LITHOS ENGINEERING

GEOTECHNICAL DESIGN MEMORANDUM

FINAL

TWP SEGMENT A PRV & METER PIPE & VAULT & CHEMICAL BUILDING

THORNTON, COLORADO

February 2023

Engineering **from the ground down**

2750 S. Wadsworth Blvd, Suite D-200
Denver, Colorado 80227
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www.LithosEng.com

February 10, 2023
Project No. 21207

Carollo Engineers
390 Interlocken Crescent, Ste 800
Broomfield, Colorado 80021

Attention: Mr. Bart Giles, PE
Senior Infrastructure Engineer

Regarding: Geotechnical Design Memorandum- Final
TWP Segment A PRV & Meter Pipe & Vault & Chemical Building
Thornton, Colorado

Mr. Giles,

The following Geotechnical Design Memorandum presents geotechnical recommendations for the Thornton Water Project (TWP) Segment A PRV & Meter Pipe & Vault & Chemical Building. This study was conducted in general accordance with our contract between Lithos Engineering and Carollo Engineers dated January 28, 2022. Contained herein are geotechnical recommendations for the design and construction of the various structures.

If you have any questions regarding the contents of this memorandum, please contact the undersigned.

Sincerely,
Lithos Engineering

COLORADO LICENSED STEVEN C. KUEHR 24369 PROFESSIONAL ENGINEER 2/10/23

Derek Magnuson, PG, CEG
Project Geologist

Steve Kuehr, PE
Senior Consultant

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1 INTRODUCTION

Carollo Engineers (Carollo) retained Lithos Engineering (Lithos) to provide geotechnical engineering services for the TWP Segment A PRV & Meter Pipe & Vault & Chemical Building (Project). The City of Thornton (City) will construct a new Chemical Building in between Colorado Boulevard and the South Platte River in Thornton, Colorado. Two vaults will also be constructed in the same vicinity along the alignment of a pipeline designed by others.

The purpose of this report is to provide geotechnical recommendations for design and construction of various project elements. A Geotechnical Data Report (GDR) dated 2/10/23 for the project has been provided under separate cover. The GDR documents subsurface conditions identified during our geotechnical exploration at the site.

1.1 Project Description

Based on correspondence with Carollo regarding the Chemical Building and review of 95 percent design drawings for the vaults prepared by Carollo, we understand the Project will include the following facilities at locations noted on Figure 1 of the GDR:

- A new Chemical Building with a footprint of approximately 30 feet by 45 feet and a finish floor elevation approximately 3 feet below the existing ground surface (bgs). The Chemical Building will be designed to include tanks of various sizes.
- A chemical injection manhole with a circular footprint approximately 11 feet in diameter. The manhole will be approximately 13 feet deep.
- A pressure reducing vault with a footprint of approximately 20 feet by 35 feet. The vault will be approximately 18 feet deep, with a finish floor elevation of 5,068.75 feet and a 3 to 5-foot thick mat slab.

2 GEOTECHNICAL DESIGN RECOMMENDATIONS

The following sections are included primarily for the engineer performing design. If additional geotechnical design recommendations are necessary, Lithos should be contacted to provide the required information.

2.1 PRV and Chemical Injection Manhole

Based on our understanding of the proposed PRV and chemical injection manhole structure elevations and the results of our subsurface investigation, we anticipate both structures will bear within loose, coarse alluvium. We recommend the vaults are supported on a minimum 1-foot thick zone of moisture conditioned and compacted granular Select Fill extending to native soil. For vault foundations bearing on Select Fill, Lithos recommends the following design criteria for mat foundations:

- The foundation should be designed using a maximum allowable bearing pressure of 3,000 psf. This value includes appropriate allowable-stress-design (ASD) safety factors.
- The foundation should be designed to withstand a total vertical movement of 1 inch and differential movements of 0.5 inches.

- It is acceptable to increase the net allowable bearing capacity by one-third if the load combination utilized considers infrequent loads such as wind or earthquake. Snow loading is not considered an infrequent load condition.
- Sliding friction between anticipated subgrade and foundation materials should be evaluated using a coefficient of 0.4.
- The coefficient of subgrade reaction (k) is typically used for flexible foundation analysis and describes the load intensity per unit of displacement. For granular select fill, a k value of 150 psi/in is recommended.

2.2 Chemical Building Foundations

The borings advanced near the Chemical Building encountered fill to depths of 11 and 27 feet bgs, followed by coarse alluvium with limited zones of fine alluvium. Bedrock was encountered at a depth of 42 feet in Boring CHM-3. We recommend the structure is founded on deep foundations bottomed in bedrock, with structural floors. Deep foundations may consist of conventional drilled shafts. Recommendations for the design of straight shaft drilled pier-type foundations (drilled shafts) are presented in the following sections.

- Individual shafts should be designed for a maximum allowable end bearing pressure of 40,000 pounds per square foot (psf) and a skin (shaft) friction value of 3,000 psf for that portion of the shaft in bedrock. The design values should be used for the dead load plus full live load. The allowable bearing pressure may be increased by 33 percent for short term or infrequent loading such as wind and seismic loads.
- Shafts should have a minimum penetration into the bedrock of 23 feet. Based on the depth to bedrock from the ground surface, Lithos anticipates overall pier lengths to be approximately 65 feet.
- Lithos recommends that a minimum dead load (in kips) of 43 times the diameter of the shaft (in feet) be maintained. Where the minimum dead load pressure cannot be achieved, the deficit should be made up by increasing penetration into the bedrock over the required minimum, using the shaft skin friction value provided above.
- The drilled shafts should be reinforced for their full length with reinforcing steel sufficient to resist tensile forces. The structural engineer should determine the size and amount of reinforcement. Each shaft should be capable of resisting an uplift (in kips) of 127 times the diameter of the shaft (in feet).
- Drilled shaft sizes should be kept small. A small diameter shaft designed to carry load by additional penetration is better than large diameter shafts. For ease of installation and inspection, a minimum shaft diameter of 18 inches is suggested.
- All floor slabs should be structurally supported on the drilled shaft foundations. Slabs-on-grade should be avoided.
- Lithos estimates that foundation settlements should not exceed approximately 0.5 inches.
- Lithos should be contacted if any shafts will be spaced closer than 3 shaft diameters.

If L-Pile modeling is performed to analyze the drilled shafts, we recommend the following p-y curves are considered for design: “soft clay” for the fill, “sand” coarse alluvium, and “weak rock” for sandstone and claystone bedrock. If an alternative modeling program is selected to analyze drilled shafts, we recommend a comparable p-y curve is selected for identified subsurface layers.

2.3 Lateral Earth Pressures

Lateral earth pressures presented below should be considered during the structural design process for foundation elements extending below grade. Lateral earth pressure values are a function of the properties and the geometry of the retained fill, soil, and/or bedrock and anticipated magnitude of lateral deflection. In addition, the presence of groundwater and saturated materials will increase the total horizontal stress, resulting in higher lateral earth pressures in comparison to retained materials above a groundwater table.

Static Lateral Earth Pressures									
Backfill Material Type	**Static Earth Pressure Coefficients**			**Static Equivalent Fluid Pressure (pcf)**					
				Active		**At-Rest**		**Passive**	
	Active	**At-Rest**	**Passive**	**Above GWT[1]**	**Below GWT[1]**	**Above GWT[1]**	**Below GWT[1]**	**Above GWT[1]**	**Below GWT[1]**
Onsite Sandy Fill	0.33	0.50	3.00	42	83	63	94	375	250

[1] GWT stands for Groundwater Table

In order for the lateral earth pressures presented above to remain applicable, backfill material placement adjacent to below-grade walls should be in accordance with procedures outlined in Section 4. In addition, backfilled material must be placed within a 1 horizontal to 1 vertical (1H:1V) backfill geometry, up and away from the base of the structure. We recommend design ground water elevations of 5,092 feet for the Chemical Building (approximate 100-year flood elevation on the unnamed drainage south of the Chemical Building) and 5,087 feet for the vault and manhole (approximate 100-year flood elevation on the adjacent segment of the South Platte River).

Consideration has not been given to vertical loads applied to the backfill surfaces during or after construction as a result of traffic and/or other surcharge loads or sloping backfill.

2.4 Frost Protection

In colder climates, certain soils can freeze and can cause heave resulting in larger than expected differential movement. Shallow foundations in non-heated areas should have a minimum cover of 36 inches for frost protection in accordance with the Adams County Building Code.

2.5 Geotechnical Parameters for Counteracting Buoyancy

Structures which extend below the highwater elevation should be evaluated for buoyancy. We recommend a design ground water elevations as noted in Section 2.3 corresponding to nearby 100-year flood elevations. Where the structure loads are not sufficient to counteract buoyancy, additional resistance to uplift can be achieved by extending the mat or footing foundations outside the vertical walls and engaging the weight of an additional wedge of soil. For design purposes, the wedge of soil providing resistance on the extended foundation can be defined by including the soil within a 12-degree slope (measured from vertical) up and away from the bottom exterior edge of the extended footing to the ground surface. A saturated unit weight of 120 pcf may be used for the soil wedge if the buoyant force on the structure includes the weight of water displaced by the soil wedge. If the buoyant force on the structure does not include the weight of water displaced by the soil wedge, i.e. only the volume of water that is displaced by the structure itself, then a soil unit weight of 55 pcf should be used.

2.6 Seismic Site Classification

Based on the International Building Code and the American Society of Civil Engineers Minimum Design Loads for Buildings and other Structures, our subsurface investigation, and our experience and knowledge of seismic conditions in the area, a Site Classification C is recommended for seismic design.

2.7 Water Soluble Sulfate

Water soluble sulfate testing was conducted on one fill sample and one sandstone sample. The test results on the fill and sandstone were 0.017 % and 0.03 %, respectively, which would characterize the concrete risk as "Not Applicable" as shown in the table below. These results should be considered when developing the concrete mix design specifications.

American Concrete Institute Code 318-08 Water Soluble Sulfates		
Class	**Water-Soluble Sulfate in Soil SO_4, Percent by Weight**	**Risk**
S0	$SO_4 < 0.10$	Not Applicable
S1	$0.10 < SO_4 < 0.20$	Moderate
S2	$0.20 < SO_4 < 2.00$	Severe
S3	$SO_4 > 2.00$	Very Severe

3 CONSTRUCTION CONSIDERATIONS

The following sections are intended for the Engineer producing specifications and the contractor constructing the proposed project. Construction considerations include temporary excavations, preparation of excavated surfaces for foundations, backfill materials, fill placement and compaction, bedrock or oversize material excavation, drilled shaft construction, and construction dewatering.

3.1 Temporary Excavations

General site safety including temporary excavations are the sole responsibility of the contractor performing construction. Lithos is providing temporary excavation information strictly as an informational benefit to the project team, specifically the general contractor. An Occupational Safety and Health Administration (OSHA) defined competent person should be identified by the contractor to be in charge of temporary excavations. In general, the contractor's competent person should have experience or training in determining soil types, benching and shoring, and have the ability to detect potential temporary slope stability and protective system issues.

OHSA defines an excavation as a man-made cut, trench, or depression formed by the removal of earth. A trench is a specific type of narrow excavation with a geometry including a greater depth than width and a width of 15 feet or less. Trenches 5 feet deep or greater should be sloped, retained with shoring, or shielded appropriately. Shielding most commonly includes trench boxes. In general, shoring can include inclined, horizontal, or vertical systems depending on the excavation geometry and availability of retention alternatives. Sloping and benching should be in accordance with OSHA recommendations. Benching should include a maximum 4-foot vertical face for each bench and the overall excavation geometry less than or equal to the OSHA defined slope.

For the vaults, deeper excavations are anticipated. A registered professional engineer should approve the contractor's approach for trenches greater than or equal to 20 feet in depth. In addition, shoring for trench excavations greater than or equal to 20 feet should be designed by a professional engineer or be based on tabulated data prepared or approved by a registered professional engineer in accordance with OSHA 1926.652(b) and (c).

Lithos has evaluated observed soil conditions likely to be penetrated by the proposed construction. Based on the OSHA determined soil types, the following table presents maximum recommended temporary excavation slopes to be utilized during construction.

OSHA Temporary Excavation Slopes		
Backfill Material Type	**OSHA Classification**	**Maximum Recommended Slope (H:V) [1,2]**
Fill and Coarse Alluvium	Type C	1½:1

[1] H:V is an abbreviation for Horizontal:Vertical

[2] Valid for trench excavations less than 20 feet in depth

During construction, heavy equipment or excavated material stockpiles should be kept away from excavation edges to the extent possible. Underground utilities should be fully understood and documented prior to initiating excavations. Finally, the contractor's competent person should inspect trenches and excavations routinely for signs of instability including sliding, toppling, subsidence and bulging, heaving or squeezing, boiling, and/or other visual concerns.

3.2 Permanent Slopes

Lithos recommends a slope 4:1 or flatter for permanent cut and fill slopes. Erosion control may be required for slope stabilization. There are several options regarding erosion control including temporary erosion control blankets in conjunction with establishment of permanent vegetation, as well as other measures

3.3 Site Grading and Earthwork

Appropriate site preparation, material placement and compaction, and backfill selection can reduce the risk of post-construction vertical movement and potential issues related to lateral earth pressures. General site grading and earthwork considerations are presented in the following sections.

3.3.1 Site Preparation

Areas supporting backfill should be properly prepared. Once the rough grade has been established in excavated areas, and prior to placement of backfill, the exposed subgrade should be carefully inspected via probing and testing, as determined necessary by the geotechnical engineer on site. Frozen, wet, soft, or loose soil, as well as any other undesirable material should be removed. Once suitable soil conditions are achieved, the subgrade should be scarified and compacted prior to fill placement. The suitable exposed soil materials should be scarified and moistened or dried, as necessary, to a minimum depth of 8 inches below the proposed construction. Scarified material should be compacted to the minimum specifications defined in the following sections.

3.3.2 Structure Backfill Material

Backfill is anticipated below and around the vaults, and around the Chemical Building. The backfill should consist of Select Fill material containing less than 60 percent fines, a plasticity index less than 20, and a liquid limit less than 40. The sandy onsite fill and coarse alluvium are suitable for use as Select Fill if properly processed as discussed below. The clayey fill and fine alluvium will likely need to blended with onsite granular soil to meet the requirements of Select Fill. Excavated bedrock should not be used as backfill, but may be appropriate for use as general site fill on a case-by-case basis as approved by the geotechnical engineer.

Processing on-site material shall include removing expansive materials, frozen chunks, wood, trash, organic material, and cobbles and boulders larger than 3 inches in diameter. If another material is preferred for any of the presented applications, Lithos should be contacted to review submitted particle size distribution, Atterberg Limits testing results, and swell testing results.

3.3.3 Fill Placement and Compaction

We recommend fill placement occurs in maximum 8-inch loose lifts for fill under and backfill adjacent to structures. Lift thickness for pipe bedding should not exceed 6 inches. Minimum recommended compaction specifications are outlined in the following table.

Soil Compaction Recommendations		
Backfill Material Type	**Moisture and Compaction Specifications**	
	Moisture Content[1]	**Dry Density[2]**
Granular Soils	-2% to +2%	≥ 95%
Cohesive Soils	-2% to +2%	≥ 95%

[1] Moisture content relative to the optimum moisture content as determined by ASTM D698

[2] Dry density relative to the maximum dry density as determined by ASTM D698

We understand the City of Thornton plans to use squeegee material as pipe bedding for the project. Pipe bedding should be compacted to a minimum relative density of 65% in accordance with ASTM D4253 and D 4254.

Mechanical compaction is required for all materials placed as backfill during construction. Compaction of cohesive materials is best accomplished with equipment such as a jumping jack or padfoot roller. Non-cohesive (granular) soils are best compacted with a vibratory plate or vibratory smooth-drum roller. Compaction utilizing any flooding type technique is not recommended. Care should be taken when compacting fill adjacent to structures. Generally, we recommend operating only light-weight compaction equipment such as jumping jacks and vibratory plates immediately adjacent to structures.

3.3.4 Bedrock or Oversized Material Excavation

Based on the subsurface investigation, bedrock below the proposed structures at the site was classified as claystone and sandstone. Bedrock excavation is not anticipated during proposed construction activities at the vaults. Bedrock will be encountered during drilled shaft excavations at the chemical building site, but will not be encountered for the remainder of the structure excavations.

3.4 Drilled Shaft Construction

An experienced and competent contractor should be retained to install the drilled shafts. Furthermore, it is recommended that Lithos be retained for full time inspection during drilled shaft installation.

The shaft holes should be kept as plumb as possible, with a maximum deviation of one percent variation from plumb in relation to shaft length is recommended. Due to the presence of groundwater and flowing sands, the use of temporary casings or the slurry method within saturated sandy soils is required to keep the shaft open during construction. The use of a tremie or concrete pump lowered to the placement depth should be anticipated. The concrete should be placed in such a manner as to prevent segregation of the aggregate. Concrete should be placed at a high slump (6- to 8-inches) to reduce the possibility of necking and to help ensure water and slurry displacement. Concrete for each shaft should be formed at the top of the shaft, if necessary, to ensure a uniform diameter at the top of the shaft and to prevent "mushrooms" from forming. Concrete placed for the piers should be placed with sufficient head maintained above groundwater and slurry levels so that the concrete is not displaced in the body of the pier by water, soil, slurry, etc., leading to constrictions and voids in the pier. If the slurry method is used, temporary shaft casing may still be needed to prevent caving of the shaft hole above the slurry level. However, the need for temporary shaft casing should be determined by the Contractor during drilled shaft installation.

3.5 Construction Dewatering

Groundwater was encountered during the subsurface investigation. Temporary construction dewatering should be anticipated for the proposed construction at locations where excavations extend below potential groundwater, such as the vaults. Lithos is available to assist with dewatering design if required. Construction dewatering must adhere to the Colorado Department of Public Health and Environment (CDPHE) regulations and discharge permit requirements. Deep wells and/or well points will likely be required to lower the groundwater table beneath the excavation limits, and significant volumes of water could be generated. Dewatering should be carefully evaluated and accounted for in the construction estimate to avoid construction cost and time increases.

4 CONSTRUCTION OBSERVATION AND QUALITY ASSURANCE

Based on project discussions between Lithos and the project team, the primary geotechnical components of construction will include excavations, backfill below the proposed foundation elements, and drilled shaft construction. Quality assurance of backfill material and backfill placement will be necessary to reduce potential for long term differential settlements. Inspection of subgrade materials prior to placing or forming and casting structural elements is also critical to project success. Lithos recommends a qualified testing agency is retained to provide quality assurance services during the backfill process. Drilled shaft installation should be observed by qualified personnel on a full-time basis, and Lithos is available to provide this service. Lithos anticipates remaining involved in the project and providing geotechnical-related guidance throughout the design and construction of the project.

5 LIMITATIONS

This study was conducted in accordance with generally accepted geotechnical engineering and engineering geologic practices and principals; no warranty, express or implied is made. The subsurface conditions described in this report were based on data obtained from widely spaced exploratory borings, geotechnical laboratory testing, information provided by the client, engineering judgement, and our experience with similar subsurface conditions and projects. The boring logs presented in this report only depict the subsurface conditions at the actual boring locations. Subsurface conditions are typically variable, both laterally and vertically, and the nature and extent of the subsurface variations across the site may not become evident until construction. The boundaries between different soil types and bedrock presented in this report are approximate and, in some cases, may be more abrupt or gradational than described herein. Groundwater levels may vary with time, adjacent surface water levels, precipitation, and changes to the hydrogeological conditions at or surrounding the project site.

This report has been prepared exclusively for our client for design purposes for the subject project. Lithos Engineering is not responsible for technical interpretations by others of the data presented in this report or use of this report by others for the subject project or other projects. If differing site conditions are encountered during further evaluation of the subsurface conditions by others or during construction, Lithos Engineering should be notified immediately to determine if any changes to our recommendations presented in this report are warranted.

The recommendations presented in this report are only intended for the proposed design and construction as understood by Lithos Engineering at the time of issuing this report. If the proposed design and construction changes, Lithos Engineering should be notified immediately and given the opportunity to review the proposed changes and if necessary, modify our recommendations presented herein.

An environmental assessment was not included in Lithos Engineering scope of work for this project. Any statements regarding the absence or presence of hazardous and/or toxic substances presented herein are only intended for informational purposes. If the client is concerned about the environmental conditions at the site, Lithos Engineering recommends the client and/or owner retain a qualified environmental firm to conduct an environmental site assessment.

Addendum

350 Indiana Street, Suite 750 ● Golden, CO 80401

To: Carollo Engineers
From: GEI
Date: April 20, 2026
Re: Generator Foundation Recommendations
TWP Chemical Building and PRV Vaults Project
Thornton, CO

City of Thornton has requested a new generator for the Thornton Water Project Chemical Building and PRV Vaults project. Lithos Engineering provided geotechnical engineering services to Carollo Engineers for the project in 2023. Lithos Engineering produced a project Geotechnical Design Memorandum and Geotechnical Data Report as presented in Appendix A and B, respectively. Drawings for the proposed generator are provided in Appendix C. The proposed generator is a slab on grade with a 1.5 ft thick mat. The total weight of the generator and fuel tank is approximately 16 kips.

Based on our understanding of the subsurface conditions at the location of the proposed generator, shallow foundations with a 3-ft overexcavation and replacement are recommended. The proposed generator may be then founded on conventional mat foundations bearing on Select Fill as defined in Section 3 of the attached Geotechnical Design Memorandum. Select Fill may be imported or derived from on-site materials and should consist of a non-compressible granular fill meeting the requirements of a CDOT Class 1 or Class 2 structure backfill. The overexcavation for the generator foundation should extend a minimum of 5 feet beyond the footprint of the mat slab in all directions. We recommend the following criteria be used for design of the generator foundation:

- The foundation should be designed using a maximum allowable bearing pressure of 3,000 psf. This value includes appropriate allowable-stress-design (ASD) safety factors.
- The foundations should be designed to withstand a total settlement of 1 inch and a differential settlement of 0.5 inches.
- It is acceptable to increase the net allowable bearing capacity by one-third if the load combination considers infrequent loads such as wind or earthquake. Snow loading is not considered an infrequent load condition.
- Sliding friction between the subgrade and the foundation materials should be evaluated using a coefficient of 0.4.
- The coefficient of subgrade reaction (k) is typically used for flexible foundation analysis and describes the load intensity per unit of displacement. For Select Fill, a k value of 150 psi/inch is recommended.

- Section 3 of the project Geotechnical Design Memorandum.

Sincerely,

GEI

Sarah Myers
Project Professional

Nate Soule, PE, PG
Vice President

Appendices

Appendix A	Lithos Engineering Geotechnical Design Memorandum
Appendix B	Lithos Engineering Geotechnical Data Report
Appendix C	Carollo Design Drawings

Appendix A Lithos Engineering Geotechnical Design Memorandum

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In colder climates, certain soils can freeze and can cause heave resulting in larger than expected differential movement. Shallow foundations in non-heated areas should have a minimum cover of 36 inches for frost protection in accordance with the Adams County Building Code.

2.5 Geotechnical Parameters for Counteracting Buoyancy

Structures which extend below the highwater elevation should be evaluated for buoyancy. We recommend a design ground water elevations as noted in Section 2.3 corresponding to nearby 100-year flood elevations. Where the structure loads are not sufficient to counteract buoyancy, additional resistance to uplift can be achieved by extending the mat or footing foundations outside the vertical walls and engaging the weight of an additional wedge of soil. For design purposes, the wedge of soil providing resistance on the extended foundation can be defined by including the soil within a 12-degree slope (measured from vertical) up and away from the bottom exterior edge of the extended footing to the ground surface. A saturated unit weight of 120 pcf may be used for the soil wedge if the buoyant force on the structure includes the weight of water displaced by the soil wedge. If the buoyant force on the structure does not include the weight of water displaced by the soil wedge, i.e. only the volume of water that is displaced by the structure itself, then a soil unit weight of 55 pcf should be used.

2.6 Seismic Site Classification

Based on the International Building Code and the American Society of Civil Engineers Minimum Design Loads for Buildings and other Structures, our subsurface investigation, and our experience and knowledge of seismic conditions in the area, a Site Classification C is recommended for seismic design.

2.7 Water Soluble Sulfate

Water soluble sulfate testing was conducted on one fill sample and one sandstone sample. The test results on the fill and sandstone were 0.017 % and 0.03 %, respectively, which would characterize the concrete risk as “Not Applicable” as shown in the table below. These results should be considered when developing the concrete mix design specifications.

American Concrete Institute Code 318-08 Water Soluble Sulfates		
Class	**Water-Soluble Sulfate in Soil SO_4, Percent by Weight**	**Risk**
S0	$SO_4 < 0.10$	Not Applicable
S1	$0.10 < SO_4 < 0.20$	Moderate
S2	$0.20 < SO_4 < 2.00$	Severe
S3	$SO_4 > 2.00$	Very Severe

3 CONSTRUCTION CONSIDERATIONS

The following sections are intended for the Engineer producing specifications and the contractor constructing the proposed project. Construction considerations include temporary excavations, preparation of excavated surfaces for foundations, backfill materials, fill placement and compaction, bedrock or oversize material excavation, drilled shaft construction, and construction dewatering.

3.1 Temporary Excavations

General site safety including temporary excavations are the sole responsibility of the contractor performing construction. Lithos is providing temporary excavation information strictly as an informational benefit to the project team, specifically the general contractor. An Occupational Safety and Health Administration (OSHA) defined competent person should be identified by the contractor to be in charge of temporary excavations. In general, the contractor’s competent person should have experience or training in determining soil types, benching and shoring, and have the ability to detect potential temporary slope stability and protective system issues.

OHSA defines an excavation as a man-made cut, trench, or depression formed by the removal of earth. A trench is a specific type of narrow excavation with a geometry including a greater depth than width and a width of 15 feet or less. Trenches 5 feet deep or greater should be sloped, retained with shoring, or shielded appropriately. Shielding most commonly includes trench boxes. In general, shoring can include inclined, horizontal, or vertical systems depending on the excavation geometry and availability of retention alternatives. Sloping and benching should be in accordance with OSHA recommendations. Benching should include a maximum 4-foot vertical face for each bench and the overall excavation geometry less than or equal to the OSHA defined slope.

For the vaults, deeper excavations are anticipated. A registered professional engineer should approve the contractor's approach for trenches greater than or equal to 20 feet in depth. In addition, shoring for trench excavations greater than or equal to 20 feet should be designed by a professional engineer or be based on tabulated data prepared or approved by a registered professional engineer in accordance with OSHA 1926.652(b) and (c).

Lithos has evaluated observed soil conditions likely to be penetrated by the proposed construction. Based on the OSHA determined soil types, the following table presents maximum recommended temporary excavation slopes to be utilized during construction.

OSHA Temporary Excavation Slopes		
Backfill Material Type	**OSHA Classification**	**Maximum Recommended Slope (H:V) [1,2]**
Fill and Coarse Alluvium	Type C	1½:1

[1] H:V is an abbreviation for Horizontal:Vertical
[2] Valid for trench excavations less than 20 feet in depth

During construction, heavy equipment or excavated material stockpiles should be kept away from excavation edges to the extent possible. Underground utilities should be fully understood and documented prior to initiating excavations. Finally, the contractor's competent person should inspect trenches and excavations routinely for signs of instability including sliding, toppling, subsidence and bulging, heaving or squeezing, boiling, and/or other visual concerns.

3.2 Permanent Slopes

Lithos recommends a slope 4:1 or flatter for permanent cut and fill slopes. Erosion control may be required for slope stabilization. There are several options regarding erosion control including temporary erosion control blankets in conjunction with establishment of permanent vegetation, as well as other measures

3.3 Site Grading and Earthwork

Appropriate site preparation, material placement and compaction, and backfill selection can reduce the risk of post-construction vertical movement and potential issues related to lateral earth pressures. General site grading and earthwork considerations are presented in the following sections.

3.3.1 Site Preparation

Areas supporting backfill should be properly prepared. Once the rough grade has been established in excavated areas, and prior to placement of backfill, the exposed subgrade should be carefully inspected via probing and testing, as determined necessary by the geotechnical engineer on site. Frozen, wet, soft, or loose soil, as well as any other undesirable material should be removed. Once suitable soil conditions are achieved, the subgrade should be scarified and compacted prior to fill placement. The suitable exposed soil materials should be scarified and moistened or dried, as necessary, to a minimum depth of 8 inches below the proposed construction. Scarified material should be compacted to the minimum specifications defined in the following sections.

3.3.2 Structure Backfill Material

Backfill is anticipated below and around the vaults, and around the Chemical Building. The backfill should consist of Select Fill material containing less than 60 percent fines, a plasticity index less than 20, and a liquid limit less than 40. The sandy onsite fill and coarse alluvium are suitable for use as Select Fill if properly processed as discussed below. The clayey fill and fine alluvium will likely need to blended with onsite granular soil to meet the requirements of Select Fill. Excavated bedrock should not be used as backfill, but may be appropriate for use as general site fill on a case-by-case basis as approved by the geotechnical engineer.

Processing on-site material shall include removing expansive materials, frozen chunks, wood, trash, organic material, and cobbles and boulders larger than 3 inches in diameter. If another material is preferred for any of the presented applications, Lithos should be contacted to review submitted particle size distribution, Atterberg Limits testing results, and swell testing results.

3.3.3 Fill Placement and Compaction

We recommend fill placement occurs in maximum 8-inch loose lifts for fill under and backfill adjacent to structures. Lift thickness for pipe bedding should not exceed 6 inches. Minimum recommended compaction specifications are outlined in the following table.

Soil Compaction Recommendations		
Backfill Material Type	**Moisture and Compaction Specifications**	
	Moisture Content[1]	**Dry Density[2]**
Granular Soils	-2% to +2%	≥ 95%
Cohesive Soils	-2% to +2%	≥ 95%

[1] Moisture content relative to the optimum moisture content as determined by ASTM D698

[2] Dry density relative to the maximum dry density as determined by ASTM D698

We understand the City of Thornton plans to use squeegee material as pipe bedding for the project. Pipe bedding should be compacted to a minimum relative density of 65% in accordance with ASTM D4253 and D 4254.

Mechanical compaction is required for all materials placed as backfill during construction. Compaction of cohesive materials is best accomplished with equipment such as a jumping jack or padfoot roller. Non-cohesive (granular) soils are best compacted with a vibratory plate or vibratory smooth-drum roller. Compaction utilizing any flooding type technique is not recommended. Care should be taken when compacting fill adjacent to structures. Generally, we recommend operating only light-weight compaction equipment such as jumping jacks and vibratory plates immediately adjacent to structures.

3.3.4 Bedrock or Oversized Material Excavation

Based on the subsurface investigation, bedrock below the proposed structures at the site was classified as claystone and sandstone. Bedrock excavation is not anticipated during proposed construction activities at the vaults. Bedrock will be encountered during drilled shaft excavations at the chemical building site, but will not be encountered for the remainder of the structure excavations.

3.4 Drilled Shaft Construction

An experienced and competent contractor should be retained to install the drilled shafts. Furthermore, it is recommended that Lithos be retained for full time inspection during drilled shaft installation.

The shaft holes should be kept as plumb as possible, with a maximum deviation of one percent variation from plumb in relation to shaft length is recommended. Due to the presence of groundwater and flowing sands, the use of temporary casings or the slurry method within saturated sandy soils is required to keep the shaft open during construction. The use of a tremie or concrete pump lowered to the placement depth should be anticipated. The concrete should be placed in such a manner as to prevent segregation of the aggregate. Concrete should be placed at a high slump (6- to 8-inches) to reduce the possibility of necking and to help ensure water and slurry displacement. Concrete for each shaft should be formed at the top of the shaft, if necessary, to ensure a uniform diameter at the top of the shaft and to prevent "mushrooms" from forming. Concrete placed for the piers should be placed with sufficient head maintained above groundwater and slurry levels so that the concrete is not displaced in the body of the pier by water, soil, slurry, etc., leading to constrictions and voids in the pier. If the slurry method is used, temporary shaft casing may still be needed to prevent caving of the shaft hole above the slurry level. However, the need for temporary shaft casing should be determined by the Contractor during drilled shaft installation.

3.5 Construction Dewatering

Groundwater was encountered during the subsurface investigation. Temporary construction dewatering should be anticipated for the proposed construction at locations where excavations extend below potential groundwater, such as the vaults. Lithos is available to assist with dewatering design if required. Construction dewatering must adhere to the Colorado Department of Public Health and Environment (CDPHE) regulations and discharge permit requirements. Deep wells and/or well points will likely be required to lower the groundwater table beneath the excavation limits, and significant volumes of water could be generated. Dewatering should be carefully evaluated and accounted for in the construction estimate to avoid construction cost and time increases.

4 CONSTRUCTION OBSERVATION AND QUALITY ASSURANCE

Based on project discussions between Lithos and the project team, the primary geotechnical components of construction will include excavations, backfill below the proposed foundation elements, and drilled shaft construction. Quality assurance of backfill material and backfill placement will be necessary to reduce potential for long term differential settlements. Inspection of subgrade materials prior to placing or forming and casting structural elements is also critical to project success. Lithos recommends a qualified testing agency is retained to provide quality assurance services during the backfill process. Drilled shaft installation should be observed by qualified personnel on a full-time basis, and Lithos is available to provide this service. Lithos anticipates remaining involved in the project and providing geotechnical-related guidance throughout the design and construction of the project.

5 LIMITATIONS

This study was conducted in accordance with generally accepted geotechnical engineering and engineering geologic practices and principals; no warranty, express or implied is made. The subsurface conditions described in this report were based on data obtained from widely spaced exploratory borings, geotechnical laboratory testing, information provided by the client, engineering judgement, and our experience with similar subsurface conditions and projects. The boring logs presented in this report only depict the subsurface conditions at the actual boring locations. Subsurface conditions are typically variable, both laterally and vertically, and the nature and extent of the subsurface variations across the site may not become evident until construction. The boundaries between different soil types and bedrock presented in this report are approximate and, in some cases, may be more abrupt or gradational than described herein. Groundwater levels may vary with time, adjacent surface water levels, precipitation, and changes to the hydrogeological conditions at or surrounding the project site.

This report has been prepared exclusively for our client for design purposes for the subject project. Lithos Engineering is not responsible for technical interpretations by others of the data presented in this report or use of this report by others for the subject project or other projects. If differing site conditions are encountered during further evaluation of the subsurface conditions by others or during construction, Lithos Engineering should be notified immediately to determine if any changes to our recommendations presented in this report are warranted.

The recommendations presented in this report are only intended for the proposed design and construction as understood by Lithos Engineering at the time of issuing this report. If the proposed design and construction changes, Lithos Engineering should be notified immediately and given the opportunity to review the proposed changes and if necessary, modify our recommendations presented herein.

An environmental assessment was not included in Lithos Engineering scope of work for this project. Any statements regarding the absence or presence of hazardous and/or toxic substances presented herein are only intended for informational purposes. If the client is concerned about the environmental conditions at the site, Lithos Engineering recommends the client and/or owner retain a qualified environmental firm to conduct an environmental site assessment.

Appendix B Lithos Engineering Geotechnical Data Report

GEOTECHNICAL DATA REPORT

FINAL

TWP SEGMENT A PRV & METER PIPE & VAULT & CHEMICAL BUILDING

THORNTON, COLORADO

FEBRUARY 2023

Engineering from the ground down

LITHOS ENGINEERING

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Denver, Colorado 80227
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February 10, 2023
Project No. 21207

Carollo Engineers
390 Interlocken Crescent, Ste 800
Broomfield, Colorado 80021

Attention: Mr. Bart Giles, PE
Senior Infrastructure Engineer

Regarding: Geotechnical Data Report- Final
TWP Segment A PRV & Meter Pipe & Vault & Chemical Building
Thornton, Colorado

Mr. Giles,

The following Geotechnical Data Report presents data collected for the Thornton Water Project (TWP) Segment A PRV & Meter Pipe & Vault & Chemical Building. This study was conducted in general accordance with the Task Order between Lithos Engineering and Carollo Engineers dated January 28, 2022. This report contains the results of our subsurface investigation concerning the structures for this project.

If you have any questions regarding the contents of this report, please contact the undersigned.

Sincerely,
Lithos Engineering

Alex Warren, EI
Staff Engineer

Derek Magnuson, PG, CEG
Project Geologist

Steve Kuehr PE
Senior Consultant

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APPENDICES

1 INTRODUCTION

Carollo Engineers (Carollo) retained Lithos Engineering (Lithos) to provide geotechnical engineering services for the TWP Segment A PRV & Meter Pipe & Vault & Chemical Building (Project). The City of Thornton (City) will construct a new Chemical Building in between Colorado Boulevard and the South Platte River in Thornton, Colorado. Two vaults will also be constructed in the same vicinity along the alignment of a pipeline designed by others.

The purpose of this report is to document subsurface conditions identified by Lithos during geotechnical exploration for the Project. The Geotechnical Design Memorandum (GDM) by Lithos, provided under separate cover, will provide geotechnical recommendations for design and construction of the project.

1.1 Project Description

Based on correspondence with Carollo regarding the Chemical Building and review of 95 percent design drawings for the vaults prepared by Carollo, we understand the Project will include the following facilities at locations noted on Figure 1:

- A new Chemical Building with a footprint of approximately 30 feet by 45 feet and a finish floor elevation approximately 3 feet below the existing ground surface (bgs). The Chemical Building will be designed to include tanks of various sizes.
- A chemical injection manhole with a circular footprint approximately 11 feet in diameter. The manhole will be approximately 13 feet deep.
- A pressure reducing vault with a footprint of approximately 20 feet by 35 feet. The vault will be approximately 18 feet deep, with a finish floor elevation of 5,068.75 feet and a 3 to 5-foot thick mat slab.

1.2 Site Description

The project site for the Chemical Building and vaults is located southeast of the intersection of E 88th Avenue and Colorado Boulevard. The site is bounded to the east and south by the South Platte River and the Thornton Gravel Ponds, respectively. The site for the Chemical Building is currently used as materials stockpile storage for the City of Thornton and has an elevation of approximately 5,095 feet. The vaults will be constructed in a relatively flat field in a park above the South Platte River with an elevation of approximately 5,082 feet. Based on our review of historical aerial imagery available on Historic Aerials (historicaerials.com), the Project site existed as undeveloped land and materials storage in the earliest image dating back to 1956 and has changed since then with more development. The following list summarizes our review of aerial imagery for the subject site:

- Aerial imagery from 1956 indicates the site of the proposed Chemical Building existed as a small storage site with structures and materials, and the site of the proposed vaults was undeveloped land. The South Platte River is located east of the site and structures for the water treatment plant and the road for Colorado Boulevard exist west of the site.
- Aerial imagery from 1971 shows further development of the water treatment plant, with the site of the proposed Chemical Building still serving as storage. The site of the vaults is undeveloped land.
- Aerial imagery from 1991 indicates the most development occurred during this time. The site of the Chemical Building shows an expanded materials storage site across the street from the water

treatment plant. One of the gravel ponds exists south of this site. The site of the vaults is undeveloped land, however a parking lot and trail were constructed on either side as part of the Platte River Trailhead Park.

- Aerial imagery from 1993 to 2019 indicates no further development occurred at the site and exists in its present state.

2 GEOTECHNICAL INVESTIGATION

Lithos conducted a subsurface investigation at the project site on January 24 and 25, 2022, and on November 16, 2022. The geotechnical investigation included geotechnical drilling, a subsequent geotechnical laboratory testing program, and field testing of hydraulic conductivity (slug testing). Subsurface conditions encountered during the investigation are discussed in Section 3.

2.1 Subsurface Investigation

Lithos completed five geotechnical borings to investigate the general subsurface conditions for the Project site (Figure 1). The geotechnical borings include CHM-1, CHM-2, and CHM-3 for the Chemical Building, and VLT-1 and VLT-2 for the PRV and chemical injection manhole. Borings were advanced to depths of 39.4 to 75.0 feet below existing ground surface (bgs).

Lithos subcontracted Vine Laboratories, Inc. from Commerce City, Colorado to drill four borings utilizing a CME 55 truck mounted drilling rig in January 2022. Lithos subcontracted Elite Drilling Services to drill one boring utilizing a Mobile 48X track mounted drilling rig on November 16, 2022. Drilling and sampling procedures were conducted in general accordance with ASTM D1586 – *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*, ASTM D3550 – *Standard Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils*. Continuous-flight, hollow-stem augers were used to advance borings below the existing ground surface to the maximum depth of exploration. During advance of the augers, Modified California or Split Spoon samples (2.0-inch, 1.4-inch inner diameter) were obtained at 5-foot intervals. The number of blows by a 140-pound hammer falling 30-inches required for 12 inches of sampler penetration (recorded in 6-inch increments) are presented on the boring logs (Appendix A). For the January 2022 borings, a photoionization detector (PID) was used on collected samples in conjunction with soil odor observations.

2.2 Geotechnical Laboratory Testing

A geotechnical laboratory testing program was developed by Lithos and performed by Martinez Associates on representative samples collected during the subsurface investigation. The geotechnical laboratory testing results are presented in Appendix B. Geotechnical laboratory tests were conducted in general accordance with local practice. If field characterized soil and bedrock descriptions differed from results indicated by laboratory classification testing, the boring logs presented in Appendix A were amended to reflect laboratory testing results.

2.3 Corrosion Laboratory Testing

A corrosion laboratory testing program was developed by Lithos and performed by Project X Corrosion Engineering on representative samples collected during the subsurface investigation. The corrosion laboratory testing results are presented in Appendix C. Corrosion laboratory tests were conducted in general accordance with associated standards presented in the table below.

Table 1 – Lab Testing Summary

Geotechnical and Corrosion Laboratory Testing	
Test	**Standard**
Chloride	ASTM D4327
pH	ASTM G51
Redox Potential	ASTM G200
Sulfate-Water Soluble	ASTM D4327
Sulfide	SM 4500-D
Resistivity	ASTM G187
Ammonium	ASTM D6919
Nitrate	ASTM D4327

2.4 Hydraulic Conductivity Testing

Slug tests were conducted in accordance with ASTM D4044 to estimate the hydraulic properties of the aquifer in the groundwater monitoring well by creating a sudden change in water level and measuring the response using a submerged transducer. The falling-head slug test, or slug-in test, was performed by inserting a solid slug instrument into the well, rapidly raising the water level and recording the falling water level until it reached equilibrium. The rising-head slug test, or slug-out test, was performed once equilibrium was reached by removing the solid slug instrument from the well, rapidly lowering the water level, and recording the rising water level until it reached equilibrium. The measured responses were analyzed according to Bouwer and Rice (1976) to determine the hydraulic conductivity of the aquifer. Table 2 below presents the hydraulic conductivity results of the slug tests conducted the monitoring well installed in Boring VLT-1.

Table 2 – Hydraulic Conductivity Results

Slug Test Results						
Boring	**Hydraulic Conductivity in cm/sec**					
	Slug In 1	Slug In 2	Slug In 3	Slug Out 1	Slug Out 2	Slug Out 3
VLT-1	2.8×10^{-3}	3.2×10^{-3}	3.2×10^{-3}	4.2×10^{-3}	3.2×10^{-3}	4.6×10^{-3}

3 SUBSURFACE CONDITIONS

Subsurface conditions were assessed based on the findings of the geotechnical investigation described in the previous section. Soil and rock descriptions noted on the boring logs and below are in general accordance with ASTM D2487 – *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)* and D2488 – *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*. Boring logs and a supplementary boring log key explaining boring log details are provided in Appendix A.

3.1 Regional Geology

Geologic mapping of the greater Denver area by Trimble and Machette (1979) indicates the Project area is underlain by Holocene Post-Piney Creek and Piney Creek alluvium and Paleocene and Upper Cretaceous Denver Formation. The alluvium is described as gravel, sand, silt, and clay of modern stream flood plains and older terraces. The Denver Formation is described as claystone, siltstone, sandstone, and conglomerate composed of altered andesitic debris.

3.2 Subsurface Conditions

Primary materials encountered during the subsurface investigation include fill, coarse alluvium, fine alluvium, and bedrock.

3.2.1 Fill

Fill was encountered in all borings at the existing ground surface or beneath asphalt pavement and extended to depths of 3 to 27 feet bgs. Based on input from the City of Thornton, we understand the fill at the chemical building site was placed as levee material. Near the vaults, the fill is likely related to the development of the parking lot and trails. Records of fill placement observation and associated materials testing have not been provided for our review and as such, the fill should be considered uncontrolled. Encountered fill was classified as the following in accordance with USCS:

- Sandy Lean Clay (CL) with varying gravel content
- Lean Clay with Sand (CL)
- Sandy Fat Clay (CH)
- Clayey Sand (SC) with varying gravel content
- Silty, Clayey Sand (SC-SM)
- Silty Sand (SM)
- Poorly Graded Sand with Silt and Gravel (SP-SM)

Fill was primarily comprised of varying amounts of clay and sand, and occasional silt and fine gravel. Blow counts in fill ranged from 6 to 29 blows per foot of sampler penetration indicating a relative consistency of medium stiff to very stiff for cohesive material, and a relative density of loose to medium dense for granular material. Cobble-size particles were suspected in the fill during drilling based on the auger behavior. Fill was further described as dark brown to gray and moist.

3.2.2 Coarse Alluvium

Coarse alluvium was encountered in all borings below fill and extended to depths of 28 feet bgs in the vault borings and the depths of exploration in the Chemical Building borings. Encountered coarse alluvium was classified as the following in accordance with USCS:

- Silty Sand (SM)
- Clayey Sand (SC) with gravel
- Well-Graded Sand (SW) with varying gravel content
- Well-Graded Sand with Silt (SW-SM) and varying gravel content
- Poorly Graded Sand (SP) with varying gravel content
- Poorly Graded Sand with Silt (SP-SM) and varying gravel content
- Poorly Graded Sand with Clay and gravel (SP-SC)

Coarse alluvium was comprised of fine to coarse sand with varying amounts of silt, clay, and gravel. Blow counts in the coarse alluvium ranged from 4 to 64 blows per foot of sampler penetration indicating a relative density of very loose to very dense. Cobble-size particles were suspected in the coarse alluvium during drilling based on the auger behavior. The coarse alluvium was further described as olive and moist to wet.

3.2.3 Fine Alluvium

Fine alluvium was encountered in Borings CHM-1 and VLT-1 layered between the coarse alluvium and extended to depths of 14 and 32 feet bgs. Encountered fine alluvium was classified as the following in accordance with USCS:

- Sandy Lean Clay (CL)
- Sandy Silt (ML)

Fine alluvium was comprised of clay and silt with varying amounts of sand. Blow counts in the fine alluvium ranged from 4 to 30 blows per foot of sampler penetration indicating a relative consistency of stiff for the cohesive material, and a relative density of very loose to medium dense for the granular material. The fine alluvium was further described as olive to yellowish brown and wet.

3.2.4 Bedrock

Sandstone, siltstone, and claystone bedrock of the Denver Formation was encountered in Borings CHM-3, VLT-1, and VLT-2 below the coarse alluvium and extended to the depths of exploration in each boring. The bedrock was generally very soft to soft, fresh, and dark greenish/blueish gray, with varying amounts of fine sand and clay.

Three swell tests were performed on samples of bedrock from Boring CHM-3 and VLT-2. The samples exhibited swells of 2.1 to 5.2 percent under inundation pressures of 500 psf, indicating a low to high swell potential in accordance with CAGE (1996) criteria. The swell pressures ranged from 4,000 to 17,560 psf.

3.2.5 Groundwater

Groundwater was encountered in all borings during the subsurface investigation and measured at depths ranging from 13.8 to 20.8 feet bgs. A temporary monitoring well was installed in Boring VLT-1. Groundwater was recorded at the time of drilling and subsequently monitored after drilling operations. Table 3 below presents groundwater fluctuations in the monitoring well as measured at the time of drilling and subsequent monitoring.

Fluctuations in groundwater levels may occur due to variations in the water level of nearby drainages, precipitation, seasonal moisture variations, temperature, future site development and other factors not evident at the time that these measurements were made.

Table 3 – Groundwater Monitoring Readings

Groundwater Depth [ft.][1]				
Boring	Date			
	1/25/22 (Drilling)	2/14/22	3/25/22	5/11/22
VLT-1	13.8	10.6	10.8	10.2

[1] Depth as measured below the ground surface

3.2.6 PID Readings

A photoionization detector (PID) with a 10.6 eV lamp was used on collected samples during the January 2022 subsurface investigation to detect the presence of volatile organic compounds (VOCs) while in the field. The PID readings are noted on the boring logs in Appendix A. Additionally, the field representative smelled the samples to detect the presence of odors that may indicate VOCs, and in some instances when no odor was detected, the representative made notes indicating as such rather than using the PID.

Samples collected from Borings CHM-1 and CHM-2 had PID readings ranging from 2 to 33 parts per million (ppm). Samples collected from Borings VLT-1 and VLT-2 had PID readings ranging from less than 2 to 88 ppm.

4 LIMITATIONS

This study was conducted in accordance with generally accepted geotechnical engineering and engineering geologic practices and principals; no warranty, express or implied is made. The subsurface conditions described in this report were based on data obtained from exploratory borings and geotechnical laboratory testing. The boring logs presented in this report only depict the subsurface conditions at the actual boring and locations. Subsurface conditions are typically variable, both laterally and vertically, and the nature and extent of the subsurface variations across the site may not become evident until construction. The boundaries between different soil types and bedrock presented in this report are approximate and may be abrupt or gradational. Groundwater levels may vary with time, precipitation, and changes to the hydrogeological conditions at or surrounding the project site.

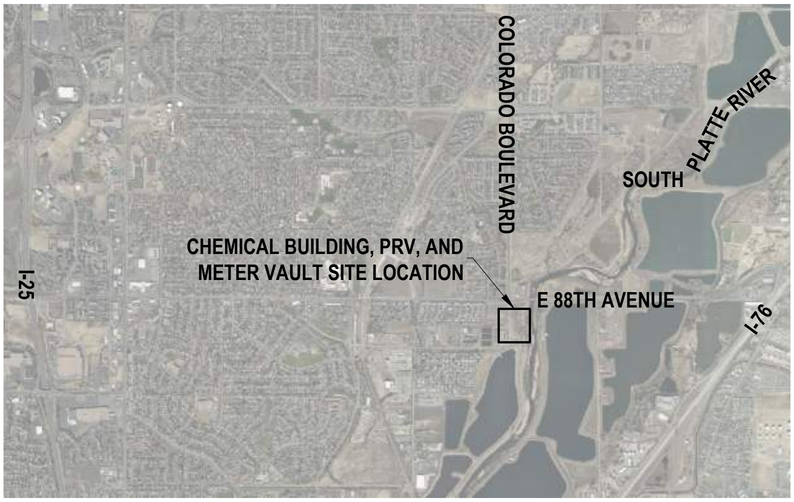
An environmental assessment was not included in Lithos Engineering scope of work for this project. Any statements regarding the absence or presence of hazardous and/or toxic substances presented herein are only intended for informational purposes. If the client is concerned about the environmental conditions at the site, Lithos Engineering recommends the client and/or owner retain a qualified environmental firm to conduct an environmental site assessment.

REFERENCES

- ASTM Standards, ASTM International, West Conshohocken, PA (2012).
- Bouwer, H. and R.C. Rice, 1976, A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.
- AECOM, September 3, 2021, Plan & Profile STA 285+00 to End, TWP Seg A, Phase 2, Project No. 12-777H5, Sheet No. PP29.
- Colorado Association of Geotechnical Engineers (CAGE), 1996, Guideline for slab performance risk evaluation and residential basement floor system recommendations, Guideline 1.
- Historic Aerials, 2022, Historic Aerial Image Viewer Web Application, accessed online on February 22 at https://www.historicaerials.com/viewer.
- Trimble, D.E. and M.N. Machette, 1979, Geologic Map of the greater Denver area, front range urban corridor, Colorado, US Geological Miscellaneous Investigations Series Map I-856-H, scale 1:100,000.

Historic Aerials Reviewed Images	
1956	1993
1964	1999
1971	2009
1991	2019

FIGURES



LEGEND:

VLT-X ◉ APPROXIMATE VAULT BORING LOCATION

CHM-X ◉ APPROXIMATE CHEMICAL BUILDING BORING LOCATION

— — — APPROXIMATE CHEMICAL BUILDING FOOTPRINT

-- / - SITE VICINITY MAP

-- / - BORING LOCATIONS

LITHOS ENGINEERING
2750 S WADSWORTH BLVD, SUITE D-200
DENVER, COLORADO 80227
303.625.9502

PROJECT TITLE	CHEMICAL BUILDING, PRV, & METER VAULT THORNTON WATER PROJECT
DRAWING TITLE	SITE VICINITY AND BORING LOCATIONS
OWNER	City of Thornton
CLIENT	carollo
PROJECT NO.:	21207
DRAWN BY:	JP
LOCATION:	THORNTON, CO
DESIGNED BY:	DF
DATE:	02/2023
CHECKED BY:	DM
FIGURE NUMBER	1

APPENDIX – A

Standard Geotechnical Drilling Keys and Boring Logs

BORING LOG KEY

67$1'$5' *(27(&+1,&$/ '5,//,1*

Soil Classifications:

Clear Square Sieve Openings — U.S. Standard Series Sieve Sizes

	12"		3"		3/4"		4		10		40		200	
Boulders		Cobbles		Gravel: Coarse		Gravel: Fine		Sand: Coarse		Sand: Medium		Sand: Fine		Silts and Clays
	300mm		75mm		19mm		4.75mm		2.0mm		0.42mm		0.075mm	

Color: Sample colors are in general accordance with basic brown, red, yellow, and gray combinations

Description of Moisture	
Description	**Criteria**
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil below the groundwater table

Description of Odor	
Description	**Criteria**
No Organic Odor	Organic odor is not present
Trace Organic Odor	Mild organic odor; mixture of soil and organics
Strong Organic Odor	Prominent organic odor; sample is primarily organic

Gradation Estimates by Field Observation	
Description	**Quantity (%)**
Trace	<5
Few	5 to 10
Little	15 to 25
Some	30 to 45
Mostly	> 50

Relative Density or Consistency of Non-cohesive and Cohesive Soils			
Non-cohesive Soils		**Cohesive Soils**	
Classification	**Blows per 12 in**	**Classification**	**Blows per 12 in**
Very Loose	0 to 4	Very Soft	0 to 2
Loose	5 to 10	Soft	3 to 4
Medium Dense	11-30	Medium Stiff	5 to 8
		Stiff	9 to 15
Dense	31 to 50	Very Stiff	16 to 30
Very Dense	>50	Hard	>30

Plasticity	
Description	**Criteria**
Nonplastic	A $\frac{1}{8}$" diameter thread cannot be rolled
Low	A $\frac{1}{8}$" in diameter thread can be rolled with difficulty; a lump cannot be formed at a moisture lower than the plastic limit
Medium	A $\frac{1}{8}$" in diameter thread can be rolled easily; a crumbly lump can be formed at a moisture lower than the plastic limit
High	A $\frac{1}{8}$" in diameter thread can be rolled very easily; a lump can be formed at a moisture lower than the plastic limit

Cementation	
Description	Criteria
Weak	Crumbles with light finger pressure
Moderate	Crumbles with considerable finger pressure
Strong	Will not crumble with finger pressure

Rock Descriptions:

Weathering	
Description	**Criteria**
Fresh	No visible sign of rock material weathering: perhaps slight discoloration on major discontinuity surfaces.
Slightly Weathered	Discoloration of rock material on discontinuity surfaces.
Moderately Weathered	Less than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as a continuous framework or as corestones.
Highly Weathered	More than half of the rock material is decompsed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones
Completely Weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.

Texture	
Description	**Criteria**
Very Fine Grained	Grains not individually visible to the unaided eye
Fine Grained	Grains barely visible to the unaided eye, up to $\frac{1}{16}$" diameter
Medium Grained	Grain diameter between $\frac{1}{16}$" and $\frac{3}{16}$"
Coarse Grained	Grains diameter between $\frac{3}{16}$" and $\frac{1}{4}$"
Very Coarse Grained	Grains larger than $\frac{1}{4}$" in diameter

Field Hardness	
Description	**Criteria**
Very Hard	Cannot be scratched with a knife or sharp pick.
Hard	Can be scratched with a knife or pick only with difficulty
Medium	Can be gouged $\frac{1}{16}$" deep by firm pressure on knife or pick point
Soft	Can be grooved or gouged readily with knife or pick point
Very Soft	Can be carved with knife and scratched readily by fingernail

Geologic Interpretation:

A *HRORJLF ,QWHUSUHWDWLRQ of encountered soil and bedrock units is provided for each specific 9LVXDO 'HVFULSWLRQ. Examples of geologic interpretations for soil that may be presented include: FILL, ALLUVIUM, AEOLIAN, AND GLACIAL TILL, AND RESIDUUM. Rock geologic interpretations are referenced based on a combination of field classifications and applicable geologic maps.

Sample Graphics and Descriptions:

California Barrel Sampler: Barrel sampler loaded with sample liners and driven to collect a relatively representative and intact specimen of soil or weak rock.

Split-Spoon Sampler: Split-barrel sampler driven in accordance with ASTM D1586 used to provide visual material descriptions and collect a disturbed specimen.

Shelby Tube Sampler: Thin wall tube hydraulically pushed into the subsurface to collect a representative and intact specimen of soil.

Bulk Sample: Bulk or bagged sample taken from auger cuttings.

Continuous Sampler: A 5-foot long sampler barrel that is driven to collect a continuous 5-foot run of cohesive and non-cohesive soil.

Groundwater Monitoring Well Graphics:

Riser Pipe with Auger Cuttings

Well Screen with Silica Sand

Riser Pipe with Silica Sand

Riser Pipe with Bentonite Chips

Auger Cuttings

Stick-Up Well

Flush Mounted Cap

First Groundwater Reading

Second Groundwater Reading

Third Groundwater Reading

Boring Graphics:

Below are the primary boring log graphics. Any classification combinations will result in a combination of graphics.

Fill

Lean Clay

Silt

Fat Clay

Elastic Silt

Well Graded Gravel

Poorly Graded Gravel

Well Graded Sand

Poorly Graded Sand

Sandstone

Claystone

Siltstone

LITHOS ENGINEERING

BORING: CHM-1

Project Name: TWP Booster and Hammer PS
Project Number: 21207
Client's Name: Carollo Engineers
Owner's Name: City of Thornton
Drilling Subcontractor: Vine Laboratories
Lithos Representative: J. Halverson
Date(s) of Drilling: 01/24/22

Drilling and Sampling Methods

Drill Make and Model: CME-55
Drilling Method: Hollow Stem Auger (HSA)
Bit Type: Cutting Head
Casing Description: HSA
Hammer Weight (lbs)/Fall (in): 140/30
Sampler Type(s): Modified California
Sampler Diameter(s): 2.0-inches

LITHOS ENGINEERING

Boring Location: 39.853567, -104.940072
Boring Elevation: 5,094' +/-
Notes: Elevation estimated based on provided site topo

Sampling Data / Laboratory Testing Results

Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psf)	Swell Pressure (psf)	Swell Percent (%)
8 8	10													
3 6	10					0.03								
3 8	10								35.5	28	7			
4 6	10													
6 8	10													
10 17	12		(20.0 ft.)				39.5	55.8	4.7					
12 18	12													
6 6	12													

Elevation (ft) scale: 5090, 5085, 5080, 5075, 5070, 5065
Depth (ft) scale: 0, 5, 10, 15, 20, 25, 30

Visual Material Description

Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions

Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions

ASPHALT PAVEMENT- 4" thick

0.3 ft.

FILL
Sandy LEAN CLAY (CL), some fine to coarse sand, few coarse gravel, very stiff, dark brown, moist, maximum particle size 2.5-inches, PID=33 ppm.
2.5' - Silty, clayey SAND (SC-SM), mostly sand, some silty clay, loose, olive to dark brown, moist, PID=7 ppm.
4' - As above except dark gray, olive yellow, dark brown, moist, PID=10 ppm.

Sandy LEAN CLAY (CL), little fine to coarse sand, trace fine to coarse gravel, stiff, dark gray, PID=5 ppm.

11.0 ft.

COARSE ALLUVIUM
Cobbles and gravel inferred based on drilling action at 11'.

Well-graded SAND (SW), mostly fine to coarse sand, few fine to coarse gravel, trace silt, medium dense, pale olive, moist, maximum particle size 1.0-inches, PID=9 ppm.

As above except some fine to coarse gravel, wet, maximum particle size 2.0-inches, PID=3 ppm.

As above except maximum particle size 1.0-inch, PID=2 ppm.

24.8 ft.

FINE ALLUVIUM
Sandy SILT (ML), some fine sand, medium dense, olive yellow, wet.

Sandy LEAN CLAY (CL), some fine sand, stiff, yellowish

General Notes:
1) Soil classifications are in general accordance with ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
01/24/22	0-days	20.0-feet

BORING: CHM-1

Project Name: TWP Booster and Hammer PS
Project Number: 21207
Client's Name: Carollo Engineers
Owner's Name: City of Thornton
Drilling Subcontractor: Vine Laboratories
Lithos Representative: J. Halverson
Date(s) of Drilling: 01/24/22

Drilling and Sampling Methods

Drill Make and Model: CME-55
Drilling Method: Hollow Stem Auger (HSA)
Bit Type: Cutting Head
Casing Description: HSA
Hammer Weight (lbs)/Fall (in): 140/30
Sampler Type(s): Modified California
Sampler Diameter(s): 2.0-inches

LITHOS ENGINEERING

Boring Location: 39.853567, -104.940072
Boring Elevation: 5,094' +/-
Notes: Elevation estimated based on provided site topo

Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Visual Material Description — Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions; Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psf)	Swell Pressure (psf)	Swell Percent (%)
30							brown, wet, PID= 3 ppm.												
32.0							**COARSE ALLUVIUM** Cobbles and gravel inferred based on drilling action at 32'.												
35	5060	MC	18 28	12			Poorly graded SAND with silt and gravel (SP-SM), mostly fine to coarse sand, little fine to coarse gravel, few silt, dense, pale olive, wet, maximum particle size 2.0-inches, PID=6 ppm.												
							Cobbles and gravel inferred based on drilling action at 37'.												
40	5055	MC	11 12	4			As above except trace gravel, medium dense, PID=2 ppm.												
40.0							**END OF EXPLORATION**												
45	5050																		
50	5045																		
55	5040																		
60	5035																		

General Notes:
1) Soil classifications are in general accordance with ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
01/24/22	0-days	20.0-feet

BORING: CHM-2

Project Name: TWP Booster and Hammer PS
Project Number: 21207
Client's Name: Carollo Engineers
Owner's Name: City of Thornton
Drilling Subcontractor: Vine Laboratories
Lithos Representative: J. Halverson
Date(s) of Drilling: 01/24/22

Drilling and Sampling Methods

Drill Make and Model: CME-55
Drilling Method: Hollow Stem Auger (HSA)
Bit Type: Cutting Head
Casing Description: HSA
Hammer Weight (lbs)/Fall (in): 140/30
Sampler Type(s): Modified California
Sampler Diameter(s): 2.0-inches

LITHOS ENGINEERING

Boring Location: 39.853406, -104.939981
Boring Elevation: 5,094' +/-
Notes: Elevation estimated based on provided site topo

Depth (ft)	Elevation (ft)	Blow Count/6 in	Recovery (in) / RQD (%)	Visual Material Description	Groundwater Depth	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psf)	Swell Pressure (psf)	Swell Percent (%)
0				**ASPHALT PAVEMENT- 7" thick**												
0.6		13, 8	10	**FILL** Clayey SAND with gravel (SC), mostly fine to medium sand, little fine gravel, little clay, medium dense, dark brown, moist, PID=5 ppm.												
		6, 6	10	1.3' - LEAN CLAY with sand (CL), little fine to medium sand, trace fine to coarse gravel, stiff, dark brown to black, moist, black organic debris.												
5	5090	3, 3	10	2.5' - As above except few fine gravel, stiff, dark brown, moist, PID=6 ppm. 4' - Clayey SAND (SC), mostly fine to coarse sand, some clay, few fine gravel, loose, dark gray to black, asphalt fragment, PID= 7 ppm.							39.3	32	11			
10	5085	3, 5	10	As above except dark gray, maximum particle size 1.0-inch, PID=28 ppm.												
				Cobbles and gravel inferred based on drilling action from 12-13'.												
15	5080	8, 13	12	Clayey SAND with gravel (SC), mostly fine to coarse sand, some clay, little fine gravel, medium dense, dark gray, moist, clear plastic debris present, PID=8 ppm.												
20	5075	8, 9	12	Silty SAND (SM), mostly fine to coarse sand, little silt, trace fine gravel, medium dense, dark gray, moist, PID=7 ppm.	(20.8 ft.)						20.2	29	6			
24.0				**COARSE ALLUVIUM**												
25	5070	6, 14	12	Poorly graded SAND (SP), mostly fine to coarse sand, trace fine to coarse gravel, medium dense, pale olive, wet, maximum particle size 2.0-inches, PID= 5 ppm.												
30	5065	8, 13	12	29' - Lean clay interlayer 6" thick, PID=11 ppm.												

General Notes:
1) Soil classifications are in general accordance with ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
01/24/22	0-days	20.8-feet

BORING: CHM-2

Project Name: TWP Booster and Hammer PS
Project Number: 21207
Client's Name: Carollo Engineers
Owner's Name: City of Thornton
Drilling Subcontractor: Vine Laboratories
Lithos Representative: J. Halverson
Date(s) of Drilling: 01/24/22

Drilling and Sampling Methods

Drill Make and Model: CME-55
Drilling Method: Hollow Stem Auger (HSA)
Bit Type: Cutting Head
Casing Description: HSA
Hammer Weight (lbs)/Fall (in): 140/30
Sampler Type(s): Modified California
Sampler Diameter(s): 2.0-inches

LITHOS ENGINEERING

Boring Location: 39.853406, -104.939981
Boring Elevation: 5,094' +/-
Notes: Elevation estimated based on provided site topo

Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Visual Material Description (Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions; Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions)	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psf)	Swell Pressure (psf)	Swell Percent (%)
30							Silty SAND (SM), mostly fine sand, little silt, yellowish brown, wet.												
							Cobbles and gravel 33'												
	5060	Modified California	13 27	12			Well-graded SAND with silt and gravel (SW-SM), mostly fine to coarse sand, little fine to coarse gravel, few silt, dense, pale olive, wet, maximum particle size 1.5-inches, PID=4 ppm.					25.7	67.8	6.5					
35																			
	5055	Modified California	18 26	12			As above except PID=12 ppm.												
40							40.0 ft.												
							END OF EXPLORATION												
	5050																		
45																			
	5045																		
50																			
	5040																		
55																			
	5035																		
60																			

General Notes:
1) Soil classifications are in general accordance with ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
01/24/22	0-days	20.8-feet

BORING: CHM-3

Project Name: TWP Booster and Hammer PS
Project Number: 21207
Client's Name: Carollo Engineers
Owner's Name: City of Thornton
Drilling Subcontractor: Elite Drilling Services
Lithos Representative: J. Halverson
Date(s) of Drilling: 11/16/22

Drilling and Sampling Methods

Drill Make and Model: Mobile 48X
Drilling Method: Hollow Stem Auger (HSA)
Bit Type: Cutting Head
Casing Description: HSA
Hammer Weight (lbs)/Fall (in): 140/30
Sampler Type(s): Mod. Cal., SPT
Sampler Diameter(s): 2.0-inches, 1.4-inches

LITHOS ENGINEERING

Boring Location: 39.853414, -104.940086
Boring Elevation: 5,095' +/-
Notes: Elevation estimated based on provided site topo

Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Visual Material Description (Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions; Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions)	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
0	5095						**PAVEMENT SECTION- AC= 1.5", ABC= 3"** (0.4 ft.)												
			5 7	11			**FILL** 0.4' - Poorly graded SAND with silt and gravel (SP-SM), mostly fine to coarse sand, little fine gravel, few silt, loose, yellowish brown, moist. 1.3' - Sandy FAT CLAY (CH), some fine to medium sand, trace fine gravel, stiff, dark blueish gray, moist.												
5	5090		3 3	6			4.5'- As above except some fine to coarse sand, medium stiff, mottled greenish gray to blueish gray.							66.2	56	36			
10	5085		6 7	7			Sandy LEAN CLAY with gravel (CL), some fine to coarse sand, little fine to coarse gravel, stiff, greenish gray, moist, medium plasticity, maximum particle size 1.5-inches.												
15	5080		7 8	9			As above except mottled dark blueish gray to greenish gray to black, organics, wood chunks.												
20	5075		4 11	11			As above, organics, wood chunks, trash present. 20'- Clayey SAND with gravel (SC), mostly fine to coarse sand, some clay, little fine gravel, medium dense, greenish gray, moist.												
								(23-0.0											
25	5070																		
							(27.0 ft.) **COARSE ALLUVIUM** Drilling smoothed out indicative of material transition.												
30	5065		12 15	18			Poorly graded SAND with clay and gravel (SP-SC), mostly fine to coarse sand, little fine gravel, few clay, medium dense, pale olive, wet.												

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
11/16/22	0-days	23-feet

BORING: CHM-3

Project Name: TWP Booster and Hammer PS
Project Number: 21207
Client's Name: Carollo Engineers
Owner's Name: City of Thornton
Drilling Subcontractor: Elite Drilling Services
Lithos Representative: J. Halverson
Date(s) of Drilling: 11/16/22

Drilling and Sampling Methods

Drill Make and Model: Mobile 48X
Drilling Method: Hollow Stem Auger (HSA)
Bit Type: Cutting Head
Casing Description: HSA
Hammer Weight (lbs)/Fall (in): 140/30
Sampler Type(s): Mod. Cal., SPT
Sampler Diameter(s): 2.0-inches, 1.4-inches

LITHOS ENGINEERING

Boring Location: 39.853414, -104.940086
Boring Elevation: 5,095' +/-
Notes: Elevation estimated based on provided site topo

Depth (ft)	Elevation (ft)	Blow Count/6 in	Recovery (in) / RQD (%)	Visual Material Description	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
				31' - Auger grinding; cobbles.											
35	5060	19 27 36	7	Clayey SAND with gravel (SC), mostly fine to coarse sand, some fine to coarse gravel, little clay, very dense, pale olive, wet, maximum particle size 1.5-inches.											
40	5055	3 5 9	4	Poorly graded SAND with clay and gravel (SP-SC), mostly fine to coarse sand, little fine to coarse gravel, few clay, medium dense, pale olive, wet, maximum particle size 1.25-inches.											
42.0 ft.				**DENVER FORMATION** Drilling difficulty increase indicative of material transition.											
45	5050	50/6"	7	Sandstone, very soft, fresh, blueish gray, mostly fine sand, some silt, mica grains, moist.						32.8					
50	5045	50/6"	7	As above except dark blueish gray to gray, claystone present at tip of sample.						40.3	NV	NP			
55	5040	50/6"	2	As above except greenish gray, some clay.	17.8		0.0								
60	5035	50/4"	6	Claystone, very soft, fresh, dark blueish gray to gray, few fine sand.						93.9	45	22			

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
11/16/22	0-days	23-feet

BORING: CHM-3

Project Name: TWP Booster and Hammer PS
Project Number: 21207
Client's Name: Carollo Engineers
Owner's Name: City of Thornton
Drilling Subcontractor: Elite Drilling Services
Lithos Representative: J. Halverson
Date(s) of Drilling: 11/16/22

Drilling and Sampling Methods

Drill Make and Model: Mobile 48X
Drilling Method: Hollow Stem Auger (HSA)
Bit Type: Cutting Head
Casing Description: HSA
Hammer Weight (lbs)/Fall (in): 140/30
Sampler Type(s): Mod. Cal., SPT
Sampler Diameter(s): 2.0-inches, 1.4-inches

LITHOS ENGINEERING

Boring Location: 39.853414, -104.940086
Boring Elevation: 5,095' +/-
Notes: Elevation estimated based on provided site topo

Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Visual Material Description	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psi)	Swell Pressure (psf)	Swell Percent (%)
65	5030		50/4"	4			As above except trace fine sand.		14.1	112.8				96.9	46	23		4,000	2.1
70	5025		50/6"	6			As above except trace fine sand.												
75	5020		50/6"	7			Siltstone, very soft, fresh, dark blueish gray to gray, trace fine sand.		14.4	118.4				96.9	45	18		17,560	5.2
							75.0 ft. **END OF EXPLORATION**												
80	5015																		
85	5010																		
90	5005																		

Visual Material Description key — Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions. Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions. Laboratory Testing Results: In-Situ States; INDEX DATA; Strength & Compressibility.

General Notes:
1) Soil classificaitons are in general accordance with ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.
4) Groundwater measurements for monitoring wells present water levels at the time of drilling, highest level, and lowest level. Refer to the respective report for a complete history of groundwater values.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
11/16/22	0-days	23-feet

BORING: VLT-1

Project Name: TWP Booster and Hammer PS
Project Number: 21207
Client's Name: Carollo Engineers
Owner's Name: City of Thornton
Drilling Subcontractor: Vine Laboratories
Lithos Representative: J. Halverson
Date(s) of Drilling: 01/25/22

Drilling and Sampling Methods

Drill Make and Model: CME-55
Drilling Method: Hollow Stem Auger (HSA)
Bit Type: Cutting Head
Casing Description: HSA
Hammer Weight (lbs)/Fall (in): 140/30
Sampler Type(s): Modified California
Sampler Diameter(s): 2.0-inches

LITHOS ENGINEERING

Boring Location: 39.854547, -104.939167
Boring Elevation: 5,082' +/-
Notes: Elevation estimated based on provided site topo

Depth (ft)	Elevation (ft)	Blow Count/6 in	Recovery (in) / RQD (%)	Visual Material Description	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psf)	Swell Pressure (psf)	Swell Percent (%)
0		13 16	10	**FILL** Sandy LEAN CLAY (CL), some fine to medium sand, very stiff, olive brown, dry to moist, roots, glass, PID=78 ppm.												
	5080															
		4 4	5	As above except medium stiff, moist, PID=11 ppm.												
5				4.8 ft. **COARSE ALLUVIUM** Poorly graded SAND with silt (SP-SM), mostly fine to coarse sand, few fine gravel, few silt, loose, pale olive, moist.												
	5075															
		2 2	12	As above except very loose, PID=33 ppm.				0.017								
10				9.5 ft. **FINE ALLUVIUM** Sandy SILT (ML), little fine sand, very loose, olive brown, wet.	(10.6 ft.)											
	5070															
					(13.8 ft.)											
15		5 7	10	14.0 ft. **COARSE ALLUVIUM** Poorly graded SAND with gravel (SP), mostly fine to coarse sand, little fine to coarse gravel, trace silt, loose, pale olive, wet, maximum particle size 2.0-inches, PID=70 ppm.												
	5065															
20		6 9	8	Silty SAND (SM), mostly fine to coarse sand, few to little silt, trace gravel, medium dense, pale olive to olive, wet, PID=45 ppm.					0.2	86.3	13.5	NV	NP			
	5060															
25		16 28	8	As above except few fine gravel, PID=7 ppm.												
	5055															
				Driller notes increase in drilling difficulty at 28'.												
				28.0 ft. **DENVER FORMATION**												
30		35 50/3"	4	Claystone, soft, fresh, dark greenish gray, PID=4 ppm.												

General Notes:
1) Soil classifications are in general accordance with ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
01/25/22	0-days	13.8-feet
2/14/22	3 weeks	10.6-feet

BORING: VLT-1

Project Name:	TWP Booster and Hammer PS
Project Number:	21207
Client's Name:	Carollo Engineers
Owner's Name:	City of Thornton
Drilling Subcontractor:	Vine Laboratories
Lithos Representative:	J. Halverson
Date(s) of Drilling:	01/25/22

Drilling and Sampling Methods

Drill Make and Model:	CME-55
Drilling Method:	Hollow Stem Auger (HSA)
Bit Type:	Cutting Head
Casing Description:	HSA
Hammer Weight (lbs)/Fall (in):	140/30
Sampler Type(s):	Modified California
Sampler Diameter(s):	2.0-inches

LITHOS ENGINEERING

Boring Location:	39.854547, -104.939167
Boring Elevation:	5,082' +/-
Notes:	Elevation estimated based on provided site topo

Visual Material Description

Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions

Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions

Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Visual Material Description	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psf)	Swell Pressure (psf)	Swell Percent (%)
30																			
	5050																		
		MC	50/3"	3			As above, PID=6 ppm.												
35																			
	5045																		
		MC	50/5"	4			As above, PID=3 ppm.												
							39.4 ft. **END OF EXPLORATION**												
40																			
	5040																		
45																			
	5035																		
50																			
	5030																		
55																			
	5025																		
60																			

General Notes:

1) Soil classifications are in general accordance with ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
01/25/22	0-days	13.8-feet
2/14/22	3 weeks	10.6-feet

BORING: VLT-2

Project Name: TWP Booster and Hammer PS
Project Number: 21207
Client's Name: Carollo Engineers
Owner's Name: City of Thornton
Drilling Subcontractor: Vine Laboratories
Lithos Representative: J. Halverson
Date(s) of Drilling: 01/25/22

Drilling and Sampling Methods

Drill Make and Model: CME-55
Drilling Method: Hollow Stem Auger (HSA)
Bit Type: Cutting Head
Casing Description: HSA
Hammer Weight (lbs)/Fall (in): 140/30
Sampler Type(s): Mod. Cal., SPT
Sampler Diameter(s): 2.0-inches, 1.4-inches

LITHOS ENGINEERING

Boring Location: 39.854247, -104.939283
Boring Elevation: 5,082' +/-
Notes: Elevation estimated based on provided site topo

Visual Material Description

Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions

Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions

Depth (ft)	Blow Count/6 in	Recovery (in) / RQD (%)	Visual Material Description	Groundwater Depth	Gravel Content (%)	Sand Content (%)	Fines Content (%)
0–3.0	7, 18	12	**FILL** Sandy LEAN CLAY with gravel (CL), some fine to medium sand, little fine gravel, very stiff, olive brown, moist, roots, PID<2 ppm.				
3.0 ft.	5, 7	10	**COARSE ALLUVIUM** Well-graded SAND with silt and gravel (SW-SM), mostly fine to coarse sand, little fine gravel, few silt, loose, pale olive, moist, maximum particle size 0.75-inches, PID=88 ppm.				
~10	5, 6, 6	12	As above except wet, maximum particle size 1.25-inches, PID<2 ppm.		44.9	48.7	6.4
~15	8, 11	8	Poorly graded SAND with silt (SP-SM), mostly fine to medium sand, few silt, trace fine gravel, medium dense, olive, wet, PID=3 ppm.	(13.9 ft.)			5.5
~20	3, 4, 3	18	As above except loose, PID<2 ppm.				
~25	6, 8, 12	14	Poorly graded SAND (SP), mostly fine to coarse sand, trace silt, trace fine gravel, medium dense, pale olive, wet, PID=33 ppm.				
28.0 ft.	20, 50	10	**DENVER FORMATION** Sandstone, soft, fresh, dark greenish gray, mostly fine sand,				

Elevation scale: 5080, 5075, 5070, 5065, 5060, 5055

Laboratory Testing Results columns: In-Situ States (Moisture Content (%), Dry Unit Weight (pcf), Water Soluble Sulfates (%)); INDEX DATA (Gravel Content (%), Sand Content (%), Fines Content (%), Liquid Limit (%), Plasticity Index (%)); Strength & Compressibility (UCS (psf), Swell Pressure (psf), Swell Percent (%))

General Notes:
1) Soil classifications are in general accordance with ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.

Groundwater Data:

Date:	Elapsed Time:	Depth to Groundwater:
01/25/22	0-days	13.9-feet

BORING: VLT-2	Drilling and Sampling Methods	LITHOS ENGINEERING
Project Name: TWP Booster and Hammer PS	Drill Make and Model: CME-55	
Project Number: 21207	Drilling Method: Hollow Stem Auger (HSA)	
Client's Name: Carollo Engineers	Bit Type: Cutting Head	
Owner's Name: City of Thornton	Casing Description: HSA	Boring Location: 39.854247, -104.939283
Drilling Subcontractor: Vine Laboratories	Hammer Weight (lbs)/Fall (in): 140/30	Boring Elevation: 5,082' +/-
Lithos Representative: J. Halverson	Sampler Type(s): Mod. Cal., SPT	Notes: Elevation estimated based on provided
Date(s) of Drilling: 01/25/22	Sampler Diameter(s): 2.0-inches, 1.4-inches	site topo

Visual Material Description

Soil: -GEOLOGIC INTERPRETATION- USCS Classification (group symbol), particle sizes, density or consistency, color, moisture, odor, other descriptions

Rock: -GEOLOGIC INTERPRETATION- Bedrock Classification, hardness, weather, color, texture, joint size, other descriptions

Depth (ft)	Elevation (ft)	Sample Identification	Blow Count/6 in	Recovery (in) / RQD (%)	Drilling Rate (min./ft.)	Geologic Graphic	Visual Material Description	Groundwater Depth / Monitoring Well Configuration	Moisture Content (%)	Dry Unit Weight (pcf)	Water Soluble Sulfates (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit (%)	Plasticity Index (%)	UCS (psf)	Swell Pressure (psf)	Swell Percent (%)
30							some lean clay, PID=2 ppm.												
	5050																		
		⧓	50/5"	5			As above.		16.3	110.8				31.0	42	18		6,370	3.7
35																			
	5045																		
		⧓	50/5"	4			As above, PID=3 ppm.												
							39.4 ft.												
40							**END OF EXPLORATION**												
	5040																		
45	5035																		
50	5030																		
55	5025																		
60																			

General Notes:
1) Soil classifications are in general accordance with ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
2) The maximum particle size identified in the material description is dependent on sampler dimensions.
3) Additional information is provided on the Boring Log Key.

Groundwater Data:

	Date:	Elapsed Time:	Depth to Groundwater:
▼	01/25/22	0-days	13.9-feet
▽			
▽			

APPENDIX – B

Geotechnical Laboratory Testing Results

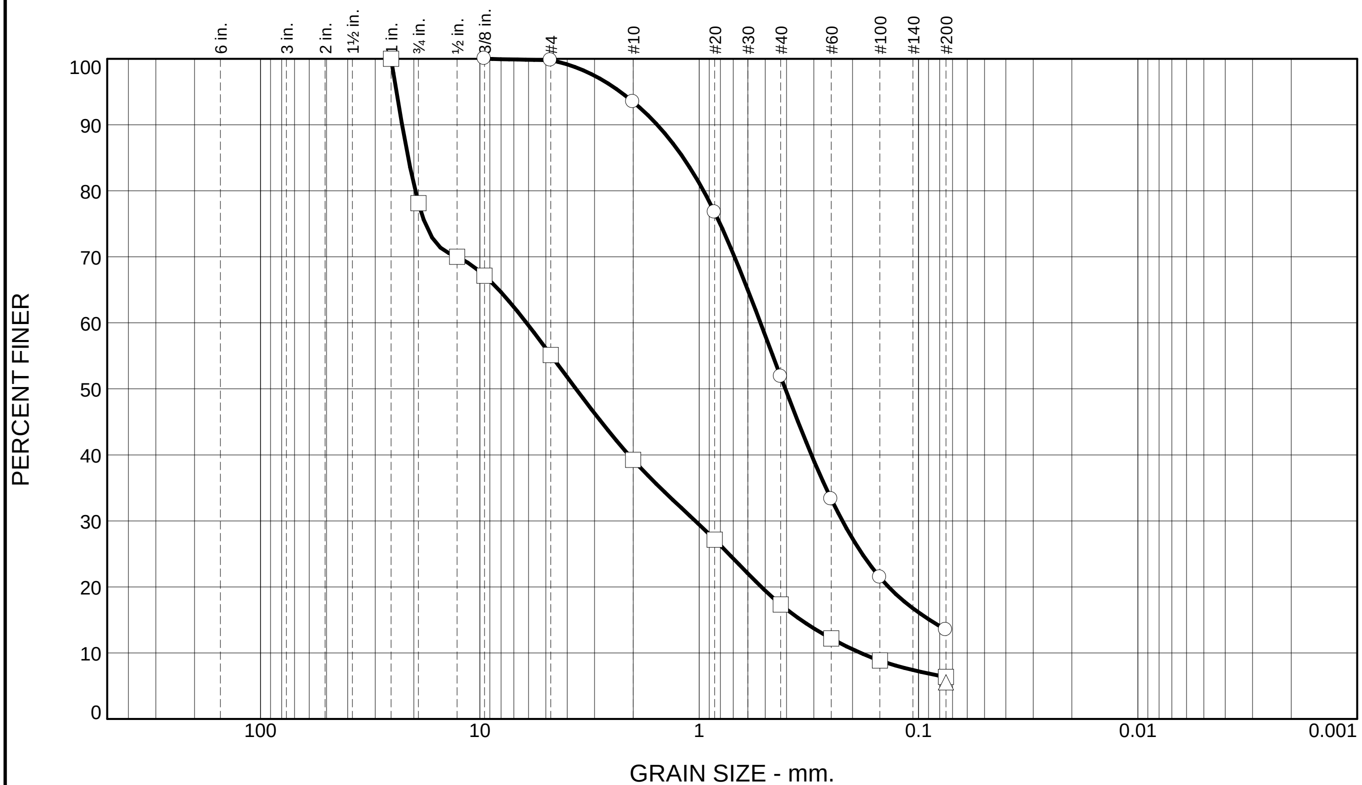
Geotechnical Laboratory Testing Results													
Sample Identification		In-Place States		Sulfates	Material Classification and Index Testing					Stress Strain Behavior		USCS Classification [1,2]	Description
					Particle Size Distribution			Atterberg Limits (%)		One-Dimensional Swell/Consolidation			
Boring	Sample Depth (ft)	Moisture Content (%)	Dry Density (pcf)	Water Soluble Sulfates (%)	Gravel (%)	Sand (%)	Fines (%)	Liquid Limit	Plasticity Index	Swell (%)	Swell Pressure (psf)		
VLT-1	19.0 - 20.0				0.2	86.3	13.5	NV	NP			SM	Silty SAND
VLT-2	9.0 - 10.0				44.9	48.7	6.4					SP-SM	Poorly Graded SAND with Silt and Gravel
VLT-2	14.0 - 15.0						5.5					SP-SM	Poorly Graded SAND with Silt
VLT-2	34.0 - 34.4	16.3	110.8				31.0	42	18	3.7	6,370	BR	Clayey Sandstone
CHM-1	4.0 - 5.0						35.5	28	7			SC-SM	Silty, Clayey SAND
CHM-1	9.0 - 10.0						68.6	39	15			CL	Sandy LEAN CLAY
CHM-1	19.0 - 20.0				39.5	55.8	4.7					SW	Well-Graded SAND with Gravel
CHM-2	4.0 - 5.0						39.3	32	11			SC	Clayey SAND
CHM-2	19.0 - 20.0						20.2	29	6			SM	Silty SAND
CHM-2	34.0 - 35.0				25.7	67.8	6.5					SW-SM	Well-Graded SAND with Silt and Gravel
CHM-3	4.5-5.5						66.2	56	36			CH	Sandy FAT CLAY
CHM-3	44.5-45.0						32.8					BR	Sandstone
CHM-3	49.5-50.0						40.3	NV	NP			BR	Sandstone
CHM-3	54.5-55.5	17.8		0.0								BR	Sandstone
CHM-3	59.5-59.8						93.9	45	22			BR	Claystone
CHM-3	64.5-64.8	14.1	112.8				96.9	46	23	2.1	4,000	BR	Claystone
CHM-3	74.5-75.0	14.4	118.4				96.9	45	18	5.2	17,560	BR	Siltstone

[1] Where Atterberg Limits and fines content testing were not performed, USCS classifications were visually determined in the field during the subsurface investigation

[2] "BR" is used in place of USCS classifications for bedrock

LITHOS ENGINEERING

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PL	PI
○	0.0	0.2	86.3	13.5		SM	NV	NP	NP
□	0.0	44.9	48.7	6.4					
△									

SIEVE inches size	PERCENT FINER ○	□	△
1"		100.0	
3/4"		78.1	
1/2"		70.0	
3/8"	100.0	67.1	
	GRAIN SIZE		
D_{60}	0.5257	6.1238	
D_{30}	0.2224	1.0421	
D_{10}		0.1835	
	COEFFICIENTS		
C_c		0.97	
C_u		33.37	

SIEVE number size	PERCENT FINER ○	□	△
#4	99.8	55.1	
#10	93.5	39.3	
#20	76.7	27.2	
#40	51.9	17.3	
#60	33.3	12.2	
#100	21.5	8.8	
#200	13.5	6.4	5.5

Material Description
○ USCS: silty sand
□
△

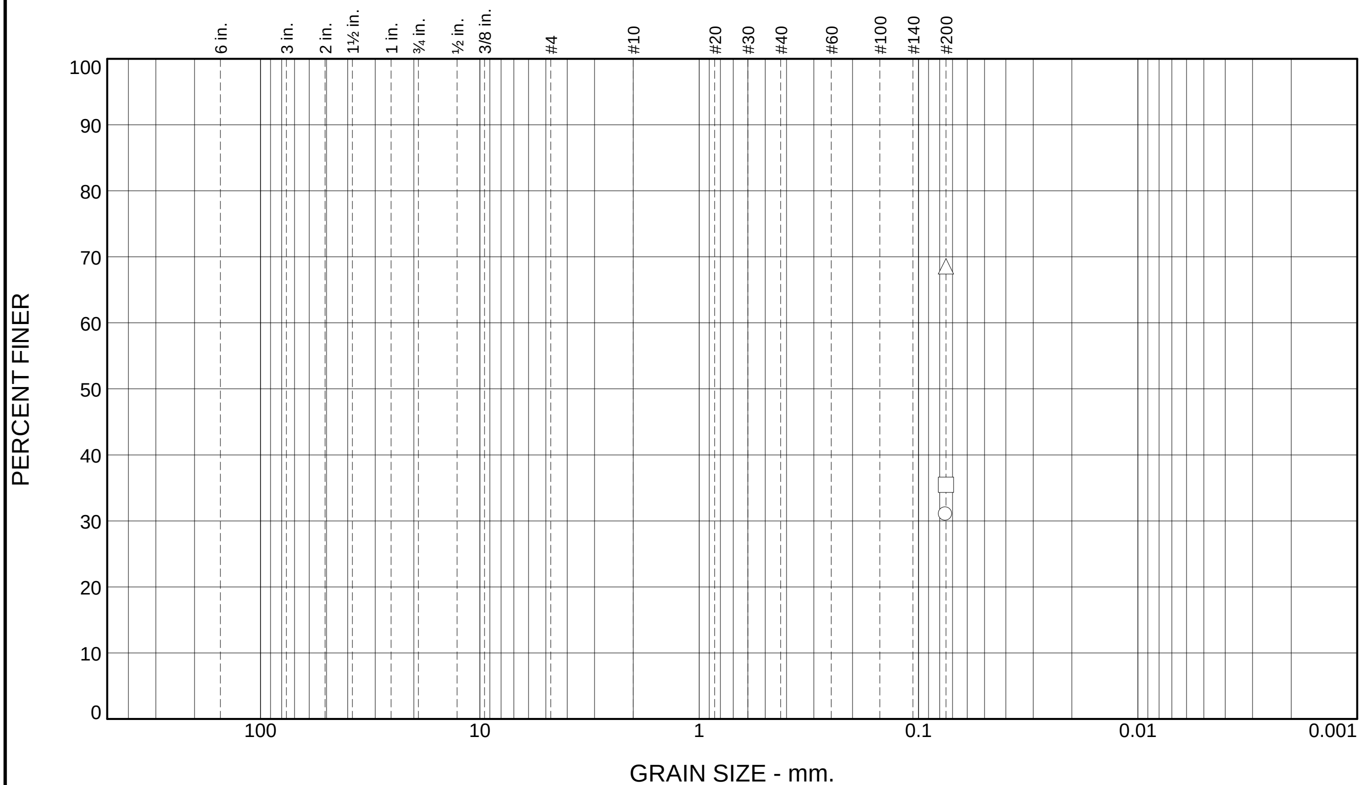
REMARKS:
○
□
△

○ Location: VLT-1 Depth: 19-20' Sample Number: 10638
□ Location: VLT-2 Depth: 9-10' Sample Number: 10639
△ Location: VLT-2 Depth: 14-15' Sample Number: 10640

Martinez Associates

Client: Lithos Engineering
Project: Thornton Water Project Chem Building & Vaults
LE Project # 21207
Project No.: 21-0198 Figure

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PL	PI
○							42	24	18
□							28	21	7
△							39	24	15

SIEVE inches size	PERCENT FINER ○	□	△
	GRAIN SIZE		
D_{60}			
D_{30}			
D_{10}			
	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#200	31.0	35.5	68.6

Material Description
○
□
△

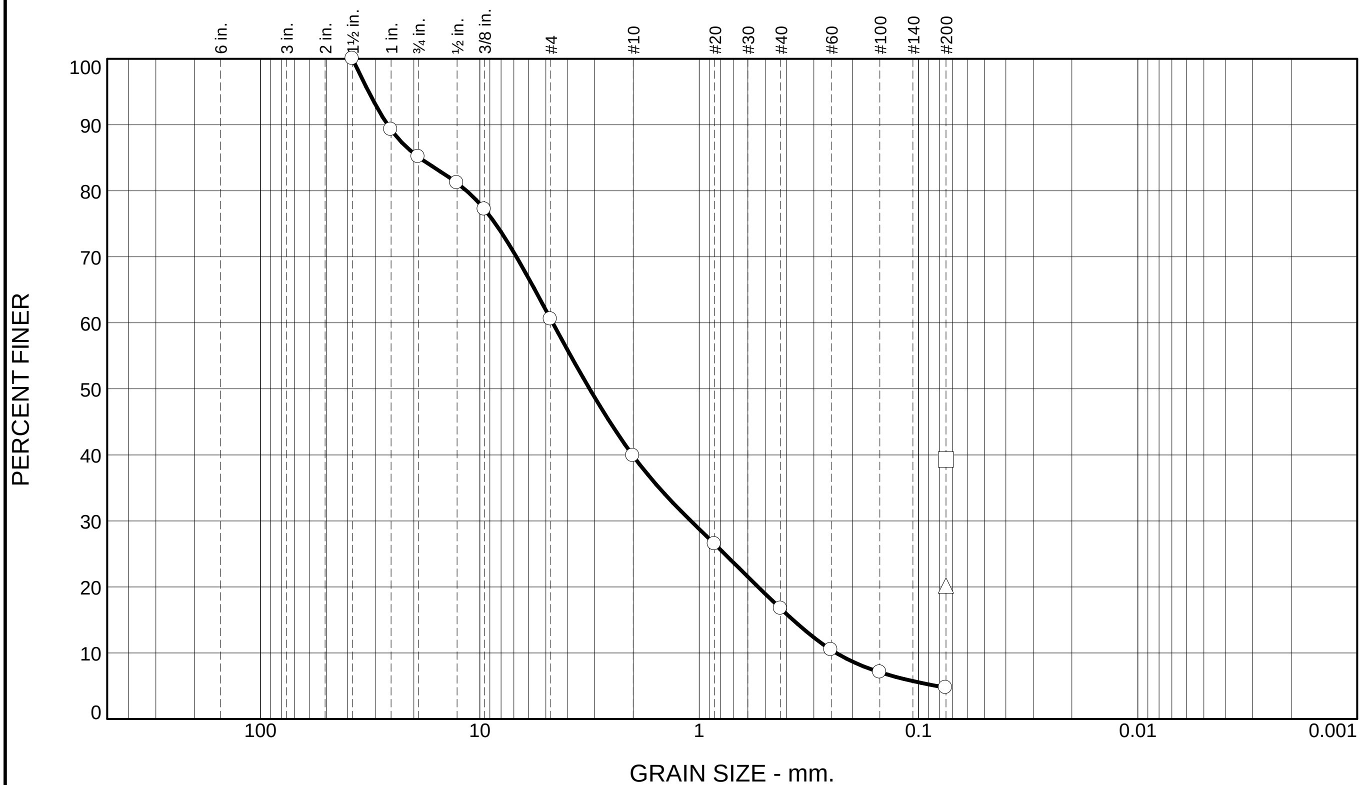
REMARKS:
○
□
△

○Location: VLT-2 Depth: 34-34.4' Sample Number: 10641
□Location: CHM-1 Depth: 4-5' Sample Number: 10642
△Location: CHM-1 Depth: 9-10' Sample Number: 10643

Martinez Associates

Client: Lithos Engineering
Project: Thornton Water Project Chem Building & Vaults
LE Project # 21207
Project No.: 21-0198 Figure

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PL	PI
○	0.0	39.5	55.8	4.7		SW			
□							32	21	11
△							29	23	6

SIEVE inches size	PERCENT FINER ○	□	△
1.5"	100.0		
1"	89.3		
3/4"	85.1		
1/2"	81.2		
3/8"	77.2		
	GRAIN SIZE		
D_{60}	4.6545		
D_{30}	1.0909		
D_{10}	0.2373		
	COEFFICIENTS		
C_c	1.08		
C_u	19.61		

SIEVE number size	PERCENT FINER ○	□	△
#4	60.5		
#10	39.9		
#20	26.5		
#40	16.7		
#60	10.5		
#100	7.1		
#200	4.7	39.3	20.2

Material Description
○ USCS: well-graded sand with gravel
□
△

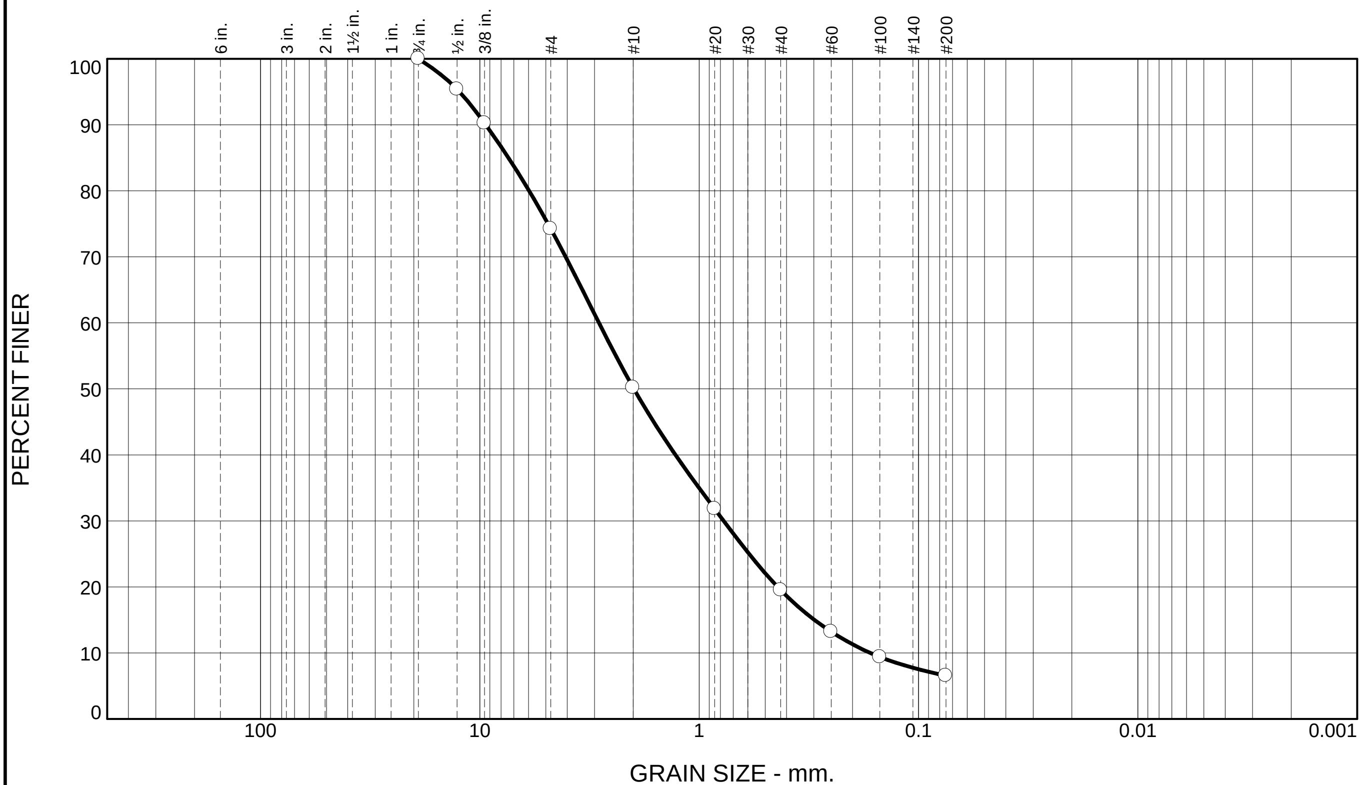
REMARKS:
○
□
△

○ Location: CHM-1 Depth: 19-20' Sample Number: 10644
□ Location: CHM-2 Depth: 4-5' Sample Number: 10645
△ Location: CHM-2 Depth: 19-20' Sample Number: 10646

Martinez Associates

Client: Lithos Engineering
Project: Thornton Water Project Chem Building & Vaults
LE Project # 21207
Project No.: 21-0198 Figure

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PL	PI
○	0.0	25.7	67.8	6.5					

SIEVE inches size	PERCENT FINER ○		
3/4"	100.0		
1/2"	95.4		
3/8"	90.3		
	GRAIN SIZE		
D_{60}	2.8635		
D_{30}	0.7735		
D_{10}	0.1660		
	COEFFICIENTS		
C_c	1.26		
C_u	17.25		

SIEVE number size	PERCENT FINER ○		
#4	74.3		
#10	50.2		
#20	31.8		
#40	19.5		
#60	13.2		
#100	9.4		
#200	6.5		

Material Description
○

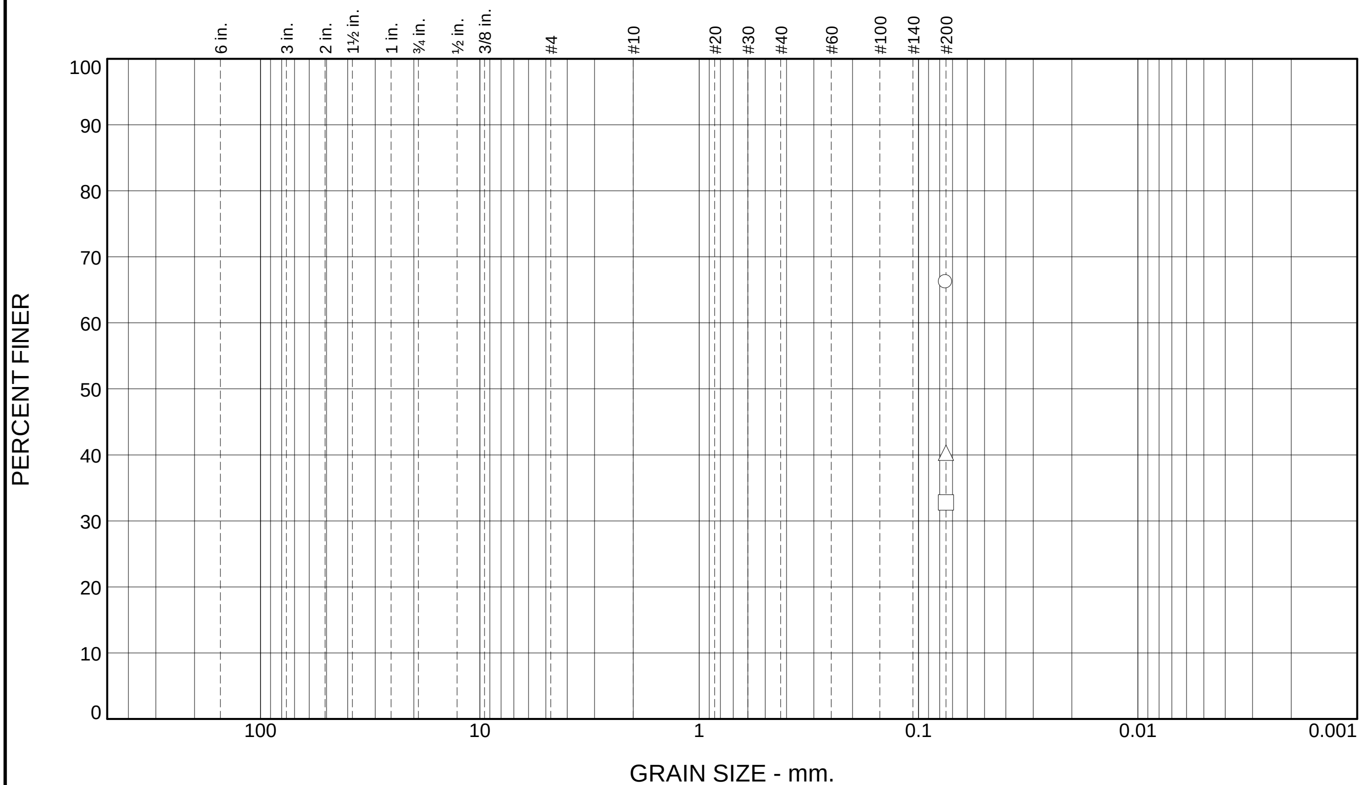
REMARKS:
○

○ Location: CHM-2 Depth: 34-35' Sample Number: 10647

Martinez Associates

Client: Lithos Engineering
Project: Thornton Water Project Chem Building & Vaults
LE Project # 21207
Project No.: 21-0198 Figure

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PL	PI
○							56	20	36
□									
△							NV	NP	NP

SIEVE inches size	PERCENT FINER ○	□	△
	GRAIN SIZE		
D_{60}			
D_{30}			
D_{10}			
	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#200	66.2	32.8	40.3

Material Description
○
□
△

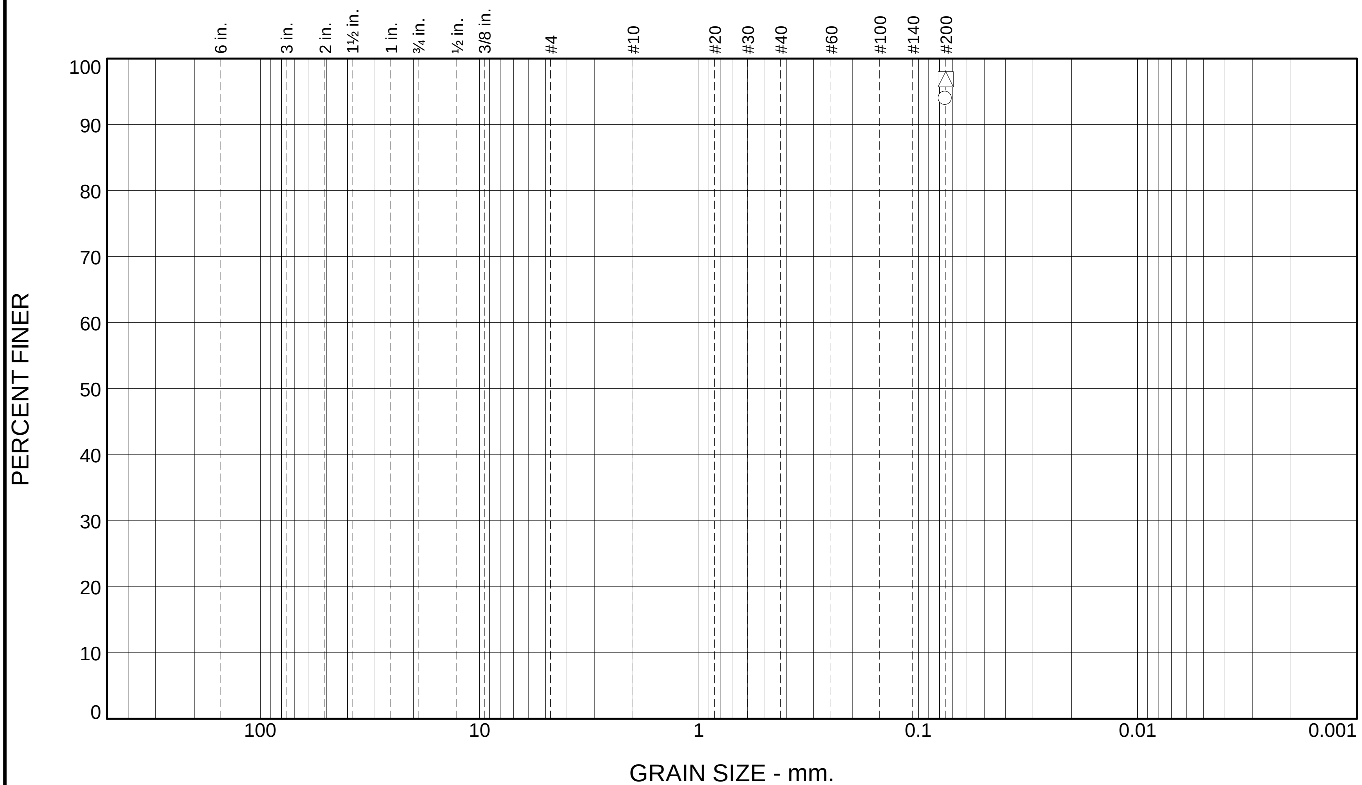
REMARKS:
○
□
△

○ Location: CHM-3 Depth: 4.5-5.5' Sample Number: 11436
□ Location: CHM-3 Depth: 44.5-45' Sample Number: 11437
△ Location: CHM-3 Depth: 49.5-50' Sample Number: 11438

Martinez Associates

Client: Lithos Engineering
Project: Thornton Water Project Chem Building & Vaults
LE Project # 21207
Project No.: 21-0198 Figure

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PL	PI
○							45	23	22
□							46	23	23
△							45	27	18

SIEVE inches size	PERCENT FINER ○	PERCENT FINER □	PERCENT FINER △
	GRAIN SIZE		
D_{60}			
D_{30}			
D_{10}			
	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	PERCENT FINER □	PERCENT FINER △
#200	93.9	96.9	96.9

Material Description
○
□
△

REMARKS:
○
□
△

○ Location: CHM-3 Depth: 59.5-60' Sample Number: 11440
□ Location: CHM-3 Depth: 64.5-65' Sample Number: 11440.5
△ Location: CHM-3 Depth: 74.5-75' Sample Number: 11441.5

Martinez Associates

Client: Lithos Engineering
Project: Thornton Water Project Chem Building & Vaults
LE Project # 21207
Project No.: 21-0198 Figure

Martinez Associates
14828 West 6th Avenue, Unit 9-B
Golden, Colorado 80401
Phone: (303) 459-2216
Fax: (303) 482-2230

Martinez Associates

One Dimensional Swell/Consolidation (ASTM D 4546)

(Denver Area Swell/Consolidation Test)

Client Project No.: 21207 Proj. Name: Thornton Water Project Chem Bldg & Vaults Sampled By: LE
Martinez Job No.: 21-0198 Lab Tech: T. Reid Test Date: 2/1/22 Sample Date: NP
Sample ID: 10641 Reviewed By: K. Runner
Sample Location: VLT-2 at 34-34.4'
Soil Description:
USCS:

Sample Data:

Ring No:	E	Dish No:	54
Ring Mass (g):	237.8	Dish Mass (g):	8.2
Sample Height (in):	0.75	Swell Machine #:	5
Pre-test Sample		**Post-test Sample**	
Ring + Sample (g):	312.5	Ring + Sample (g):	313.6
Dish wt:	8.2	Dish wt:	8.6
Wet wt (g):	356.9	Wet wt (g):	84.5
Dry wt (g):	308.0	Dry wt (g):	71.1

Results:

Pre-test Sample		**Post-test Sample**	
Moisture Content:	16.3%	Moisture Content:	21.4%
Wet Density (pcf):	128.9	Wet Density (pcf):	132.4
Dry Density (pcf):	110.8	Dry Density (pcf):	109.1

Swell/Consolidation

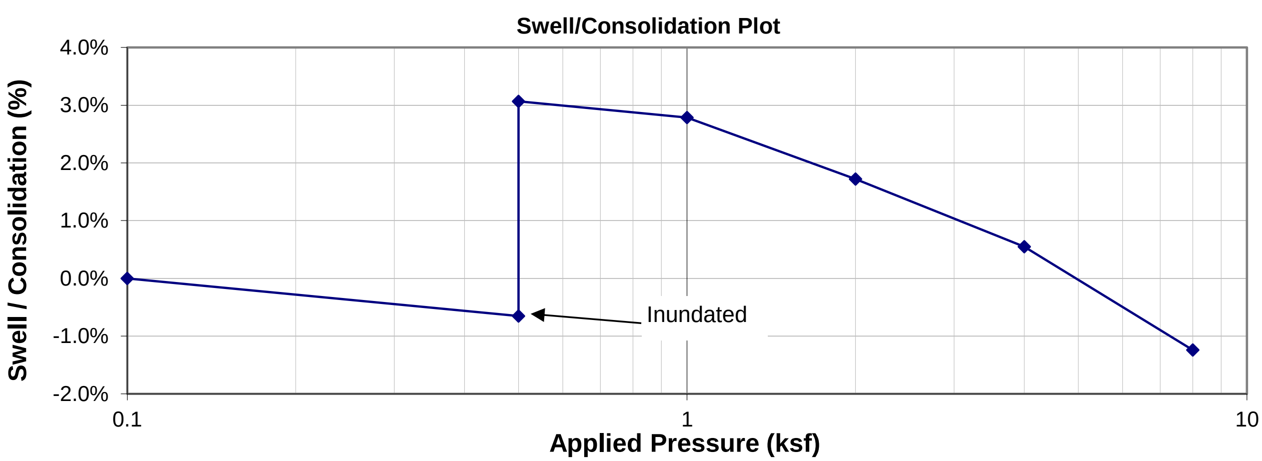
Load (ksf):	0.1	0.5	Add Water	0.5	1	2	4	8	
Correction (x 10-4):	0	14		14	32	65	94	119	
Dial Reading (x 10-4):	2922	2859		3138	3099	2986	2869	2710	
Swell/Consolidation %:	**0.0%**	**-0.7%**		**3.1%**	**2.8%**	**1.7%**	**0.5%**	**-1.2%**	

Results:

Swell Upon Wetting @ 500 psf: **3.7%**

Swell Pressure (psf): **6,370**

Tested By: T. Reid
Checked By K. Runner



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14828 West 6th Avenue, Unit 9-B
Golden, Colorado 80401
Phone: (303) 459-2216
Fax: (303) 482-2230

One Dimensional Swell/Consolidation (ASTM D 4546)

(Denver Area Swell/Consolidation Test)

Client Project No.: 21207 Proj. Name: Thornton Water Project Chem Building & Vaults Sampled By: LE
Martinez Job No.: 21-0198 Lab Tech: WSG Test Date: 11/22/22 Sample Date: NP
Sample ID: 11440.5 Reviewed By: K. Runner
Sample Location: CHM-3 64.5-65'
Soil Description:
USCS:

Sample Data:

Ring No:	G	Dish No:	16
Ring Mass (g):	237.30	Dish Mass (g):	8.00
Sample Height (in):	0.75	Swell Machine #:	7
Pre-test Sample		**Post-test Sample**	
Ring + Sample (g):	311.90	Ring + Sample (g):	314.10
Dish wt:	8.00	Dish wt:	8.08
Wet wt (g):	337.30	Wet wt (g):	84.38
Dry wt (g):	296.50	Dry wt (g):	72.83

Results:

Pre-test Sample		**Post-test Sample**	
Moisture Content:	14.1%	Moisture Content:	17.8%
Wet Density (pcf):	128.7	Wet Density (pcf):	135.2
Dry Density (pcf):	112.8	Dry Density (pcf):	114.7

Swell/Consolidation

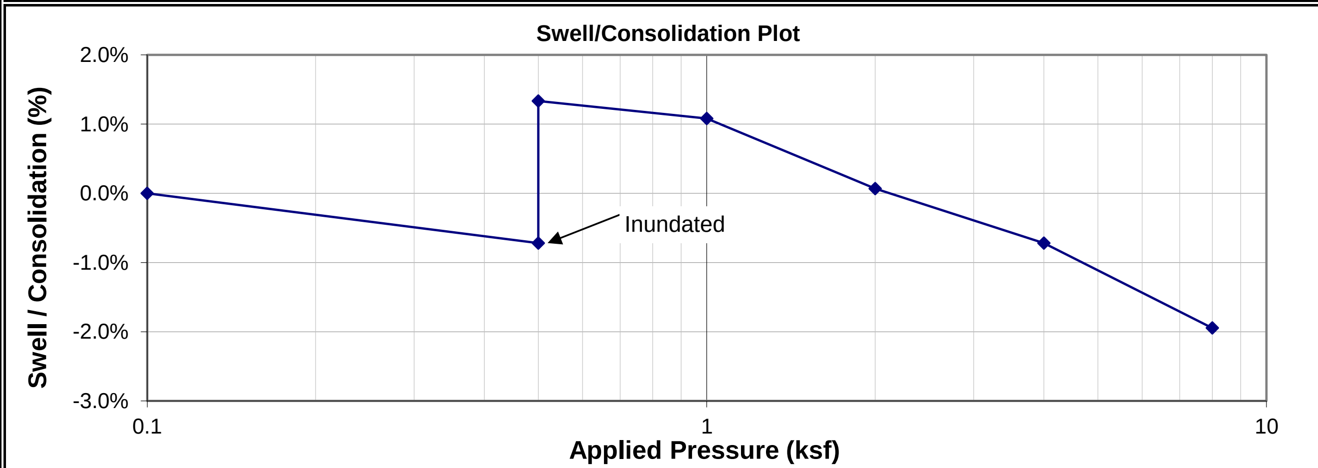
Load (ksf):	0.1	0.5	Add Water	0.5	1	2	4	8	
Correction (x 10-4):	0	20		20	36	59	76	95	
Dial Reading (x 10-4):	2382	2308		2462	2427	2328	2252	2141	
Swell/Consolidation %:	**0.0%**	**-0.7%**		**1.3%**	**1.1%**	**0.1%**	**-0.7%**	**-1.9%**	

Results:

Swell Upon Wetting @ 500 psf: **2.1%**

Swell Pressure (psf): **4,000**

Tested By: WS Greer
Checked By K. Runner



Martinez Associates
14828 West 6th Avenue, Unit 9-B
Golden, Colorado 80401
Phone: (303) 459-2216
Fax: (303) 482-2230

Martinez Associates

One Dimensional Swell/Consolidation (ASTM D 4546)

(Denver Area Swell/Consolidation Test)

Client Project No.: 21207 Proj. Name: Thornton Water Project Chem Building & Vaults Sampled By: LE
Martinez Job No.: 21-0198 Lab Tech: WSG Test Date: 11/22/22 Sample Date:
Sample ID: 11441.5 Reviewed By: K. Runner
Sample Location: CHM-3 74.5-75'
Soil Description:
USCS:

Sample Data:

Ring No:	H	Dish No:	48
Ring Mass (g):	236.80	Dish Mass (g):	8.00
Sample Height (in):	0.75	Swell Machine #:	8

Pre-test Sample		**Post-test Sample**	
Ring + Sample (g):	315.30	Ring + Sample (g):	317.20
Dish wt:	8.00	Dish wt:	8.09
Wet wt (g):	359.20	Wet wt (g):	87.90
Dry wt (g):	315.00	Dry wt (g):	76.03

Results:

Pre-test Sample		**Post-test Sample**	
Moisture Content:	14.4%	Moisture Content:	17.5%
Wet Density (pcf):	135.5	Wet Density (pcf):	141.7
Dry Density (pcf):	118.4	Dry Density (pcf):	120.6

Swell/Consolidation

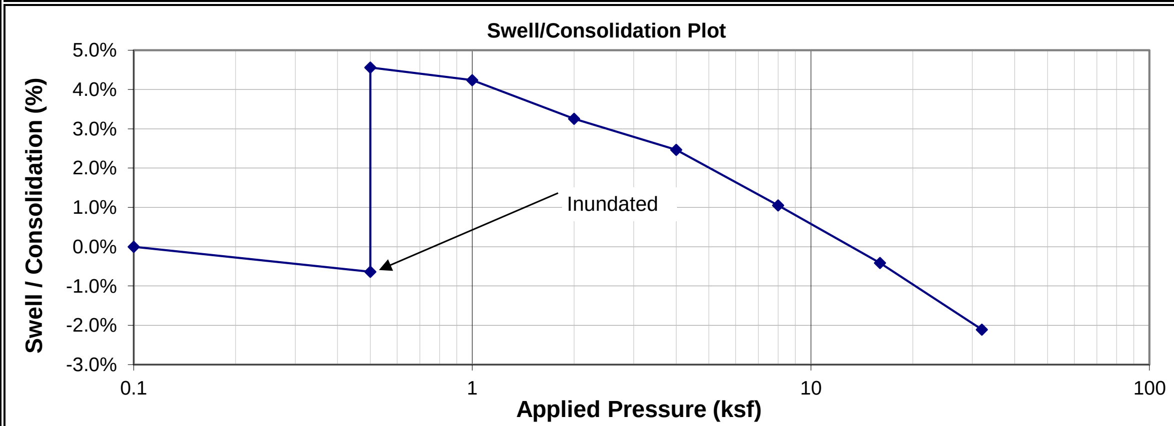
Load (ksf):	0.1	0.5	Add Water	0.5	1	2	4	8	16	32
Correction (x 10-4):	0	12		12	27	46	68	87	114	144
Dial Reading (x 10-4):	2821	2761		3151	3112	3019	2938	2813	2676	2519
Swell/Consolidation %:	**0.0%**	**-0.6%**		**4.6%**	**4.2%**	**3.3%**	**2.5%**	**1.1%**	**-0.4%**	**-2.1%**

Results:

Swell Upon Wetting @ 500 psf: **5.2%**

Swell Pressure (psf): **17,560**

Tested By: WS Greer
Checked By K. Runner



Martinez Associates

Water Soluble Sulfates/Colorado Procedure- Laboratory 2103 (Method B)

Project:	Thornton Water Project Chem Building & Vaults	**Date:**	12/1/2022
Sample Location:	CHM-3 at 54.5-55'	**Client Job No.:**	21207
Lab ID Number:	11439	**Martinez Job No.:**	21-0198
Soil Description:		**Lab Technician:**	R. Kay
		Reviewed by:	K. Runner

Sample Flask ID:	B
Date Test Set Up:	11/21/2022
Date in Solution:	11/21/2022
Date of Test:	11/22/2022

A	Number of Dilutions	2	
B	Final Dilution	100	:1
C	Reading	0	mg/L
C.1	Corrected Reading	0	mg/L
D	Sulfate Concentration ; D=(BxC.1)	0	ppm
E	Percent Sulfate Concentration E=D/10,000	0	%

Moisture Content

Dish ID:	25
Dish Mass (g):	8.3
Mass of Wet Soil+Dish (g):	217.7
Mass of DrySoil+Dish (g):	186.1
Moisture Content:	17.8%

APPENDIX – C

Laboratory Corrosion Results

Results Only Soil Testing for Thornton Water Project Chemical Building & Vaults

February 7, 2022

Prepared for:

Derek Magnuson
Lithos Engineering
2750 S. Wadsworth Blvd, Suite D-200
Denver, CO 80227
derek@lithoseng.com

Project X Job#: S220203E
Client Job or PO#: 21207, Task 1.3.7

Respectfully Submitted,

Eduardo Hernandez, M.Sc., P.E.
Sr. Corrosion Consultant
NACE Corrosion Technologist #16592
Professional Engineer
California No. M37102
ehernandez@projectxcorrosion.com

Soil Analysis Lab Results

Client: Lithos Engineering
Job Name: Thornton Water Project Chemical Building & Vaults
Client Job Number: 21207, Task 1.3.7
Project X Job Number: S220203E
February 7, 2022

	Method	ASTM D4327		ASTM D4327		ASTM G187		ASTM G51	ASTM G200	SM 4500-D	ASTM D4327	ASTM D6919	ASTM D6919	ASTM D6919	ASTM D6919	ASTM D6919	ASTM D6919	ASTM D4327	ASTM D4327
Bore# / Description	**Depth**	**Sulfates** SO_4^{2-}		**Chlorides** Cl^-		**Resistivity** As Rec'd	Minimum	**pH**	**Redox**	**Sulfide** S^{2-}	**Nitrate** NO_3^-	**Ammonium** NH_4^+	**Lithium** Li^+	**Sodium** Na^+	**Potassium** K^+	**Magnesium** Mg^{2+}	**Calcium** Ca^{2+}	**Fluoride** F_2^{--}	**Phosphate** PO_4^{3-}
	(ft)	(mg/kg)	(wt%)	(mg/kg)	(wt%)	(Ohm-cm)	(Ohm-cm)		(mV)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
VLT-1 Soil	9-10	165.5	0.0166	75.3	0.0075	2,077	2,077	7.9	110	0.27	0.3	3.2	0.02	158.9	4.1	15.0	6.5	7.1	1.0
CHM-1 Soil	2.5-3.5	295.9	0.0296	404.0	0.0404	804	670	8.0	121	0.03	1.0	6.4	0.07	275.0	3.2	23.4	2.2	7.2	0.5

Cations and Anions, except Sulfide and Bicarbonate, tested with Ion Chromatography
mg/kg = milligrams per kilogram (parts per million) of dry soil weight
ND = 0 = Not Detected | NT = Not Tested | Unk = Unknown
Chemical Analysis performed on 1:3 Soil-To-Water extract
PPM = mg/kg (soil) = mg/L (Liquid)

Project X
Corrosion Engineering
Corrosion Control · Soil, Water, and Metallurgy Lab

Lab Request Sheet Chain of Custody

Phone: (213) 928-7213 · Fax (951) 226-1720 · www.projectxcorrosion.com

Ship Samples To: 29990 Technology Dr, Suite 13, Murrieta, CA 92563

Project X Job Number S220203 E Lithos 21207 Thornton W 2 Full

IMPORTANT: Please complete Project and Sample Identification Data as you would like it to appear in report & include this form with samples.

Company Name:	Lithos Engineering	**Contact Name:**	Derek Magnuson — **Phone No:** 510.543.5852
Mailing Address:	2750 S. Wadsworth Blvd, Suite D-200, Denver, CO 80227	**Contact Email:**	derek@lithoseng.com
Accounting Contact:	Sissy Morphew	**Invoice Email:**	sissy@lithoseng.com
Client Project No:	21207, Task 1.3.7	**Project Name:**	Thornton Water Project Chemical Building & Vaults

P.O. #:		**3-5 Day Standard**	**3 Day Guarantee** 50% mark-up	**24 Hr RUSH** 100% mark-up
	(Business Days) Turn Around Time:	✔		

Results By: ☐ Phone ☐ Fax ☐ Email

Date & Received by :

Special Instructions:

ANALYSIS REQUESTED (Please circle)

Analysis	Group	Default Method	Alternate Methods
Soil Resistivity	Full Corrosion Serries / Geo Quad	ASTM G187	AASHTO T288; Caltrans CTM643
pH	Full Corrosion Serries / Geo Quad	ASTM G 51	AASHTO T 289; Caltrans CTM643
Sulfate	Full Corrosion Serries / Geo Quad	ASTM D4327	AASHTO T 290; Caltrans CTM417
Chloride	Full Corrosion Serries / Geo Quad	ASTM D4327	AASHTO T 291; Caltrans CTM422
Redox Potential	Full Corrosion Serries	ASTM G200	SM 2580B
Sulfide	Full Corrosion Serries	SM 4500-S2	
Ammonia	Full Corrosion Serries	ASTM D4327	SM 4500-NH3
Nitrate	Full Corrosion Serries	ASTM D4327	SM 4500-NO3
Flouride	Full Corrosion Serries	SM 2320B	
Phosphate	Full Corrosion Serries	ASTM D4327	
Lithium	Full Corrosion Serries	ASTM D4327	
Sodium	Full Corrosion Serries	ASTM D4327	
Potassium	Full Corrosion Serries	ASTM D4327	
Magnesium	Full Corrosion Serries	ASTM D4327	
Calcium	Full Corrosion Serries	ASTM D4327	
BiCarbonate	Full Corrosion Serries	SM 2320B	
Full Corrosion Series			
Soil Corrosivity Evaluation Report	Reports	*Req: Min. 3 Samples, site map, and groundwater info	
Water Corrosivity Mini Report	Reports		
Moisture Content		ASTM D2216	
Total Alkalinity		SM 2520B	
Thermal Resistivity			
Metallurgical Analysis			
Langelier Index			
Puckorius Index			
XRF Elemental Analysis			
Water Hardness			

	#	SAMPLE ID - BORE #	DESCRIPTION	DEPTH (ft)	DATE COLLECTED	Soil Resistivity	pH	Sulfate	Chloride	Redox Potential	Sulfide	Ammonia	Nitrate	Flouride	Phosphate	Lithium	Sodium	Potassium	Magnesium	Calcium	BiCarbonate	Full Corrosion Series	Soil Corrosivity Evaluation Report	Water Corrosivity Mini Report	Moisture Content	Total Alkalinity	Thermal Resistivity	Metallurgical Analysis	Langelier Index	Puckorius Index	XRF Elemental Analysis	Water Hardness
59	1	VLT-1	soil	9-10'	1/25/22	X	X	X	X	X	X	X	X																			
60	2	CHM-1	soil	2.5-3.5'	1/24/22	X	X	X	X	X	X	X	X																			
	3																															
	4																															
	5																															
	6																															
	7																															
	8																															
	9																															
	10																															
	11																															
	12																															
	13																															
	14																															
	15																															

Appendix C Carollo Design Drawings

Smith Power Products, Inc.
Darrell Caldwell
dcaldwell@smithppi.com
303-927-8469

<u>Recommended Dimension & Pad Depth</u>

TOTAL UNIT WEIGHT	15740
WIDTH in inches	72
LENGTH in inches	245
PAD DEPTH IN FEET	0.856599
PAD DEPTH IN INCHES	10.27918
Rebar every 18" on Center	

**Pad dimensions do not include NEC/AHJ 36" clearances. Only housekeeping pad dimensions.*

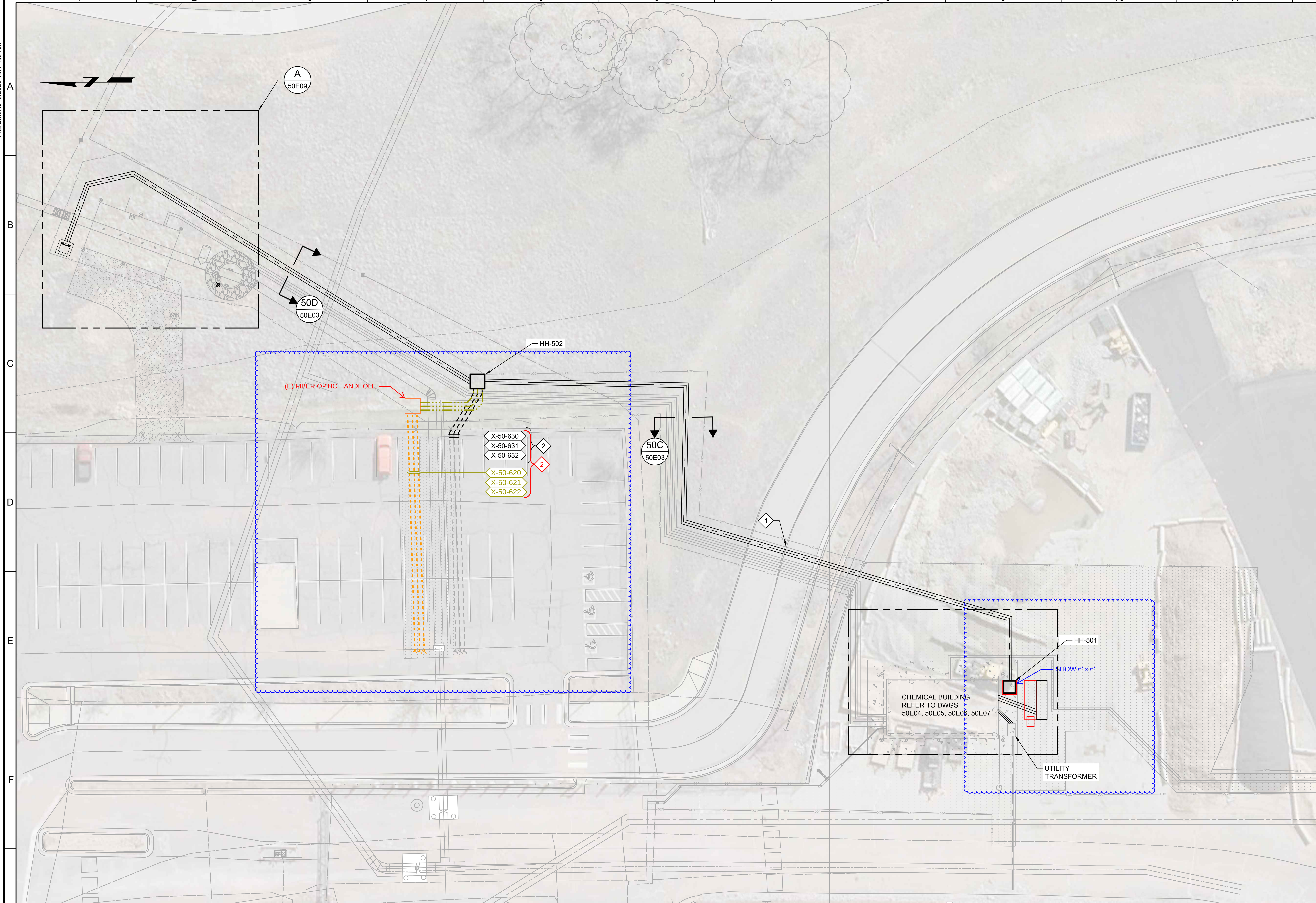
Gen Length	220.5
Gen Width	48.0
Gen Height	134.0
Total Dry Weight	8515
Gallons of Diesel	850
Fuel Weight	6375
Total Wet Weight	15740
Service Apron Width	12.0

***All Dimensions are in Inches
***Length Dimension Includes Air Intake & Discharge Ducts (If Applicable)
***Smith PPI is not an structural engineering firm. These are recommended dimensions only.
***Due to variations in local soil profiles, consult a structural engineer for specific sites.

<u>EXAMPLE PAD LAYOUT</u>

BLUE Rectangle = Concrete Pad Outline
ORANGE Rectangle = Generator Enclosure Outline
***Enclosure Outline Includes Air Intake & Discharge Ducts
GREEN Rectangle = Fuel Tank Footprint
LIGHT GREEN Rectangle = Electrical Stub Up Area

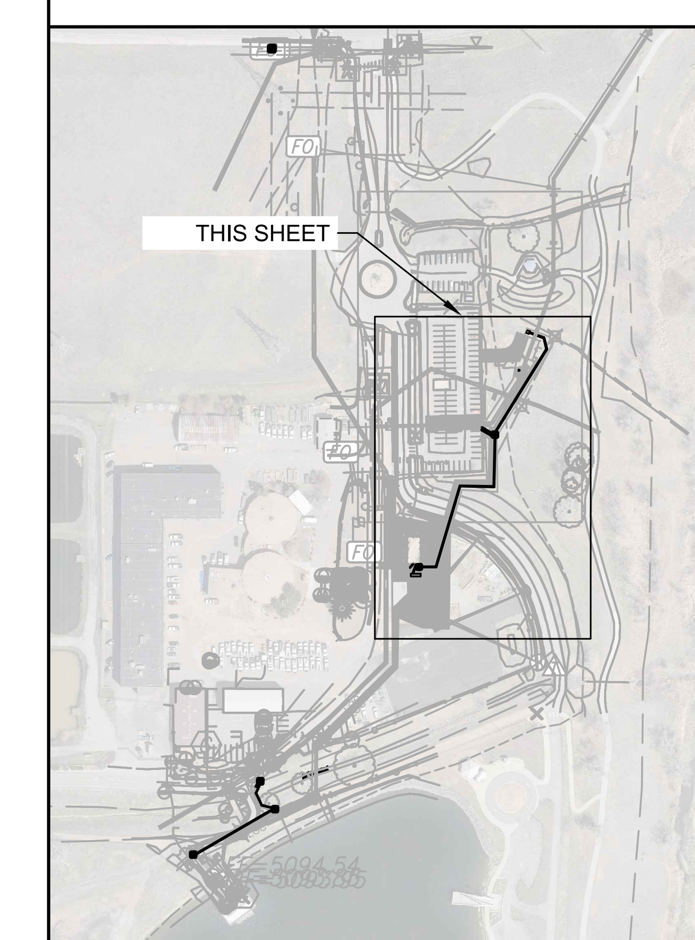
Plot Date: 3/10/2026 10:17:09 AM



KEY NOTES:

1. MAINTAIN ONE LANE OF TRAFFIC OPEN AT ALL TIMES.
2. EXISTING SPARE CONDUITS IN DUCT BANK FOR FUTURE FIBER CONNECTION BETWEEN CHEMICAL BUILDING AND WES BROWN WTP. EXTEND DUCT BANK TO HH-502 AND CONTINUE CONDUITS TO CHEM BUILDING VIA DUCT BANK 50C.

811
Know what's below. Call before you dig.
usanorth811.org



SCALE

0 10' 20' 40'
SCALE: 1" = 20'

REV	DATE	BY	DESCRIPTION

AGENCY REVIEW SUBMITTAL
NOT FOR CONSTRUCTION

DESIGNED KWG
DRAWN SGH
CHECKED SLB
DATE JANUARY 2026

COLORADO LICENSED PROFESSIONAL ENGINEER KELLEN GROSS 55107

carollo®

THORNTON WATER PROJECT

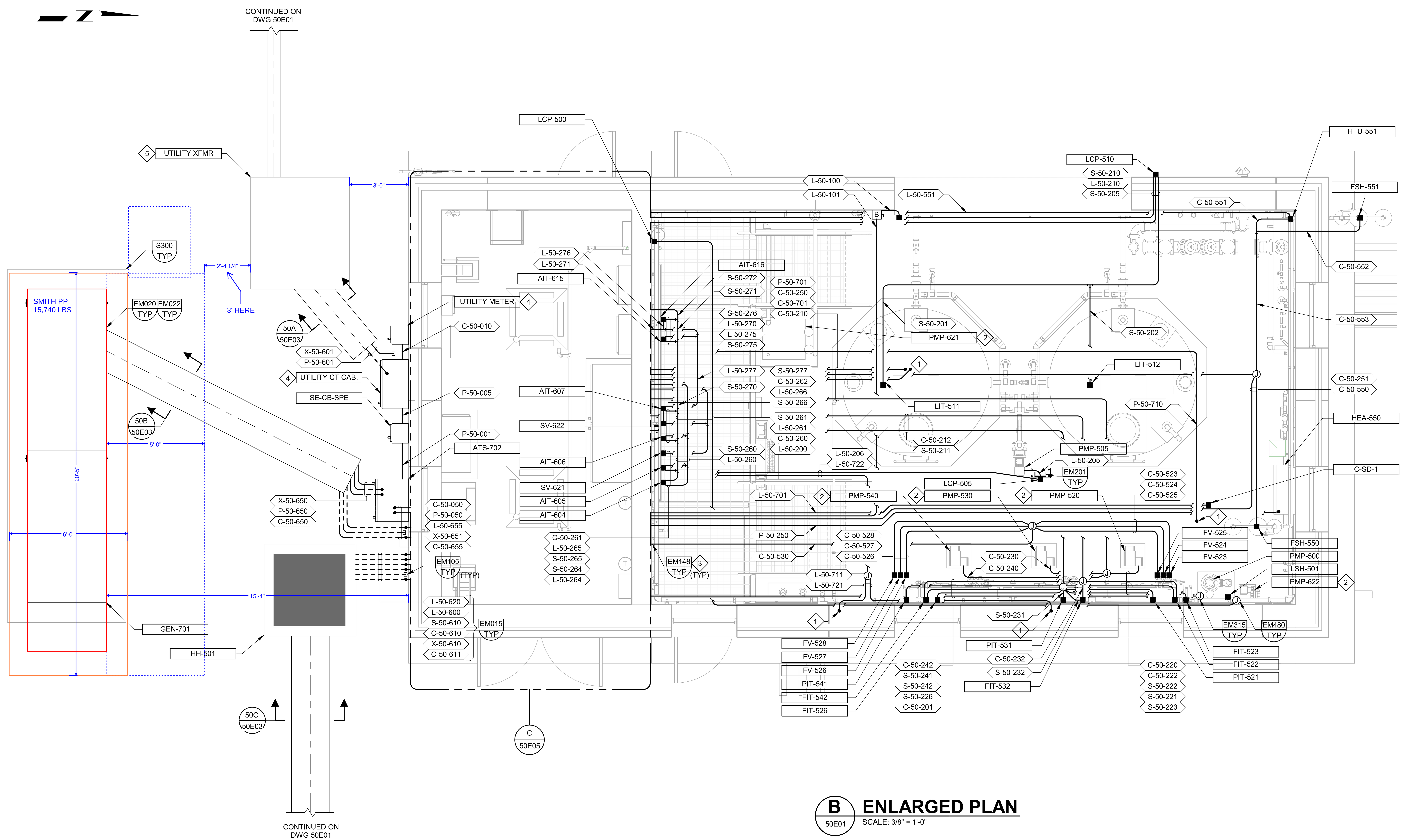
CITY OF THORNTON - THORNTON WATER PROJECT
CHEMICAL BUILDING AND PRV VAULTS
ELECTRICAL
CHEMICAL BUILDING AND PRV VAULT
OVERALL ELECTRICAL SITE PLAN

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

JOB NO. 204403
DRAWING NO. 50E01
SHEET NO. 99 OF 167

LAST SAVED BY: NFerdousi

PROJECT NO. 200417-100000 FILE NAME: 204403_50E02.dwg



B ENLARGED PLAN
50E01
SCALE: 3/8" = 1'-0"

GENERAL NOTES:

1. ROUTE EXPOSED CONDUITS PER DETAIL EA010/TYP, EA080/TYP, EM102/TYP, AND EM103/TYP AS NECESSARY.
2. AVOID ROUTING CONDUITS WITHIN THE CONTAINMENT AREA.
3. CABLE AND CONDUIT FOR HVAC CONTROL IS BY HVAC SUBCONTRACTOR AND NOT SHOWN ON ELECTRICAL PLANS.
4. COORDINATE WITH CITY TO OBTAIN IL-101 KEY REQUIREMENTS FOR GENERATOR AND OUTDOOR PANELS.

KEY NOTES:

1. CONDUITS ROUTE TO EQUIPMENT ON ROOF. SEE 50E08 FOR CONTINUATION.
2. EQUIPMENT POWERED FROM RECEPTACLE. SEE 50E06 FOR RECEPTACLE LOCATIONS.
3. PROVIDE NON-DESTRUCTIVE TESTING TO DETERMINE LOCATIONS OF REINFORCEMENT. MAINTAIN A MIN 2" CLEAR BETWEEN OPENING AND REINFORCEMENT.
4. CTs AND METER-SOCKET ARE UTILITY PROVIDED AND CONTRACTOR INSTALLED. CONTRACTOR TO PROVIDE AND INSTALL CONDUIT AND CONDUCTORS. CONTRACTOR TO TERMINATE LINE-SIDE AND LOAD-SIDE CONDUCTORS IN THE CT CABINET.
5. UTILITY TO PROVIDE TRANSFORMER AND TRANSFORMER PAD. COORDINATE WITH UTILITY FOR DUCT BANK RISER LOCATION. CONTRACTOR TO PROVIDE CONDUIT AND CONDUCTORS TO UTILITY TRANSFORMER SECONDARY CONNECTION CABINET. UTILITY TO TERMINATE CONDUCTORS.

AGENCY REVIEW SUBMITTAL
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION

DESIGNED KWG
DRAWN SGH
CHECKED SLB
DATE JANUARY 2026

COLORADO LICENSED PROFESSIONAL ENGINEER 55107

carollo®
THORNTON WATER PROJECT

CITY OF THORNTON-THORNTON WATER PROJECT
CHEMICAL BUILDING AND PRV VAULTS
ELECTRICAL
CHEMICAL BUILDING LOWER FLOOR POWER AND CONTROL PLAN

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

JOB NO. 204403
DRAWING NO. 50E04
SHEET NO. 102 OF 167

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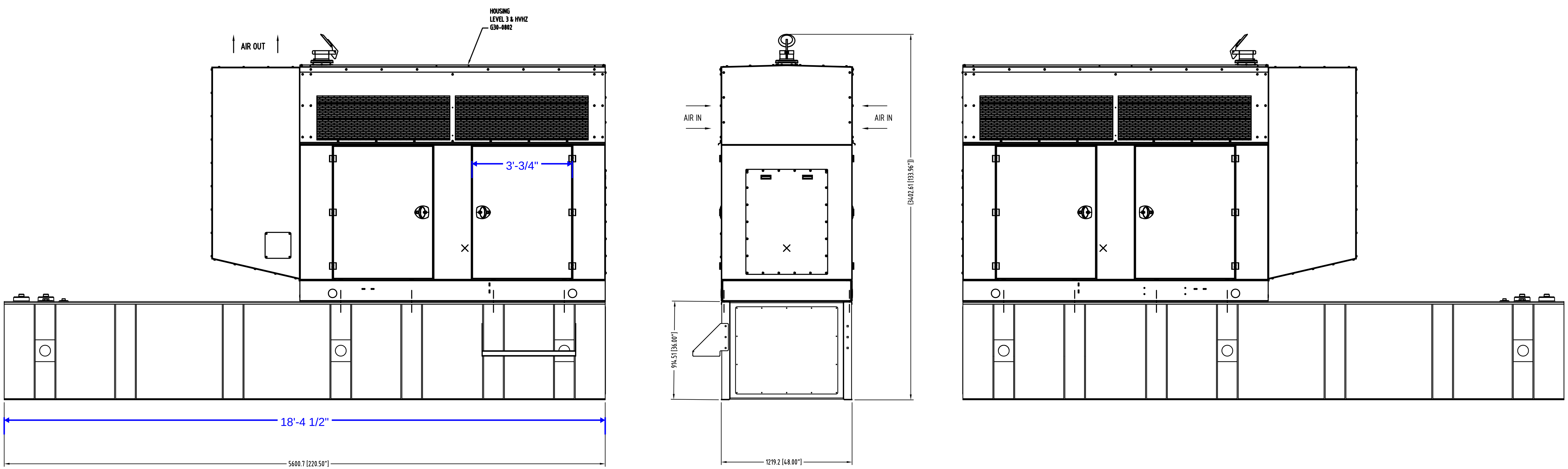


FRONT VIEW LEFT VIEW REAR VIEW RIGHT VIEW

DS150 (150kW unit) burns 11.8 GPH, and this tank is 850 gal, so 72HR of fuel.

WEIGHTS AND
PAD DEPTH RECOMMENDATION ON NEXT PAGE

REVISION	DATE	DESCRIPTION

A Rolls-Royce solution

APPLICABLE MODELS:
mtu 6R0113 DS150
mtu 6R0113 DS180
mtu 6R0113 DS200

THIRD ANGLE PROJECTION

DRAWN TO SCALE
DIMENSIONS: MM [INCH]

DATE CREATED:

DIMENSIONAL LAYOUT

DESCRIPTION: DS150-200 JD L3 48HR EXT 850G Stack DWG

ENGINE: John Deere 6068

WEIGHT (MIN-MAX):

DRAWING NUMBER:

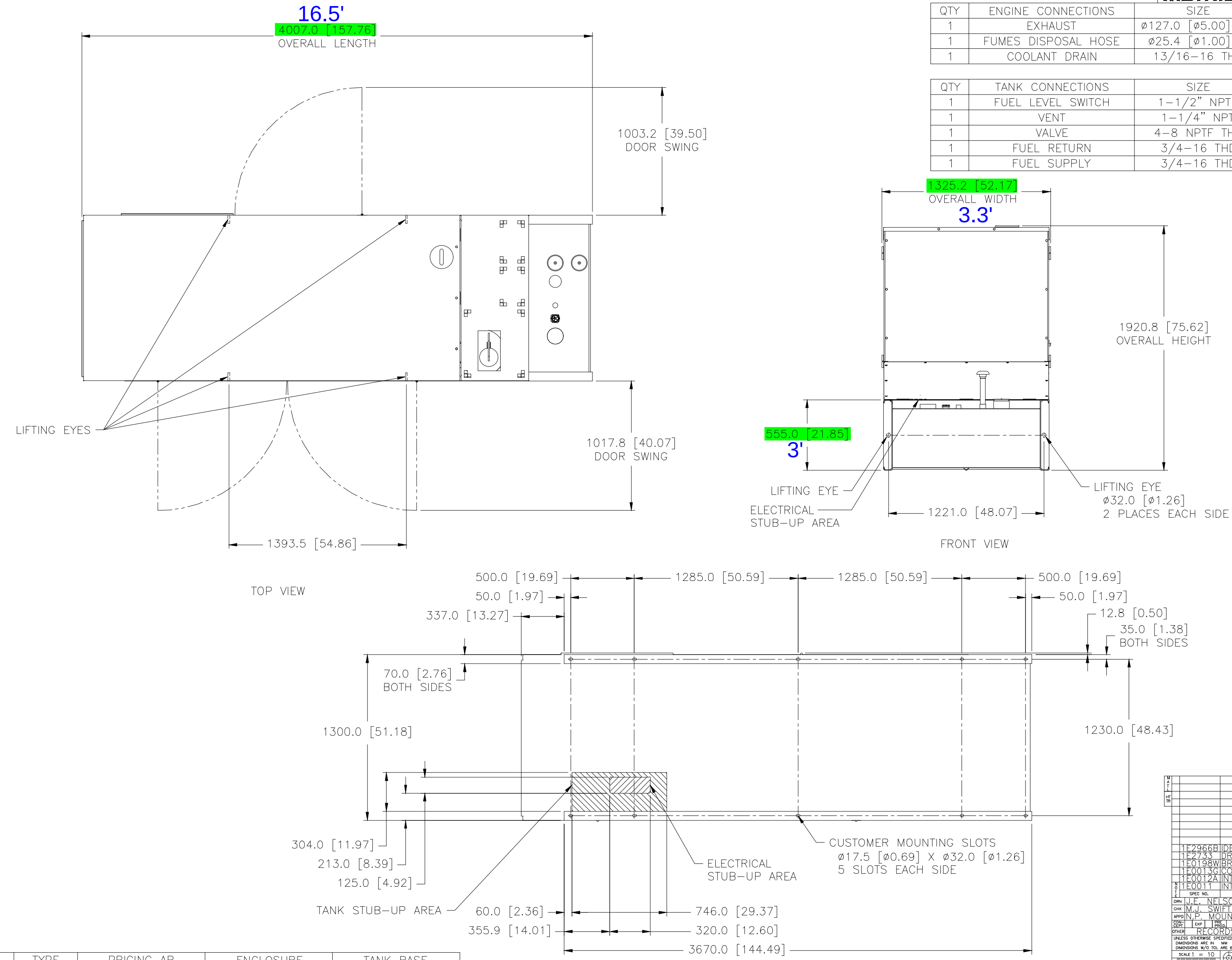
SHEET:

GEN DRY WEIGHT + TANK WEIGHT + FUEL WEIGHT + ENCLOSURE WEIGHT =
3307 + 2524 + 5517 + 896 = 12,244 lbs

METRIC 610-4588

QTY	ENGINE CONNECTIONS	SIZE	SHEETS
1	EXHAUST	ø127.0 [ø5.00] OD	2
1	FUMES DISPOSAL HOSE	ø25.4 [ø1.00] ID	3
1	COOLANT DRAIN	13/16-16 THD	3

QTY	TANK CONNECTIONS	SIZE	SHEET
1	FUEL LEVEL SWITCH	1-1/2" NPTF	4
1	VENT	1-1/4" NPT	4
1	VALVE	4-8 NPTF THD	4
1	FUEL RETURN	3/4-16 THD	4
1	FUEL SUPPLY	3/4-16 THD	4



MODEL	TYPE	PRICING AR	ENCLOSURE	TANK BASE
C7.1	–	LS-4238 CHG 00	LS-4330 CHG 00	LS-4267 CHG 00
		LS-4239 CHG 00		
		LS-4240 CHG 00	LS-4331 CHG 00	
		LS-4241 CHG 00		

PACKAGE LIFTED IN 4 PLACES ON TANK

PACKAGE SHOWN WITH MORE DETAIL ON FOLLOWING SHEETS

1E2966B IDENT
1E2733 DRAWING-AUTOCAD
1E0198W BRAND MARKINGS
1E0013G CONFIDENTIALITY
1E0012A INTERPRETATION
1E0011 INTPR & TOL

DRN J.E. NELSON
CHK M.J. SWIFT
APPD N.P. MOUNTJOY
RECORDS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MM [INCH]

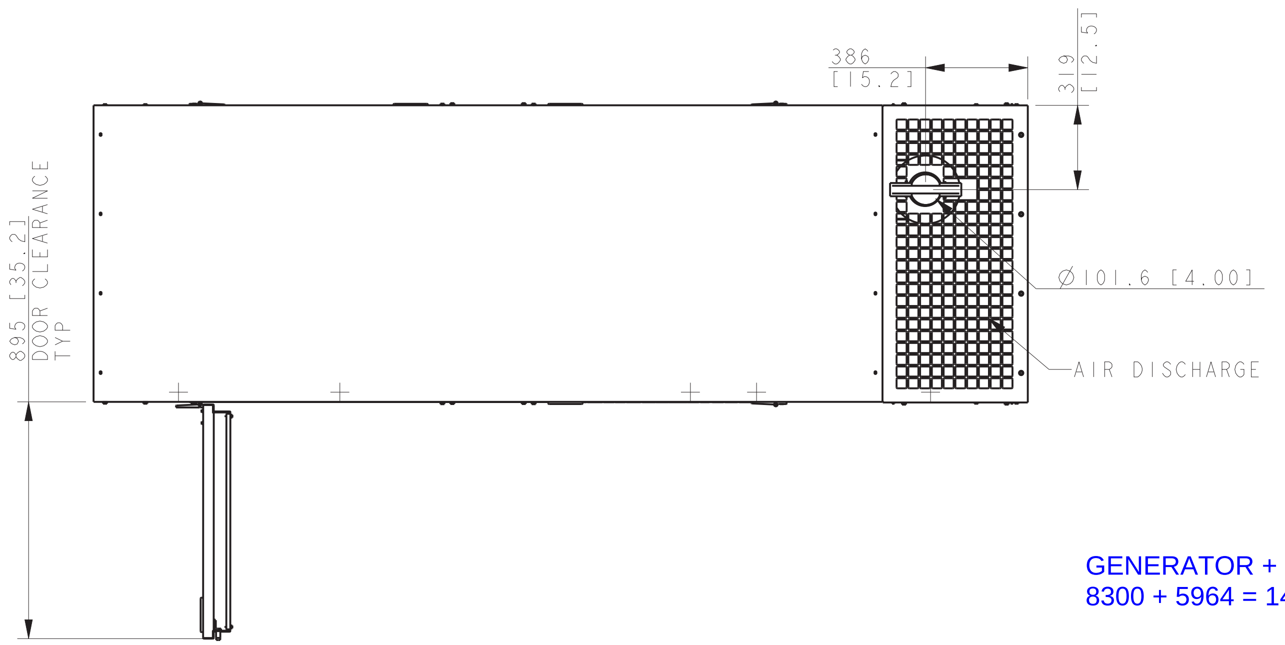
SHEET 1 OF 4

01 26APR21

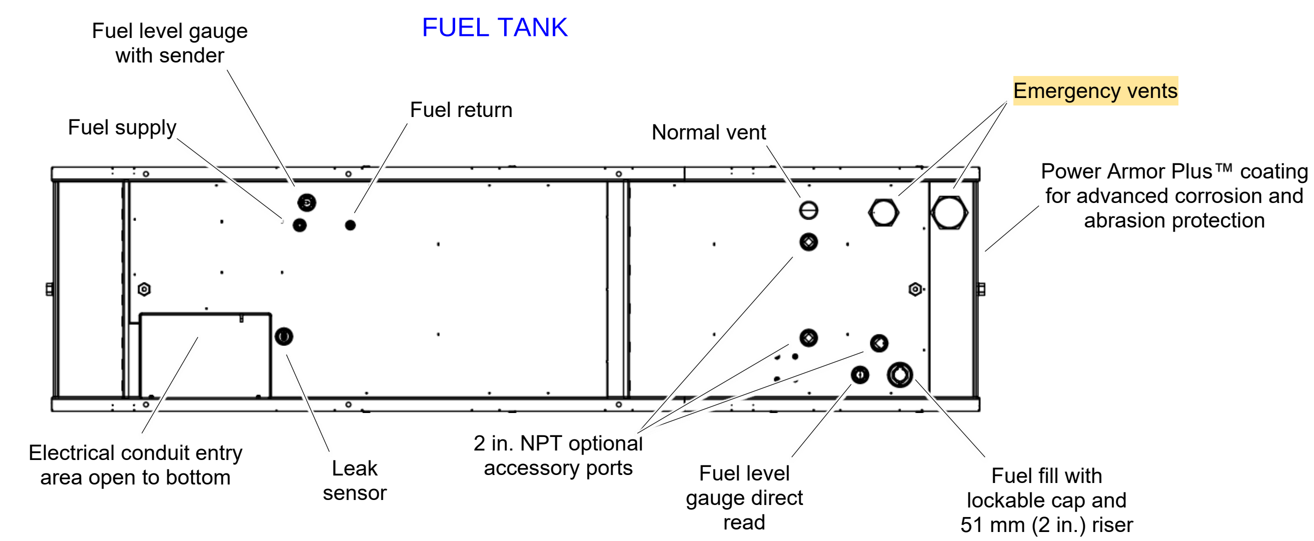
CATERPILLAR INC.

INSTALLATION-COMPOSITE
C7.1 ENCL W/TANK BASE

610-4588 E

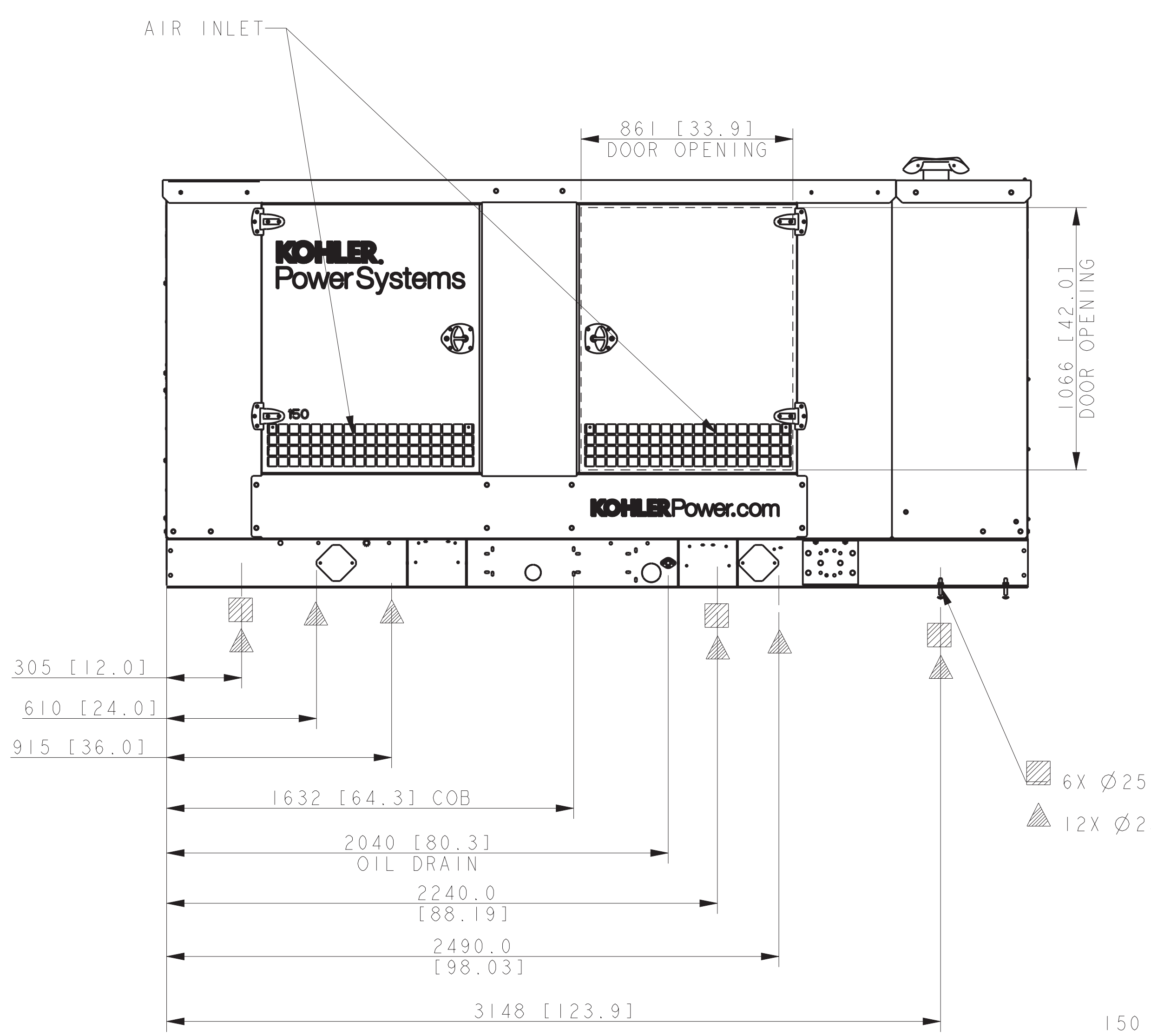


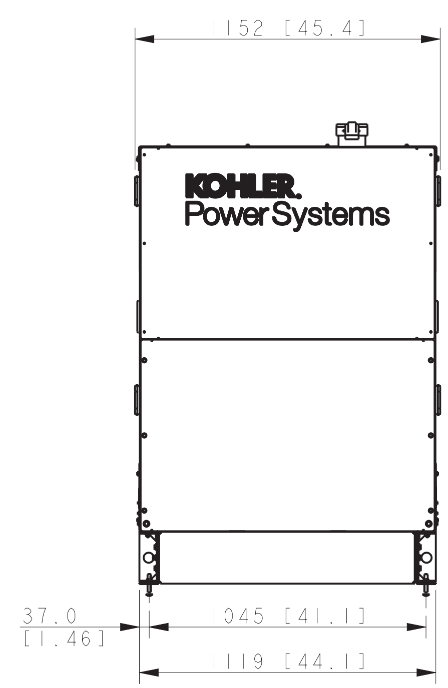
FUEL TANK



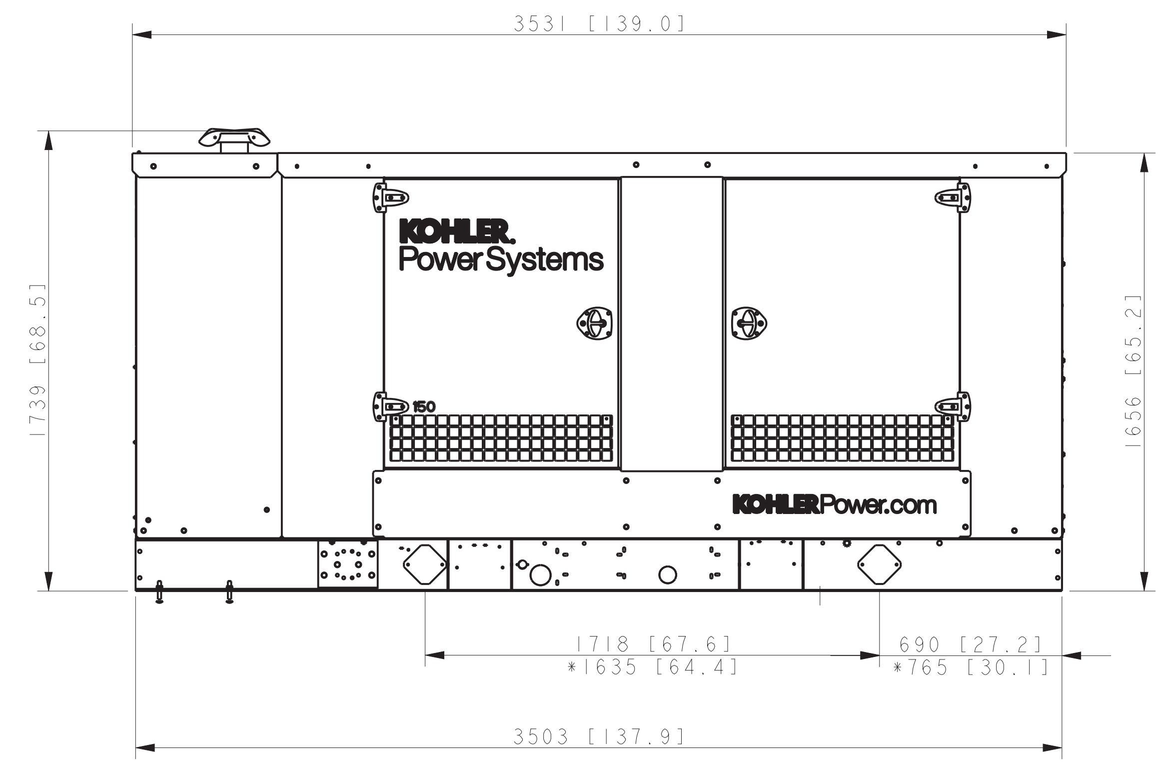
GENERATOR + ENCLOSURE + DRY TANK + FUEL
8300 + 5964 = 14,264 lbs

NOTE:
1. TANK (IF ORDERED) MOUNTS BELOW SKID
2. TANK MAY EXTEND BEYOND ENCLOSURE (DISCHARGE END ONLY)





6X Ø25.4 [1.0] STD MOUNTING HOLES
12X Ø25.4 [1.0] IBC MOUNTING HOLES



DIMENSIONS IN [ ] ARE INCH EQUIVALENTS

(*) DESIGNATES 125KW 4045HF ENGINE

125 MODEL 4S11, 4S13, 4R12X, 4R13X, 4T13X
150 MODEL 4S13, 4S15, 4R13X, 4T13X, 4S12X, 4S13X
RECONNECTABLE
IMPROVE MOTOR STARTING (IMS) RECONNECTABLE
600V & 1 PHASE ALTERNATORS
4045HF285 & 6068HF285 JOHN DEERE TIER III

REV	DATE	ON COMPOSITE DWGS, SEE PART NO. FOR REVISION LEVEL	BY
B	7-29-10	(A-6) 6X 17.5 NOTE ADDED [90041]	SAM
C	9-28-10	(A-5) 12X Ø17.5 ADDED [90301]	SAM
D	1-3-12	(A-4) 125 & 150 MODEL NOTE UPDATED [92681]	PKD
E	2-5-12	(A-1) 1-2 WAS 1-1, SEE SHEET 2 [CT32174]	SAM
F	10-3-13	(A-5) Ø25.4 [1.0] WAS Ø17.5 [.69]; SEE SHEET 2 [CT59787]	SVP
G	8-4-17	(D-6) DIM. Ø101.6 (4.00) ADDED [CT177004]	SRM
H	9-27-18	ALL VIEWS AND DIMENSIONS UPDATED; SEE SHEET 2 [CT190707]	PAR

UNLESS OTHERWISE SPECIFIED -
1) DIMENSIONS ARE IN MILLIMETERS
2) TOLERANCES ARE:
X.XX ± 0.25
X.X ± 1.0
X ± 1.5
ANGLES ± 0° 30′
SURFACE FINISH MAX.

THIRD ANGLE PROJECTION

APPROVALS		DATE
DRAWN	MRS	11-5-09
CHECKED	MRS	11-5-09
APPROVED	ALC	11-5-09

KOHLER CO. | METRIC | PRO-E

POWER SYSTEMS, KOHLER, WI 53044 U.S.A.

TITLE
DIMENSION PRINT

SCALE 0.07 | CAD NO. | SHEET 1 of 2

DWG NO. ADV-7825 | D

PTC® Creo® Parametric

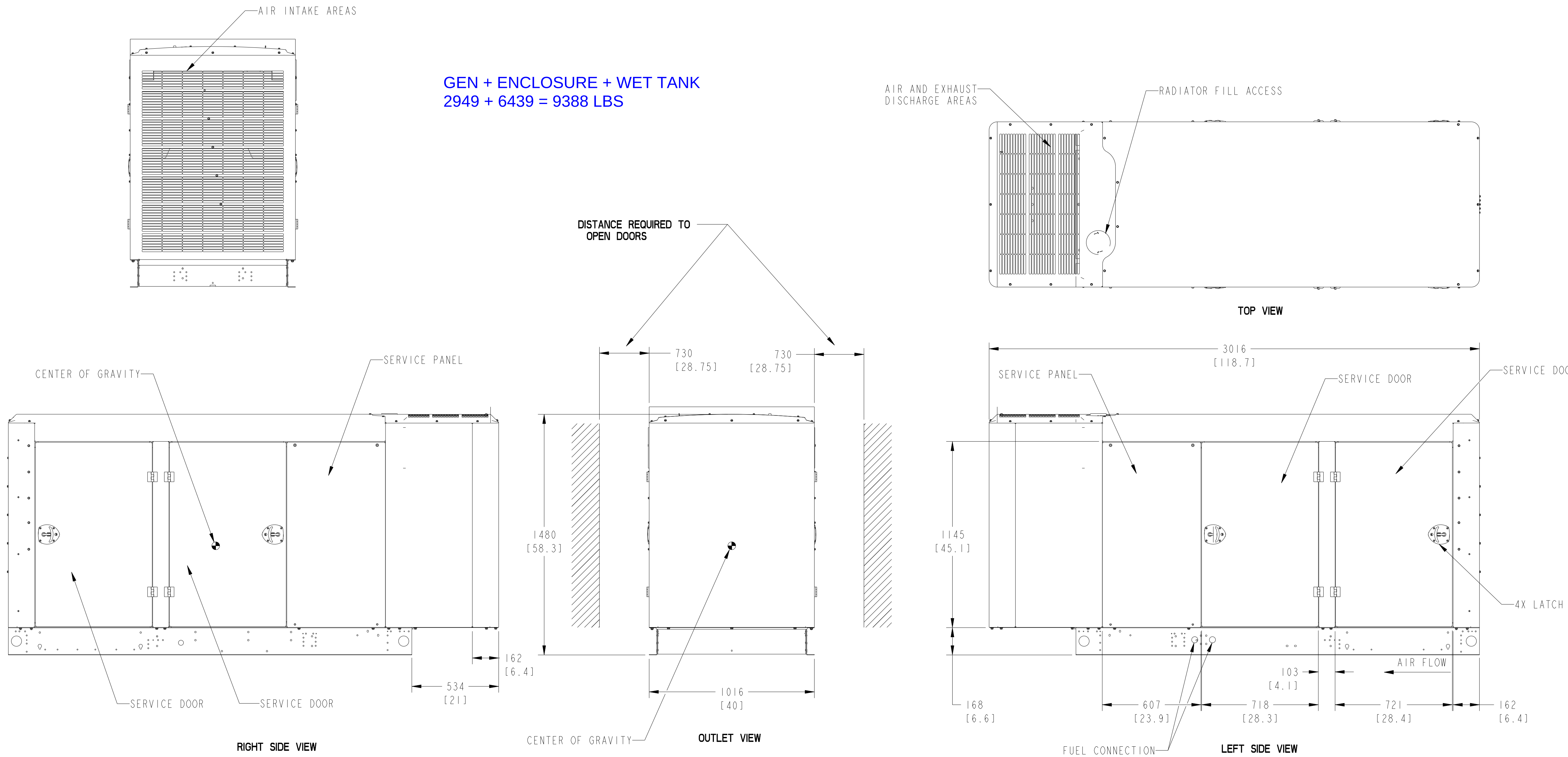
REL NO	LTR	NO	REVISION	DWN	CKD	APVD	DATE
ECO-152551	A	1	PRODUCTION_RELEASE	CG	NK	M_WICKMANN	14MAY15

NOTES:

1. DIM [] IN INCHES

2. WHEN THE HOUSING INSTALLED ON AN OPEN GENERATOR SET, THE TOTAL WEIGHT WILL INCREASE BY 131.5 KG (290 LBS). THIS INCLUDES THE MUFFLER.

3. THE CENTER OF GRAVITY(CG) OF THE GENERATOR SET WHEN EQUIPPED WITH THIS HOUSING SHIFTS APPROXIMATELY 65mm (2.55 inch) TOWARDS THE AIR DISCHARGE END OF THE HOUSING AND 42MM (1.66 INCH) HIGHER FROM THE GROUND. COMPARED TO THE EQUIVALENT NON-HOUSED PRODUCT WITH THE F179 SKID. SEE HOUSING READY SKID BASE OUTLINE DRAWING FOR CG LOCATION OF NON HOUSED PRODUCT.



F231-2 ENCLOSURE CONFIGURATION

UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS

DIM: X ± 1; .X ± 0.8; .XX ± 0.38

HOLE: 0.00- 4.99 +0.15/-0.08; 5.00- 9.99 +0.20/-0.10; 10.00-17.49 +0.25/-0.13; 17.50-24.99 +0.30/-0.13

ANG TOL: ± 1.0° SCALE: ~3/32

SIM TO NONE

DO NOT SCALE PRINT

- CONFIDENTIAL - PROPERTY OF CUMMINS POWER GENERATION GROUP

DWN C_GADE
CKD N_KASIBHOTLA
APVD M_WICKMANN
DATE 14MAY15

FOR INTERPRETATION OF DIMENSIONING AND TOLERANCING, SEE ASME Y14.5M-1994

FIRST USED ON ARROW

SITE CODE PGF

CUMMINS POWER GENERATION

OUTLINE, ENCLOSURE

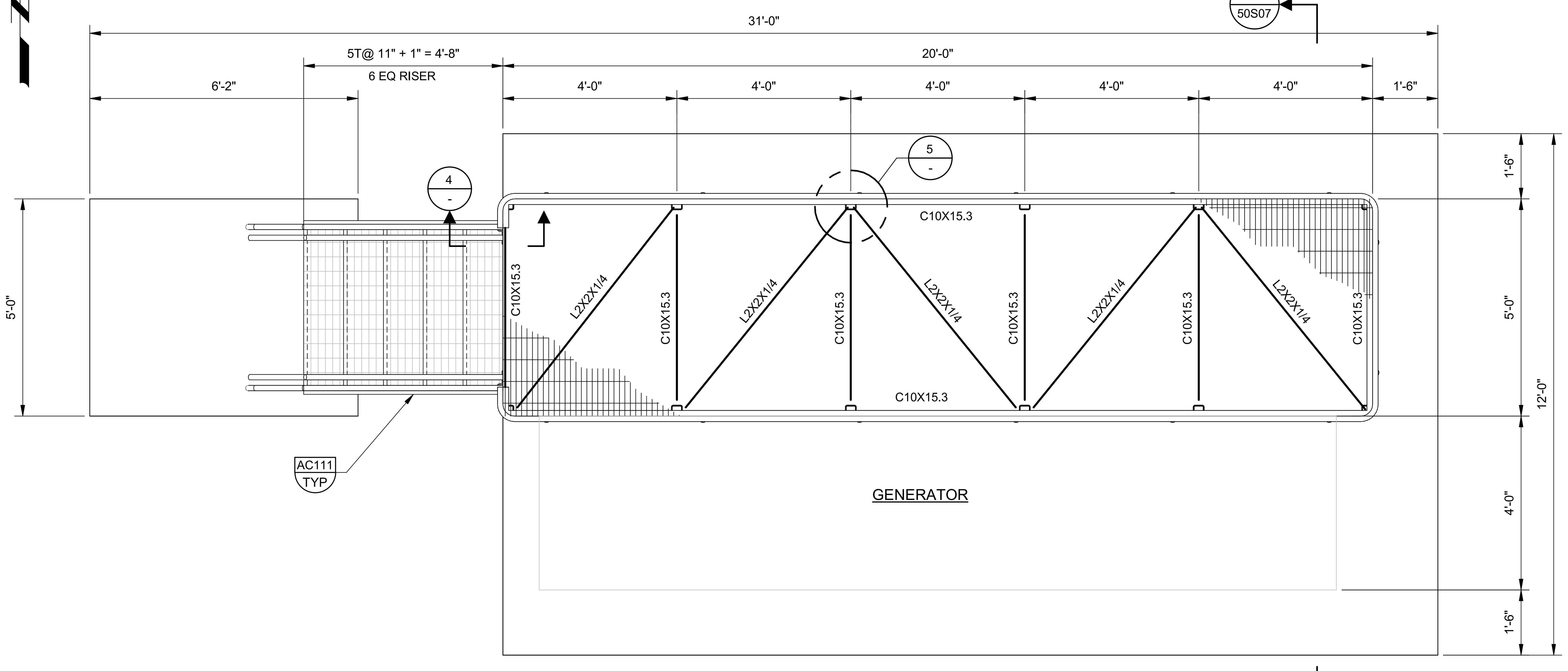
DWG SIZE D A051P365 SHEET 1 OF 2 DWG REV A

GENERAL NOTES:

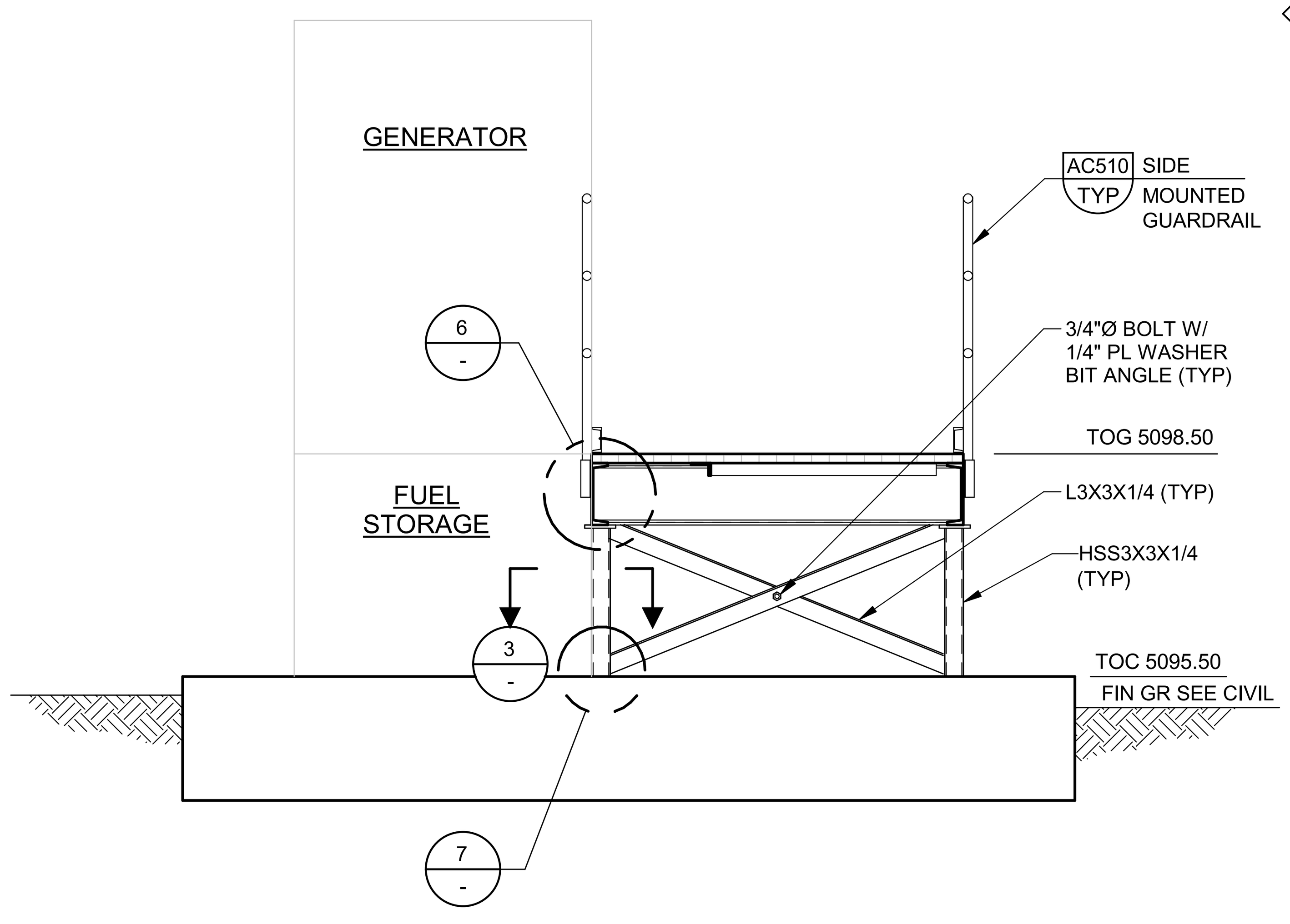
1. SEE DRAWING 00GS01 FOR GENERAL STRUCTURAL NOTES.
2. NOTE THAT ALL MEMBERS AND CONNECTION NEED TO BE HOT DIPPED GALVANIZED

KEY NOTES:

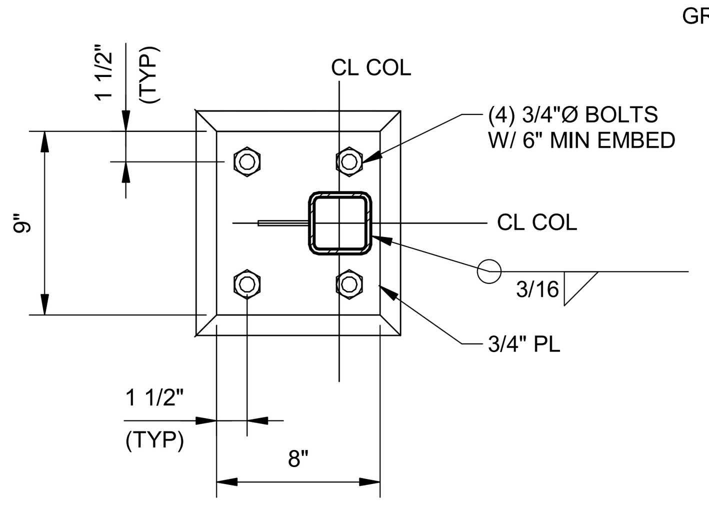
1. SEE CIVIL DRAWINGS FOR LOCATION OF THE GENERATOR PAD.
2. PROVIDE BRACING ON ALL FOUR SIDES.
3. GENERATOR PAD DIMENSIONS, PLATFORM DIMENSIONS, AND LOCATION IS BASED ON CUMMINS POWER GENERATOR. COORDINATED AND VERIFY DIMENSIONS AND ELEVATIONS WITH APPROVED EQUIPMENT MANUFACTURER'S ANCHORAGE CALCULATION REQUIREMENTS.
4. PROVIDE HANDRAILS AS REQUIRED TO SUIT THE EQUIPMENT.



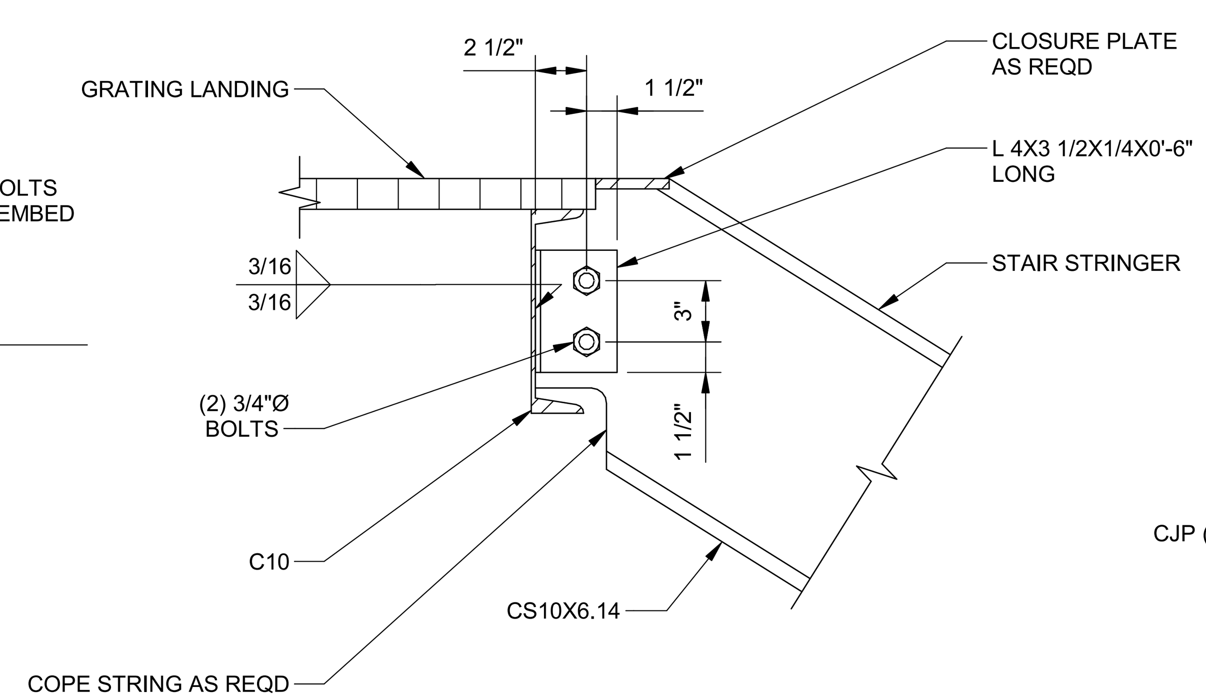
L PLAN
SCALE: 1/2" = 1'-0"



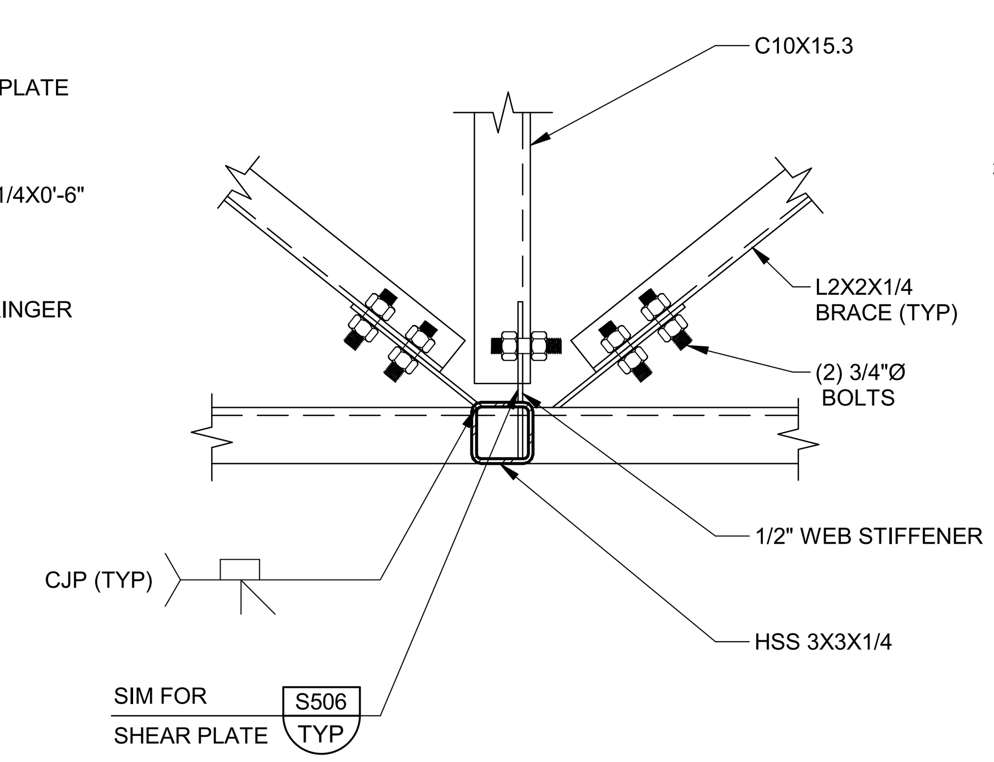
M SECTION 50S07
SCALE: 1/2" = 1'-0"



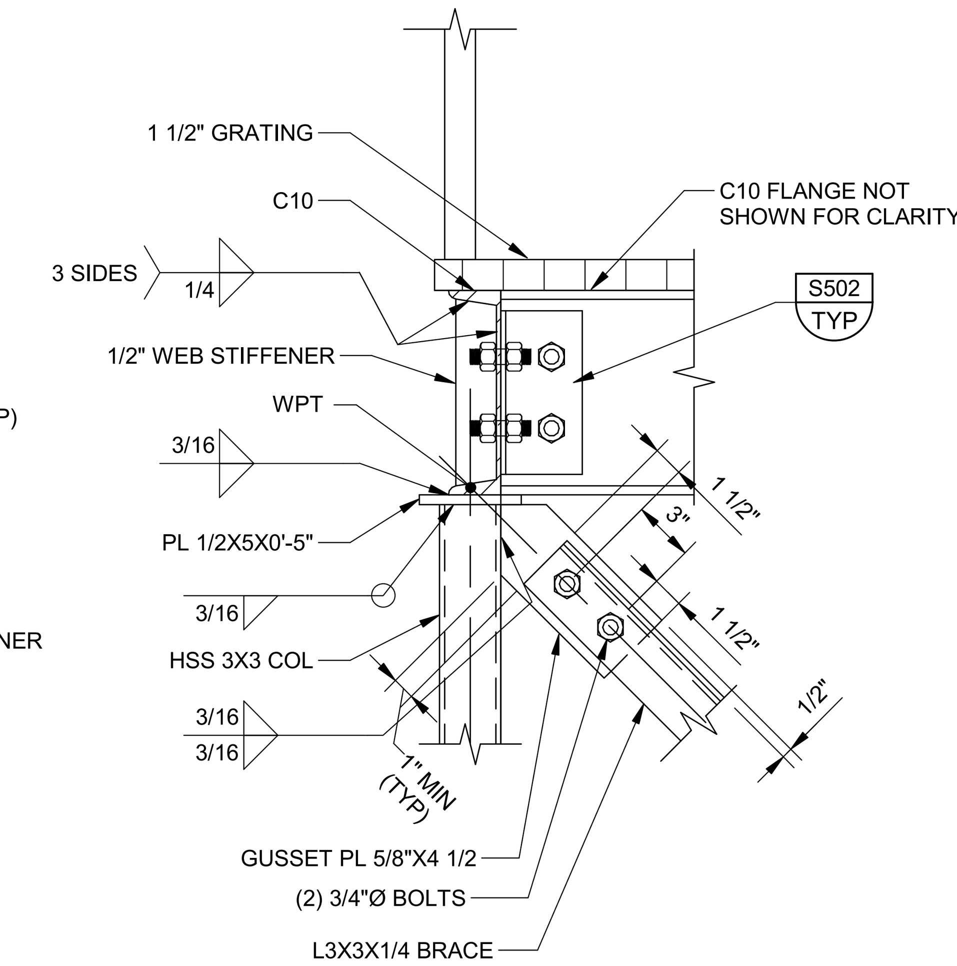
3 DETAIL
SCALE: 1 1/2" = 1'-0"



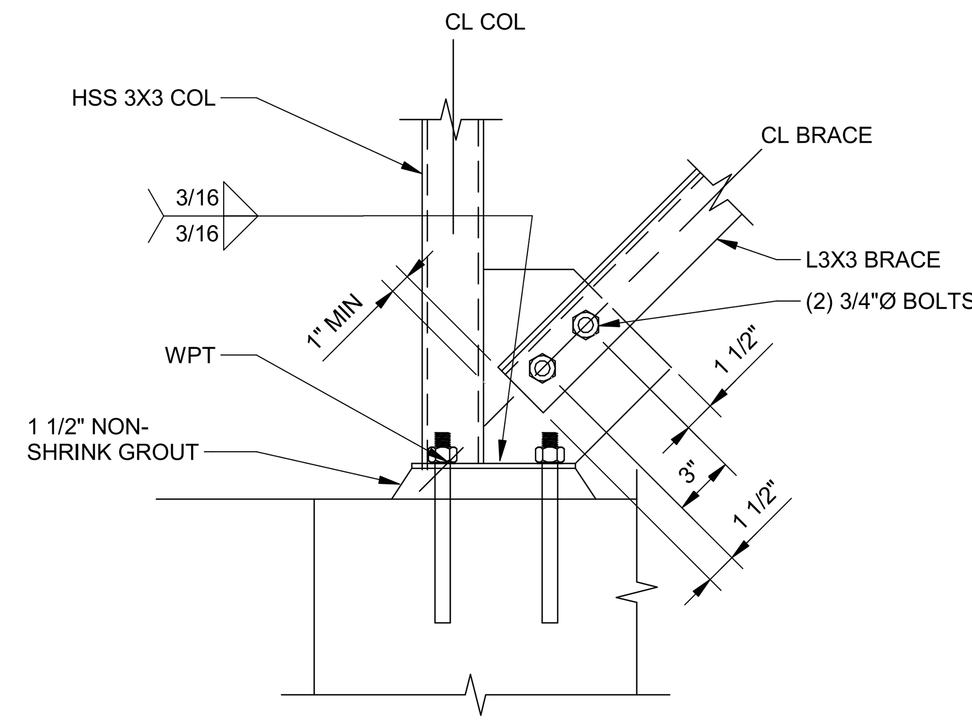
4 DETAIL
SCALE: 1 1/2" = 1'-0"



5 DETAIL
SCALE: 1 1/2" = 1'-0"



6 DETAIL
SCALE: 1 1/2" = 1'-0"



7 DETAIL
SCALE: 1 1/2" = 1'-0"

REV	DATE	BY	DESCRIPTION
			BID SET

DESIGNED NV
DRAWN JBB
CHECKED MAK
DATE APRIL 2026

COLORADO REGISTERED PROFESSIONAL ENGINEER MARK ALAN KELLEY 34300

carollo

THORNTON WATER PROJECT

CITY OF THORNTON-THORNTON WATER PROJECT
CHEMICAL BUILDING AND PRV VAULTS
STRUCTURAL
CHEMICAL BUILDING
GENERATOR PAD PLAN AND DETAILS

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

JOB NO. 204403
DRAWING NO. 50S07
SHEET NO. 89 OF 168

PLOT DATE: 4/1/2026 11:48:08 AM
FILE NAME: R:\d0583920\204403_50S0802.rvt