shows a total of two woodland/shrubland riparian areas within the footprint of the FEIS Quarry. In comparison, this figure shows a total of three woodland/shrubland riparian areas located in the area proposed for either the spoil area or the Osprey Point Quarry footprint. ***Regardless of the quarry location***, these five woodland/shrubland riparian areas would be impacted and are located within the proposed inundation area of the new high water line.

Impacts to Other Waters of the U.S., riparian areas, and wetlands associated with the Osprey Point Quarry site are anticipated ***to be the same*** as those for the FEIS Quarry site, whereby all impacts to Other Waters of the U.S., riparian areas, and wetlands would be fully mitigated by Denver Water "in accordance with current Corps mitigation policies and the conditions of the Section 404 Permit" to ensure no net loss (Section 5.8.7; Corps 2014).

Cumulative (Total Environmental) Effects. The Proposed Action (including the FEIS Quarry site) with RFFAs would result in ***permanent impacts*** to 1.95 acres of wetlands and 4.1 acres of riparian habitat from construction and inundation (Corps 2014). Impacts would mostly occur from inundation of creek inlets and the existing shoreline. RFFAs are not likely to have adverse effects on wetlands and riparian areas at Gross Reservoir, beyond those associated with the Proposed Action (including the FEIS Quarry site), because no major actions that would impact wetlands or riparian areas are planned in these areas. In addition, ***permanent losses of wetlands are unlikely*** because of mitigation and permitting requirements under Section 404 of the Clean Water Act for the Project (Section 4.6.8, Corps 2014). Cumulative impacts to riparian and wetland areas associated with the Osprey Point Quarry site are anticipated ***to be the same*** as those for the FEIS Quarry site, whereby all impacts would be fully mitigated to ensure no net loss.

Wildlife

Proposed Action Effects. ***Permanent, direct impacts*** to wildlife would result from loss or degradation of habitat, mortality from ground-disturbing activities, and from vegetation clearing and inundation of natural habitat under the Proposed Action (including the FEIS Quarry and proposed spoil area). Both quarry locations have the same wildlife habitat types. Impacts to wildlife habitat associated with the 16-acre Osprey Point Quarry site are anticipated ***to be less than*** those associated with the 29-acre FEIS Quarry site based on area disturbed. ***Temporary impacts*** consist of displacement of wildlife by noise and disturbance resulting from on-site construction, blasting, quarrying, and transport of materials and people. ***Temporary impacts*** to wildlife due to quarry activities, in particular, ***would be the same regardless of quarry location*** because the type of activities, schedule and durations contemplated and analyzed for the quarry construction and operation in the FEIS (except for blasting) would not change due to the new approach to be used to produce 100 percent aggregate on-site. ***Temporary impacts due to blasting may increase regardless of location*** because the frequency of blasting may increase resulting in additional temporary disturbance during the quarry production.

Cumulative (Total Environmental) Effects. ***No cumulative effects*** to wildlife were identified related to the FEIS Quarry site or proposed spoil area (Section 4.6.9, Corps 2014). Since the quarry activities to be conducted at the Osprey Point Quarry site and type of wildlife habitat would be similar to those analyzed for the FEIS Quarry site, ***no cumulative effects*** to wildlife are anticipated from implementation of the Osprey Point Quarry site.

Special Status Species

Proposed Action Effects. ***No permanent or temporary impacts*** to special status species are anticipated from the FEIS Quarry site or proposed spoil area (Section 5.10, Corps 2014). There are no known special status species or habitat at either quarry location. The quarry activities to be conducted at the Osprey Point Quarry site would be similar to those analyzed for the FEIS Quarry site under the Proposed Action. Therefore, ***no permanent or temporary impacts*** to special status species are anticipated from implementation of the Osprey Point Quarry site.

Cumulative (Total Environmental) Effects. ***No cumulative effects*** to special status species were identified related to the FEIS Quarry site or proposed spoil area (Section 4.6.10, Corps 2014). Since the habitat and quarry activities to be conducted at the Osprey Point Quarry site would be similar to those analyzed for the FEIS Quarry site, ***no cumulative effects*** to special status species are anticipated from implementation of the Osprey Point Quarry site.

Aquatic Biological Resources

Proposed Action Effects. ***No permanent or temporary impacts*** to aquatic biological resources are anticipated from the FEIS Quarry site and proposed spoil area (Section 5.11, Corps 2014). The quarry activities to be conducted at the Osprey Point Quarry site would be similar to those analyzed for the FEIS Quarry site under the Proposed Action. Therefore, ***no permanent or temporary impacts*** to aquatic biological resources are anticipated from implementation of the Osprey Point Quarry site.

Cumulative (Total Environmental) Effects. ***No cumulative effects*** to aquatic biological resources were identified related to the FEIS Quarry site or proposed spoil area (Section 4.6.11, Corps 2014). Since the quarry activities to be conducted at the Osprey Point Quarry site would be similar to those analyzed for the FEIS Quarry site, ***no cumulative effects*** to aquatic biological resources are anticipated from implementation of the Osprey Point Quarry site.

Transportation

Proposed Action Effects. Under the Proposed Action (including the FEIS Quarry) there would be ***temporary impacts*** resulting from delays caused by slow-moving construction vehicles on CR 77S, SH 72, SH 93, and other roads in the Gross Reservoir area. Denver Water would work with Jefferson and Boulder counties to address local traffic concerns. Overall there are ***no permanent impacts or significant, unavoidable adverse impacts*** for either construction traffic or recreational traffic that cannot be mitigated under the Proposed Action (including the FEIS Quarry) (Section 5.12, Corps 2014). ***However, regardless of the quarry location,*** since recent preliminary engineering evaluations have verified the ability to produce all sand and gravel aggregate on-site (ASI 2015), this impact-reduction method ***would reduce temporary impacts*** of construction truck trips and traffic (by reducing the number of truck trips necessary to haul the materials needed to make concrete from an off-site location by approximately 72 percent) from the Proposed Action (including quarry construction and operation), as compared to those impacts identified in the FEIS. Refer to **Attachment 2** for revised traffic assumptions.

Section 5.12.1 of the FEIS provides estimates of construction-related traffic impacts for the Proposed Action (including the FEIS Quarry), which would occur over a total 4.1-year (49 month) period during construction and expansion of the dam. The estimates provided for the following categories of traffic impacts ***would remain unchanged*** from those identified in the FEIS in Section 5.12.1 ***regardless of the quarry location***: *Construction Workforce Travel Trips*, *Construction Equipment Travel Trips*, and *Tree*

Removal and Disposal. However, the traffic impacts estimated for the category *Supply Delivery Trips* in the FEIS would be reduced given the findings of the recent technical study (ASI 2015) that confirms the ability to produce all sand and gravel aggregate on-site, ***regardless of the quarry location***; therefore, traffic related to the delivery of aggregate material would no longer occur. This impact-reduction method would reduce the number of trucks hauling materials to make the concrete by approximately 72 percent of the *Supply Delivery Trips* estimate in the FEIS. As explained in section II.A.2 above, by producing all of the aggregate on-site, Denver Water estimates that 6,552 truck trips would be necessary to haul only the materials that cannot be produced on-site (cement and flyash) from an off-site location. This represents an approximate 72 percent reduction from the approximate 23,452 truck estimate that can be calculated based on data in the FEIS. These 6,552 truck trips represent the remaining 10 percent of materials needed to make the concrete that would not be produced on-site.

Regardless of the quarry location, the elimination of these truck trips would alleviate traffic conditions on roads serving the Proposed Action by reducing driver delays caused by slow-moving trucks on the road and queuing at intersections. Since the FEIS concluded that the "temporary moderate indirect impacts to traffic operations" would "pose no significant indirect impacts" to transportation, the ability to reduce the number of trucks on the road ***would further reduce*** the Proposed Action's effects on local traffic (Section 5.12, Corps 2014).

Cumulative (Total Environmental) Effects. The number of anticipated construction-related trips is anticipated to have a negligible impact on the operating conditions (i.e., level of service) of the freeways, major arterials, and minor arterials that serve the Gross Reservoir site. Traffic impacts associated with travel delays would end when construction is completed. Only ***temporary impacts***, and ***no permanent impacts***, would occur to transportation under the Proposed Action (including the FEIS Quarry). Overall, ***minimal cumulative effects*** to transportation from the Proposed Action (including the FEIS Quarry) are anticipated (Section 4.6.12, Corps 2014). ***However, regardless of the quarry location***, since recent preliminary engineering evaluations have verified the ability to produce all sand and gravel aggregate on-site (ASI 2015) this impact-reduction method ***would further reduce the minimal cumulative effects*** of construction truck trips and traffic from the Proposed Action (including quarry construction and operation), as compared to those impacts identified in the FEIS.

Air Quality

Proposed Action Effects. Under the Proposed Action (including the FEIS Quarry) ***temporary, direct impacts*** would occur to air quality, which are primarily related to construction activities at the dam and the quarry. The Proposed Action (including the FEIS Quarry) would undergo a general conformity analysis to ensure that the region remains in compliance with the National Ambient Air Quality Standards. ***Overall, no permanent impacts*** are anticipated. With regard to long-term impacts, the Proposed Action (including the FEIS Quarry) would cause relatively small increases in fugitive dust and personal vehicle emissions. Fugitive dust emissions would be considered ***unavoidable adverse impacts*** because they depend, in part, on the extent of bare soil exposed by fluctuation of the water level in the reservoir (Section 5.13, Corps 2014).

The air quality impact analysis was based on construction emission calculations presented in Appendix I of the FEIS. ***Regardless of the quarry location***, **Attachment 2** of this report shows how the assumptions would change by producing 100 percent of the aggregate on-site. The assumptions used in the FEIS are very conservative and as explained in section II.A.5 above, there would be no change to processing, equipment type, diesel power usage, duration of activities, manpower and overall construction disturbance. The only assumptions that would change are:

- Supply Truck Trips – the estimated trips per day would decrease from 22 to 6
- Volume of Rock Crushed – the volume would increase from 426,600 to 796,600 cubic yards

Table 5.13-1 in the FEIS presents the results of the construction emissions for the Proposed Action. Greenhouse gases and hazardous air pollutants are well below the major source status thresholds for permitting requirements. This conclusion is not expected to change based on the revised assumptions. Emissions related to delivery vehicles should be significantly reduced due to the reduction in truck trips. Processing additional volume of aggregate would likely result in a temporary increase of particulate matter from the processing activities. The fugitive dust emissions from construction activities would still be considered an unavoidable adverse impact.

As stated in Section 5.18 of the FEIS, the general conformity process would ensure that construction emissions would not cause exceedances of the NAAQS. During the general conformity process, the CDPHE APCD would review the Project to determine if the Project conforms to the State Implementation Plans (SIP) for NOx, CO, and PM10. During its conformity analysis, the CDPHE APCD would determine if the Project's estimated emissions are included in the State's emission inventory. If Project emissions (in conjunction with other known projects) do not exceed the SIP budget, the Project conforms to the SIP and the Project can go forward without change. If the CDPHE APCD determines that Project emissions could cause significant adverse air quality impacts, the agency can request mitigation to reduce Project emissions (Corps 2014).

Cumulative (Total Environmental) Effects. ***Cumulative air quality impacts*** from the Proposed Action (including the FEIS Quarry) are anticipated ***to be negligible***, particularly in comparison with regional emissions associated with ongoing development in the area (Section 4.6.13, Corps 2014). However, ***regardless of the quarry location,*** since recent preliminary engineering evaluations have verified the ability to produce all sand and gravel aggregate on-site (ASI 2015) (thereby reducing the number of truck trips necessary to haul the materials needed to make concrete from an off-site location), there would be ***negligible cumulative effects*** to air quality from construction truck trips and traffic from the Proposed Action (including quarry construction and operation).

Noise

Proposed Action Effects. On-site construction related noise, including blasting, is anticipated to be a ***moderate, temporary impact***. ***No long-term, permanent impacts*** are anticipated from the operation of the Proposed Action (including the FEIS Quarry and proposed spoil area shown at Osprey Point). The FEIS concludes that the proposed activities associated with the enlargement of Gross Reservoir are not predicted to exceed relevant noise standards or guidelines. Overall, noise from construction is unavoidable, but is a short-term impact that is predicted to not be significant for the Proposed Action (including the FEIS Quarry). ***No unavoidable adverse impacts*** are anticipated from construction and operation of the FEIS Quarry (Section 5.14, Corps 2014).

<u>On-site Construction-Related Noise</u>. ***Regardless of the quarry location***, the following description applies to on-site construction related noise. The FEIS analysis was conservative in estimating the number of processing equipment, processing time, and generator power to produce the coarse (gravel) aggregate on-site, as shown in Section 5.14.1 and Appendix I. Based on the recent aggregate study (ASI 2015) a

similar process to that described and analyzed in the FEIS would be used to create both the sand and gravel aggregate. Additionally, the estimated equipment running time was also conservative and the sand and gravel aggregate could be created in the same amount of run hours as analyzed in the FEIS.

On-site construction noise may periodically exceed the EPA noise threshold of 70 dBA for public exposure, but the public would not be exposed to these levels on a continuous basis. The noise levels described are predicted at distances of less than 50 feet from the source and would be temporary and remote. Thus, noise impacts are anticipated to be ***temporary and moderate*** during on-site construction.

The Osprey Point Quarry is approximately 1,000 feet further from the closest (Lakeshore) residential community as compared to the noise analysis performed for the impacts of the FEIS Quarry in the FEIS. The Osprey Point Quarry would be approximately 1,000 feet closer to the seasonal private property owner (Miramonte) south of Gross Reservoir. Given the location of the Osprey Point Quarry site, noise impacts from quarrying are anticipated to be ***similar*** to those impacts identified in the FEIS.

<u>Blasting</u>. ***Regardless of the quarry location***, the blasting frequency would increase to up to one blast per day, but the timeframe would be ***similar***, to what was identified in the FEIS.

Drilling and blasting noise measurements were collected as part of the recent aggregate study (ASI 2015), wherein a test quarry was mined to the north of the Osprey Point Quarry site, just east of the FEIS Quarry footprint. To evaluate the noise associated with drilling and blasting on nearby residents, noise monitoring equipment was set up a the closest residence to the test quarry, which was approximately one mile from the test quarry location. The results of the test quarry noise monitoring concluded that the future drilling operations would generate approximately 26.8 A-weighted decibel scale (dBA) and blasting would generate 52.3 dBA of sound at the nearest residence site. This falls within the estimates used in the FEIS for the FEIS Quarry wherein the equipment used to construct the Project facilities (e.g., loaders, backhoes, scrapers, generators, etc.) were assumed to operate between 70 to 90 dBA (Section 5.14, Corps 2014). These noise levels are estimated at 50 feet from the sources and diminish rapidly at greater distances. As a general rule, when the radius or distance that a sound wave travels has doubled, the sound level is reduced by 6 dBA (Whitaker and Benson 2002).

As explained in the FEIS, sound travels omni-directionally (i.e., does not travel upward or downward), which means that it dissipates outward in all directions from its source the further away it travels (generally sound levels are reduced by 6 dBA when the radius of distance that a sounds wave travels has doubled). Thus, at distances greater than 50 feet, noise levels would diminish rapidly (Section 5.14, Corps 2014). Thus, ***regardless of the quarry location,*** the temporary noise disturbance from blasting would be ***similar***.

<u>Off-site Construction-Related Noise</u>. The FEIS concluded that noise impacts associated with increased construction traffic using site access roads are anticipated to be ***temporary and minor***. ***Regardless of the quarry location,*** noise related to construction truck trips and traffic would be ***significantly reduced*** by reducing the number of truck trips necessary to haul the materials needed to make concrete from an off-site location.

Cumulative (Total Environmental) Effects. Noise impacts, including blasting, are anticipated to be ***temporary*** **and moderate** during on-site construction. Since noise generated during construction activities and commuting traffic associated with the Proposed Action (including the FEIS Quarry and proposed spoil area) is not expected to exceed applicable standards on a continuous basis, overall temporary noise impacts would result in ***minor to moderate cumulative effects*** (Section 4.6.14, Corps 2014). However, ***regardless of the quarry location,*** producing all sand and gravel aggregate on-site and eliminating 70 percent of the truck trips ***would further reduce the minor to moderate cumulative effects*** of noise related to construction truck trips and traffic from the Proposed Action (including quarry construction and operation), as compared to those impacts identified in the FEIS.

Recreation

Proposed Action Effects. The Haul Road Recreation Area (i.e., Osprey Point) would be closed during certain phases of construction due to the proximity to the proposed FEIS Quarry, spoil areas and auxiliary spillway or saddle dam, which would result in a ***temporary impact*** to recreation under the Proposed Action. ***No permanent impacts*** to recreation are anticipated. ***No unavoidable adverse impacts*** are anticipated (Section 5.15, Corps 2014).

Regardless of the quarry location, both sites are located in areas where recreation access would be closed during construction for the duration of construction of the Proposed Action. Post-construction, both areas would reopen to recreation as the relocated Haul Road Recreation Area and scenic trails. However, post-construction the FEIS Quarry site and highwall that would remain exposed above the reservoir surface would be less accessible to recreation. By comparison, the Osprey Point Quarry site and associated highwall would likely be completely inundated by the new high water line. For these reasons, impacts to recreation associated with the Osprey Point Quarry site are anticipated to be the ***same as or less than*** those for the FEIS Quarry site because ***regardless of the quarry location*** the Haul Road Recreation Area would be relocated.

Cumulative (Total Environmental) Effects. The Proposed Action with RFFAs (including the FEIS Quarry) is anticipated to have ***minor, if any, cumulative effects*** on recreation at Gross Reservoir (Section 4.6.15, Corps 2014). Cumulative impacts to recreation associated with the Osprey Point Quarry site are anticipated to be the ***same*** as those for the FEIS Quarry site owing to the fact that the existing facilities at the Haul Road Recreation Area (i.e. Osprey Point) would be relocated.

Land Use

Proposed Action Effects. The existing land use of the FEIS Quarry is primarily forest land owned by the USFS. Approximately 24 acres of the FEIS Quarry would be located on NFS land and 5 acres on Denver Water land. The existing land use of the proposed spoil area shown at Osprey Point (Figure 2-3; Corps 2014) is forested land and the existing Haul Road Recreation Area owned by Denver Water. The FEIS concluded that overall, impacts to existing land uses at or adjacent to Gross Reservoir are expected to be ***minor***. Construction-related activities (e.g., increases in noise and dust) would temporarily impact adjacent land uses including the Lakeshore residential subdivision. ***No permanent impacts or unavoidable adverse effects*** to land use are anticipated under the Proposed Action (including the FEIS Quarry and proposed spoil area shown at Osprey Point) (Section 5.16, Corps 2014).

The existing land use of the Osprey Point Quarry is the same as the proposed spoil area; forested land and the Haul Road Recreation Area. Landownership is entirely Denver Water. The recreation area will be directly impacted by either the Osprey Point Quarry or the FEIS spoil area, and would be relocated regardless of the activity causing the direct impact. The temporary impacts to the Lakeshore and Miramonte subdivisions from construction noise would be ***similar regardless of quarry location***. However, the adverse visual effects to the Lakeshore and Miramonte residents would be ***significantly***

less because the Osprey Point Quarry would be shielded from the residences' viewshed due to its location in the inlet where it occupies a smaller length of the shoreline. By contrast, the FEIS Quarry, and the 250-foot highwall that would remain exposed post-construction, would be directly in the viewshed of the Lakeshore Subdivision. Additionally, since the Osprey Point Quarry site is located entirely on Denver Water property there would be a complete elimination of land use and natural resource impacts of a quarry site to NFS lands, which is a significant impact-reduction strategy as compared to the impacts and mitigation identified for the FEIS Quarry in the FEIS. Most and potentially all of the Osprey Point Quarry would be submerged below the new high water line of the reservoir unlike the FEIS Quarry, which thereby reduces the total land use disturbance post-construction. ***Regardless of the quarry location,*** the land use impacts related to construction traffic would be ***significantly reduced*** by eliminating approximately 72 percent of the truck trips. Overall, impacts to existing land uses are ***expected to be less*** from developing the Osprey Point Quarry site compared to the FEIS Quarry site.

Cumulative (Total Environmental) Effects. Overall, cumulative effects to existing and planned land uses from the Proposed Action with RFFAs (including the FEIS Quarry) are anticipated to be ***negligible*** (Section 4.6.16, Corps 2014). Cumulative impacts to land use associated with the Osprey Point Quarry site are anticipated to ***be less than*** as those for the FEIS Quarry site.

Visual Resources

Proposed Action Effects. Under the Proposed Action ***temporary impacts*** to visual resources include disturbance and restoration of borrow material areas, stockpile, spoil areas, and associated haul roads. ***Permanent impacts*** to visual resources under the Proposed Action include the development of a primary quarry with a cut slope of 20 percent and terraced horizontal benches. A mitigation plan for rehabilitation of the quarry site would be implemented to minimize permanent impacts. Overall, for the Proposed Action, there would be ***unavoidable adverse impacts*** to the scenic quality of Gross Reservoir since the existing native vegetation and landform in the quarry, auxiliary spillway area, and dam staging and stockpile areas would be changed to engineered features (Section 5.17, Corps 2014). Post-construction, an approximate 250 foot highwall (MWH 2015) would remain above the water surface revealing an exposed rock face with benches approximately 13 acres in size (Corps 2014).

In comparison, the most notable advantage of the Osprey Point Quarry is that it has been designed so that the majority or optimally the entirety of the quarry pit and highwall would occur completely below the new high water line once the reservoir is raised (MWH 2015).

Post-construction reclamation activities would be minimal for the Osprey Point Quarry location since most or all of the quarry site would be inundated by the expanded reservoir. Regardless, the uppermost benches would be regraded to reduce vertical walls and cliffs along the reservoir edge. The quarry would also be rough graded to drain back towards the reservoir as part of the site decommissioning. If the final configuration of the Osprey Point Quarry results in a portion of the quarry exposed above the new water level, mitigation activities similar to those described in the FEIS would be used to reclaim slopes. However, Denver Water is optimistic that the layout of the Osprey Point Quarry would allow for the entire quarry to be inundated by the new reservoir water surface. Therefore, Denver Water would only mine above the new high water line (7,406 ft) if required by material characteristics or quantities criteria. As the recent preliminary engineering evaluations have shown, implementation of the Osprey

Point Quarry would ***greatly reduce permanent impacts and unavoidable adverse impacts*** to visual resources in the viewshed of residences and recreationists (refer to **Figures 1** and **2**).

Cumulative (Total Environmental) Effects. With the exception of the FEIS Quarry site and the auxiliary spillway under the Proposed Action, the general character of the landscape would not change. Overall, with time, these impacts are anticipated to result in ***minor to moderate cumulative effects*** (Section 4.6.17, Corps 2014). As the recent preliminary engineering evaluations have shown, implementation of the Osprey Point Quarry ***would further reduce the minor to moderate cumulative effects*** to visual resources in the viewshed of residences and recreationists, as compared to those impacts identified in the FEIS for the FEIS Quarry (refer to **Figures 1** and **2**).

Cultural/Historical/Paleontological Resources

Proposed Action Effects. ***No permanent or temporary impacts*** to cultural/historical/paleontological resources are anticipated from the FEIS Quarry site or proposed spoil area shown at Osprey Point (Section 5.18, Corps 2014). Both sites are within the Area of Potential Effect (APE) as shown in Appendix L of the FEIS. Denver Water has entered into a Programmatic Agreement (PA) with the Corps, Colorado State Historic Preservation Officer, Advisory Council on Historic Preservation, and U.S. Forest Service, which provides a framework for monitoring the recommended mitigation measures and addressing any additional discoveries during construction. As part of the PA, site-specific field assessments would be conducted prior to land disturbance associated with quarry activities or related construction, ***regardless of the quarry location***. This protection measure provides assurance that cultural/historical/paleontological resources that may be present onsite, ***regardless of the quarry location***, would be avoided or mitigated according to the requirements in the PA.

The Osprey Point Quarry site is located in the same location as the proposed spoil area, which is within the APE. There are no cultural/historical/paleontological resources identified in the vicinity of either quarry location. Therefore, ***no permanent or temporary impacts*** to cultural/historical/paleontological resources are anticipated from implementation of the Osprey Point Quarry site.

Cumulative (Total Environmental) Effects. ***No cumulative effects*** to cultural/historical/paleontological resources were identified related to the FEIS Quarry site or proposed spoil area shown at Osprey Point (Section 4.6.18, Corps 2014). Since the quarry activities to be conducted at the Osprey Point Quarry site would be similar to those analyzed for the FEIS Quarry site, ***no cumulative effects*** to cultural/historical/paleontological resources are anticipated from implementation of the Osprey Point Quarry site.

Socioeconomics

Proposed Action Effects. The FEIS concludes that overall the majority of socioeconomic impacts resulting from an enlargement of Gross Reservoir would be ***temporary*** and associated with the construction period. Generally, the ***temporary impacts would be positive in nature, but minor*** due in part to the addition of new jobs and new expenditures on materials and supplies (Executive Summary and Section 5.19.1.8, Corps 2014). Impacts to residents of the Gross Reservoir Primary Impact Area (PIA) would be ***short-term and minor to moderate*** in nature due in part to the temporary disturbances caused by the 4-year duration of construction and associated noise, dust, traffic, closure of recreations areas and change in visual quality due to the quarry scar as described in Section 5.19.1.2 (Corps 2014).

The quarry activities to be conducted at the Osprey Point Quarry site would be ***similar*** to those contemplated and analyzed for the construction and operation of the FEIS Quarry site under the Proposed Action. Therefore, the overall socioeconomic impacts from implementation of the Osprey Point Quarry site are ***anticipated to be the same***. The minor to moderate impacts to local residents in the Gross Reservoir PIA are ***expected to be reduced*** due to the significant reduction in traffic volume on local roads and the improvement to visual quality since the quarry highwall would be beneath the high water line of the expanded reservoir.

Cumulative (Total Environmental) Effects. ***No cumulative effects*** to socioeconomics were identified related to the FEIS Quarry under the Proposed Action (Section 4.6.19, Corps 2014). Since the quarry activities to be conducted at the Osprey Point Quarry site would be similar to those analyzed for the FEIS Quarry site, ***no cumulative effects*** to socioeconomics are anticipated from implementation of the Osprey Point Quarry site.

Hazardous Materials

Proposed Action Effects. ***No permanent or temporary impacts*** from hazardous materials are anticipated from the FEIS Quarry site (Section 5.20, Corps 2014). The quarry activities to be conducted at the Osprey Point Quarry site would be similar to those analyzed for the FEIS Quarry site under the Proposed Action. Therefore, ***no permanent or temporary impacts*** from hazardous materials are anticipated from implementation of the Osprey Point Quarry site.

Cumulative (Total Environmental) Effects. ***No cumulative effects*** from hazardous materials were identified related to the FEIS Quarry site (Section 4.6.20, Corps 2014). Since the quarry activities to be conducted at the Osprey Point Quarry site would be similar to those analyzed for the FEIS Quarry site, ***no cumulative effects*** from hazardous materials are anticipated from implementation of the Osprey Point Quarry site.

Summary

The findings of the preliminary engineering evaluations were positive, and based on the results, Denver Water intends to minimize impacts of the Project by producing all of the sand and gravel aggregate needed for dam construction from an on-site quarry. It is Denver Water's opinion that the findings of the preliminary engineering evaluations presented in this Report demonstrate several benefits of the Osprey Point Quarry site, including:

- significant minimization of traffic impacts through a 72 percent reduction in the number of truck trips necessary to haul the materials needed to make concrete from an off-site location
- significant minimization of visual impacts of the quarry by configuring the quarry pit and highwall such that it would occur completely below the new high water line of Gross Reservoir
- minimization of the area of land disturbance from approximately 29 to 16 acres
- elimination of quarry impacts to NFS lands

It is Denver Water's opinion that neither the change in location nor the activities required to produce 100 percent of the sand and gravel aggregate on-site would result in a significant increase in impacts to any of the resources analyzed in the FEIS.

For these reasons, Denver Water intends to develop and design the dam expansion using the Osprey Point Quarry as the primary quarry site. Denver Water believes that the impact avoidance and minimization approach presented in this Report is consistent with and falls within the scope of the FEIS. For example, the FEIS states that during the design phase, additional core drilling and laboratory testing would be used to refine construction elements of the quarry and that "alternative quarry sites may be considered, if needed" (Section 2.0; Corps 2014). Since the Corps' issuance of the FEIS in 2014, Denver Water has proceeded with some engineering and geotechnical analyses to respond to stakeholder input received during the FEIS process, the FERC license amendment process, and voluntary public outreach sessions, where concerns had been expressed regarding the quarry activities related to the dam raise. Denver Water's avoidance and minimization approach to quarry construction is rooted in the spirit of doing the right thing by responding to stakeholders' concerns, and echoed in the FEIS where Denver Water provides commitments throughout to reduce adverse impacts of the Proposed Action wherever possible. Denver Water provides the information contained in this Report, including the referenced studies, to the Corps for its review.

References

ASI. 2015. *Gross Dam Test Quarry Report.*

MWH. 2015. *Draft Gross Dam Raise Quarry Evaluation.*

MWH Americas. 2006. *Moffat Collection System EIS Gross Dam Raise - Aggregate Production and Potential Borrow Sources for Permitting (Draft).*

Shannon and Wilson. 2016. *Geotechnical Data Report – Gross Reservoir Field Investigations.*

Shannon and Wilson. 2015. *Geotechnical Report – Gross Reservoir Enlargement*.

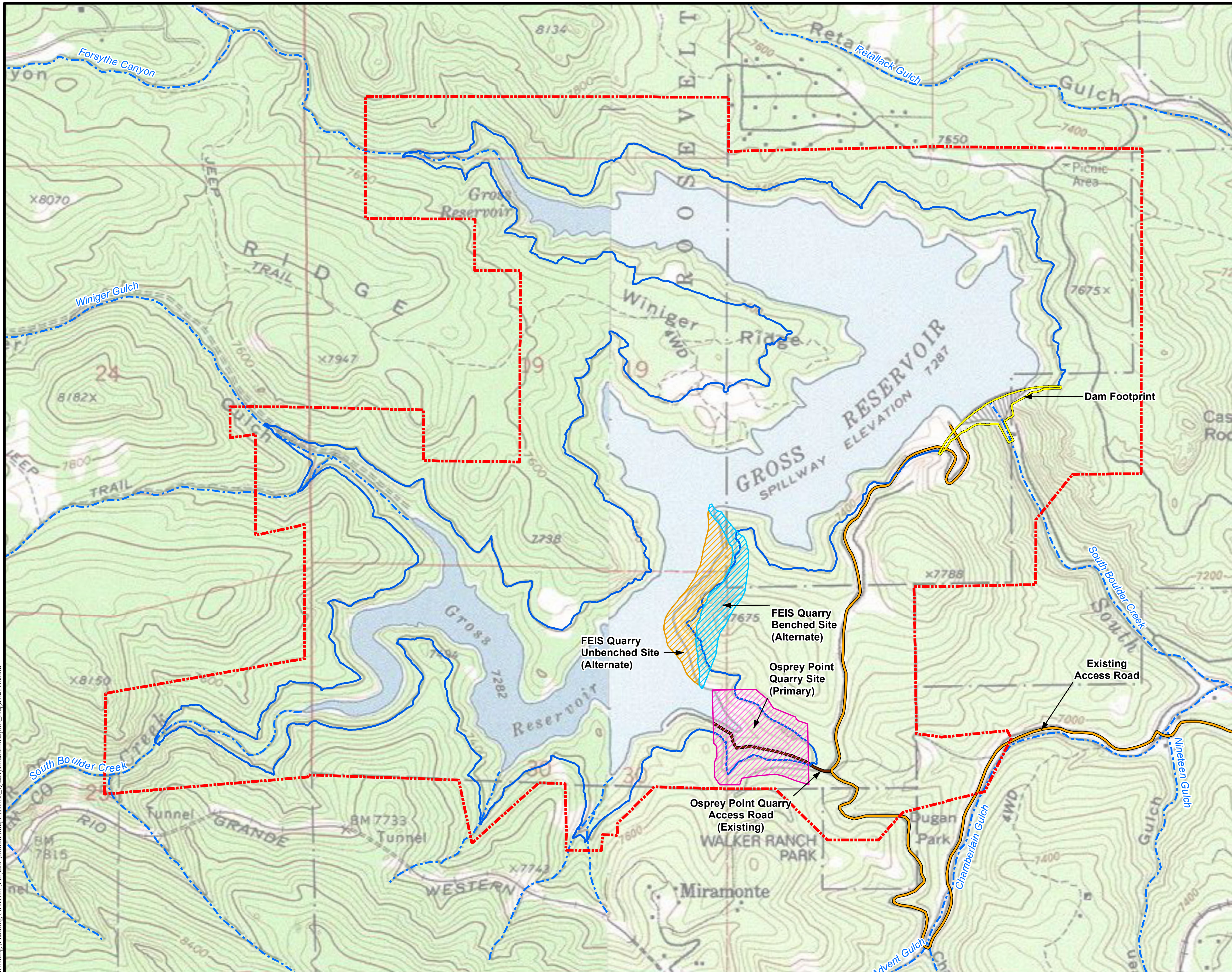
U.S. Army Corps of Engineers (Corps). 2014. *Final Environmental Impact Statement - Moffat Collection System Project*.

Attachments

Attachment 1 – Location Map showing the Osprey Point Quarry and FEIS Quarry

Attachment 2 – Revised assumptions presented in Appendix I of the FEIS

Attachment 1 – Location Map showing the Osprey Point Quarry and FEIS Quarry



- Gross Reservoir Study Area
- Alt. 1a Gross Reservoir with Environmental Pool - 77,000 AF Enlargement
- Dam Footprint
- Osprey Point Quarry Site (Primary)
- FEIS Quarry Unbenched Site (Alternate)
- FEIS Quarry Benched Site (Alternate)
- Osprey Point Quarry Access Road (Existing)
- Existing Access Road
- Stream/River

Reference:
1:24,000-scale quad maps originally from USGS (1972 & 1994) and created with TOPO!, ©2006 National Geographic Maps, All Rights Reserved.

NOTE: Identical GIS datasets were also posted on similar figures within the Moffat Collection System Project Final EIS dated 04/25/14. Osprey Point Quarry has been added to this figure.

AUTHOR:
This plot has been produced by the Planning and Water Resources Division of Denver Water for use in the general resource display and analysis.

DENVER WATER

N W E S

1,200 0 1,200 Feet

1:14,400

Moffat Collection System Project FEIS

Gross Reservoir Components

08/10/16

\Working\Planning\WRGIS\Projects\moffat\maps\Gross_QuarryLocationReport_August2016.mxd

Attachment 2 – Revised assumptions presented in Appendix I of the FEIS

Data: Construction Duration - NO CHANGE PER DENVER WATER, 9-9-16
Alternative: All
Project: Moffat Collection System Project

Alternative	Task	Construction Duration (months)	Days/ Week	Hours/ Day	Hours/ Week	Hours per Month*
Proposed Action (1a)	Gross Reservoir	49	5	8	40	173
1c	Gross Reservoir	37	5	8	40	173
	Leyden Gulch Reservoir	42	5	8	40	173
8a	Gross Reservoir	38	5	8	40	173
	Gravel Pit Storage	30	5	8	40	173
	Conduit O	30	5	8	40	173
10a	Gross Reservoir	38	5	8	40	173
	ASR Wells	30	5	24	120	520
	Conduit M	30	5	8	40	173
13a	Gross Reservoir	43	5	8	40	173
	Gravel Pit Storage	30	5	8	40	173
	Conduit O	30	5	8	40	173

* Assumes 4.33 weeks per month.

Data: Construction Equipment Usage - NO CHANGE PER DENVER WATER, 9-9-16
Alternative: All
Project: Moffat Collection System Project

Equipment Type	Horse-power (HP)	Proposed Action (Alternative 1a)		Alternative 1c					Alternative 8a						
		Gross Reservoir		Gross Reservoir		Leyden Gulch Reservoir		Total	Gross Reservoir		Gravel Pit Storage		Conduit O		Total
		Quantity	Equip.-Months	Quantity	Equip.-Months	Quantity	Equip.-Months	Equip.-Months	Quantity	Equip.-Months	Quantity	Equip.-Months	Quantity	Equip.-Months	Equip.-Months
Air Compressor	75	1	49	1	37	1	42	79	1	38	1	30	1	30	98
Backhoe	101	2	98	2	74	2	84	158	2	76	1	30	1	30	136
Compactor	232	2	98	2	74	2	84	158	2	76	1	30	1	30	136
Crane	275	0	0	0	0	0	0	0	0	0	1	30	1	30	60
Dozer	185	2	98	2	74	2	84	158	2	76	0	0	0	0	76
Dump Truck	250	8	392	8	296	4	168	464	8	304	0	0	0	0	304
Front End Loader	135	0	0	0	0	4	168	168	0	0	0	0	0	0	0
Fuel Truck	250	1	49	1	37	1	42	79	1	38	1	30	1	30	98
Generator, Diesel	50	2	98	2	74	2	84	158	2	76	1	30	1	30	136
Motor Grader	220	1	49	1	37	4	168	205	1	38	0	0	0	0	38
Pickup Truck	225	10	490	10	370	10	420	790	10	380	4	120	4	120	620
Pile Driver	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scraper	460	8	392	8	296	8	336	632	8	304	0	0	0	0	304
Water Truck	250	1	49	1	37	4	168	205	1	38	1	30	1	30	98
Welder	75	1	49	1	37	1	42	79	1	38	1	30	1	30	98
Tunnel Boring Machine	250	0	0	0	0	1	42	42	0	0	0	0	0	0	0
Well Drilling Rig	2100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		39	1911	39	1443	46	1932	3375	39	1482	12	360	12	360	2202

Data: Construction Equipment Usage - NO CHANGE PER DENVER WATER, 9-9-16
Alternative: All
Project: Moffat Collection System Project

Equipment Type	Horse-power (HP)	Alternative 10a							Alternative 13a						
		Gross Reservoir		ASR		Conduit M		Total	Gross Reservoir		Gravel Pit Storage		Conduit O		Total
		Quantity	Equip.-Months	Quantity	Equip.-Months	Quantity	Equip.-Months	Equip.-Months	Quantity	Equip.-Months	Quantity	Equip.-Months	Quantity	Equip.-Months	Equip.-Months
Air Compressor	75	1	38	1	30	1	30	98	1	43	1	30	1	30	103
Backhoe	101	2	76	1	30	1	30	136	2	86	1	30	1	30	146
Compactor	232	2	76	1	30	1	30	136	2	86	1	30	1	30	146
Crane	275	0	0	1	30	1	30	60	0	0	1	30	1	30	60
Dozer	185	2	76	0	0	0	0	76	2	86	0	0	0	0	86
Dump Truck	250	8	304	1	30	0	0	334	8	344	0	0	0	0	344
Front End Loader	135	0	0	1	30	0	0	30	0	0	0	0	0	0	0
Fuel Truck	250	1	38	1	30	1	30	98	1	43	1	30	1	30	103
Generator, Diesel	50	2	76	1	30	1	30	136	2	86	1	30	1	30	146
Motor Grader	220	1	38	0	0	0	0	38	1	43	0	0	0	0	43
Pickup Truck	225	10	380	6	180	4	120	680	10	430	4	120	4	120	670
Pile Driver	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scraper	460	8	304	0	0	0	0	304	8	344	0	0	0	0	344
Water Truck	250	1	38	1	30	1	30	98	1	43	1	30	1	30	103
Welder	75	1	38	1	30	1	30	98	1	43	1	30	1	30	103
Tunnel Boring Machine	250	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Well Drilling Rig	2100	0	0	1	30	0	0	30	0	0	0	0	0	0	0
Total		39	1482	17	510	12	360	2352	39	1677	12	360	12	360	2397

Additional Equipment Usage - NO CHANGE PER DENVER WATER, 9-9-16

Equipment Type	Months[1]	Days/ Week	Hours/ Day[2]	Hours/ Week	Hours per Month[3]
Diesel Engines for rock crushing/screening	24	5	11.2	56	242
Diesel Engines for concrete	15	5	24	120	520

Equipment Type	Horse-power (HP)	All Alternatives	
		Gross Reservoir	
		Quantity	Equip.- Months
Diesel Engines for rock crushing/screening	150	7	168
Diesel Engines for concrete	100	6	90
Total		13	258

1. Rock crushing/screening will occur for 8 months per year for 3 years. Concrete production will occur for 5 months per year for 3 years.
2. Rock crushing/screening is assumed to operate 24 hr/day 20% of the time and 8 hr/day 80% of the time.
   Concrete production is assumed to operate 24 hr/day.
3. Assumes 4.33 weeks per month.

Data: **Traffic Trips - REVISED PER DENVER WATER, 9-9-16**
Alternative: **All**
Project: **Moffat Collection System Project**

Construction Schedule	Roundtrip Distance (mi)	Trips Per Day for Alternatives				
		1a (Proposed Action)	1c	8a	10a	13a
Daily Averages						
Gross Reservoir Haul and Concrete Trucks	96	~~22~~ 6	17	21	21	21
Commuting Worker Vehicles	60	60	193	163	215	149
Peak						
Gross Reservoir Haul and Concrete Trucks	96	37	28	35	35	34
Commuting Worker Vehicles	60	101	319	279	359	231

Haul trucks operate 260 days/yr for Gross Reservoir. The roundtrip distance for Gross Reservoir is 96 miles.
Leyden Gulch Reservoir requires no offsite fill hauling.

TOTAL TRUCK TRIPS - 22 X 4.1 YEARS X 260 DAYS PER YEAR = 23,452

TRUCK TRIPS ASSOCIATED WITH HAULING FLYASH & CEMENT - 163,800 TONS / 25-TON TRUCKS = 6,552 TRUCK TRIPS

6,552 / 260 / 4.1 = 6 DAILY TRUCK TRIPS INSTEAD OF 22; THE PEAK NUMBER OF 37 DOES NOT CHANGE DUE TO THE FLYASH & CEMENT TRUCKS

TOTAL TRUCK TRIPS MINUS FLYASH & CEMENT TRUCK TRIPS - 23,452 - 6,552 = 16,900 TRUCKS ELIMINATED BY PRODUCING 100% AGGREGATE ON-SITE

16,900 / 23,452 = 0.72 = 72% REDUCTION IN TOTAL TRUCK TRIPS

Data: **Construction Manpower - NO CHANGE PER DENVER WATER, 9-9-16**
Alternative: **All**
Project: **Moffat Collection System Project**

Construction Schedule	Number of Workers				
	1a (Proposed Action)	1c	8a	10a	13a
Year 1					
1st Qtr	16	50	60	66	44
2nd Qtr	32	113	109	140	84
3rd Qtr	47	163	156	200	116
4th Qtr	60	214	248	286	150
Year 2					
1st Qtr	91	325	343	415	223
2nd Qtr	121	438	382	490	298
3rd Qtr	132	475	418	538	322
4th Qtr	142	478	418	538	346
Year 3					
1st Qtr	151	478	367	524	346
2nd Qtr	151	445	283	361	346
3rd Qtr	146	364	217	328	284
4th Qtr	121	282	154	251	223
Year 4					
1st Qtr	95	251	109	176	174
2nd Qtr	73	134	101	122	125
3rd Qtr	53	104	NA	NA	104
4th Qtr	44	NA	NA	NA	84
Year 5					
1st Qtr	43	NA	NA	NA	NA
Daily Average	90	290	244	322	223
Quarterly Peak	151	478	418	538	686

Assume 1.5 workers per vehicle.

Data:	**Proposed Action (Alternative 1a) Additional Data - REVISED PER DENVER WATER, 9-9-16**
Alternative:	**Proposed Action (Alternative 1a) — Enlarged Gross Reservoir with Environmental Pool for Mitigation [Additional 77,000 AF]**
Project:	**Moffat Collection System Project**

Construction Disturbance	Acres
Gross Reservoir	183.8
Total Area Disturbed	183.8

Gross Reservoir - Roads

Type	Length (ft)	Width (ft)
Access Roads	5,605	30
Haul Roads	3,050	50

Access road length is 2,300 ft for permanent spillway road, 1,500 ft for each permanent dam access roads, and 305 ft for temporary spillway road.

Gross Reservoir - Volume of Dirt Moved for Dam

Volume Moved:	**200,000**	**yd^3**

Volume of Rock Crushed

Volume Crushed:	**426,600**	**yd^3**

THIS NUMBER WOULD BE INCREASED TO 796,600

Volume of Concrete Produced

Volume Produced:	**853,200**	**yd^3**

Notes:

Concrete placement would occur during May through September for three years.