Initial Geotechnical Report

Sunset Road
Interstate 10 to River Rd

Prepared for:

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TRANSPORTATION

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1.0 INTRODUCTION

This report presents the results of Golder Associates Inc.'s (Golder) geotechnical study conducted in support of the design of a new portion of Sunset Road from Interstate 10 (I-10) to River Road in Tucson, Arizona. CONSOR Engineers (CONSOR) is providing overall design services for the project to develop scoping and environmental documents including a design concept report (DCR), environmental assessment (EA), and 30 percent level plans and cost estimates. The work is being performed for the Pima County Department of Transportation (County) under Project No. 4SRRIV. CONSOR has retained Golder to provide geotechnical and pavement design services associated with the project.

1.1 Project Background

The Regional Transportation Authority 20-year multimodal plan included improvements for Sunset Road from Silverbell Road to River Road. The improvements were divided into two phases: Silverbell Road to I-10 (Phase 1) and I-10 to River Road (Phase 2). Construction was completed on Phase 1 in 2017.

The Arizona Department of Transportation (ADOT) completed a DCR and EA for I-10 from Ina Road to Ruthrauff Road which included eventual reconstruction of the Sunset Road Traffic Interchange (TI). This project and follow-on final design work will tie in with the planned ADOT improvements. The current I-10 geometry consists of underpass structures to carry the freeway over Sunset Road. The planned ultimate configuration will invert that geometry with new overpass structures and associated retaining walls and approach embankments to carry Sunset Road over I-10, which will be at grade. This new connection to River Road will also require a new bridge structure over the Union Pacific Railroad Track (UPRR) located on the east side of the westbound (WB) I-10 frontage road.

The new Sunset Road alignment also includes a bridge over the Rillito Creek (Rillito) ephemeral channel, just before the intersection with River Road. The existing channel of the Rillito has soil cement bank protection, and an asphalt multi-use path on both sides of the channel that is part of "The Loop" network of interconnected bicycle paths around metropolitan Tucson.

The total length of the project is approximately 0.6 miles. Most of the project is located within the City of Tucson with two relatively small portions being located within unincorporated Pima County.

Design of the I-10 overpass structures, ramps, and frontage road approach retaining walls is not included in this project.

1.2 Scope of Services

Golder has provided the following services as part of the development of this report.

- Review and summary of available geotechnical information.
- A field investigation consisting of seven boreholes drilled for characterizing subsurface conditions at bridge substructure locations, retaining walls alignments, and pavement widening areas.
- Laboratory testing of representative samples.
- Identification of any geotechnical issues or hazards that may critically impact or limit design options.
- Engineering analyses and recommendations for the foundations of the new bridges.

- Preliminary recommendations for approach and abutment retaining walls.
- Evaluation of the suitability of site soils for the proposed construction.
- Development of earthwork and ground compaction factors.
- Preliminary settlement analysis of a 60-inch diameter sanitary sewer pipe due to embankment loading and recommendations for mitigation.
- Provide subgrade evaluation in support of new pavement structures. The pavement design recommendations are presented in a separate Initial Pavement Design Report (Golder 2020).
- Preparation of this report summarizing the results of the geotechnical study.

1.3 Data Sources

Golder has obtained several geotechnical reports and as-built drawings that are relevant to this project. We have utilized borehole logs and laboratory test results from the following reports in developing our own interpretations and recommendations.

- NCS Consultants, LLC (NCS, now SCE) was the geotechnical engineer for Phase 1 of the Sunset Road project. That report (NCS 2015a) contains boreholes relevant to the proposed embankment between I-10 and the Rillito, and pier boreholes in the Rillito.
- As part of the I-10 DCR project between Ina Road and Ruthrauff Road, NCS prepared a preliminary geotechnical report (NCS 2011) that included boreholes along the I-10 frontage roads near Sunset, and for the proposed overpass bridge structures at Sunset Road.
- Terracon Consultants Western, Inc. (Terracon) prepared a geotechnical report for River Road from Shannon Road to Thornydale (Terracon 1995) which includes boreholes along the River Road near the proposed intersection with Sunset Road, just west of North El Camino de la Tierra.

In addition to these reports, NCS prepared a report (NCS 2015b) documenting the results of their infiltration study at the Santa Cruz River (for Sunset Phase 1) and at the Rillito (relevant to this project). Their work used numerical modeling of a series of flood events to develop a porewater pressure profile to use for deep foundation design. This analysis is discussed in greater detail in Section 4.3.

We obtained plan and profile sheets for the 60-inch Pima County Regional Wastewater Reclamation District (PCRWRD) pipeline that crosses Sunset Road just west of the eastbound (EB) I-10 Frontage Road (Brown and Caldwell 2010). This pipe is discussed in Section 5.9.

Record drawings for the I-10 Frontage Roads from Sunset Road to Ruthrauff Road (ADOT 2003) were useful in planning investigations for the UPRR abutment borehole, including ensuring that the footings for adjacent retaining walls and existing storm drain infrastructure could be avoided with the planned borehole.

1.4 Standards and Procedures

The County's goal is for the project be constructed by ADOT under an inter-governmental agreement in conjunction with their I-10 improvements between Ina Road and Ruthrauff Road. Accordingly, we have used ADOT standards and procedures where appropriate. Golder utilized or referenced the following design codes and procedures in preparing the geotechnical recommendations in this report:

- ADOT Materials Group Preliminary Engineering and Design Manual (PE&D Manual 1989): This manual contains requirements for borehole layout with respect to bridge foundation elements and retaining walls as well as the number of boreholes. Golder followed these guidelines when laying out the geotechnical investigation.
- ADOT Standard Specification (ADOT 2008a): Normally relevant PAG standards would be referenced for a County project, but in this case, ADOT standards were used.
- ADOT Materials Testing Manual (ADOT 2008b): This document references laboratory test standards relevant to ADOT projects.
- ADOT Policy Memoranda (ADOT 2010a – 2010f): These documents contain the most recent design guidance for drilled shaft and spread footing design from ADOT. They reference the 5th Edition of the American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications.
- AASHTO LRFD Bridge Design Specifications – 8th Edition (AASHTO 2017): These are the most current LRFD specifications and Golder has referenced them for various aspects of the bridge foundation design, except as noted below.
- AASHTO LRFD Bridge Design Specifications – 6th Edition (AASHTO 2012 with 2013 Interims): ADOT Policy Memoranda refers to the 5th Edition, but the relevant portions of the code were largely unchanged between the 5th and 6th Editions. The most notable differences between this edition and the 8th edition with respect to this report are associated with drilled shaft axial capacity design. Golder utilized axial capacity design procedures for side resistance from this edition in order to be consistent with ADOT Policy Memoranda. This decision can be revisited during final design if necessary.
- Guidelines for Establishing Scour and Freeboard for Bridges in Pima County (PCRFCD and PCDOT 2012): This document is primarily relevant to drainage and hydraulics engineers, but there are discussions with respect to bridge scour and foundations that are relevant to this report.

2.0 REGIONAL GEOLOGY

The Tucson Basin is a structural depression within the Basin and Range physiographic province. The basin is filled with sediments and generally trends north to northwest. The basin is further characterized by a broad and gently sloping valley floor bounded on the east by the Santa Rita, Empire, Rincon, Tanque Verde, Santa Catalina, and Tortolita Mountains and on the west by the Sierrita, Black, and Tucson Mountains. The basin is 15- to 20-miles wide in the southern and central parts and narrows to 4-miles wide at the northwest outlet; it is approximately 50-miles long. The Project site is located in the northwestern part of the basin.

The project site is geographically located at the convergence of the alluvial fans extant on the surfaces of the piedmonts flanking the Santa Catalina and Tucson Mountains. The Santa Cruz River is located at the base of the convergence, and episodes of downcutting along the Santa Cruz River and Rillito Creek have resulted in the deposition of a series of fluvial terrace deposits against the piedmont surfaces. The alluvial material associated with the southwestern piedmont of Santa Catalina Mountains exhibits a down fan decrease in grain size from the proximal to distal portions of the fan. Because of this, much of the material deposited next to I-10 consists of silt and clay. Terrace deposits associated with the Santa Cruz River and Rillito Creek consist of some mixed material consisting of fluvial silty sand and these piedmont distal fines.

Underlying the piedmont and terrace deposits is the regional Fort Lowell Formation. The Fort Lowell Formation was developed as a result of sedimentation during the Pleistocene (1.7 to 1.3 million years before present) as the Tucson Basin transitioned from a closed, internally draining system to the modern open interbasin drainage system. The Fort Lowell Formation, which is generally 300- to 400-feet thick, grades from silty gravel near the edges of the basin to silty sand and clayey silt in the central part of the basin. In most of the basin, the Fort Lowell Formation was deposited in fans by streams that spread out from the canyons in the surrounding mountains. The upper part of the Fort Lowell Formation was intersected by the boreholes drilled at the proposed bridge structures.

3.0 SITE INVESTIGATION

3.1 Geotechnical Exploration Program

The field investigation for this project consisted of a total of eight boreholes performed at the various roadway and structure locations. The boring layout was designed to meet the guidelines of the ADOT Materials Group Preliminary Engineering & Design (PE&D) Manual (ADOT 1989) for a Preliminary level design. Golder confirmed with the ADOT State Geotechnical Engineer that the borehole plan was in conformance with the PE&D Manual (Brun 2020). The locations of the boreholes are shown on Figures A-1 and A-2 in Appendix A. A summary of the borehole locations and depths is provided in Table 1. The locations of the boreholes were surveyed in advance of drilling by Engineering & Environmental Consultants, Inc. in the project coordinate system. Some boreholes were field adjusted from the marked location. In these instances, Golder measured the offset relative to the staked locations and adjusted the coordinates accordingly. The coordinates reported here are for the as-drilled locations. Borehole BH-01 was not drilled by the time of writing due permitting and logistical issues including conflicts with traffic control associated with the Ruthrauff Road TI construction project.

Table 1: Summary of Boreholes

Borehole No.	Northing (feet)	Easting (feet)	Existing Ground Elevation (feet)	Depth (feet)	Purpose of Borehole / Test Pit
BH-01	477,500	970,528	2229.5	130	UPRR Bridge Abutment #1
BH-02	477,608	970,733	2,224.9	131.5	UPRR Bridge Abutment #2
BH-03	477,632	970,930	2,225.1	81.5	Embankment Retaining Wall
BH-04	478,099	971,248	2,227.5	131.5	Rillito River Bridge Abutment #1
BH-05	478,462	971,397	2,227.9	131.5	Rillito River Bridge Abutment #2
BH-06	478,872	971,055	2,229.5	6.5	Pavement thickness and subgrade
BH-07	478,553	971,443	2,235.8	21.5	Pavement thickness and subgrade
BH-08	478,257	971,993	2,236.0	6.5	Pavement thickness and subgrade

Southlands Engineering, LLC drilled borings BH-02 through BH-08 between February 26th and April 21, 2020, and BH-01 was drilled on August 7 and 8, 2020. All boreholes were drilled using a truck-mounted CME-75 drill rig equipped with 8-inch outside diameter (OD) hollow stem augers. Standard Penetration Tests (SPT) were

performed at intervals of 2.5 to 5 feet. A 2-inch OD, 18-inch long split spoon sampler or a 3-inch OD modified California sampler were used to perform the SPT in general accordance with ASTM D-1586. The split-spoon sampler was driven 18 inches (12 inches for modified California samples) into the soil with a 140-pound CME automatic hammer falling freely from a height of 30 inches. The number of blows required for each 6 inches of penetration is shown on the boring logs included in Appendix A. The number of blows required to advance the sampler the last 12 inches is the penetration resistance N value, or blow count, and provides a qualitative measure of the relative density of cohesionless soils or the consistency of cohesive soils. Traffic control services were provided by Border Traffic Safety, LLC.

All samples that were collected from the split-spoon sampler during the drilling program were placed and sealed in plastic bags. Bulk samples of auger cuttings were collected as well. These samples were sent to Atek Engineering Consultants, LLC (ATEK) for testing to determine material classification and material geotechnical properties.

Golder geotechnical personnel were present throughout the field investigation program to observe the drilling operations, assist in sampling, and to prepare the descriptive logs of each boring.

Soils were classified in general accordance with ASTM D 2488, “Standard Recommended Practice for Description of Soils (Visual-Manual Procedure)”. The boring logs present soil descriptions based on the field classifications that have been updated where necessary based on the results of the laboratory testing in accordance with ASTM D 2487, “Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)”.

Pavement cores were collected on River Road. The results of the coring investigation are included in the Initial Pavement Design Report (Golder 2020).

3.2 Laboratory Testing

Selected representative samples collected from the boreholes were tested for classification and material properties by ATEK for use in the evaluation of the subsurface conditions and to aid in engineering design for the proposed facilities.

The soils laboratory testing program included moisture content determination, grain-size analysis, Atterberg limit tests (plasticity), Resilient Modulus or R-Value, and one-dimensional consolidation (for collapse potential). The laboratory tests were performed in accordance with the standard test procedures listed in Table 3. Results of all laboratory tests are included in Appendix B. The soils that were tested were checked against the field classifications, which were then updated where appropriate in accordance with ASTM D 2487.

Table 2: Geotechnical Test Methods Applied to Representative Soil Samples

Geotechnical Test	Test Procedure
In Situ Moisture Content	ASTM D 2216 / AASHTO T 265
Sieve (Grain Size) Analysis	ASTM C 136/C 117, ARIZ 201d
Atterberg Limits (Soil Plasticity)	ASTM D 4318, AASHTO T 89/T 90
R-Value	AASHTO T 190, ASTM D 2844
In-place Density	ASTM D 2937
One-Dimensional Consolidation Properties of Soils	ASTM D 2435

Notes:
ARIZ = Arizona Department of Transportation Test Method (ADOT 2019)

4.0 SITE CONDITIONS

4.1 Subsurface Conditions

The subsurface can be divided into two main categories: Rillito river channel soil deposits and Rillito riverbank/terrace or historical channel soil deposits. The riverbank soil is generally medium dense and dry consisting of fine sand, some gravel, and non-plastic to low plasticity fines for the first 15 to 25 feet below existing grade. Very loose to loose soil of the same gradation and plasticity can be found in this interval interspersed throughout the area. Moist soils of increasing gravel content can be found from approximately 25 to 80 feet below ground, the soil in this stratum is cohesionless and generally dense to very dense in consistency. Cobbles are inferred from observations made during drilling from approximately 35 to 45 ft and 50 to 65 ft, although they were not directly observed at the surface. This area was marked with large washouts and difficult drilling conditions. Below 80 feet, the soil grades as fine to medium sand with low to medium plasticity silts and clays and trace gravel. The soil is moist and cohesionless and very dense in consistency. Soil in the first 15 to 20 feet of the Rillito river channel is medium to coarse sand with non-plastic silt, the soil is characterized as dry and loose to very loose in consistency. The soil becomes compact to dense in consistency and moist with the same gradation and fines characteristics from approximately 20 to 40 feet below grade. Below 40 feet, the soil grades as low to medium plasticity silty/clayey fines sand and fine to coarse gravel, moist and dense to very dense in consistency. Cobbles were observed in the cutting accompanied with rough drilling from 37 to 49 feet and 54 to 65 feet below grade.

4.2 Engineering Properties of Soils

Golder derived material properties for the simplified soil units based on SPT-N value correlations and correlations with index tests using published relationships (AASHTO 2017, Samtani and Nowatzki 2006, NAVFAC 1986a, NAVFAC 1986b, Bowles 1996). SPT-N values and the correlated relationships for each SPT sample were analyzed according to the (LRFD) procedures described in Section C10.5.5.2.3 of AASHTO. Table 3 summarizes the resulting recommended design values for the material properties of interest. The simplified soil profiles used for design with these material properties are presented in the relevant sections.

The SPT tests were conducted using a CME automatic hammer. The automatic hammer exhibits an energy efficiency of approximately 78 to 85 percent of the theoretical free fall energy (Bureau of Reclamation 1999). This high efficiency was considered when using the SPT to derive correlated geotechnical parameters. For example, correlations between soil relative density and the SPT typically use N values standardized to 60 percent energy efficiency (N_{60}). Therefore, use of these correlations using the SPT results from the project borings requires the N values to be corrected by multiplying them by a factor of approximately 80/60 (or 1.33) prior to use.

A 3-inch OD, split-spoon ring sampler was also used to sample soils at select locations to attempt to obtain relatively undisturbed samples for laboratory testing. The sampling method was similar to the SPT, but because of the larger diameter of this sampler, blow counts were typically higher than those obtained with the SPT sampler and they should not directly be equated to SPT blow counts without further correction. A correction factor of 0.44 was used based on correlations to the oversize sampler diameter (Arman et al. 1997).

Table 3: Recommended Soil Properties for Geotechnical Design

Layer Name (Abbreviated Name)	Description	N_{60} (blows/ft)	$N1_{60}$ (blows/ft)	Relative Density, D_r (%)	Bulk Unit Weight, γ (pcf)	Drained Friction Angle, ϕ' (deg)	Elastic Modulus (ksf)	Lateral Soil Modulus, k (pci) [1]
Surficial Deposits (SD)	Compact silty clayey sand, dry, cohesionless	19	21.5	59	100	33	375	100
Soft Surficial Deposits (sSD)	Loose silty clayey sand, dry to moist, cohesionless	7	8.5	38	95	29	75	40
Sandy Gravel Layer (sGL)	Compact gravely sand, dry to moist, cohesionless	25	20.5	60	110	33	400	125
Gravel Layer (GL)	Very dense silty clayey gravel, dry to moist, cohesionless	74	43	86	130	37	1600	225
Hard Gravel Layer (hGL)	Very dense silty sand and gravel, dry to moist, cohesionless, cobbles present in layer but not observed	79	51.5	93	115	39	1250	225
Sands with Clay and Silts (SCS)	Very dense sand with silt and clay, moist, cohesionless	81	40	89	120	37	900	225
Upper Channel (UC)	Very loose to loose silty clayey sand, dry, cohesionless	7.5	8	35	100	29	105	40
Dense Upper Channel (dUC)	Compact to dense silty clayey sand and gravel, dry to moist, cohesionless, cobbles observed in borehole cuttings	47	35	75	125	36	640	225
Lower Channel (LC)	Compact to dense silty clayey sand, moist, cohesionless	40.5	20	65	110	33	600	225

Layer Name (Abbreviated Name)	Description	N_{60} (blows/ft)	$N1_{60}$ (blows/ft)	Relative Density, D_r (%)	Bulk Unit Weight, γ (pcf)	Drained Friction Angle, ϕ' (deg)	Elastic Modulus (ksf)	Lateral Soil Modulus, k (pci) [1]
Dense Lower Channel (dLC)	Dense to very dense clayey gravel and sand, moist cohesionless, cobbles observed in borehole cuttings	60	20	75	115	33	750	225
Embankment Fill (Fill)	Assumed to be clayey or silty sand, compacted to 95% standard proctor density	-	32	75	115	33	650	125
Structure Backfill (SBF)	Meeting requirements of Section 203-5.03 of ADOT Standard Specifications (2008)	-	32	75	120	33	768	225

Notes: 1. The recommended values of k assume that the LPILE program will be utilized. Golder should be contacted to determine the applicability of these values for other programs.

4.3 Groundwater

No groundwater was encountered in any of the boreholes. The regional static groundwater table is approximately 130 feet to 160 feet below ground surface based on several data points from the Arizona Department of Water Resources (ADWR) Ground Water Site Inventory database (ADWR 2020), although one nearby depth to water measurement from 2001 was 116 feet indicating that some fluctuation in the depth to groundwater is possible. Golder selected an elevation of 2,080 for the static groundwater table, which is consistent with available measurements from 2005 through 2019.

The state of the practice for accounting for groundwater in deep foundation design for bridges over ephemeral waterways has been to design for fully saturated (fully buoyant) conditions during the design flood events. NCS performed a laboratory and desktop study to model porewater pressures in the subsurface after a series of transient flood events (NCS 2015b). In general terms, a full hydro-static pressure distribution used for design results in reduced effective overburden pressure and a corresponding decrease in side resistance for the foundation. By modeling more realistic partially buoyant conditions, there is the potential for cost savings in the bridge foundations. The reader is referred to the NCS report for a detailed discussion of the study. Golder used the results of the modeling to develop a design porewater pressure profile given in Table 4 for the design storm event. The 500-year extreme event porewater pressure profile is similar.

Table 4: Design Porewater Pressure Profile for Deep Foundations at Rillito Creek

Depth from Thalweg Elevation (ft)	Elevation (ft)	Porewater Pressure (ksf)	Comments
-9	2,224	0.00	100-Yr Water Surface Elevation [1]
0	2,215	0.56	Thalweg elevation per 15% plans [1]
25	2,190	2.12	Scour elevation for 100-yr event [1]
65	2,150	4.62	Bottom of “Layer 1” from NCS Report
135	2,080	0.00	Static groundwater level (ADWR Data)
155	2,060	1.25	Bottom of model

Notes: 1. Per WSP Drainage Report (WSP 2020).

4.4 Geologic Hazards

4.4.1 Seismicity

AASHTO requires that seismic analysis incorporate a Peak Ground Acceleration (PGA) and spectral response values corresponding to a 7 percent probability of exceedance in 75 years (approximately a 1000-Year return period). Figures 3.10.2.1-1 to 3.10.2.1-3 of AASHTO 8th Edition (2017) provide these values for the contiguous United States. However, the code also allows the use of software tools that interpolate more accurately from the data used to derive these figures. Golder used the US Geological Survey (USGS) Seismic Design Maps online tool (USGS 2020).

Using the USGS application with the latitude and longitude values of the bridge site, the PGA is 0.076g, the horizontal response spectral acceleration coefficient at 0.2-sec return period (Ss) is 0.174g and the horizontal

response spectral acceleration coefficient at 1.0-sec return period (S_1) is 0.049g. The bridge site should be considered Class D based on the profile descriptions given in Table 3.10.3.1-1 of AASHTO (2017). For this subsurface profile, the modification coefficients are F_{pga} = 1.6, Fa = 1.6, and Fv = 2.4. Accordingly, the Peak Seismic Ground Acceleration coefficient modified by the short-period site factor (As) is 0.121g, the horizontal response spectral acceleration coefficient at 0.2-sec return period modified by short-period site factor (S_{Ds}) is 0.279g, and the horizontal response spectral acceleration coefficient at 1.0-sec return period modified by long period site factor (S_{D1}) is 0.118g. The bridge site is classified as Seismic Zone 1 since the S_{D1} value is less than 0.15 in accordance with Table 3.10.6-1.

4.4.2 Hydro-collapsible Soil

Hydro-compactive or collapsible soils are subject to significant volume reduction when wetted. This occurs primarily because of the breakdown of the soil structure as light calcium carbonate cementation or bonding between sand particles softens or weakens under increased moisture content. Wetting and loading history of the soil influence the collapse potential, and a soil may collapse under even relatively low loads, such as that imposed by pavement structures or small embankments, when the soil moisture content exceeds past levels. Often, the placement of a new structure changes the drainage or evapotranspiration regime of the soil, increasing the likelihood of a collapse event (Houston et al. 2002). The general criteria for field identification of soils with collapse potential are as follows (adapted from Beckwith 1979):

- Plasticity Index (PI) less than 10
- Dry density less than 95 pounds per cubic foot (pcf)
- Moisture content less than 8 percent
- SPT N-value less than 15 blows per foot

Several boreholes encountered potentially collapsible material based on the above criteria, particularly considering the SPT N-value. These include BH-02, BH-03, BH-04, and BH-05. ATEK performed collapsible potential tests on samples retrieved from these boreholes. The tests were performed to standard ASTM D 2435 (One Dimensional Consolidation Properties of Soils) with loading carried out under in situ moisture conditions up to a load of 4 kilopounds per square foot (ksf), followed by inundation. The results of the collapse tests are provided in Table 5.

Table 5: Summary of Collapse Test Results

Borehole	Depth (ft)	In Situ Dry Density (pcf)	SPT N60 Value [A] (blows/ft)	In Situ Moisture Content (%)	Collapse Index, I_e[B] (%)	Degree of Collapse [C]
BH-02	21	93.2	30	4.1	8	Moderately Severe
BH-03	7.75	97.5	30	7.9	7.3	Moderately Severe
BH-05	20.75	100.1	25	8.1	2.2	Moderate

Notes:

A = Corrected for sampler diameter and estimated hammer efficiency.

B = Collapse index is the difference in height of the sample before and after inundation divided by the initial height of the specimen when the test is performed at an inundation stress of 4 ksf.

C = Based on Table 1 of ASTM D 5333-03.

ft = feet

pcf = pounds per cubic feet

% = percent

The results in Table 5 indicate that potentially collapsible soils can be anticipated on the project, and that overexcavation and recompaction of near-surface soil below embankment fills and shallow foundations will be required to minimize potential for excessive post-construction settlement. Recommendations related to mitigation of collapsible soil are presented in Section 5.4.

4.4.3 Expansive Soils

Swelling soils may result in uplift of deep foundations or heave of shallow foundation. The following Table after Table 10.4.6.3-1 of AASHTO (2017) provides criteria for identifying potentially expansive soils. Golder did not encounter any high plasticity clay soil would rate as marginal or high, accordingly, no additional testing or mitigation is required.

Table 6: Method for Identifying Potentially Expansive Soils

Liquid Limit (%)	Plastic Limit (%)	Potential Swell (%)	Potential Swell Classification
>60	>35	>1.5	High
50-60	25-35	0.5-1.5	Marginal
<50	<25	<0.5	Low

5.0 ALIGNMENT GEOTECHNICAL DESIGN RECOMMENDATIONS

5.1 Geotechnical Feasibility

Based on the results of the preliminary field explorations, laboratory testing, and geotechnical analyses conducted for the project, construction of the proposed Sunset Road improvements is feasible from a geotechnical standpoint. The site soils will generally support the proposed improvements and will provide for adequate bearing capacity, pavement subgrade support, serviceability for settlement, global stability, and constructability. However, some subgrade improvement will be necessary and additional geotechnical analysis will be required during the final design phase.

5.2 Alignment Cut/Fill Recommendations

5.2.1 Fill Slopes

Embankment fill slopes will primarily be constructed from imported soil types within limited material borrowed from cut areas within the project limits. Based on these considerations, the borrow soils are expected to be granular in nature, although they may contain substantial proportions of clay and/or silt. If compacted in accordance with applicable ADOT standards (Section 203), fill slopes as steep as 1.5 horizontal to 1 vertical (H:V) may have acceptable factors of safety, in regard to geotechnical slope stability. However, fill slopes at this angle may not perform acceptably in regard to revegetation, erosion control, maintenance, and aesthetics. Therefore, we recommend fill slopes no steeper than 2.5H:1V for this project unless they are protected by hard facing, such as concrete or grouted rip rap.

5.2.2 Cut Slopes

Cuts into native granular material as encountered in this investigation are expected to have adequate factors of safety for slope stability at permanent slopes no steeper than 1.5H:1V. However, such slopes would not perform acceptably in regard to revegetation, erosion control, maintenance, and aesthetics. Accordingly, permanent cut slopes that will not be protected through revegetation or through erosion control measures should be constructed no steeper than 2.5H:1V.

Temporary cut slopes for construction that are less than 20-feet deep should be excavated in accordance with OSHA Health and Safety Standards for Excavations, 29 CFR Part 1926, Subpart P. Undisturbed, compact granular soils and stiff to very stiff cohesive native soils may typically be considered Type “B” soils in accordance with Subpart P, Appendix A. Manmade fill, previously disturbed soil, loose granular soil, or soft to medium stiff clay within the upper 7.5 feet of existing grade should be considered Type “C’ soils. For excavations less than 20-feet deep, Subpart P, Appendix B indicates maximum allowable unshored slopes of 1H:1V and 1.5H:1V for Type “B” and Type “C” soils, respectively. Where soils are highly cemented and conditions are confirmed by a qualified inspector, a classification as Type “A” may be warranted. In this case, excavations less than 20-feet deep may be constructed at 0.75H:1V. Should steeper slopes be required due to the proximity of existing structures or utilities, the stability of the slope should be further evaluated by a geotechnical engineer, or shoring should be considered.

Heavy excavation equipment should be maintained at least 10 feet from the edge of any excavation, and the perimeter of all temporary excavations should be protected against surface water runoff to prevent raveling and erosion of the slopes into the excavation.

5.3 Embankment Construction

Areas to receive new embankment fill should be prepared in general accordance with Section 201 of the Standard Specifications except as noted below. Embankment construction should confirm to Section 203-10 of the Standard Specification. The proposed embankments are anticipated to be constructed almost entirely of borrow, accordingly no standard proctor tests were conducted. Compaction testing will be required during construction for control of all imported embankment materials. Embankment fill placed within 3 feet of the finished subgrade elevation in pavement areas should meet the project's minimum construction control R-value. Golder recommends using a design and construction control R-Value of 25. This is consistent with the nearby I-10: Ruthrauff TI project that is currently under construction where the construction control R-Value is 25 for the I-10 mainline and ramps. That project also had significant borrow quantities. Refer to the Initial Pavement Report for more information (Golder 2020).

5.4 Subgrade Mitigation

As noted in Section 4.4.2, potentially hydro-compactive soil has been identified within the project limits. Accordingly, Golder has provided the following preliminary recommendations for treatment of these soils pending additional investigations and analysis during final design.

1) Overexcavate and recompact beneath the **embankment** footprint to a depth of 3 feet below existing grade. Overexcavation should extend to the toe of the embankment slope. Recompact to a minimum of 95 percent of the maximum dry density and ±2 percent of optimum moisture content as determined by ARIZ 225/226.

2) Overexcavate and replace with structure backfill beneath **shallow foundations for bridge abutments** (if used) to a depth of 5 feet below bottom of footing. Extend the overexcavation zone two feet beyond the plan limits of the footings. Recompact to a minimum of 100 percent of the maximum dry density and ±2 percent of optimum moisture content as determined by ARIZ 225/226.

3) Overexcavate and replace with structure backfill beneath **cast in place retaining wall footings** to a depth of 3 feet below bottom of footing. Extend the overexcavation zone two feet beyond the plan limits of the footings. Recompact to a minimum of 100 percent of the maximum dry density and ±2 percent of optimum moisture content as determined by ARIZ 225/226.

4) Overexcavate and recompact beneath **mechanically stabilized earth (MSE) walls** to a depth of 3 feet below bottom of wall elevation. Recompact to a minimum of 100 percent of the maximum dry density and ±2 percent of optimum moisture content as determined by ARIZ 225/226.

5.5 Earthwork Factors and Ground Compaction

Golder recommends that roadway designers assume 20 percent shrink for on-site soils that are compacted to 95 percent relative compaction (standard proctor). This value may be refined in final design by targeting additional in-situ density data and standard proctor testing and further analysis of existing data once areas of excavation are better identified.

Ground compaction is anticipated beneath the proposed embankment loads. Settlement analyses were performed for the embankment between the UPRR tracks and the Rillito River. Table 7 presents the preliminary ground compaction factors recommended for design. Overexcavation measures described in the previous section will reduce the magnitude of ground compaction slightly, but most of the settlement occurs below the overexcavation zone because of the depth of influence of the embankment.

Table 7: Estimated Ground Compaction Beneath Embankment Sections

Sunset Road Station	Ground Compaction (feet)
92+00 to 95+00	0.3
95+00 to 97+50	0.5
104+50 to 108+00	0.5
108+00 to 111+00	0.4

5.6 Water for Compaction

For estimating purposes, allow 65 gallons of water per cubic yard for compaction of base materials and 45 gallons of water per cubic yard for compaction of subgrade and embankment materials. These amounts are considerably higher than what is required to raise in situ moisture content to near the optimum moisture content for compaction to account for losses due to seepage, evaporation, spilling, etc. Precipitation during construction may significantly reduce the required water volume.

5.7 Electrochemical Properties of Site Soil at Drainage Structures

No information was available on the location of proposed drainage structures when Golder's investigation was planned, so no electrochemical testing was performed as a part of this study. We recommend that the need for such testing be confirmed with the drainage engineer during the scoping phase of the final design effort.

5.8 Geotechnical Recommendations for Drainage Structures

We understand that a ditch approximately 2- to 3-feet deep is proposed to convey surface water from the east side of the proposed embankment to the west side and ultimately to the Rillito. The proposed ditch alignment is shown in blue on Figure A-1 in Appendix A. The portion of the ditch that goes beneath the UPRR bridge is shown as rectangular with a concrete lining. Presumably, the remaining portion of the ditch (with side slopes of 3H:1V to 4H:1V) is unlined.

As noted in Section 4.4.2, the surficial soils on the project are potentially hydro-collapsible. Golder recommends consideration of the following items to reduce the likelihood of water from the ditch infiltrating beneath retaining walls and the embankment:

- Extend the concrete lining for the channel approximately 125 to 150 feet to the east of the terminus shown on the 15 percent plans. Provide approximately 50 feet of separation between the ditch and the approach MSE wall before transitioning to an unlined channel.
- Construction sequencing should be detailed such that rough grading of the channel is allowed at any time, but final grading and lining of the channel is delayed until all or most of the embankment material is placed. The embankment loading (and approach walls) will cause settlement, even beyond the footprint of the embankment, that could potentially cause cracking of the concrete channel lining, which would increase the risk of infiltration of water beneath embankments or structures.

We are not aware of any water harvesting, detention or retention basin structures at this time. However, if any are planned in the future, Golder recommends a setback of approximately 50 feet from all embankments, retaining walls, and other structures to reduce risk of hydro-collapse induced settlement. If this setback cannot be achieved, then additional mitigation measures may be required.

5.9 Pima County Regional Wastewater Reclamation Department Line

The Sunset Road embankment will pass over the PCRWRD's Santa Cruz Interceptor sewer pipe to the west of the EB I-10 frontage road. The pipe is a 72-inch diameter Hobas brand fiberglass pipe that transitions to a 60-inch diameter Hobas pipe at a manhole on the south side of Sunset Road before passing beneath Sunset Road. The pipe is a gravity main flowing to the north that was constructed in 2010 and the pipe invert elevation in the vicinity of the embankment ranges from approximately 2214 to 2216 feet based on the record drawings (Brown and Caldwell 2010), which is approximately 17 to 19 feet below existing grade. The embankment height at this location will be approximately 23 feet with side slopes of 3H:1V.

Golder modeled the settlement beneath the embankment loading using the software program Settle3 by Rocscience. This analysis models the embankment in three dimensions and computes the stress increase with depth using a Boussinesq elastic solution. The soil modulus values used in the analysis were based on correlations with SPT N-Values for NCS Boreholes SUW-SW06, SUB01, and PE-04 with the idealized soil profile based on these boreholes as well. There is no soil-pipe interaction modeled with this analysis.

The results of the analysis are depicted graphically in Figure 1 below. The figure shows two displacement profiles: one at the ground surface and one at elevation 2216 at the bottom of the pipe. The X-Axis is the approximate pipe stationing based on the pipe record drawings (Brown and Caldwell 2010). The maximum settlement occurring below elevation 2216 (approximate bottom of the pipe) was computed as 4 inches at the center of the embankment. The transition from the 60-inch pipe to the 72-inch pipe occurs at roughly Station 122+18 and the computed settlement below this point is approximately 0.8 inches indicating a differential settlement of approximately 3 inches over a distance of roughly 100 feet. The maximum slope of the settlement profile is approximately 0.003 feet/feet which is approaching the slope of the 60-inch pipe, as indicated on the record drawings, of 0.00484 feet/feet. This means the pipe could become virtually flat over a short area.

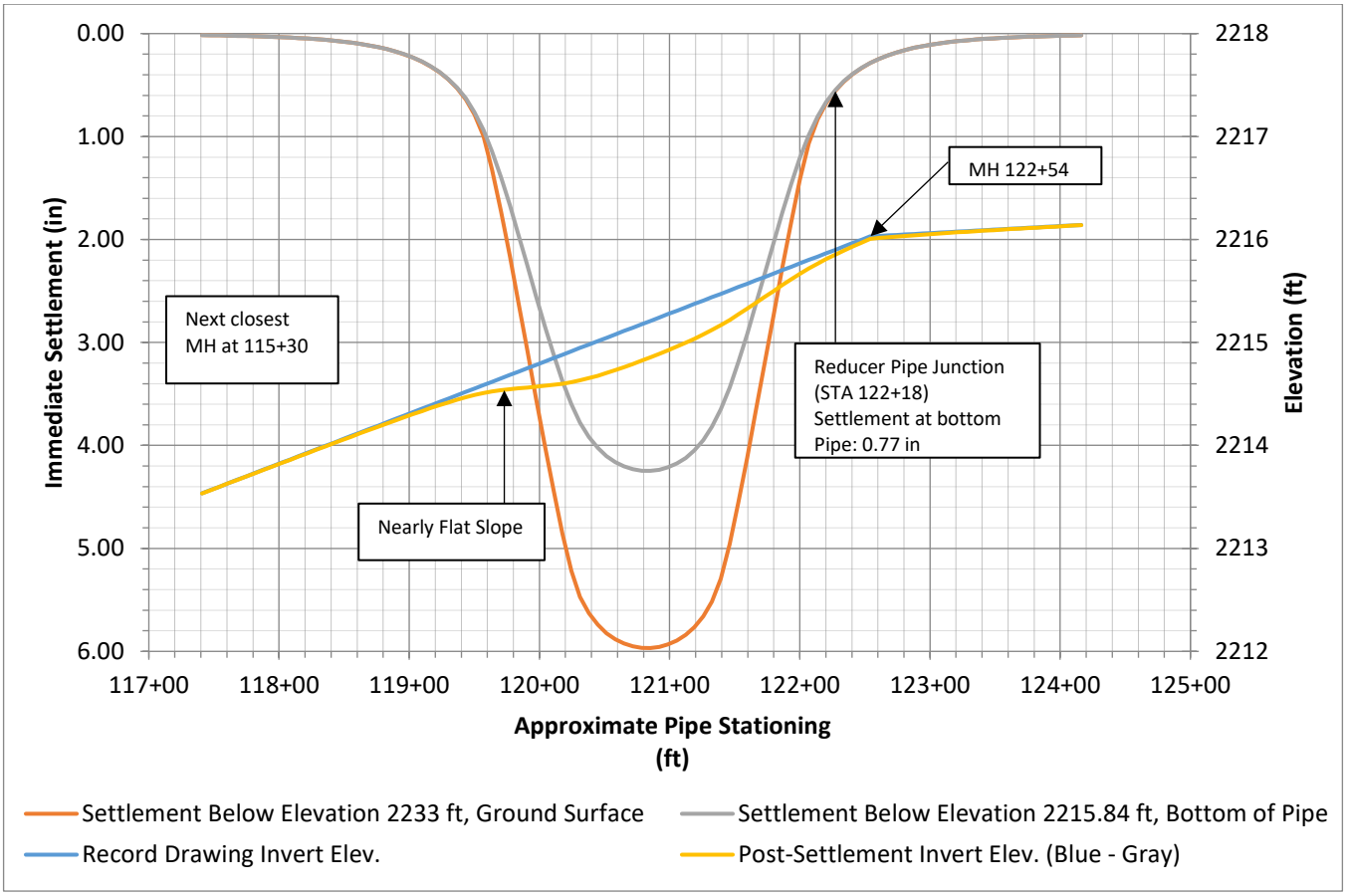

Figure 1: Pipe Settlement Summary and Anticipated Pipe Profile

Golder and the project team provided this information to Hobas PCRWRD, and others to determine if the predicted embankment settlement will adversely affect the pipe, requiring mitigation. Although we received some responses regarding the ability of the pipe to tolerate various overburden pressures, the ability to tolerate deflection resulting from embankment settlement remains unresolved. Accordingly, we recommend additional study of this pipe and other impacted utilities during final design.

We coordinated with the project team to evaluate several conceptual mitigation options to address deformations beneath the 60-inch pipe. These included constructing the embankment with lightweight fill over the pipe, a structural slab supported on deep foundations, or an open-bottom equipment pass structure supported on deep foundation elements. The project team decided on the equipment pass option to be included in the 30 percent plans and DCR. Golder recommends deep foundations consisting of 18-inch diameter drilled shafts, 40-feet deep, spaced at 6 feet supporting each side of the equipment pass abutment walls. These recommendations are preliminary and should be revisited during final design once tolerable settlement has been determined.

6.0 BRIDGE STRUCTURES

6.1 Structures Overview

6.1.1 Union Pacific Railroad Bridge

The currently proposed bridge over the UPRR tracks consists of two asymmetrical spans. The main span clears the entire UPRR right-of-way (ROW) and is approximately 206-feet long and will consist of built-up steel plate girders (86-inches deep). The second span is approximately 45 between the pier and Abutment 2 and will consist of WF 24x117 rolled steel beams, spanning over a maintenance road and a concrete lined drainage channel. The total bridge length is approximately 255 feet.

The subsurface conditions at the bridge were characterized by Boreholes BH-01, BH-02, and NCS Boreholes SUB05 and SUW-NE07.

6.1.2 Rillito Creek Bridge

The Rillito Creek Bridge is currently planned as a 390-foot long, three-span bridge. The superstructure will consist of AASHTO Type V Modified Girders. The abutments will be located behind the existing soil cement bank protection which will be modified to allow the asphalt multi-use path to pass beneath the bridge. This will require lowering the path profile to several feet above the channel elevation.

The subsurface conditions at the bridge were characterized by Boreholes BH-04 and BH-05 at the abutments, and NCS Boreholes B-12 and B-13 at the pier locations.

6.2 Foundation Type Selection

Golder considered three different foundation types for the proposed bridge structures: spread footings, steel driven piles (H-pile or closed-end pipe), and cast-in-drilled hole shafts (drilled shafts). Historically, both ADOT and the County have favored drilled shafts over driven piles for new bridge structures. Accordingly, driven piles have been excluded from further analysis.

Drilled shafts are commonly used for bridges in Arizona. They can be drilled through dense and otherwise problematic soil units, such as the Ft. Lowell Formation soils, thanks to the prevalence of high-torque auger rigs. They are able to overcome scour issues at river crossings, and can often be used without a cap by transitioning the drilled shaft directly into the bridge column. The drawbacks of this foundation type include that you cannot visually inspect the foundation and must rely on integrity testing, and caving soil conditions require casing or wet-method installation that increases cost.

Spread footings are often more economical than drilled shafts, particularly when full-height abutments are used. Spread footings are only feasible at the UPRR bridge because of the potential for abutment and pier scour at Rillito Creek. One of the major advantages of spread footings is that the bearing stratum can be readily inspected, and so can the concrete and steel. Because of the loose soil encountered in the near-surface portions of the boreholes, overexcavation and recompaction or replacement will be required beneath spread footings. The embedment depth combined with this overexcavation will create potential conflicts with utilities located in the UPRR ROW and potentially with the I-10 Frontage Road.

Drilled shafts are the recommended foundation type for the Rillito Bridge. Golder also recommends drilled shafts for the UPRR bridge to avoid the issues associated with overexcavation near the utilities in the railroad ROW. However, we have provided recommendations for both drilled shafts and spread footings at the UPRR bridge to allow CONSOR to select the most feasible and economical foundation type.

6.3 Subsurface Conditions at Proposed Bridge Substructures

The following subsurface profile information has been used for geotechnical analysis. The material properties associated with each layer are provided in Table 3.

Table 8: Subsurface Profile for Drilled Shafts at UPRR Bridge

Depth Below Top of Shaft (ft) [A]	Elevation (ft)	Layer ID
0 – 14	2220 – 2206	SD
14 – 82	2206 – 2138	hGL
82 and deeper	2138 and deeper	SCS

Notes:

A – Top of shaft elevation assumed to be el. 2220 ft.

Table 9: Subsurface Profile for Abutment Drilled Shafts at Rillito Creek Bridge

Depth Below Top of Shaft (ft) [A]	Elevation (ft)	Layer Name
0 – 23	2218– 2195	SD
23 – 54	2195 – 2164	hGL
54 and deeper	2164 and deeper	SCS

Notes:

A – Top of shaft elevation assumed to be el. 2,218 ft for Abutment 1 and 2,212 ft for Abutment 2.

Table 10: Subsurface Profile for Piers Drilled Shafts at Rillito Creek Bridge

Depth Below Channel Thalweg (ft) [A]	Elevation (ft)	Layer Name
0 – 20	2215 – 2195	UC
20– 50	2195 – 2165	dUC
50 – 110	2165 – 2105	LC
110 and deeper	2105 and deeper	dLC

Notes:

A – Channel thalweg elevation assumed to be el. 2,215 ft.

6.4 Scour Condition and Rillito Creek Bridge

Scour analysis for the Rillito Creek Bridge was performed by WSP (2020). They note that there is virtually no long-term bed degradation since PCRFCD has been observing aggregation at this location. The bend scour and contraction/general scour were also noted as minimal. Accordingly, pier scour is the primary contribution to

total scour values. Scour calculations provided in Appendix C of their report provide the scour depths listed in Table 11, which are assumed to apply to a channel thalweg elevation of 2,215.

Table 11: Pier Scour Depths for Rillito River Bridge

Scour Type	100-Year Event		500-Year Event	
	Reported	Design	Reported	Design
Bed degradation	0	0	0	0
Contraction (General)	0.07	0	0.75	1
Pier	24.65	25	26.12	26
Total	24.72	25	26.87	27

Golder utilized procedures from the Federal Highway Association (FHWA) manual – Geotechnical Engineering Circular 10 (GEC10): Drilled Shafts: Construction Procedures and LRFD Design Methods (Brown, Turner, and Castelli 2010) which recommend that effective stress be calculated according to the procedure indicated in Figure 2 with regards to pier scour.

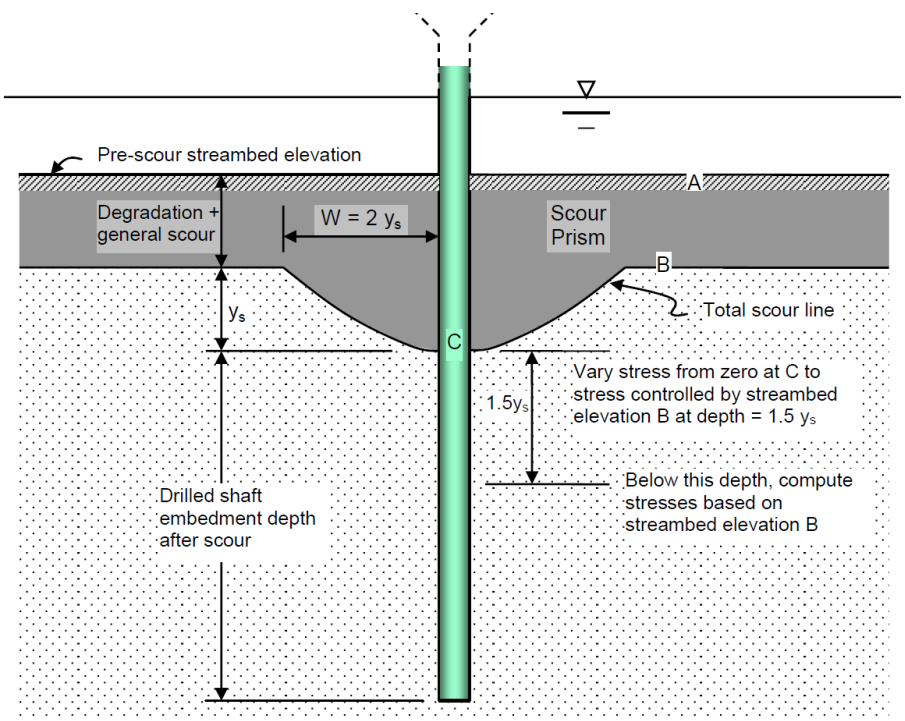

Figure 2: Effect of Scour on Calculation of Overburden Stresses (From Brown et al. 2010)

6.5 Geotechnical Recommendations for Drilled Shaft Foundations

The design of drilled shaft foundations involves an evaluation of the axial and lateral capacities for a given set of loading and soil conditions. The length of the drilled shafts will be based on the more conservative length

determined from these two analyses. Recommendations and procedures for design of drilled shafts are presented in the following sections.

6.5.1 Single Shaft Axial Capacity at Strength Limit

Axial resistance at the strength limit state for single shafts was computed using AASHTO LRFD. Golder followed the procedures outlined in ADOT Policy Memo DS-1 (ADOT 2010a) for the development of axial resistance charts.

The Beta (β-) method was used for computing side resistance in cohesionless soils, and the nominal tip resistance was based on the SPT blow count according to Section 10.8.3.5.2c of AASHTO. Factored drilled shaft axial resistances were computed from Equation 10.8.3.5-1 of AASHTO as follows:

$$R_R = \varphi R_n = \varphi_{qp} R_p + \varphi_{qs} R_s$$

Where:

φR_n = Factored axial resistance (kips)

R_p= Nominal tip resistance (kips)

R_s= Nominal side resistance (kips)

φ_{qp}= Resistance factor for tip resistance specified in Table 10.5.5.2.4-1

φ_{qs}= Resistance factor for side resistance specified in Table 10.5.5.2.4-1

The resistance factor values, φ_{qp} and φ_{qs} are 0.50 and 0.55, respectively, for cohesionless materials according to Table 10.5.5.2.4-1 of AASHTO. No significant continuous deposits of gravel were encountered in the subsurface investigation that were judged to warrant further exploration with an 18-inch auger per ADOT's interim guidance on design in this material (ADOT 2010b).

6.5.1.1 Tip Resistance

Nominal tip resistance was determined in accordance with Equation 10.8.3.5-2 of AASHTO, as:

$$R_p = q_p \cdot A_p$$

Where:

A_p =cross-sectional area of the shaft tip (ft^2)

For cohesionless soils with SPT N_{60} values less than or equal to 50, nominal unit tip resistance was determined in accordance with Equation 10.8.3.5.2c-1 of AASHTO, as:

$$q_p = 1.2 \cdot N_{60}$$

Where:

N_{60} =average SPT blow count corrected only for hammer efficiency in the design zone under consideration (blows/foot)

For cohesionless soils with SPT N_{60} greater than 50, the material is considered an intermediate geomaterial and the nominal unit tip resistance is determined in accordance with Equation 10.8.3.5.2c-2 of AASHTO, as:

$$q_p = 0.59 \cdot \left[N_{60} \left(\frac{p_a}{\sigma'_v} \right) \right]^{0.8} \sigma'_v$$

Where:

p_a =Atmospheric pressure (2.12 ksf)

σ'_v = Vertical effective stress at the tip elevation of the shaft (ksf)

The IGM equations were not utilized on this project, and the design N_{60} value was limited to 50 for drilled shaft design in all layers.

6.5.1.2 Side Resistance

Nominal side resistance was determined in accordance with Equation 10.8.3.5-3 of AASHTO, as:

$$R_s = q_s \cdot A_s$$

For layered systems:

$$R_S = \sum_{i=1}^{N} q_{si} \cdot A_{si}$$

$$A_{Si} = \pi \cdot D \cdot \Delta z_i$$

Where:

q_{si} = nominal unit side resistance of the ith soil layer (ksf)

A_{si} =drilled shaft surface area within the ith soil layer (ft^2)

D = drilled shaft diameter (feet)

Δz_i =thickness of ith soil layer (feet)

N =total number of soil layers considered

For cohesionless soils, nominal unit side resistance was determined in accordance with Equation 10.8.3.5.2b-1 of AASHTO, as:

$q_{Si} = \gamma'_i \cdot z_i \cdot \beta_i \leq 4.0$ for β between 0.25 and 1.2 (inclusive)

Where:

γ'_i =unit weight of ith soil layer (ksf)

z_i =depth to midpoint of ith soil layer (feet)

The value of β_i is determined in accordance with Equations 10.8.3.5-2b-2 and 10.8.3.5.2b-3 of AASHTO, as:

$$\beta_i = 1.5 - 0.135\sqrt{z_i} \quad \text{for SPT } N_{60} \geq 15 \text{ blows/foot}$$

$$\beta_i = \left(\frac{N_{60}}{15}\right) \cdot (1.5 - 0.135\sqrt{z_i}) \quad \text{for SPT } N_{60} < 15 \text{ blows/foot}$$

Where gravelly sands or gravels are encountered and the SPT N_{60} is greater than 15 blows/foot, AASHTO equation 10.8.3.5.2b-4 is used which was based on the work of O'Neil and Reese (1999), as:

$$\beta_i = 2.0 - 0.06 \cdot (z_i)^{0.75}$$

6.5.1.3 Axial Resistance Chart

Golder prepared design charts to present the recommended strength limit axial resistance for drilled shaft foundations at piers and abutments derived using the procedures in Section 6.5.1. The design charts are included in Appendix C and are consistent with the procedures in ADOT Policy Memo DS-1 (ADOT 2010a). The soil material properties (unit weight and average SPT blow count at 60 percent energy efficiency, N_{60}) and design soil profile used in developing the design charts are given in Table 3, and Table 8 through Table 10, respectively. These parameters are based on the conditions encountered in the geotechnical boreholes and results of laboratory testing.

To size the drilled shaft foundations based on axial capacity at the strength limit state, the following procedure should be used: draw a vertical line corresponding to the required factored resistance per shaft. The intersection of the vertical line with the curve corresponding to the desired drilled shaft diameter will indicate the minimum drilled shaft length or the maximum drilled shaft tip elevation.

The following assumptions were made relative to the development of the design charts:

- For the shafts at the Rillito Creek, partially saturated conditions are assumed as discussed in Section 4.3.
- The charts have been developed assuming redundant drilled shafts at each foundation element.
- Both side resistance and tip resistance have been considered for axial resistance of the drilled shafts.

The weight of the drilled shaft below ground level is not deducted from the total factored axial resistance and should not be included in the computation of structural loads. The weight of all structural elements above the top of shaft elevation should be considered as additional dead load.

6.5.2 Drilled Shaft Group Axial Capacity

The design charts in Appendix C apply to drilled shafts with center-to-center spacing of at least three times the shaft diameter. For closer spacing, the structural engineer is advised to apply an appropriate Group Reduction Factor (GRF) to the factored loads prior to entering the charts. Refer to Table 10.8.3.6.3.1 of AASHTO for GRF values.

6.5.3 Service Limit State Analysis

No saturated fine-grained soil layers were encountered in the geotechnical investigation, so no consolidation settlements (long term settlements) are expected. Drilled shafts can be anticipated to experience most of the computed settlement by the end of construction.

6.5.3.1 Immediate Settlement of Single Shafts

The methodology prescribed in AASHTO for analyzing immediate settlement of single drilled shafts is based on the use of normalized load-settlement curves from O'Neill and Reese (1999). The use of these curves to prepare service limit state design charts is described in ADOT Geotechnical Design Policy DS-1 (ADOT 2010a). Service limit charts are presented in Appendix C representing factored service limit resistances corresponding to a total drilled shaft downward deflection (settlement plus elastic compression) ranging from 0.1 inches to 2.0 inches. Policy memo DS-1 provides a detailed description of how to use this information to perform service limit state analysis of drilled shaft foundations.

6.5.3.2 Immediate Settlement of Shaft Groups

AASHTO refers to procedures in Section 10.7.2.3.1 for analyzing settlement of groups of shafts using an equivalent footing analogy. However, the commentary for this section states that "For piles embedded adequately into dense granular soil such that the equivalent footing is located on or within the dense granular soil, and furthermore are not subjected to downdrag loads, a detailed assessment of the pile group settlement may be waived." This is expected to be the case for this project; accordingly, no equivalent footing analysis was performed.

6.5.3.3 Discussion of Downdrag Loads

Downdrag loads are not addressed in this initial geotechnical report. Downdrag loading will be considered during final design if drilled shafts are anticipated to be constructed prior to placement of embankment fill.

6.5.3.4 Horizontal Drilled Shaft Foundation Movement

A lateral load analysis should be performed by the structural designer once a drilled shaft is sized based on axial capacity considerations. The required length of the shaft will be the longer of the lengths computed in the axial and lateral load analyses. The use of the LPILE computer program or equivalent is recommended for this purpose. The lateral moduli and simplified subsurface profiles for input into LPILE are given in Table 3, and Table 8 through Table 10. ADOT Memo DS-3 (ADOT 2010c) provides guidance for structural engineers on performing lateral load analysis for drilled shafts.

6.5.4 Drilled Shaft Construction Considerations

6.5.4.1 Drilling Conditions

Unstable excavation conditions should be expected during the drilled shaft excavation. The presence of silty sand and well-graded sand lenses are strong indicators that the sides of shaft excavations will not be stable if

unsupported. **The drilled shaft contractor should anticipate the use of stabilizing techniques (e.g., temporary casing or polymer slurry) during drilling.**

6.5.4.2 Cobbles and Boulders

The presence of cobbles is sometimes only indicated on the borehole logs by the numerous instances of sampler refusal (indicated on the logs where blow counts reached or exceeded 50 before a penetration of 6 inches was achieved) and by description of drilling action (e.g., auger chattering or grinding). The samplers used to perform SPTs during the field program are limited in diameter so that the largest particle that can be retrieved is less than 2.5 inches. This introduces a bias toward smaller particles in the soil samples that were collected so that the subsequent sieve analysis indicates material that is finer than the actual condition of the soil in the ground. Golder recommends that the drilled shaft contractor be prepared to retrieve rounded cobbles and boulders approximately 12 to 24 inches in diameter from the drilled shaft excavations.

6.5.4.3 General Issues

Drilled shafts should be constructed in general accordance with Section 609 of the ADOT Standard Specifications. The following construction considerations are provided to ensure the design assumptions are satisfied:

- The majority of the drilled shaft loads are expected to be carried in side resistance. However, over the long term some load will be transferred to the base of shafts. Accordingly, Golder recommends that the bottom of the drilled shafts be cleaned by at least two passes of a flat-bottom auger or “spin-bottom” bucket cleaner immediately (no more than two hours) prior to placement of the reinforcement cage and concrete.
- A qualified inspector should complete a drilled shaft construction observation report for each drilled shaft constructed. The report should detail the nature of the materials encountered during shaft excavation and verify proper shaft depth and diameter, cleaning of the shaft base, reinforcement cage materials and installation, and concrete placement.
- A temporary surface casing is recommended to prevent surface sloughing or raveling and to ensure personnel safety. The casing diameter should not be more than 12 inches larger than the drilled shaft diameter. Common practice is to use a corrugated steel casing for this purpose. For pier shafts in the Rillito Creek, the casing may be left in the ground without affecting the geotechnical capacity of the shaft since this casing will be located in the scour zone.
- Fall protection should be provided for workers at the open shaft as required by OSHA.

There should be coordination between the geotechnical and structural designers for the preparation of special provisions to address these and other drilled shaft construction issues as part of the final design process.

6.5.5 Demonstration Shaft

Caving soil conditions are anticipated as noted in Section 6.5.4.1. In Golder’s experience, quality drilled shaft contractors are experienced with these issues on projects located adjacent to the major drainages in the Tucson area, and will use casing or polymer drilling fluid to stabilize the hole. However, a demonstration shaft program may ensure that the drilling equipment and methods that will be required to do the job are properly documented to reduce the likelihood of claims for changed conditions. The relatively small number of shafts on the County portion of the Sunset project may not justify the expense to the project. If the project is combined with the ADOT I-10 widening project as planned, then a demonstration shaft program could address these issues at one of the Rillito

Creek bridge locations where conditions are likely to be similar. Additional consideration of the benefit of a demonstration shaft program will be made during final design.

6.6 Geotechnical Recommendations for Spread Footings

6.6.1 Bearing Resistance at Strength and Service Limit State

A factored net bearing resistance chart has been provided in Appendix D for design of spread footings at the UPRR bridge with respect to bearing resistance at the strength and service limit states. The chart assumes a minimum depth of embedment of 3 feet. The structural engineer is referred to ADOT Materials Group Policy Memorandum SF-1 (ADOT 2010d) for a discussion on the development and use of this type of design chart. The computation of the effective footing width is described on pages 5 through 7 of SF-1. The computation of the equivalent net uniform bearing stress is also described in SF-1, and the actual depth of embedment, D_f, should be used with a soil unit weight of 120 pcf in Equation 3 of SF-1. The bearing resistance chart for the bridge structure assumes that the subgrade soil will be prepared according to the recommendations in the following section.

6.6.2 Subgrade Preparation

SPT blowcounts indicate loose conditions in the top 10 feet of Borehole BH-02. Golder recommends overexcavation as indicated in Section 5.4.

6.6.3 Lateral Earth Pressure

Full height abutment walls with level backfill that are free to displace at least 0.1 percent of the wall height at the top of the wall should be designed for the active earth pressure condition. An equivalent fluid pressure of 35 pounds per square foot per foot (psf/ft) may be applied to the back of the wall to simulate this loading condition.

Rigid walls, where wall displacements sufficient to develop the active earth pressure condition are not anticipated, should be designed for the at-rest earth pressure condition. An equivalent fluid pressure of 55 psf/ft may be applied to the back of the wall to simulate this loading condition.

The passive earth pressure condition is appropriate for earth pressure resistance to sliding in the case of spread footings or in the case of computing the resistance provided by a shear key. Special consideration must be given to the possibility of disturbance or removal of the material providing the passive resistance over the life of the structure. An equivalent fluid pressure of 400 psf/ft may be applied to locations of permanent soil resistance to simulate this loading condition. Horizontal displacements on the order of 0.02 times the height of the passive wedge are required to develop this resistance. The value of 400 psf/ft may be prorated down based on the anticipated deformation.

6.6.4 Sliding

Nominal sliding resistance may be computed using a coefficient of base friction of 0.60 applied to the total vertical force on the footing. A resistance factor, ϕ_τ, of 0.80 for CIP concrete on sand shall be applied to the coefficient of base friction to compute factored sliding resistance.

The procedure for accounting for the sliding resistance of a sliding key is presented below based on ADOT Policy Memorandum SF-3 (ADOT 2010f) and modified for this project.

1) Use the resistance factor, ϕ_τ, of 0.90 for soil-on-soil interface for the bottom horizontal plane of the footing between the toe and the front of the sliding key.

2) For the balance of the bottom horizontal plane of the footing, use ϕ_τ, of 0.80 for CIP concrete on sand.

Refer to Section 6.6.3 for a discussion on passive earth pressure and the required deformations to mobilize the full resistance. Conventional geotechnical practice is to neglect the passive resistance in front of the footing and include the passive resistance of a shear key, if used. A resistance factor, ϕ_{ep}, of 0.50 should be used on the passive earth pressure component.

6.6.5 Limiting Eccentricity

ADOT Materials Group has issued Policy Memorandum SF-2 (ADOT 2010e) that provides revised requirements for the computation of limiting eccentricity of footings as compared to the AASHTO Code. The structural designer should refer to SF-2 for the procedures for analyzing the limiting eccentricity of spread footings.

7.0 RETAINING WALLS

7.1 Retaining Wall Type Selection

Two wall types are considered feasible for fill retaining walls on this project, MSE walls and ADOT standard Cast-In-Place (CIP) concrete retaining walls. MSE walls have typically been cost competitive for relatively high wall heights, and they are known to tolerate more settlement than CIP walls, which is likely to be a key factor on this project. Golder recommends that MSE walls be utilized for the approach and likely abutment walls of the UPRR bridge. CIP walls may be more economical for the wingwalls and abutment walls of the Rillito Creek Bridge.

7.2 Subsurface Profile for Retaining Wall Analysis

Golder recommends the same soil profiles used for the UPRR bridge (see Table 8) and the Rillito Creek Abutments (see Table 9) be utilized for the preliminary analysis of the approach and abutment walls of the UPRR bridge and the Rillito Creek bridge, respectively.

7.3 Cast in Place (CIP) Concrete Walls

7.3.1 Minimum Embedment Depths

Golder recommends a minimum of 1.5-feet of cover over the footing measured vertically from the top of the footing at the toe to the finished grade as indicated in the ADOT Standard Drawings for CIP walls (ADOT 2015).

7.3.2 Foundation Preparation and Overexcavation

Golder recommends that wall foundation subgrade be overexcavated and recompacted to mitigate against excessive settlement and hydro-collapse potential. The requirements for overexcavation are described in Section 5.4.

7.3.3 Backfill Requirements and Soil Properties

Structure backfill should be in accordance with Section 203 of the ADOT Standard Specifications and placed in accordance with ADOT Standard Drawings SD 7.01. An effective friction angle of 33 degrees and a moist unit weight of 120 pounds pcf were assumed for development of lateral loads described below (see section 7.3.4.2) per ADOT Standard Drawing SD 7.01.

7.3.4 External Stability Analysis

7.3.4.1 Bearing Resistance and Settlement

Factored net bearing resistance charts have been provided in Appendix D for the following locations:

- Rillito Creek Abutment/Wingwalls
- UPRR Bridge Approach Walls/Abutment Wall

These charts may be used for design of wall foundations with respect to bearing resistance at the strength and service limit states. The chart assumes a minimum of 2 feet of cover over the top of the wall footing (approximate depth of embedment of 3 feet). The structural engineer is referred to ADOT Materials Group Policy Memorandum SF-1 (ADOT 2010d) for a discussion on the development and use of this type of design chart. The computation of the effective footing width is described on pages 5 through 7 of SF-1. The computation of the equivalent net uniform bearing stress is also described in SF-1, and the actual depth of embedment, Df, should be used with a soil unit weight of 120 pcf in Equation 3 of SF-1. The recommendations presented in Appendix D are location specific, and only apply to the proposed walls shown on the Stage I project plans. If the wall configuration changes or additional walls are needed, Golder should be contacted to review these recommendations or provide additional site-specific recommendations.

7.3.4.2 Lateral Earth Pressure

Lateral earth pressure recommendations from Section 6.6.3 may be applied to CIP walls as well.

Surcharge loads, such as traffic loading and temporary construction loads, and hydrostatic pressure, if applicable, should be included with lateral earth pressures as appropriate based on anticipated loading conditions.

7.3.4.3 Sliding

The sliding recommendations from Section 6.6.4 can be applied to CIP walls as well.

7.3.4.4 Limiting Eccentricity

The limiting eccentricity recommendations from Section 6.6.5 can be applied to CIP walls as well.

7.3.4.5 Overall (Global) Stability

A slope stability analysis was performed for general CIP retaining wall configurations. These analyses were performed using material properties described in Section 4.2 and structural backfill material properties from the ADOT standard drawings. The slope and wall geometries were obtained from the Stage I drawings and cross-sections provided by CONSOR and the subsurface profiles were consistent with those listed in Section 6.3. The overall stability failure mode was not found to govern the design of the CIP retaining walls as all models resulted in a factor of safety in excess of 1.7.

7.4 Mechanically Stabilized Earth (MSE) Retaining Walls

MSE walls are proprietary products provided by pre-approved MSE Wall manufacturers. Internal and external stability analysis should meet the requirements of ADOT's latest version of MSE Wall stored specifications. Golder performed a representative global stability analysis for southeast wingwall of the UPRR Bridge where this wall type is most likely. The purpose of the analysis was to determine the required reinforcement length based on global stability considerations. The factor of safety versus global stability was in excess of 1.8 for a reinforcement

length of 0.7 times the wall height. MSE walls with this minimum reinforcement length to height ratio will also satisfy external stability requirements for sliding and overturning.

The wall designer can check for the need for wall slip joints to accommodate longitudinal differential settlement along the wall using the appropriate bearing resistance chart in Appendix D by taking the reinforcement length as the effective footing width.

8.0 LIMITATIONS AND CLOSING

This report has been prepared exclusively for the use of CONSOR and Pima County for the specific application to the Roadway Improvement Project – Sunset Road: I-10 to River Road. No third-party engineer or consultant shall be entitled to rely on any of the information, conclusions, or opinions contained in this report without the prior written approval from CONSOR and Golder Associates Inc.

The conclusions and recommendations in this report have been prepared in a manner consistent with the level of care and skill ordinarily exercised by engineering professionals currently practicing under similar conditions, subject to the time limits and financial and physical constraints imposed on, or otherwise applicable to, Golder's analyses. Appendix E contains further detailed information regarding the proper use and interpretation of this geotechnical report.

In preparing its conclusions and recommendations, Golder has relied upon information provided by the client, such as referenced reports, laboratory data and topographical data. Golder is not responsible for errors or omissions in the information provided by others.

Signature Page

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RMP/MLP/rm

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https://golderassociates.sharepoint.com/sites/113372/project files/6 deliverables/005 geotech report/rev1/19128078-r-005-rev1-20200904.docx

9.0 REFERENCES

AASHTO (American Association of State Highway and Transportation Officials). 2012. AASHTO LRFD Bridge Design Specifications, 6th Edition with 2013 interims, Washington, D.C.

AASHTO. 2017. AASHTO LRFD Bridge Design Specifications, 8th Edition, Washington, D.C.

ADOT (Arizona Department of Transportation). 1989. Preliminary Engineering & Design Manual, 3rd Edition, March 1989.

ADOT. 2003. Record Drawings, I-10 Frontage Roads Ruthrauff Road to Sunset Road. AC-NH-010-4(170)A, 010 PM 251. January 3, 2003.

ADOT. 2008. Standard Specifications for Road and Bridge Construction, Phoenix, AZ.

ADOT. 2010a. Development of Drilled Shaft Axial Resistance Charts for Use by Bridge Engineers Based on Load and Resistance Factor Design (LRFD) Methodology. Memorandum DS-1 from N. H. Wetz and J. D. Wilson to J. Lawson, Dated December 1, 2010 (Revision 1), Phoenix, AZ.

ADOT. 2010b. Interim Guidance – Design of Drilled Shafts in Gravels and Gravelly Soils Exhibiting Drained Behavior. Memorandum DS-2 from N. H. Wetz and J. D. Wilson to J. Lawson, Dated December 1, 2010 (Revision 1), Phoenix, AZ.

ADOT. 2010c. Analysis of Drilled Shafts Subjected to Lateral Loads Based on Load and Resistance Factor (LRFD) Methodology. Memorandum DS-3 from N. H. Wetz and J. D. Wilson, A. Islam and N. Viboolmate to J. Lawson and J. Nehme, Dated December 1, 2010, Phoenix, AZ.

ADOT. 2010d. Development of Factored Bearing Resistance Chart by a Geotechnical Engineer for Use by a Bridge Engineer to Size Spread Footings on Soils Based on Service and Strength Limit States Based on Load and Resistance Factor Design (LRFD) Methodology. Memorandum SF-1 from N. H. Wetz and J. D. Wilson to J. Lawson, Dated December 1, 2010 (Revision 2), Phoenix, AZ.

ADOT. 2010e. Limiting Eccentricity Criteria for Spread Footings Based on Load and Resistance Factor Design (LRFD) Methodology. Memorandum SF-2 from N. H. Wetz and J. D. Wilson, A. Islam and N. Viboolmate to J. Lawson and J. Nehme, Dated December 1, 2010, Phoenix, AZ.

ADOT. 2010f. Resistance Factors for the Estimation of Factored Sliding and Bearing Resistance for Spread Footings of Gravity and Semi-gravity Walls Based on Load and Resistance Factor Design (LRFD) Methodology. Memorandum SF-3 from N. H. Wetz and J. D. Wilson, A. Islam and N. Viboolmate to J. Lawson and J. Nehme, Dated December 1, 2010, Phoenix, AZ.

ADOT (Bridge Group). 2015. Standard Drawings, Retaining Wall (Reinforced Concrete Cantilever), SD 7.01., issued January 26, 2015.

ADOT. 2019. Materials Testing Manual – Sampling and Testing Procedures. Phoenix, AZ. Revision date: November 13, 2019

Arman, A., N. Samtani, R. Castelli, and G. Munfkah. (1997). Geotechnical and Foundation Engineering Module 1 – Subsurface Investigations. Federal Highway Administration Report No. FHWA-NHI-97-021, Washington D.C.

Bowles, J. E. (1996). Foundation Analysis and Design. 5th Edition, McGraw-Hill, New York.

Brown and Caldwell. 2010. Record Drawings, Roger Road WRF to Ina Road WRS Plant Interconnect (Santa Cruz Interceptor – Phase IV). Sheets PP14-PP15. December 1, 2010.

Brown, D.A., J.P. Turner and R.J. Castelli. 2010. Drilled Shafts: Construction Procedures and LRFD Design Methods. Federal Highways Administration (FHWA) Technical Report No. FHWA-10-016, NHI Course No. 132014, Geotechnical Engineering Circular No. 10.

Brun, P. 2020. ADOT State Geotechnical Engineer, personal communication, February 20, 2020.

Golder. 2020. Sunset Road: I-10 to River Road, Initial Pavement Report. PCDOT Project No. 4SRRIV. SGI Project NO. 19023.00. Golder Project No. 19128078. August 2020.

HDR Engineering Inc. (HDR). 2011. Preliminary Structure Selection Report. I-10, Ina Road Traffic Interchange (TI) to Ruthrauff Road TI. ADOT Project No. 010 PM 247 H7583 01L. HDR Project No. 116768. November 30, 2011.

HDR. 2012. Interstate 10, Ina Road Traffic Interchange (TI) to Ruthrauff Road TI, Draft Final Design Concept Report. ADOT Project No. 010 PM 247 H7583 01L. HDR Project No. 116768. May 2012.

NAVFAC (Department of the Navy, Naval Facilities Engineering Command). 1986a. Design Manual 7.01 - Soil Mechanics., Alexandria, VA.

NAVFAC. 1986b. Design Manual 7.02 - Foundation and Earth Structures. Alexandria, VA.

NCS Consultants, LLC (NCS). 2011. Preliminary Geotechnical Report (Based on Phase 1 Investigations). I-10, Ina Road Traffic Interchange (TI) to Ruthrauff Road TI. ADOT Project No. 010 PM 247 H7583 01L. Federal Aid No. 010-D (BCL) A.

NCS. 2015a. Final Geotechnical Report for Sunset Road – Silverbell Road to River Road. PCDOT Job No. 4RTSUN. October 6, 2015.

NCS. 2015b. Infiltration Study Final Report for Drilled Shaft Foundations of Sunset Road Bridges over the Santa Cruz River and Rillito Creek. June 15, 2015.

PCRFCD and PCDOT. 2012. “Guidelines for Establishing Scour and Freeboard for Bridges in Pima County”, August 2012, Pima County Regional Flood Control District, Pima County Department of Transportation.

Samtani, N. C. and E.A. Nowatzki. 2006. Soils and Foundations – Volumes I and II, Federal Highway Administration Report No., FHWA-NHI-06-088 and FHWA-NHI-06-089, Washington, D.C.

Terracon Consultants Western, Inc. (Terracon). 1995. Geotechnical Engineering Report, River Road – Shannon to Thornydale. Marana, Arizona. Terracon Project No. 63955120. December 15, 1995.

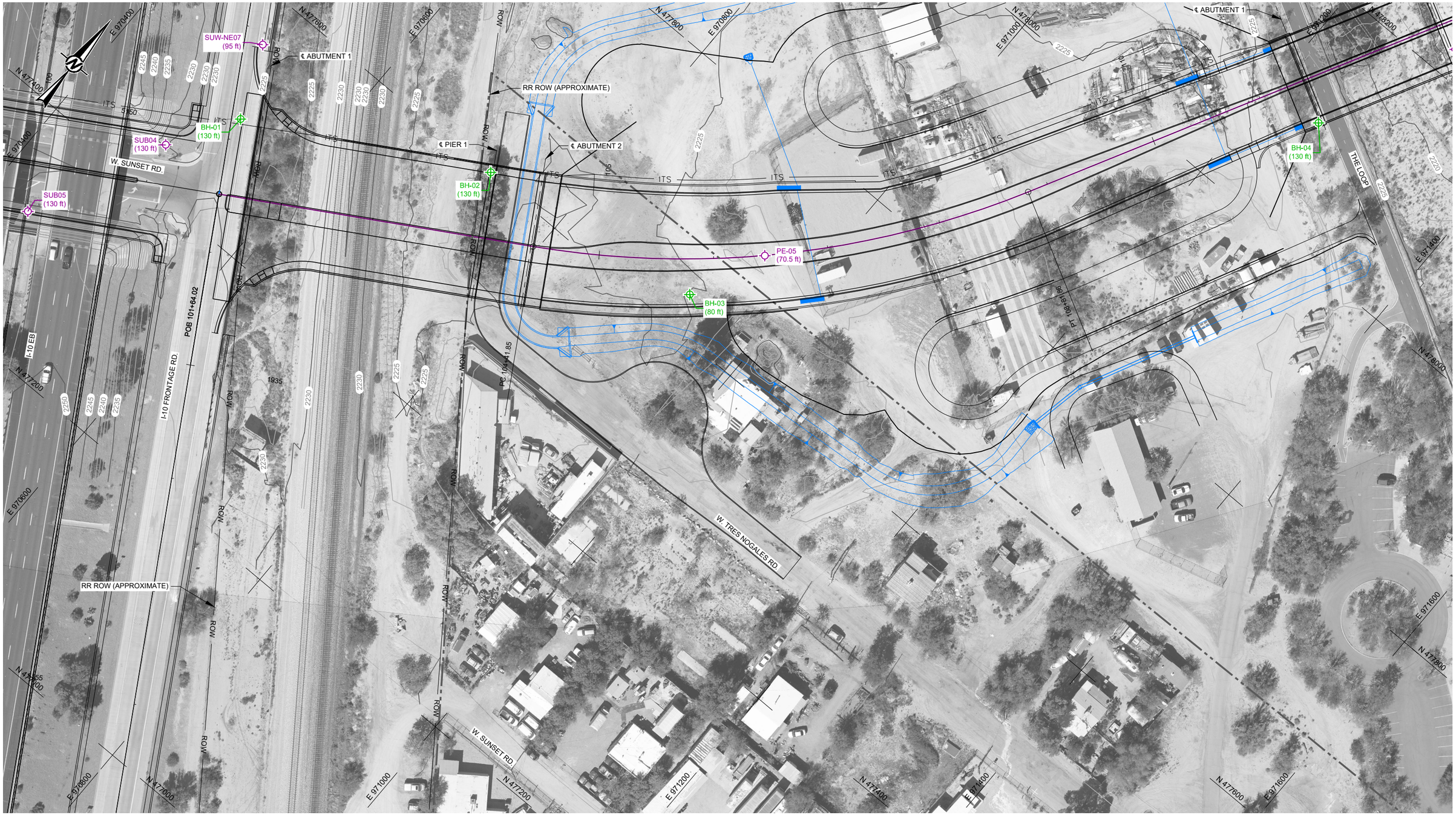
USBR. 1999. CME Automatic Hammer Operations Bulletin. U.S. Department of the Interior, Bureau of Reclamation, Earth Sciences and Research Library, DSO-99-03.

US Geological Survey (USGS). 2020. Seismic Design Web Service Documentation, https://earthquake.usgs.gov/ws/designmaps/. Accessed April, 2020.

WSP. 2020. Draft Drainage Overview. Sunset Road: Interstate 10 to River Road. PCDOT Project No. 4SRRIV, WSP Project No. 30900007A. April 2020.

APPENDIX A

Geotechnical Field Investigation Information



LEGEND

BH-01 (130 ft)	GEOTECHNICAL BOREHOLE FOR BRIDGE ABUTMENTS (DEPTH)
BH-12 (130 ft)	BOREHOLE FROM NCS GEOTECHNICAL INVESTIGATION (APPROXIMATE) (DEPTH)

REFERENCE(S)

1. AERIAL PHOTOGRAPH AND TOPOGRAPHY PROVIDED BY CONSOR ENGINEERS , FROM A NOVEMBER 21, 2019 AERIAL SURVEY CONDUCTED BY ENGINEERING AND ENVIRONMENTAL CONSULTANTS, INC.

0 40 80
1" = 80' FEET

CLIENT
CONSOR ENGINEERS

CONSULTANT
GOLDER

YYYY-MM-DD	2020-08-03
DESIGNED	KR
PREPARED	NIL
REVIEWED	KR
APPROVED	RP

PROJECT
SUNSET ROAD
GEOTECHNICAL INVESTIGATION

TITLE
GEOTECHNICAL INVESTIGATION PLAN (1 OF 2)

PROJECT NO.	CONTROL	REV.	FIGURE
19128078	0101	0	A-1

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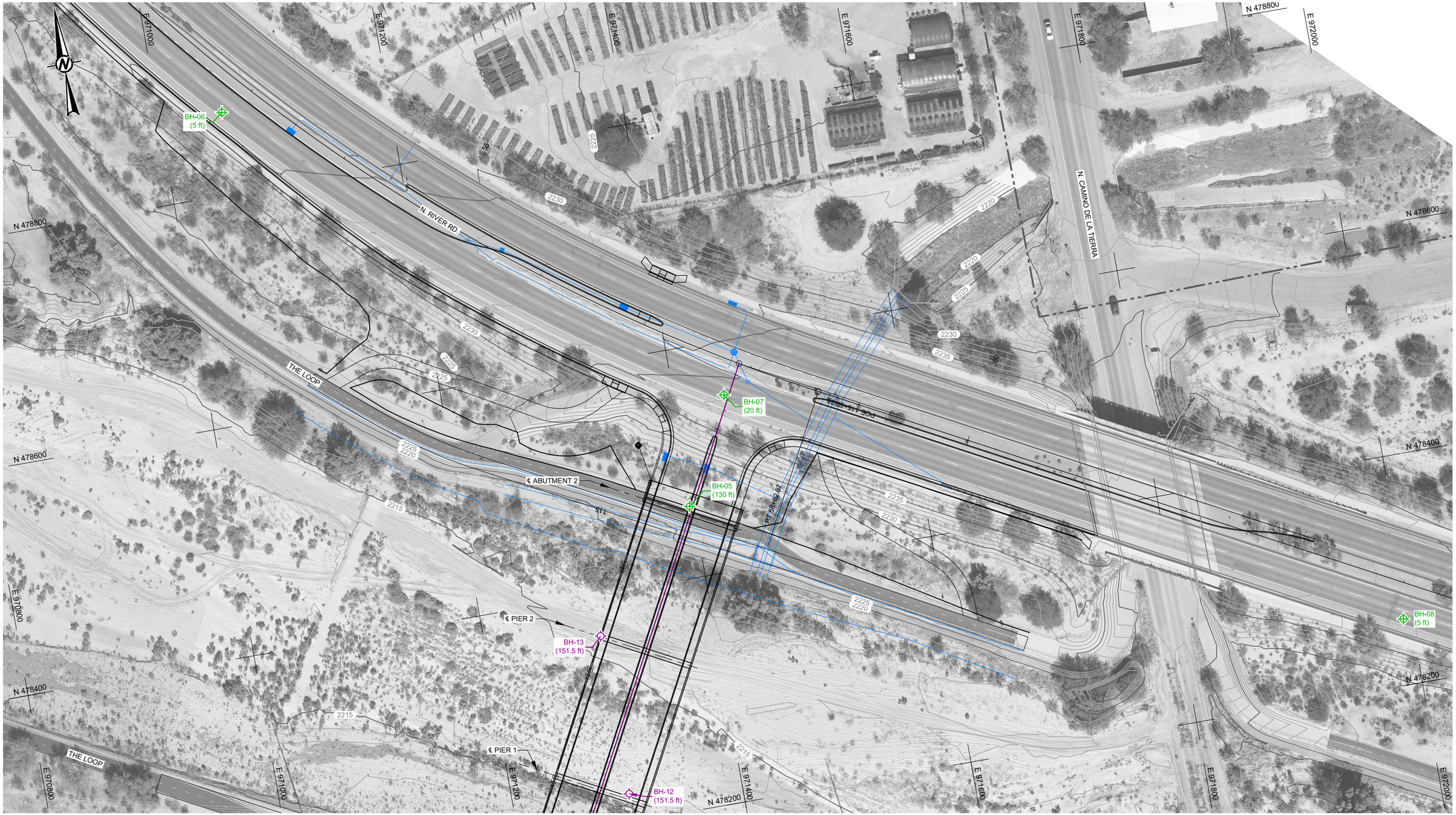

LEGEND

BH-01 (130 ft)	GEOTECHNICAL BOREHOLE FOR BRIDGE ABUTMENTS (SEE NOTE 2) (DEPTH)
BH-12 (130 ft)	BOREHOLE FROM NCS GEOTECHNICAL INVESTIGATION (APPROXIMATE) (DEPTH)

REFERENCE(S)

1. AERIAL PHOTOGRAPH AND TOPOGRAPHY PROVIDED BY CONSOR ENGINEERS, FROM A NOVEMBER 21, 2019 AERIAL SURVEY CONDUCTED BY ENGINEERING AND ENVIRONMENTAL CONSULTANTS, INC.
2. PAVEMENT CORE WAS TAKEN AT BOREHOLES BH-06, BH-07 AND BH-08.

0 40 80
1" = 80' FEET

CLIENT
CONSOR ENGINEERS

CONSULTANT
GOLDER

YYYY-MM-DD	2020-08-03
DESIGNED	KR
PREPARED	NIL
REVIEWED	KR
APPROVED	RP

PROJECT
SUNSET ROAD
GEOTECHNICAL INVESTIGATION

TITLE
GEOTECHNICAL INVESTIGATION PLAN (2 OF 2)

PROJECT NO.	CONTROL	REV.	FIGURE
19128078	0101	0	A-2

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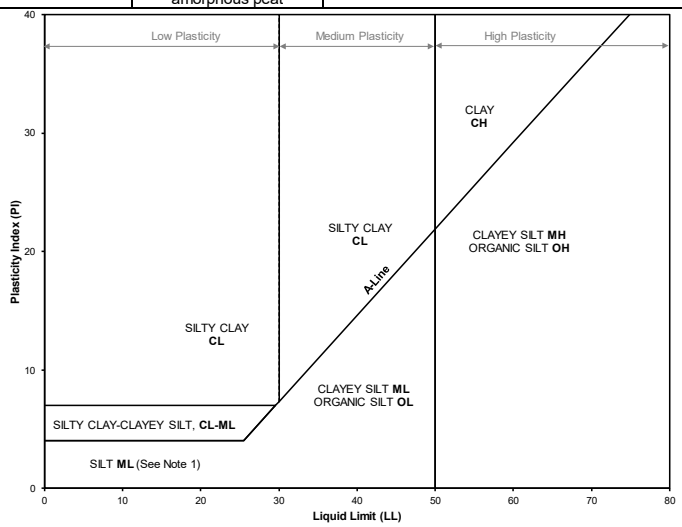
METHOD OF SOIL CLASSIFICATION

The Golder Associates Inc. Soil Classification System is based on the Unified Soil Classification System (USCS)

Organic or Inorganic	Soil Group	Type of Soil		Gradation or Plasticity	$Cu = \frac{D_{60}}{D_{10}}$	$Cc = \frac{(D_{30})^2}{D_{10} x D_{60}}$	Organic Content	USCS Group Symbol	Group Name
INORGANIC (Organic Content <30% by mass)	COARSE-GRAINED SOILS (>50% by mass is larger than 0.075 mm)	GRAVELS (>50% by mass of coarse fraction is larger than 4.75 mm)	Gravels with <12% * fines (by mass)	Poorly Graded	<4	≤1 or ≥3	<30%	GP	GRAVEL
				Well Graded	≥4	1 to 3		GW	GRAVEL
			Gravels with >12% fines (by mass)	Below A Line	n/a			GM	SILTY GRAVEL
				Above A Line	n/a			GC	CLAYEY GRAVEL
		SANDS (>50% by mass of coarse fraction is smaller than 4.75 mm)	Sands with <12% * fines (by mass)	Poorly Graded	<6	≤1 or ≥3		SP	SAND
				Well Graded	≥6	1 to 3		SW	SAND
			Sands with >12% fines (by mass)	Below A Line	n/a			SM	SILTY SAND
				Above A Line	n/a			SC	CLAYEY SAND

Organic or Inorganic	Soil Group	Type of Soil	Laboratory Tests	Field Indicators: Dilatancy	Dry Strength	Shine Test	Thread Diameter	Toughness (of 3 mm thread)	Organic Content	USCS Group Symbol	Primary Name
INORGANIC (Organic Content <30% by mass)	FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm)	SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below*)	Liquid Limit <50	Rapid	None	None	>6 mm	N/A (can't roll 3 mm thread)	<5%	ML	SILT
				Slow	None to Low	Dull	3 mm to 6 mm	None to low	<5%	ML	CLAYEY SILT
				Slow to very slow	Low to medium	Dull to slight	3 mm to 6 mm	Low	5% to 30%	OL	ORGANIC SILT
			Liquid Limit ≥50	Slow to very slow	Low to medium	Slight	3 mm to 6 mm	Low to medium	<5%	MH	CLAYEY SILT
				None	Medium to high	Dull to slight	1 mm to 3 mm	Medium to high	5% to 30%	OH	ORGANIC SILT
		CLAYS (PI and LL plot above A-Line on Plasticity Chart below*)	Liquid Limit <30	None	Low to medium	Slight to shiny	~ 3 mm	Low to medium	0% to 30% (see Note 2)	CL	SILTY CLAY
			Liquid Limit 30 to <50	None	Medium to high	Slight to shiny	1 mm to 3 mm	Medium		CL	SILTY CLAY
			Liquid Limit ≥50	None	High	Shiny	<1 mm	High		CH	CLAY
HIGHLY ORGANIC SOILS (Organic Content >30% by mass)		Peat and mineral soil mixtures							30% to 75%	PT	SILTY PEAT, SANDY PEAT
		Predominantly peat, may contain some mineral soil, fibrous, or amorphous peat							75% to 100%		PEAT



Note 1 – Fine-grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are Non-plastic (i.e. a PL cannot be measured) are named SILT.
Note 2 – For soils with <5% organic content, include the descriptor "trace organics." For soils with between 5% and 30% organic content include the prefix "organic" before the Primary name.

* Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, and, CL-ML. For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between "clean" and "dirty" sand or gravel).
For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see plasticity chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to indicate a range of similar soil types within a stratum.

SYMBOLS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimeters	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	> 300	> 12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
SILT/CLAY	Classified by plasticity	< 0.075	< (200)

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

Percentage by Mass	Modifier
>35	Use 'and' to combine major constituents (*i.e.*, SAND and GRAVEL)
> 12 to 35	Primary soil name prefixed with "gravelly, sandy, SILTY CLAYEY" as applicable
> 5 to 12	Some
≤ 5	trace

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT):
An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Test (DCPT), N_d:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

SOIL TESTS

w	water content
PL , w_P	plastic limit
LL , w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

1. Tests anisotropically consolidated prior to shear are shown as CAD, CAU.

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample

NON-COHESIVE (COHESIONLESS) SOILS

Compactness[2]

Term	SPT 'N' (blows/0.3m)[1]
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects.
2. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996) and correspond to typical N_{60} values. Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), groundwater conditions, and grainsize. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the compactness term. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	Undrained Shear Strength (tsf)	SPT 'N'[1,2] (blows/foot)
Very Soft	<12	<0.12	0 to 2
Soft	12 to 25	0.12 to 0.25	2 to 4
Firm	25 to 50	0.25 to 0.5	4 to 8
Stiff	50 to 100	0.5 to 1	8 to 15
Very Stiff	100 to 200	1 to 2	15 to 30
Hard	>200	>2	>30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does not apply. Rely on direct measurement of undrained shear strength or other manual observation.

Water Content

Term	Description
w < PL	Material is estimated to be drier than the Plastic Limit.
w ~ PL	Material is estimated to be close to the Plastic Limit.
w > PL	Material is estimated to be wetter than the Plastic Limit.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
$\rho(\gamma)$	bulk density (bulk unit weight)* ($\gamma' = \gamma - \gamma_w$)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
p	mean total stress $(\sigma_1 + \sigma_3)/2$
τ_p, τ_r	peak and residual shear strength
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1 $\tau = c' + \sigma' \tan \phi'$

2 shear strength = (compressive strength)/2

RECORD OF BOREHOLE: BH-01

CLIENT:	Structural Grace	START DATE:	August 07, 2020	ELEVATION:	2229.5 ft (Ground)
PROJECT:	Sunset Road I10 to River	END DATE:	August 08, 2020	COORDINATES:	N: 477500.0 ft E: 970528.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:		HORZ DATUM:	NAD83

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES (Hammer: Automatic ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop): NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT (Plastic & Liquid Limits (%), Water Content (%), NP Nonplastic)	SHEAR STRENGTH (Nat Vane, Rem Vane, Pocket Pen, Q, U)	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
			CONCRETE.			0.0 / 2228.6										
1			ASPHALT.			0.9 / 2228.2										
			FILL - (SC) Clayey sand with gravel, mostly fine to coarse SAND, little gravel, little low plasticity fines; dark brown; moist, Overall non-cohesive, trace gravel.	SC		1.2										
2																
3																
4																
5																
6							S1	SS	93	3-3-4	7					
7																
8			(SC) Clayey sand with gravel, mostly fine to coarse SAND, little gravel, little low plasticity fines; dark brown; moist, Overall non-cohesive.			2221.5 / 8.0										
9																
10																
11							S2	SS	100	15-15-8	23					
12																
13			(SW) Well graded sand, medium to coarse, well graded, few rounded gravel, trace non plastic fines; light brown; dry, Trace well rounded gravel.	SW		2217.0 / 12.5										
14																
15																
16							S3	SS	100	8-1-1	2					
17																
18			(SM) Silty sand, mostly fine to coarse SAND, some non plastic FINES, trace fine gravel; light brown; non-cohesive, moist, compact, Some disking occurred.	SM		2212.0 / 17.5										
19																
20																20.00 ft: Some disking of sample.
21							S4	SS	100	8-6-7	13					
22																
23			(SM) Silty sand with gravel, some subrounded to subangular gravel, few non plastic fines; light brown; dry to moist, Up to 1" in size.			2207.0 / 22.5										
24																
25																

Continued on Next Page

DEPTH SCALE: 1:131

REV:

GOLDER

LOGGED: Adriana Garcia DATE: Aug 07, 2020

CHECKED: Randy Post DATE: Sep 02, 2020

RECORD OF BOREHOLE: BH-01

CLIENT:	Structural Grace	START DATE:	August 07, 2020	ELEVATION:	2229.5 ft (Ground)
PROJECT:	Sunset Road I10 to River	END DATE:	August 08, 2020	COORDINATES:	N: 477500.0 ft E: 970528.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:		HORZ DATUM:	NAD83

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES (Hammer: Automatic ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop): NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT (Plastic & Liquid Limits (%), Water Content (%), NP Nonplastic)	SHEAR STRENGTH (Nat Vane, Rem Vane, Pocket Pen, Q, U)	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
26			(SM) Silty sand with gravel, some subrounded to subangular gravel, few non plastic fines; light brown; dry to moist, Up to 1" in size.	SM			S5	SS	80	8-6-5	11					
27						2202.0 / 27.5										
28			(SM) Silty sand with gravel, some subrounded to subangular gravel, few non plastic fines; light brown; dry to moist, Up to 1" in size.													
29																
30																
31							S6	SS	13	20-4-3	7					
32						2197.0 / 32.5										
33			(GP) Poorly graded gravel with sand, fine to coarse, poorly graded, subrounded to subangular, some fine to coarse sand, few low plasticity fines; brown; moist, Gravel/ rock fragments up to 1.5".	GP												
34																
35																
36							S7	SS	67	9-21-13	34					
37						2192.0 / 37.5										
38			(GP) Poorly graded gravel with sand, fine to coarse, poorly graded, subrounded to subangular, some fine to coarse sand, few low plasticity fines; brown; moist, Gravel/ rock fragments up to 1.5".													
39																
40							S8	SS	72	15-50/4"						
41																
42						2187.0 / 42.5										
43			(SC) Clayey sand with gravel, mostly fine to coarse SAND, little angular gravel, little low plasticity fines; dark brown; moist, Cohesive with gravel up to 1" in diameter.	SC												
44																
45							S9	SS	95	50/5"						
46																
47						2182.0 / 47.5										
48			(GC) Clayey gravel with sand, some fine to coarse sand, few low plasticity fines; moist.	GC												
49																
50																

Continued on Next Page

DEPTH SCALE: 1:131

REV:

GOLDER

LOGGED: Adriana Garcia DATE: Aug 07, 2020

CHECKED: Randy Post DATE: Sep 02, 2020

RECORD OF BOREHOLE: BH-01

CLIENT:	Structural Grace	START DATE:	August 07, 2020	ELEVATION:	2229.5 ft (Ground)
PROJECT:	Sunset Road I10 to River	END DATE:	August 08, 2020	COORDINATES:	N: 477500.0 ft E: 970528.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:		HORZ DATUM:	NAD83

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES (Hammer: Automatic ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop): NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT (Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic)	SHEAR STRENGTH (Nat Vane; Rem Vane; Pocket Pen; Q; U)	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
51			(GC) Clayey gravel with sand, some fine to coarse sand, few low plasticity fines; moist.	GC			S10	SS	100	16-26-33	59					
52						2177.0										
53			(SW-SC) Well graded sand with clay and gravel, fine to coarse, well graded; light brown.	SC		52.5										
55																
56							S11	SS	100	20-40-43	83					
57						2172.0										
58			(GC) Clayey gravel with sand, fine to coarse, angular, some fine to coarse sand, few low plasticity fines; moist, Gravel up to 1.5" in diameter.	GC		57.5										
59																
60							S12	SS	312	50/2"						
61																
62						2167.0										
63			(GC) Clayey gravel with sand, fine to coarse, angular, some fine to coarse sand, few low plasticity fines; moist, Gravel up to 1.5" in diameter.			62.5										
64																
65							S13	SS	273	50/4"						
66																
67						2162.0										
68			(GC) Clayey gravel with sand, mostly fine to coarse angular GRAVEL, some fine to coarse sand, little low plasticity fines; moist.			67.5										
69																
70							S14	SS	100	31-21-19	40					
71																
72						2157.0										
73			(GC) Clayey gravel, mostly fine to coarse angular GRAVEL, little low plasticity fines, few fine to coarse sand; dark brown; moist.			72.5										
74																
75																

Continued on Next Page

DEPTH SCALE: 1:131

REV:

GOLDER

LOGGED: Adriana Garcia DATE: Aug 07, 2020

CHECKED: Randy Post DATE: Sep 02, 2020

RECORD OF BOREHOLE: BH-01

CLIENT:	Structural Grace	START DATE:	August 07, 2020	ELEVATION:	2229.5 ft (Ground)
PROJECT:	Sunset Road I10 to River	END DATE:	August 08, 2020	COORDINATES:	N: 477500.0 ft E: 970528.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:		HORZ DATUM:	NAD83

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES: NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT	SHEAR STRENGTH	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
76			(GC) Clayey gravel, mostly fine to coarse angular GRAVEL, little low plasticity fines, few fine to coarse sand; dark brown; moist.	GC			S15	SS	100	20-19-25	44					
77						2152.0 / 77.5										
78			(SC) Clayey sand with gravel, mostly fine to coarse SAND, little fine subrounded to angular gravel, little low plasticity fines; dark brown; w < PL, compact, Cohesive, some gravel, up to 1.25".	SC												
80																
81							S16	SS	100	13-11-13	24					
82						2147.0 / 82.5										
83			(SP-SC) Poorly graded sand with clay and gravel, mostly fine to coarse SAND, some fine to coarse subangular to angular gravel, little low plasticity fines; dark brown; moist, Cohesive, gravel up to 1.25".	SP-SC												
85																
86							S17	SS	100	13-23-27	50					
87						2142.0 / 87.5										
88			(GC) Clayey gravel, mostly fine to coarse GRAVEL, little low plasticity fines, little fine to coarse sand; dark brown; moist, Poorly graded with rock fragments up to 1.25", cohesive.	GC												
90							S18	SS	143	50/6"						
92						2137.0 / 92.5										
93			(SC) Clayey sand with gravel, mostly SAND, little subangular to angular gravel, little low plasticity fines; dark brown; moist, Gravel up to 3/4".	SC												
95																
96							S19	SS	100	16-13-23	36					
97						2132.0 / 97.5										
98			(SP-SC) Poorly graded sand with clay and gravel, mostly fine to coarse SAND, some fine to coarse subangular to angular GRAVEL, little medium plasticity fines; dark brown; moist, Cohesive, gravel up to 1.5".	SP-SC												
100																

Continued on Next Page

Hammer: Automatic ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH: Nat Vane; Rem Vane; Pocket Pen; Q; U

DEPTH SCALE: 1:131

REV:

GOLDER

LOGGED: Adriana Garcia DATE: Aug 07, 2020

CHECKED: Randy Post DATE: Sep 02, 2020

RECORD OF BOREHOLE: BH-01

CLIENT:	Structural Grace	START DATE:	August 07, 2020	ELEVATION:	2229.5 ft (Ground)
PROJECT:	Sunset Road I10 to River	END DATE:	August 08, 2020	COORDINATES:	N: 477500.0 ft E: 970528.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:		HORZ DATUM:	NAD83

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES: NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT	SHEAR STRENGTH	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
101			(SP-SC) Poorly graded sand with clay and gravel, mostly fine to coarse SAND, some fine to coarse subangular to angular GRAVEL, little medium plasticity fines; dark brown; moist, Cohesive, gravel up to 1.5".	SP-SC			S20	SS	100	17-21-41	62					
102						2127.0 / 102.5										
103			(GC) Clayey gravel with sand, mostly fine to coarse subangular to angular GRAVEL, some fine to coarse sand, little low plasticity fines; dark brown; w < PL, Cohesive, fragments up to 1".	GC												
104																
105																
106							S21	SS	100	21-18-35	53					
107						2122.0 / 107.5										
108			(GC) Clayey gravel with sand, mostly fine to coarse subangular to angular GRAVEL, some fine to coarse sand, little low plasticity fines; dark brown; w < PL, Cohesive, fragments up to 1".													
109																
110																
111							S22	SS	100	7-7-9	16					
112						2117.0 / 112.5										
113			(GC) Clayey gravel with sand, mostly fine to coarse subrounded to subangular GRAVEL, some fine to coarse sand, little high plasticity fines; dark brown; w < PL, Cohesive, gravel up to 1".													
114																
115																
116							S23	SS	100	19-32-33	65					
117						2112.0 / 117.5										
118			(SC) Clayey sand with gravel, mostly fine to coarse SAND, some fine to coarse subrounded to subangular gravel, little medium plasticity fines; dark brown; w < PL, Cohesive, rock fragments up to 1.75".													
119																
120																
121							S24	SS	100	12-19-19	38					
122						2107.0 / 122.5										
123			(GC) Clayey gravel with sand, fine to coarse, subrounded to subangular, some fine to coarse sand, few high plasticity fines; dark brown; w < PL, Cohesive, rock fragments up to 1.75".													
124																
125																

Continued on Next Page

Hammer: Automatic ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

Plastic & Liquid Limits (%) ⊢ ; Water Content (%) ○ ; NP Nonplastic

Nat Vane ⊗ ; Rem Vane ■ ; Pocket Pen ● ; Q ○ ; U

DEPTH SCALE: 1:131

REV:

GOLDER

LOGGED: Adriana Garcia DATE: Aug 07, 2020

CHECKED: Randy Post DATE: Sep 02, 2020

RECORD OF BOREHOLE: BH-01

CLIENT:	Structural Grace	START DATE:	August 07, 2020	ELEVATION:	2229.5 ft (Ground)
PROJECT:	Sunset Road I10 to River	END DATE:	August 08, 2020	COORDINATES:	N: 477500.0 ft E: 970528.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:		HORZ DATUM:	NAD83

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES (Hammer: Automatic ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop): NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT (Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic)	SHEAR STRENGTH (Nat Vane; Rem Vane; Pocket Pen; Q; U)	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
126			(GC) Clayey gravel with sand, fine to coarse, subrounded to subangular, some fine to coarse sand, few high plasticity fines; dark brown; w < PL, Cohesive, rock fragments up to 1.75".	GC			S25	SS	100	22-26-34	60					
127						2102.0										
128			(GC) Clayey gravel with sand, fine to coarse, subrounded to subangular, some fine to coarse sand, few high plasticity fines; dark brown; w < PL, Cohesive, rock fragments up to 1.75".			127.5										
129																
130																
131						2098.0	S26	SS	93	15-25-30	55					
132			End of hole at 131.5 ft.													
133																
134																
135																
136																
137																
138																
139																
140																
141																
142																
143																
144																
145																
146																
147																
148																
149																
150																

DEPTH SCALE: 1:131

REV:

GOLDER

LOGGED: Adriana Garcia DATE: Aug 07, 2020

CHECKED: Randy Post DATE: Sep 02, 2020

RECORD OF BOREHOLE: BH-02

CLIENT:	Structural Grace	START DATE:	February 27, 2020	GROUND ELEV:	2224.9 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 13, 2020	COORDINATES:	N: 477607.5 ft E: 970726.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH: Nat Vane; Rem Vane; Pocket Pen; Q; U

DEPTH (ft)	MATERIAL PROFILE: DESCRIPTION	USCS	ELEV. / DEPTH (ft)	SAMPLES: NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING
0	(SP) Poorly graded sand, fine, poorly graded, trace non plastic fines; light brown, no HCL reaction; dry.	SP	0.0						
5–6					SS	100	2-3-4	7	
8			2216.6 / 8.2						
8	(ML) Sandy silt, mostly low plasticity fines, some fine sand; dark brown, strong HCL reaction; w < PL.	ML							
10–11					SS	63	4-5-7	12	
13			2211.6 / 13.2						
13	(SP-SM) Poorly graded sand with silt and gravel, fine, poorly graded, few fine to coarse subrounded to subangular gravel, few non plastic fines; no HCL reaction; dry to moist.	SP-SM							
15–16				S3	SS	67	2-3-8	11	
20–21				S4-B / S4-A	MC	100	16-35	51	1, 2

Continued on Next Page

GROUNDWATER OBSERVATIONS

ADDITIONAL OBSERVATIONS

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Feb 27, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-02

CLIENT:	Structural Grace	START DATE:	February 27, 2020	GROUND ELEV:	2224.9 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 13, 2020	COORDINATES:	N: 477601.5 ft E: 970726.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH: Nat Vane; Rem Vane; Pocket Pen; Q; U

DEPTH (ft)	MATERIAL PROFILE: DESCRIPTION	USCS	ELEV. / DEPTH (ft)	NUMBER	TYPE	REC %	BLOWS	N-VALUE
26	(SP-SM) Poorly graded sand with silt and gravel, fine, poorly graded, few fine to coarse subrounded to subangular gravel, few non plastic fines; no HCL reaction; dry to moist.	SP-SM			SS	63	26-29-28	57
27								
28								
29								
30								
31				S6	SS	100	33-31-49	80
32								
33			2191.6 / 33.2					
34	(SP-SM) Poorly graded sand with silt and gravel, fine to medium, poorly graded, some fine to coarse subrounded to subangular gravel, few non plastic fines; light brown, no HCL reaction; dry to moist.							
35								
36					SS	73	12-28-40	68
37								
38								
39								
40								
41				S8	SS	67	18-16-25	41
42								
43								
44								
45					SS	250	50/1"	
46								
47			2177.4 / 47.5					
48	(SM) Silty sand with gravel, some low plasticity fines, few fine to coarse subrounded to subangular gravel; dark brown, no HCL reaction; dry to moist.	SM						
49								
50								

Continued on Next Page

ADDITIONAL LAB TESTING

GROUNDWATER OBSERVATIONS

ADDITIONAL OBSERVATIONS

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Feb 27, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-02

CLIENT:	Structural Grace	START DATE:	February 27, 2020	GROUND ELEV:	2224.9 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 13, 2020	COORDINATES:	N: 477601.5 ft E: 970726.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES (Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop): NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT (Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic)	SHEAR STRENGTH (Nat Vane; Rem Vane; Pocket Pen; Q; U)	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
50	CME-75	Hollow Stem Auger - 8-in Hole Dia.	(SM) Silty sand with gravel, some low plasticity fines, few fine to coarse subrounded to subangular gravel; dark brown, no HCL reaction; dry to moist.	SM			S10	SS	195	50/5"						
51																
52																
53																
54																
55							S11	SS	250	50/1"						
56																
57																
58																
59																
60							S12	SS		50/4"						
61																
62																
63																
64																
65																
66								SS	67	29-32-33	65					
67																
68																
69																
70							S14	SS	100	50/1"						
71																
72						2152.4 / 72.5										
73			(ML) Sandy silt, mostly low plasticity fines, some fine to medium sand, few fine to coarse subrounded to subangular gravel; dark brown, no HCL reaction; w < PL.	ML												
74																
75																

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REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Feb 27, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-02

CLIENT:	Structural Grace	START DATE:	February 27, 2020	GROUND ELEV:	2224.9 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 13, 2020	COORDINATES:	N: 477601.5 ft E: 970726.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH: Nat Vane; Rem Vane; Pocket Pen; Q; U

DEPTH (ft)	MATERIAL PROFILE: DESCRIPTION	USCS	ELEV. / DEPTH (ft)	SAMPLE NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING
76	(ML) Sandy silt, mostly low plasticity fines, some fine to medium sand, few fine to coarse subrounded to subangular gravel; dark brown, no HCL reaction; w < PL.	ML		S15	SS	45	19-44-43	87	
77									
78			2146.4 / 78.5						
79	(SC) Clayey sand with gravel, some low plasticity fines, few fine to coarse subrounded to subangular gravel; light brown to pale brown gray, no HCL reaction; dry to moist.	SC							
80									
81				S16	SS	93	28-34-47	81	3
82									
83									
84									
85				S17	SS		50/5"		
86									
87									
88									
89									
90				S18	SS	100	50/5"		
91									
92									
93									
94									
95									
96				S19	SS	87	31-34-49	83	
97									
98			2126.6 / 98.2						
99	(SC) Clayey sand with gravel, some fine subrounded to subangular gravel, few medium plasticity fines; light brown, no HCL reaction; dry to moist.								
100									

GROUNDWATER OBSERVATIONS

ADDITIONAL OBSERVATIONS

Continued on Next Page

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Feb 27, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-02

CLIENT:	Structural Grace	START DATE:	February 27, 2020	GROUND ELEV:	2224.9 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 13, 2020	COORDINATES:	N: 477601.5 ft E: 970726.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES (Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop): NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT (Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic)	SHEAR STRENGTH (Nat Vane; Rem Vane; Pocket Pen; Q; U)	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
	CME-75	Hollow Stem Auger - 8-in Hole Dia.	(SC) Clayey sand with gravel, some fine subrounded to subangular gravel, few medium plasticity fines; light brown, no HCL reaction; dry to moist.	SC				SS	90	27-0.41/6"						
101																
102																
103																
104																
105								SS	73	38-35-46	81					
106																
107																
108																
109																
110								SS	80	29-25-28	53					
111																
112																
113																
114																
115								SS	77	21-23-32	55					
116																
117																
118																
119																
120							S24	SS	100	28-34-46	80			4		
121																
122																
123																
124																
125																

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REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Feb 27, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-02

CLIENT:	Structural Grace	START DATE:	February 27, 2020	GROUND ELEV:	2224.9 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 13, 2020	COORDINATES:	N: 477601.5 ft E: 970726.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES (Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop): NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT (Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic)	SHEAR STRENGTH (Nat Vane; Rem Vane; Pocket Pen; Q; U)	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
126	CME-75	Hollow Stem Auger - 8-in Hole Dia.	(SC) Clayey sand with gravel, some fine subrounded to subangular gravel, few medium plasticity fines; light brown, no HCL reaction; dry to moist.	SC				SS	77	20-15-23	38					
127																
128																
129																
130								SS	33	21-30-26	56					
131						2093.4										
			End of hole at 131.5 ft.													
132																
133																
134																
135																
136																
137																
138																
139																
140																
141																
142																
143																
144																
145																
146																
147																
148																
149																
150																

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Feb 27, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-03

CLIENT:	Structural Grace	DATE:	February 26, 2020	GROUND ELEV:	2225.1 ft
PROJECT:	Sunset Road I10 to River			COORDINATES:	N: 477631.5 ft E: 970927.5 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

DEPTH (ft)	DESCRIPTION	USCS	ELEV. / DEPTH (ft)	NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT	SHEAR STRENGTH	ADDITIONAL LAB TESTING
0	(SM) Silty sand, few non plastic fines; dark brown, strong HCL reaction.	SM	0.0	S1	SS	65	6-9-5	14			
3				S2	SS	87	4-4-6	10			
4	(CL) Sandy lean clay, mostly low plasticity fines; strong HCL reaction; w < PL.	CL	2221.3 / 3.8	S2A							
5	(SM) Silty sand, few non plastic fines; light brown, strong HCL reaction.	SM	2220.6 / 4.5	S3	SS	90	4-7-9	16			
6	(CL) Sandy lean clay, mostly low plasticity fines, mostly fine SAND; dark brown, strong HCL reaction.	CL	2218.8 / 6.4	S3							
7	(SM) Silty sand, few non plastic fines; dark brown, strong HCL reaction; dry.	SM	2218.1 / 7.0	S4-A	MC	100	28-24	52			5
8				S4-B							6
9	(SP) Poorly graded sand with gravel, fine, poorly graded, trace non plastic fines; light brown, strong HCL reaction; dry.	SP	2215.9 / 9.2								
11				S5	SS	100	9-5-12	17			
16				S6	MC	100	37-36	73			
21				S7	SS	20	9-17-23	40			

GROUNDWATER OBSERVATIONS

ADDITIONAL OBSERVATIONS

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REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Feb 26, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-03

CLIENT:	Structural Grace	DATE:	February 26, 2020	GROUND ELEV:	2225.1 ft
PROJECT:	Sunset Road I10 to River			COORDINATES:	N: 477631.5 ft E: 970927.5 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH: Nat Vane; Rem Vane; Pocket Pen; Q; U

DESCRIPTION	USCS	ELEV. / DEPTH (ft)	NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING
(SP) Poorly graded sand with gravel, fine, poorly graded, trace non plastic fines; light brown, strong HCL reaction; dry.	SP		S8	SS	100	13-18-35	53	
		2196.9 / 28.2						
(CL) Sandy lean clay, mostly non plastic fines, few fine to coarse subrounded to subangular gravel; no HCL reaction; w < PL.	CL		S9	SS	40	17-15-21	36	
		2191.9 / 33.2						
(SP-SM) Poorly graded sand with silt and gravel, fine, poorly graded, some fine to coarse subrounded to subangular gravel, few non plastic fines; light brown, no HCL reaction; dry to moist.	SP-SM		S10	SS	87	21-25-24	49	
			S11	SS	60	10-18-25	43	7
		2181.9 / 43.2						
(SP-SC) Poorly graded sand with clay and gravel, fine, poorly graded, some fine to coarse subrounded to subangular gravel, few non plastic fines; light brown to pale gray, no HCL reaction; dry to moist.	SP-SC		S12	SS	90	28-36-50/4"		
		2176.9 / 48.2						
(GC) Clayey gravel with sand, fine to coarse, subrounded to subangular, some non plastic fines, few fine sand; light brown, desiccated, no HCL reaction; dry to moist.	GC							

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GROUNDWATER OBSERVATIONS

ADDITIONAL OBSERVATIONS

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Feb 26, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-03

CLIENT:	Structural Grace	DATE:	February 26, 2020	GROUND ELEV:	2225.1 ft
PROJECT:	Sunset Road I10 to River			COORDINATES:	N: 477631.5 ft E: 970927.5 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH: Nat Vane; Rem Vane; Pocket Pen; Q; U

MATERIAL PROFILE: DESCRIPTION	USCS	ELEV. / DEPTH (ft)	SAMPLE NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING
(GC) Clayey gravel with sand, fine to coarse, subrounded to subangular, some non plastic fines, few fine sand; light brown, desiccated, no HCL reaction; dry to moist.	GC		S13	SS	100	50/4"		
		2172.4 / 52.7						
(SP-SM) Poorly graded sand with silt and gravel, some fine subrounded to subangular GRAVEL, few non plastic fines; light brown, no HCL reaction; dry to moist.	SP-SM		S14	SS	100	50/5"		
		2167.4 / 57.7						
(SC) Clayey sand with gravel, few fine subrounded to subangular gravel, few medium plasticity fines; light brown to, no HCL reaction; dry to moist.	SC		S15	SS	100	50/1"		
			S16	SS	83	31-30-28	58	8
			S17	SS	62	21-13-13	26	

GROUNDWATER OBSERVATIONS:

ADDITIONAL OBSERVATIONS:

Continued on Next Page

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Feb 26, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-03

CLIENT:	Structural Grace	DATE:	February 26, 2020	GROUND ELEV:	2225.1 ft
PROJECT:	Sunset Road I10 to River			COORDINATES:	N: 477631.5 ft E: 970927.5 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES (Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop): NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT (Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic)	SHEAR STRENGTH (Nat Vane; Rem Vane; Pocket Pen; Q; U)	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
76	CME-75	Hollow Stem Auger - 8-in Hole Dia.	(SC) Clayey sand with gravel, few fine subrounded to subangular gravel, few medium plasticity fines; light brown to, no HCL reaction; dry to moist.	SC			S18	SS	46	28-29-24	53					
77																
78																
79																
80																
81						2143.6	S19	SS	57	27-20-22	42					
			End of hole at 81.5 ft.													
82																
83																
84																
85																
86																
87																
88																
89																
90																
91																
92																
93																
94																
95																
96																
97																
98																
99																
100																

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Feb 26, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-04

CLIENT:	Structural Grace	START DATE:	March 11, 2020	GROUND ELEV:	2227.5 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 12, 2020	COORDINATES:	N: 478098.8 ft E: 971251.5 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: ⊢ Plastic & Liquid Limits (%); ○ Water Content (%); NP Nonplastic

SHEAR STRENGTH: ⊗ Nat Vane; ■ Rem Vane; ● Pocket Pen; ○ Q; U

DEPTH (ft)	MATERIAL PROFILE: DESCRIPTION	USCS	ELEV. / DEPTH (ft)	SAMPLE NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
0	(ML) Sandy Silt, Mostly low plasticity fines, few fine sand; dark brown, strong HCL reaction; w < PL.	ML	0.0								
5–6					SS	93	4-5-6	11			
8			2219.2 / 8.2								
8–13	(ML) Sandy silt, mostly non plastic fines, some fine to medium SAND, trace fine subrounded to subangular gravel; light brown, strong HCL reaction; w < PL.										
10–11					SS	100	4-8-7	15	9		
13			2214.2 / 13.2								
13–25	(CL) Sandy lean clay, mostly medium plasticity fines, some fine sand; light brown, strong HCL reaction; w < PL.	CL									
15–16					SS	80	6-8-10	18			
20–21					SS	93	8-10-11	21			

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REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Mar 11, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-04

CLIENT:	Structural Grace	START DATE:	March 11, 2020	GROUND ELEV:	2227.5 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 12, 2020	COORDINATES:	N: 478098.8 ft E: 971251.5 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH: Nat Vane; Rem Vane; Pocket Pen; Q; U

DEPTH (ft)	MATERIAL PROFILE DESCRIPTION	USCS	ELEV. / DEPTH (ft)	NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING
26	(CL) Sandy lean clay, mostly medium plasticity fines, some fine sand; light brown, strong HCL reaction; w < PL.	CL			MC	50	10-16	26	10
30					SS	93	4-5-8	13	
33			2194.2						
	(SP) Poorly graded sand with gravel, fine to medium, poorly graded, few fine to coarse subrounded to subangular gravel, trace non plastic fines; light brown, no HCL reaction; dry.	SP	33.2						
36					SS	58	12-21-25	46	
38			2188.9						
	(SM) Silty sand with gravel, some low plasticity fines, few fine to coarse subrounded to subangular gravel; dark brown, strong HCL reaction; dry to moist.	SM	38.6						
41			2186.6	S8	SS	53	19-12-10	22	
	(SP) Poorly graded sand with gravel, fine to medium, poorly graded, few fine to coarse subrounded to subangular gravel, trace non plastic fines; light brown, no HCL reaction; dry to moist.	SP	40.9	S8					
43			2184.2						
	(CL) Gravelly lean clay with sand, mostly low plasticity fines, some fine subrounded to subangular gravel, few fine to medium sand; dark brown, no HCL reaction; w < PL.	CL	43.2						
45					SS	79	20-35-50/1"		
48			2179.4						
	(ML) Sandy silt with gravel, mostly low plasticity fines, some fine to medium sand, few fine to coarse subrounded to subangular gravel; light brown to pale brown, no HCL reaction; w < PL.	ML	48.0						
50									

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GROUNDWATER OBSERVATIONS

ADDITIONAL OBSERVATIONS

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Mar 11, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-04

CLIENT:	Structural Grace	START DATE:	March 11, 2020	GROUND ELEV:	2227.5 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 12, 2020	COORDINATES:	N: 478098.8 ft E: 971251.5 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH: Nat Vane; Rem Vane; Pocket Pen; Q; U

DEPTH (ft)	MATERIAL PROFILE DESCRIPTION	USCS	ELEV. / DEPTH (ft)	NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING
51	(ML) Sandy silt with gravel, mostly low plasticity fines, some fine to medium sand, few fine to coarse subrounded to subangular gravel; light brown to pale brown, no HCL reaction; w < PL.	ML		S10	SS	93	23-30-31	61	
52									
53			2174.1 / 53.4						
54	(SP) Poorly graded sand, fine to medium, poorly graded, trace low plasticity fines; light brown, no HCL reaction.	SP							
55			2172.0 / 55.5	S11					
56	(ML) Sandy silt with gravel, mostly low plasticity fines, some fine to medium sand, few fine to coarse subrounded to subangular gravel; light brown, no HCL reaction; w < PL to w ~ PL.	ML		S10	SS	100	17-25-32	57	
57									
58									
59									
60					SS	132	35-50/5"		
61									
62									
63									
64									
65									
66				S13	SS	73	18-19-36	55	
67									
68			2159.2 / 68.2						
69	(SC) Clayey sand with gravel, few fine to coarse subrounded to subangular gravel, few medium plasticity fines; light brown, no HCL reaction; w < PL to w ~ PL.	SC							
70									
71					SS	100	8-9-18	27	11
72									
73									
74									
75									

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GROUNDWATER OBSERVATIONS

ADDITIONAL OBSERVATIONS

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Mar 11, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-04

CLIENT:	Structural Grace	START DATE:	March 11, 2020	GROUND ELEV:	2227.5 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 12, 2020	COORDINATES:	N: 478098.8 ft E: 971251.5 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES — Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT — Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH — Nat Vane; Rem Vane; Pocket Pen; Q; U

DEPTH (ft)	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES: NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
76	(SC) Clayey sand with gravel, few fine to coarse subrounded to subangular gravel, few medium plasticity fines; light brown, no HCL reaction; w < PL to w ~ PL.	SC				SS	83	7-19-35	54			
77												
78												
79												
80						SS	100	18-22-24	46			
81												
82												
83												
84												
85						SS	67	20-29-28	57			
86												
87												
88												
89												
90						SS	55	18-50/5"				
91												
92												
93												
94												
95						SS	67	14-20-28	48			
96												
97												
98												
99												
100												

Continued on Next Page

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Mar 11, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-04

CLIENT:	Structural Grace	START DATE:	March 11, 2020	GROUND ELEV:	2227.5 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 12, 2020	COORDINATES:	N: 478098.8 ft E: 971251.5 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH: Nat Vane; Rem Vane; Pocket Pen; Q; U

DEPTH (ft)	MATERIAL PROFILE: DESCRIPTION	USCS	ELEV. / DEPTH (ft)	SAMPLES: NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
101	(SC) Clayey sand with gravel, few fine to coarse subrounded to subangular gravel, few medium plasticity fines; light brown, no HCL reaction; w < PL to w ~ PL.	SC		S20	SS	92	28-39-50/5"		12		
105–106					SS	80	23-31-48	79			
108			2119.2								
108–110	(CL) Sandy lean clay with gravel, mostly low plasticity fines, some fine to medium sand, few fine subrounded to subangular gravel; light brown, no HCL reaction; w < PL.	CL	108.2								
110			2117.2								
110–112	(ML) Sandy silt with gravel, mostly low plasticity fines; light brown, no HCL reaction; w < PL.	ML	110.3		SS	100	11-26-41/0"				
112			2114.5								
112–118	(CL) Sandy lean clay with gravel, mostly low plasticity fines, some fine to medium sand, few fine subrounded to angular gravel; light brown, no HCL reaction; w < PL.	CL	113.0		SS	83	22-28-34	62			
118			2109.2								
118–123	(GC) Clayey gravel with sand, fine, subrounded to subangular, some fine to medium sand, few low plasticity fines; light brown to pale brown, no HCL reaction; w < PL.	GC	118.2		SS	93	32-37-43	80			
123			2104.2								
123–125	(GM) Silty gravel with sand, fine to coarse, subrounded to subangular, some fine sand, few low plasticity fines; light brown with light orange brown, no HCL reaction; dry to moist.	GM	123.2								

Continued on Next Page

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Mar 11, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-04

CLIENT:	Structural Grace	START DATE:	March 11, 2020	GROUND ELEV:	2227.5 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 12, 2020	COORDINATES:	N: 478098.8 ft E: 971251.5 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES (Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop): NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT (Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic)	SHEAR STRENGTH (Nat Vane; Rem Vane; Pocket Pen; Q; U)	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
126	CME-75	Hollow Stem Auger - 8-in Hole Dia.	(GM) Silty gravel with sand, fine to coarse, subrounded to subangular, some fine sand, few low plasticity fines; light brown with light orange brown, no HCL reaction; dry to moist.	GM				SS	93	27-38-48	86					
127																
128						2099.2 / 128.2										
129			(CL) Sandy lean clay with gravel, mostly low plasticity fines, some fine sand, few fine to coarse subrounded to subangular gravel; light brown to light brown gray, no HCL reaction; w < PL.	CL												
130																
131						2096.1		SS	71	25-42-50/5"						
132			End of hole at 131.5 ft.													
133																
134																
135																
136																
137																
138																
139																
140																
141																
142																
143																
144																
145																
146																
147																
148																
149																
150																

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Mar 11, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-05

CLIENT:	Structural Grace	START DATE:	March 16, 2020	GROUND ELEV:	2227.9 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 17, 2020	COORDINATES:	N: 478462.2 ft E: 971397.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83
				HOLE LOC:	North Loop

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: ⊢ Plastic & Liquid Limits (%); ○ Water Content (%); NP Nonplastic

SHEAR STRENGTH: ⊗ Nat Vane; ■ Rem Vane; ● Pocket Pen; ○ Q; U

MATERIAL PROFILE: DESCRIPTION	USCS	ELEV. / DEPTH (ft)	NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING
(SC) Clayey sand, some medium plasticity fines, trace fine subrounded to subangular gravel; dark brown, strong HCL reaction; dry to moist.	SC	0.0						
				SS	40	6-6-5	11	
		2219.7 / 8.2						
(S-SM) fine to coarse,, few fine subrounded to subangular gravel, few non plastic fines; light brown, strong HCL reaction; dry to moist.	SM							
				SS	87	2-1-4	5	13
		2214.7 / 13.2						
(SM) Silty sand, few non plastic fines; strong HCL reaction.	SM							
		2212.2 / 15.7		SS	93	11-7-10	17	
(CL) Lean clay with sand, mostly medium plasticity fines; strong HCL reaction.	CL							
		2209.7 / 18.2						
(CL) Sandy lean clay, mostly medium plasticity fines, some fine sand; dark brown, strong HCL reaction; w < PL to moist.	CL							
				MC	100	16-26	42	14

Continued on Next Page

GROUNDWATER OBSERVATIONS

ADDITIONAL OBSERVATIONS

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Mar 16, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-05

CLIENT:	Structural Grace	START DATE:	March 16, 2020	GROUND ELEV:	2227.9 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 17, 2020	COORDINATES:	N: 478462.2 ft E: 971397.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83
				HOLE LOC:	North Loop

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH: Nat Vane; Rem Vane; Pocket Pen; Q; U

DEPTH (ft)	MATERIAL PROFILE DESCRIPTION	USCS	ELEV. / DEPTH (ft)	NUMBER	TYPE	REC %	BLOWS	N-VALUE
	(CL) Sandy lean clay, mostly medium plasticity fines, some fine sand; dark brown, strong HCL reaction; w < PL to moist.	CL	2202.7 / 25.2					
25	(SP-SM) Poorly graded sand with silt and gravel, fine to coarse, poorly graded, few fine subrounded to subangular gravel, few non plastic fines; light brown, no HCL reaction; dry.	SP-SM			SS	73	5-6-8	14
26								
27								
28								
29								
30								
31					SS	77	8-8-10	18
32								
33			2194.7 / 33.2					
	(SM) Silty sand with gravel, some fine to coarse subrounded to subangular gravel, few non plastic fines; light brown, no HCL reaction; dry to moist.	SM						
34								
35								
36					SS	37	8-9-11	20
37								
38								
39								
40					SS	30	17-50/2"	
41								
42								
43								
44								
45								
46					SS	39	13-16-50/5"	
47								
48			2179.7 / 48.2					
49	(SP-SM) Poorly graded sand with silt and gravel, fine to coarse, poorly graded, some fine to coarse subrounded to subangular gravel, few non plastic fines; pale gray, no HCL reaction; dry.	SP-SM						
50								

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ADDITIONAL LAB TESTING

GROUNDWATER OBSERVATIONS

ADDITIONAL OBSERVATIONS

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Mar 16, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-05

CLIENT:	Structural Grace	START DATE:	March 16, 2020	GROUND ELEV:	2227.9 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 17, 2020	COORDINATES:	N: 478462.2 ft E: 971397.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83
				HOLE LOC:	North Loop

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH: Nat Vane; Rem Vane; Pocket Pen; Q; U

DEPTH (ft)	MATERIAL PROFILE: DESCRIPTION	USCS	ELEV. / DEPTH (ft)	SAMPLE NUMBER	TYPE	REC %	BLOWS	N-VALUE
50–55	(SP-SM) Poorly graded sand with silt and gravel, fine to coarse, poorly graded, some fine to coarse subrounded to subangular gravel, few non plastic fines; pale gray, no HCL reaction; dry.	SP-SM			SS	49	50/5"	
55			2172.7 / 55.2	S11	SS		50/4"	
55–67	(SC) Clayey sand with gravel, some low plasticity fines, few fine to coarse subrounded to subangular gravel; dark brown, no HCL reaction; moist.	SC			SS	61	50/5"	
65					SS	49	50/5"	
67			2160.2 / 67.7					
67–75	(GC) Clayey gravel with sand, fine to coarse, subrounded to subangular, some fine to medium sand, few medium plasticity fines; light brown to light gray, chemical odor, no HCL reaction; dry to moist.	GC			SS	122	50/5"	

ADDITIONAL LAB TESTING

GROUNDWATER OBSERVATIONS

ADDITIONAL OBSERVATIONS

Continued on Next Page

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Mar 16, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-05

CLIENT:	Structural Grace	START DATE:	March 16, 2020	GROUND ELEV:	2227.9 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 17, 2020	COORDINATES:	N: 478462.2 ft E: 971397.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83
				HOLE LOC:	North Loop

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH: Nat Vane; Rem Vane; Pocket Pen; Q; U

DEPTH (ft)	MATERIAL PROFILE: DESCRIPTION	USCS	ELEV. / DEPTH (ft)	SAMPLES: NUMBER	TYPE	REC %	BLOWS	N-VALUE
76, 77	(GC) Clayey gravel with sand, fine to coarse, subrounded to subangular, some fine to medium sand, few medium plasticity fines; light brown to light gray, chemical odor, no HCL reaction; dry to moist.	GC			SS	100	50/3"	
			2150.3 / 77.6					
78, 79, 80, 81, 82, 83	(GM) Silty gravel with sand, fine to coarse, subrounded to subangular, some fine to coarse SAND, few non plastic fines; dark brown, chemical odor, no HCL reaction; moist.	GM			SS	13	20-21-26	47
			2144.7 / 83.2					
84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100	(GC) Clayey gravel with sand, fine to coarse, subrounded to subangular, some fine to coarse sand, few low plasticity fines; dark brown, no HCL reaction; dry to moist.	GC			SS	57	23-24-22	46
					SS	110	29-50/5"	
					SS	60	10-15-30	45

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ADDITIONAL LAB TESTING

GROUNDWATER OBSERVATIONS

ADDITIONAL OBSERVATIONS

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Mar 16, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-05

CLIENT:	Structural Grace	START DATE:	March 16, 2020	GROUND ELEV:	2227.9 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 17, 2020	COORDINATES:	N: 478462.2 ft E: 971397.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83
				HOLE LOC:	North Loop

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: ⊢ Plastic & Liquid Limits (%); ○ Water Content (%); NP Nonplastic

SHEAR STRENGTH: ⊗ Nat Vane; ■ Rem Vane; ● Pocket Pen; ○ Q; U

DEPTH (ft)	MATERIAL PROFILE: DESCRIPTION	USCS	ELEV. / DEPTH (ft)	NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
101, 102	(GC) Clayey gravel with sand, fine to coarse, subrounded to subangular, some fine to coarse sand, few low plasticity fines; dark brown, no HCL reaction; dry to moist.	GC			SS	22	34-50/5"				
103			2124.9 / 103.0								
104, 105, 106, 107, 108, 109, 110	(SC) Clayey sand with gravel, some fine subrounded to subangular gravel, few medium plasticity fines; dark brown, no HCL reaction; dry to moist.	SC			SS	67	24-40-44	84	15		
110, 111					SS	27	27-50/3"				
112			2115.0 / 112.9								
113, 114, 115, 116, 117, 118, 119, 120	(GM) Silty gravel with sand, fine to coarse, subrounded to angular, some fine to coarse sand, few low plasticity fines; dark brown, no HCL reaction; dry to moist.	GM			SS	67	30-32-27	59			
120			2107.2 / 120.8	S24	SS		29-50/3"				
121, 122, 123, 124, 125	(GC) Clayey gravel with sand, fine to coarse, subrounded to subangular, some fine to coarse sand, few low plasticity fines; dark brown, no HCL reaction; dry to moist.	GC									

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REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Mar 16, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-05

CLIENT:	Structural Grace	START DATE:	March 16, 2020	GROUND ELEV:	2227.9 ft
PROJECT:	Sunset Road I10 to River	END DATE:	March 17, 2020	COORDINATES:	N: 478462.2 ft E: 971397.0 ft
PROJECT NO:	19128078	INCLINATION:	90.0°	COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83
				HOLE LOC:	North Loop

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES (Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop): NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT (Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic)	SHEAR STRENGTH (Nat Vane; Rem Vane; Pocket Pen; Q; U)	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
126	CME-75	Hollow Stem Auger - 8-in Hole Dia.	(GC) Clayey gravel with sand, fine to coarse, subrounded to subangular, some fine to coarse sand, few low plasticity fines; dark brown, no HCL reaction; dry to moist.	GC				SS	60	12-34-34	68					
127																
128																
129																
130																
131						2096.4		SS	67	20-19-17	36					
132			End of hole at 131.5 ft.													
133																
134																
135																
136																
137																
138																
139																
140																
141																
142																
143																
144																
145																
146																
147																
148																
149																
150																

REV:

GOLDER

LOGGED: Joshua Torres Galvez DATE: Mar 16, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-06

CLIENT:	Structural Grace	DATE:	April 21, 2020	GROUND ELEV:	2229.5 ft
PROJECT:	Sunset Road I10 to River			COORDINATES:	N: 478871.7 ft E: 971054.8 ft
PROJECT NO:	19128078			COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES (Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop): NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT (Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic)	SHEAR STRENGTH (Nat Vane; Rem Vane; Pocket Pen; Q; U)	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
			Asphalt			0.0 / 2229.2	PC-06							PC-06		
			Aggregate Base	GP-GM		0.3 / 2228.5										
1			FILL - (SM) Silty sand with gravel, fine to medium, subrounded, few fine subrounded to subangular gravel, few non plastic fines; brown, no HCL reaction, trace presence of roots; non-cohesive, moist, dense, Embankment Fill.	SM		1.0										
2																
3	CME-75	Hollow Stem Auger - 8-in Hole Dia.					MC-01	MC	100	22-27	49					
4																
5																
6						2223.0	SPT-02	SS	100	12-14-19	33					
			End of hole at 6.5 ft. Backfilled with clean sand to bottom of AC layer and finished with PermaPatch													
7																
8																
9																
10																

REV:

GOLDER

LOGGED: Kenneth Rood DATE: Apr 21, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-07

CLIENT:	Structural Grace	DATE:	April 21, 2020	GROUND ELEV:	2235.8 ft
PROJECT:	Sunset Road I10 to River			COORDINATES:	N: 478552.8 ft E: 971443.4 ft
PROJECT NO:	19128078			COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH: Nat Vane; Rem Vane; Pocket Pen; Q; U

DEPTH (ft)	MATERIAL PROFILE: DESCRIPTION	USCS	ELEV. / DEPTH (ft)	SAMPLE NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
	Asphalt		0.0 / 2235.4	PC-07					PC-07		
	Aggregate Base	GP-GM	0.4 / 2234.8								
1	FILL - (SP-SM) Poorly graded sand with silt, fine to medium, poorly graded, subrounded, few fine to medium subrounded to subangular gravel, few non plastic fines; brown, trace presence of roots; non-cohesive, moist, loose to dense, Embankment Fill.	SP-SM	1.0								
2											
3				SPT-01	SS	100	21-17-15	32			
4											
5				MC-02	MC	100	22-40	62			
6											
7											
8											
9											
10											

Continued on Next Page

REV:

GOLDER

LOGGED: Kenneth Rood DATE: Apr 21, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-07

CLIENT:	Structural Grace	DATE:	April 21, 2020	GROUND ELEV:	2235.8 ft
PROJECT:	Sunset Road I10 to River			COORDINATES:	N: 478552.8 ft E: 971443.4 ft
PROJECT NO:	19128078			COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DRILL RIG: CME-75

DRILL METHOD: Hollow Stem Auger - 8-in Hole Dia.

SAMPLES: Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop

WATER CONTENT PERCENT: Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic

SHEAR STRENGTH: Nat Vane; Rem Vane; Pocket Pen; Q; U

DEPTH (ft)	MATERIAL PROFILE: DESCRIPTION	USCS	ELEV. / DEPTH (ft)	SAMPLES: NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
11	FILL - (SP-SM) Poorly graded sand with silt, fine to medium, poorly graded, subrounded, few fine to medium subrounded to subangular gravel, few non plastic fines; brown, trace presence of roots; non-cohesive, moist, loose to dense, Embankment Fill.	SP-SM		SPT-03	SS	100	10-12-13	25			
12											
13											
14											
15				SPT-04	SS	89	3-2-3	5			
16											
17											
18			2217.5 / 18.2								
19	(SM) Silty sand with gravel, medium to coarse, subrounded, few fine to coarse subrounded to subangular gravel, few non plastic fines; light brown and light gray; non-cohesive, moist, compact, Native Soil.	SM									
20											

Continued on Next Page

REV:

GOLDER

LOGGED: Kenneth Rood DATE: Apr 21, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-07

CLIENT:	Structural Grace	DATE:	April 21, 2020	GROUND ELEV:	2235.8 ft
PROJECT:	Sunset Road I10 to River			COORDINATES:	N: 478552.8 ft E: 971443.4 ft
PROJECT NO:	19128078			COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES (Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop): NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT (Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic)	SHEAR STRENGTH (Nat Vane; Rem Vane; Pocket Pen; Q; U)	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
21	CME-75	Hollow Stem Auger - 8-in Hole Dia.	(SM) Silty sand with gravel, medium to coarse, subrounded, few fine to coarse subrounded to subangular gravel, few non plastic fines; light brown and light gray; non-cohesive, moist, compact, Native Soil.	SM		2214.3	SPT-05	SS	100	7-8-9	17					
22			End of hole at 21.5 ft. Backfilled with clean sand to bottom of AC layer and finished with PermaPatch													
23																
24																
25																
26																
27																
28																
29																
30																

REV:

GOLDER

LOGGED: Kenneth Rood DATE: Apr 21, 2020

CHECKED: KAR DATE: May 05, 2020

RECORD OF BOREHOLE: BH-08

CLIENT:	Structural Grace	DATE:	April 21, 2020	GROUND ELEV:	2236.0 ft
PROJECT:	Sunset Road I10 to River			COORDINATES:	N: 478257.5 ft E: 971993.3 ft
PROJECT NO:	19128078			COORD SYS:	SP AZ Central FIPS 0202 Ft
LOCATION:	Tucson, AZ	CONTRACTOR:	Southlands Engineering, LLC	HORZ DATUM:	NAD83

DEPTH (ft)	DRILL RIG	DRILL METHOD	MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES (Hammer: Automatic hammer ASTM D1586, Blows per 6 in 140-lb hammer, 30-in drop): NUMBER	TYPE	REC %	BLOWS	N-VALUE	WATER CONTENT PERCENT (Plastic & Liquid Limits (%); Water Content (%); NP Nonplastic)	SHEAR STRENGTH (Nat Vane; Rem Vane; Pocket Pen; Q; U)	ADDITIONAL LAB TESTING	GROUNDWATER OBSERVATIONS	ADDITIONAL OBSERVATIONS
			Asphalt			0.0 / 2235.6	PC-08							PC-08		
			Aggregate Base	GP-GM		0.3 / 2235.0										
1			FILL - (SP-SM) Poorly graded sand with silt, fine to medium, poorly graded, subrounded, few fine subrounded to subangular gravel, few non plastic fines; brown, trace presence of roots; non-cohesive, moist, compact, Embankment Fill.	SP-SM		1.0										
2																
3	CME-75	Hollow Stem Auger - 8-in Hole Dia.					SPT-01	SS	100	23-15-15	30					
4																
5							SPT-02	SS	67	7-6-7	13					
6						2229.5										
			End of hole at 6.5 ft. Backfilled with clean sand to bottom of AC layer and finished with PermaPatch													
7																
8																
9																
10																

REV:

GOLDER

LOGGED: Kenneth Rood DATE: Apr 21, 2020

CHECKED: KAR DATE: May 05, 2020

APPENDIX B

Geotechnical Laboratory Testing

atek ENGINEERING CONSULTANTS

PROJECT: Golder Associates 2020 On-Call
LOCATION: Request 3 - 19128078 - Sunset Rd.: I-10 to River Rd.
SAMPLE DATE: 8/25/2020

PROJECT: 200063-02
WORK ORDER: 2010301
REVIEWED BY: R. Hernandez, PE

MOISTURE CONTENT OF SOIL -- ASTM D 2216

LAB #	SAMPLE SOURCE	MOISTURE WET WEIGHT (g)	MOISTURE DRY WEIGHT (g)	MOISTURE MOISTURE CONTENT
1	SPT BH-01 S4 @ 20'-21.5'	883.9	835.7	5.8%
2	SPT BH-01 S16 @ 80'-81.5'	1,005.3	936.3	7.4%
3	SPT BH-01 S24 @ 120'-121.5'	1,057.3	965.8	9.5%

atek ENGINEERING CONSULTANTS

PROJECT: Golder Associates 2020 On-Call
LOCATION: Request 19128078 - Sunset Rd.: I-10 to River Rd.
SAMPLE DATE: 4/2/2020

PROJECT: 200063-02
WORK ORDER: 2010114
REVIEWED BY: James Floyd, PE

DENSITY OF SOIL IN PLACE BY THE DRIVE-CYLINDER METHOD -- ASTM D 2937

LAB #	SAMPLE SOURCE	MOISTURE WET WEIGHT (g)	MOISTURE DRY WEIGHT (g)	MOISTURE MOISTURE CONTENT	# OF RINGS	WET WEIGHT + RINGS (g)	WEIGHT OF RINGS (g)	DRY DENSITY (pcf)
1	Ring BH-02 S4-A @ 20.5-21'	385.8	379.6	1.6%	5	861.7	225.2	103.7
2	Ring BH-02 S4-B @ 21-25'	556.2	548.5	1.4%	4	727.4	167.5	114.3
3	SPT Sample, BH-02 S 16 @ 80-81.5'	855.7	804.8	6.3%				
4	SPT Sample, BH-02 S24 @ 120-121.5'							
5	Ring BH-03 S4-A @ 7.5-8'	618.2	587.6	5.2%	6	1013.3	269.8	97.5
6	Ring BH-03 S4-B @ 40-41.5'	729.2	717.4	1.6%	6	1036.4	271.8	103.8
7	SPT Sample, BH-03 S11 @ 40-41.5'	636.8	623.2	2.2%				
8	SPT Sample, BH-03 S16 @ 65-66.5'	798.2	756.1	5.6%				
9	SPT Sample, BH-04 S2 @ 10-11.5'	1,043.4	1,009.2	3.4%				
10	Ring Sample, BH-04 S5 @ 25-26'	704.1	648.5	8.6%				
11	SPT Sample, BH-04 S14 @ 70-71.5'	983.9	884.8	11.2%				
12	SPT Sample, BH-04 S20 @ 100-101.41'	659.6	618.9	6.6%				
13	SPT Sample, BH-05 S2 @ 10-11.5'	797.3	784.0	1.7%				
14	Ring BH-05 S4-A @ 20.5-21'	573.2	537.8	6.6%	4	673.5	177.5	96.3
15	SPT Sample BH-05 S21 @ 105-106.5'	643.4	597.9	7.6%				

Test not performed due to insufficient sample size.

atek ENGINEERING CONSULTANTS

PROJECT:	Golder Associates 2020 On-Call	**PROJECT NO:**	200063-02
LOCATION:	Request 3 - 19128078 - Sunset Rd.: I-10 to River Rd.	**WORK ORDER NO:**	2010301
DATE SAMPLED:	8/25/2020	**REVIEWED BY:**	Rafael Hernandez, PE

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (ASTM D-2487)

SIEVE SIZES

					COBBLES		GRAVEL									SAND								Silt or	
							Coarse					Fine				Coarse		Medium			Fine			Clay	
Location & Depth	**USCS**	**LL**	**PL**	**PI**	**6"**	**4"**	**3"**	**2"**	**1 1/2"**	**1 1/4"**	**1"**	**3/4"**	**1/2"**	**3/8"**	**1/4"**	**#4**	**#8**	**#10**	**#16**	**#30**	**#40**	**#50**	**#100**	**#200**	**Lab #**

PERCENT PASSING BY WEIGHT

SPT, BH-01 S4 @ 20-21.5	SM	NV	NP	NP	100	100	100	100	100	100	100	100	100	99	98	97	95	94	92	82	72	65	48	36	1
SPT, BH-01 S16 @ 80'-81.5'	SC	30	18	12	100	100	100	100	100	100	100	97	92	90	86	83	70	66	56	45	40	36	26	17	2
SPT, BH-01 S24 @ 120'-121.5	SC	31	15	16	100	100	100	100	100	100	96	94	89	84	76	71	58	53	45	35	31	27	21	15	3

This is a summarized report of the referenced procedures and does not include all reporting requirements. Additional data can be provided at client's request.

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PROJECT:	Golder Associates 2020 On-Call	**PROJECT NO:**	200063-02
LOCATION:	Request 19128078 - Sunset Rd.: I-10 to River Rd.	**WORK ORDER NO:**	2010114
DATE SAMPLED:	4/2/2020	**REVIEWED BY:**	James Floyd, PE

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (ASTM D-2487)

SIEVE SIZES

					COBBLES		GRAVEL									SAND								Silt or Clay	
							Coarse					Fine				Coarse		Medium			Fine				
Location & Depth	**USCS**	**LL**	**PL**	**PI**	**6"**	**4"**	**3"**	**2"**	**1 1/2"**	**1 1/4"**	**1"**	**3/4"**	**1/2"**	**3/8"**	**1/4"**	**#4**	**#8**	**#10**	**#16**	**#30**	**#40**	**#50**	**#100**	**#200**	**Lab #**

PERCENT PASSING BY WEIGHT

Ring Sample, BH-02 S4-A @ 20.5-21	SP-SM	NV	NP	NP	100	100	100	100	73	73	73	73	72	70	67	65	58	56	56	37	30	22	14	10	1
SPT Sample, BH-02 S16 @ 80-81.5	SC	38	17	21	100	100	100	100	100	100	97	94	86	83	75	70	58	54	46	37	33	29	22	16	3
SPT Sample, BH-02 S24 @ 120-121.5																									4
Ring Sample, BH-03 S4-A @ 7.5-8	CL-ML	23	17	6	100	100	100	100	100	100	100	100	100	100	100	100	98	97	94	87	82	75	62	51	5
SPT Sample, BH-03 S11 @ 40-41.5	SP-SM	NV	NP	NP	100	100	100	100	100	100	82	79	69	65	59	56	49	48	44	39	32	22	11	7.3	7
SPT Sample, BH-03 S 16 @ 65-66.5	SC	29	16	13	100	100	100	100	100	100	100	95	89	85	79	74	60	56	46	36	31	27	21	16	8
SPT Sample, BH-04 S2 @ 10-11.5					100	100	100	100	100	100	100	98	95	95	94	92	85	82	69	52	45	40	32	26	9
Ring Sample, BH-04 S5 @ 25-26	CL	29	20	9	100	100	100	100	100	100	100	100	100	100	100	100	98	98	97	94	93	91	80	66	10
SPT Sample, BH-04 S14 @ 70-71.5	SC	36	17	19	100	100	100	100	100	100	100	98	92	90	84	78	60	55	44	33	29	25	18	13	11
SPT Sample, BH-04 S20 @ 100-101.41	SC	29	19	10	100	100	100	100	100	100	100	98	97	94	86	79	64	59	48	36	32	27	20	14	12

Test not performed due to insufficient sample size.

This is a summarized report of the referenced procedures and does not include all reporting requirements. Additional data can be provided at client's request.

atek ENGINEERING CONSULTANTS

PROJECT:	Golder Associates 2020 On-Call	**PROJECT NO:**	200063-02
LOCATION:	Request 19128078 - Sunset Rd.: I-10 to River Rd.	**WORK ORDER NO:**	2010114
DATE SAMPLED:	4/2/2020	**REVIEWED BY:**	James Floyd, PE

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (ASTM D-2487)

SIEVE SIZES

					COBBLES		GRAVEL									SAND								Silt or	
							Coarse					Fine				Coarse		Medium			Fine			Clay	
Location & Depth	**USCS**	**LL**	**PL**	**PI**	**6"**	**4"**	**3"**	**2"**	**1 1/2"**	**1 1/4"**	**1"**	**3/4"**	**1/2"**	**3/8"**	**1/4"**	**#4**	**#8**	**#10**	**#16**	**#30**	**#40**	**#50**	**#100**	**#200**	**Lab #**

PERCENT PASSING BY WEIGHT

SPT Sample, BH-05 S2 @ 10-11.5	SP-SM	NV	NP	NP	100	100	100	100	100	100	100	100	99	99	96	94	79	72	54	33	25	-103	11	7.9	13
Ring Sample BH=05 S4-A @ 20.5-51	CL	32	19	13	100	100	100	100	100	100	100	100	100	100	100	100	99	99	98	96	95	94	87	69	14
SPT Sample, BH-05 S21 @ 105-106.5	SP-SC	36	21	15	100	100	100	100	100	100	100	94	89	82	71	64	52	48	40	30	27	23	16	11	15

This is a summarized report of the referenced procedures and does not include all reporting requirements. Additional data can be provided at client's request.

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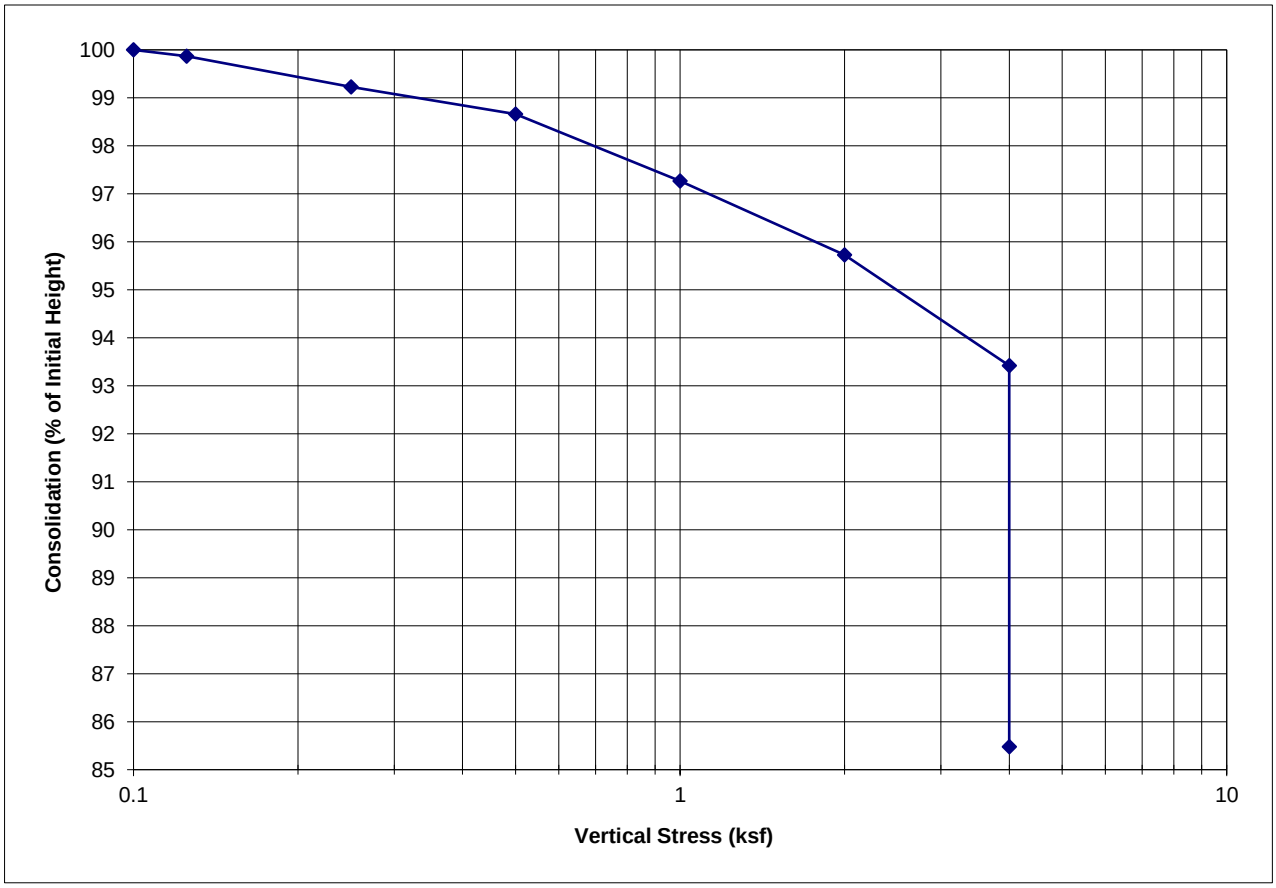
Project:	Golder Associates 2020 On-Call	**Project Number:**	200063-02
Project Location:	Request 19128078 - Sunset Rd.: I-10 to River Rd.	**Work Order Number:**	2010114
Client:	Golder	**Lab Number:**	1
Material:	Native	**Date Sampled:**	04/02/20
Sample Source:	Ring Sample BH-02 S4-A @ 20.5'-21.5'	**Reviewed By:**	J. Floyd, PE
Sample Prep:	In-Situ		

One-Dimensional Consolidation Properties of Soils (ASTM D2435)

Initial Volume (cu.in)	4.60	Final Volume (cu.in)	3.94
Initial Moisture Content	4.1%	Final Moisture Content	19.3%
Initial Dry Density(pcf)	93.2	Final Dry Density(pcf)	108.9
Initial Degree of Saturation	14%	Final Degree of Saturation	99%
Initial Void Ratio	0.8	Final Void Ratio	0.5
Estimated Specific Gravity	2.65	Saturated at	4 ksf



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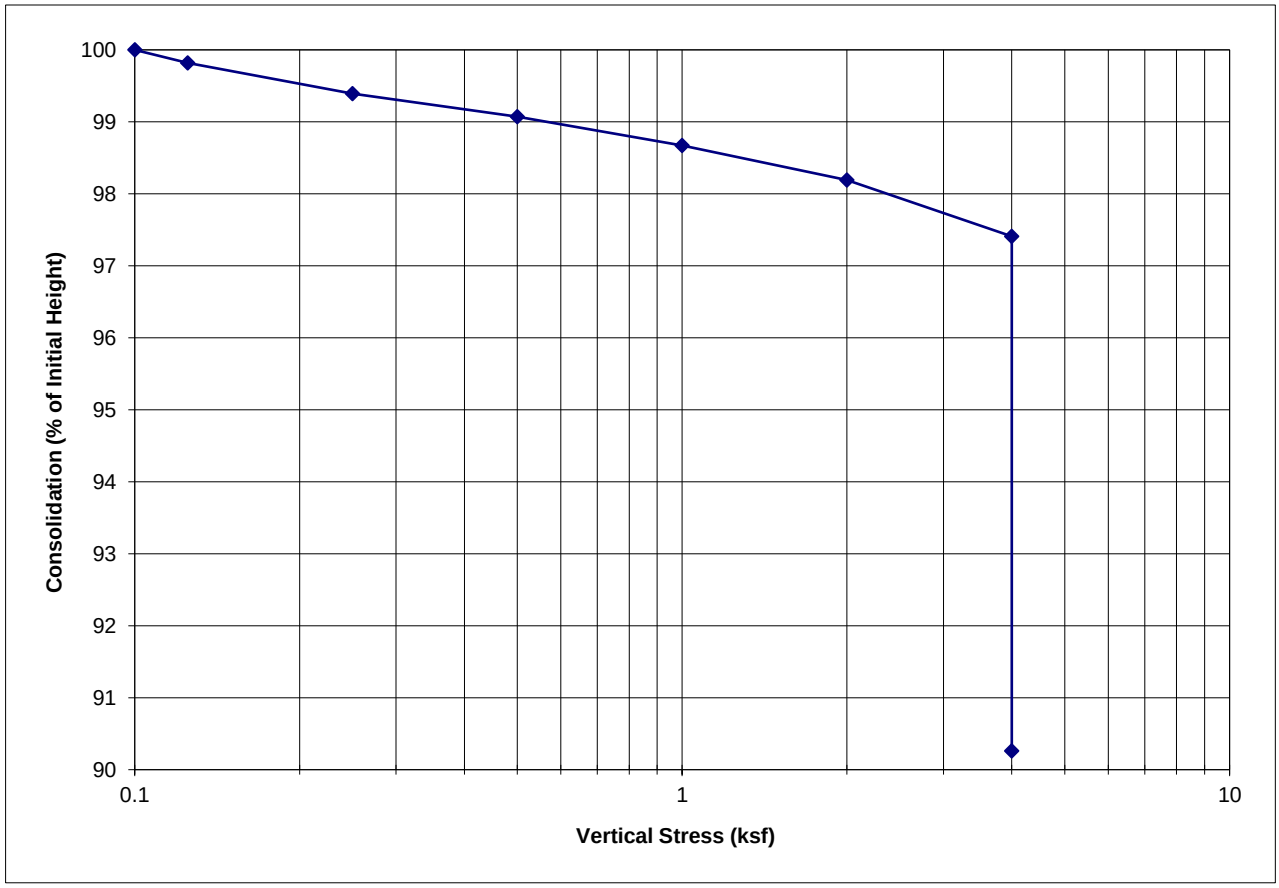
Project:	Golder Associates 2020 On-Call	**Project Number:**	200063-02
Project Location:	Request 19128078 - Sunset Rd.: I-10 to River Rd.	**Work Order Number:**	2010114
Client:	Golder	**Lab Number:**	5
Material:	Native	**Date Sampled:**	04/02/20
Sample Source:	Ring Sample BH-03 S4-A @ 7.5'-8'	**Reviewed By:**	J. Floyd, PE
Sample Prep:	In-Situ		

One-Dimensional Consolidation Properties of Soils (ASTM D2435)

Initial Volume (cu.in)	4.60	Final Volume (cu.in)	4.16
Initial Moisture Content	7.9%	Final Moisture Content	19.8%
Initial Dry Density(pcf)	97.5	Final Dry Density(pcf)	108.0
Initial Degree of Saturation	30%	Final Degree of Saturation	99%
Initial Void Ratio	0.7	Final Void Ratio	0.5
Estimated Specific Gravity	2.65	Saturated at	4 ksf



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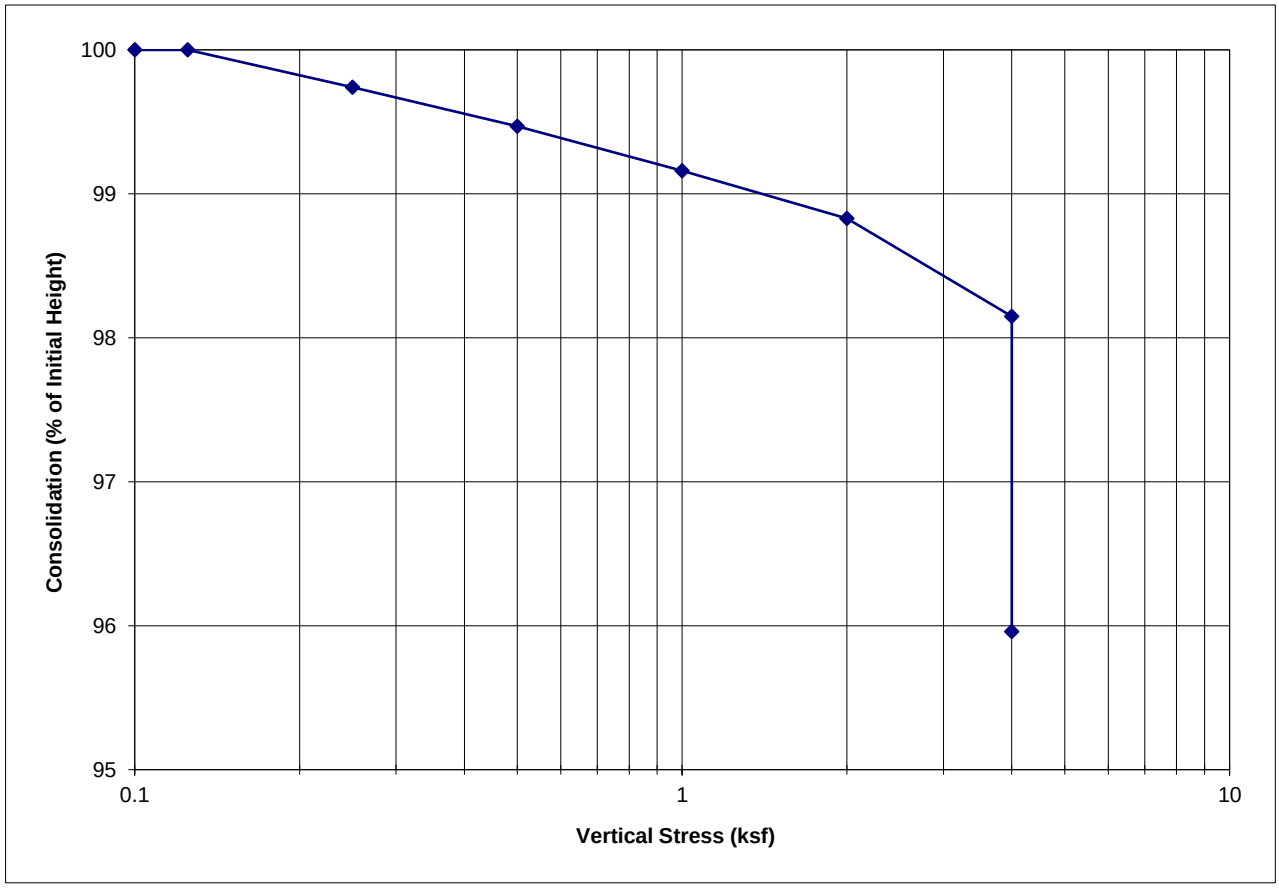
Project:	Golder Associates 2020 On-Call	**Project Number:**	200063-02
Project Location:	Request 19128078 - Sunset Rd.: I-10 to River Rd.	**Work Order Number:**	2010114
Client:	Golder	**Lab Number:**	14
Material:	Native	**Date Sampled:**	04/02/20
Sample Source:	Ring Sample BH-05 S4-A @ 20.5'-21'	**Reviewed By:**	J. Floyd, PE
Sample Prep:	In-Situ		

One-Dimensional Consolidation Properties of Soils (ASTM D2435)

Initial Volume (cu.in)	4.60	Final Volume (cu.in)	4.42
Initial Moisture Content	8.1%	Final Moisture Content	21.8%
Initial Dry Density(pcf)	100.1	Final Dry Density(pcf)	104.3
Initial Degree of Saturation	33%	Final Degree of Saturation	99%
Initial Void Ratio	0.7	Final Void Ratio	0.6
Estimated Specific Gravity	2.65	Saturated at	4 ksf



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APPENDIX C

Drilled Shaft Axial Resistance Charts

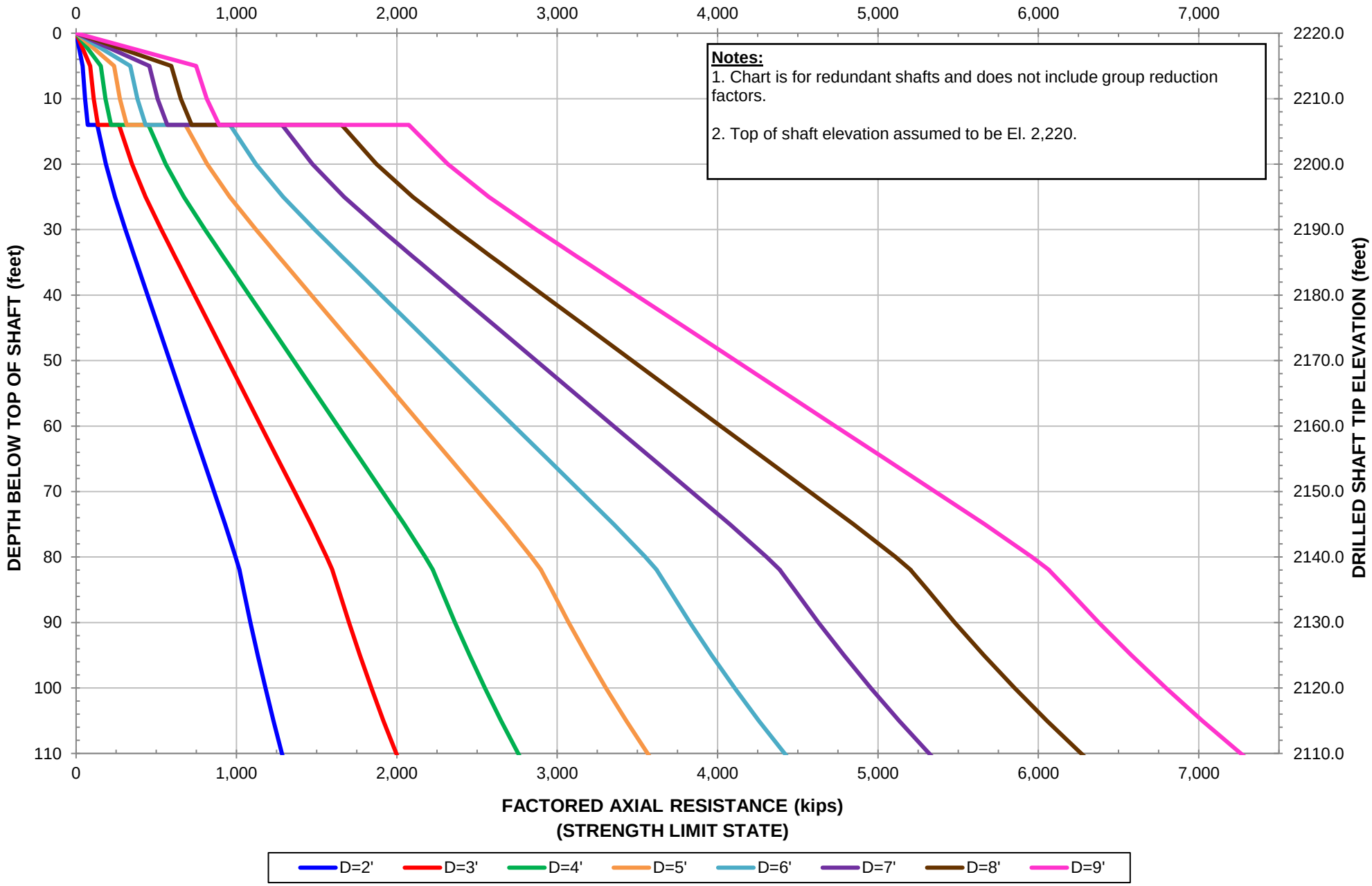
INITIAL

5/11/2020

19128078

FACTORED DRILLED SHAFT AXIAL RESISTANCE - STRENGTH I LIMIT STATE

Sunset Road: I-10 to River: UPRR Bridge Pier 1, Abutments 1 and 2 - Preliminary Design



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

UPRR-1

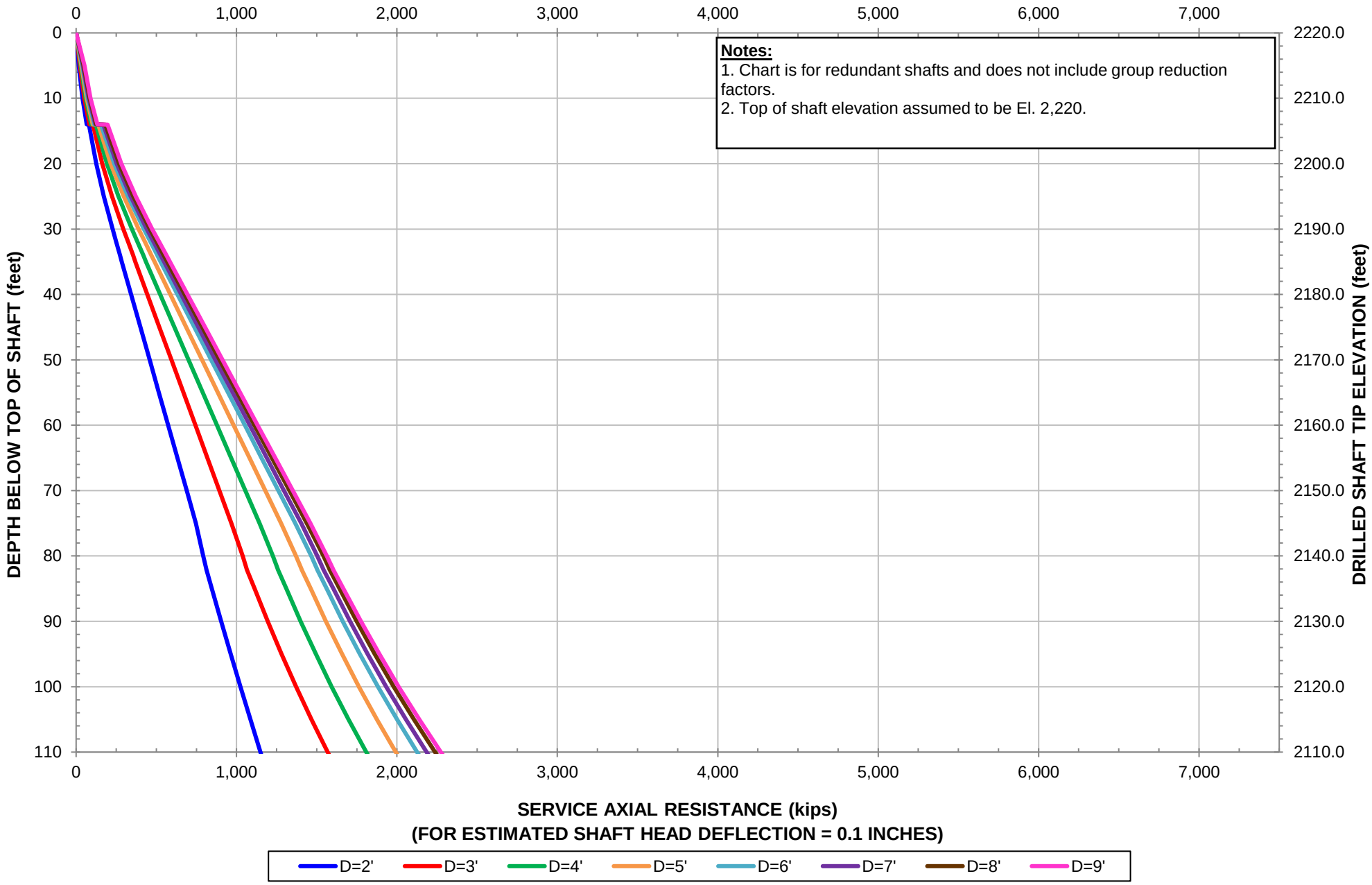
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road: I-10 to River: UPRR Bridge Pier 1, Abutments 1 and 2 - Preliminary Design



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

UPRR-2

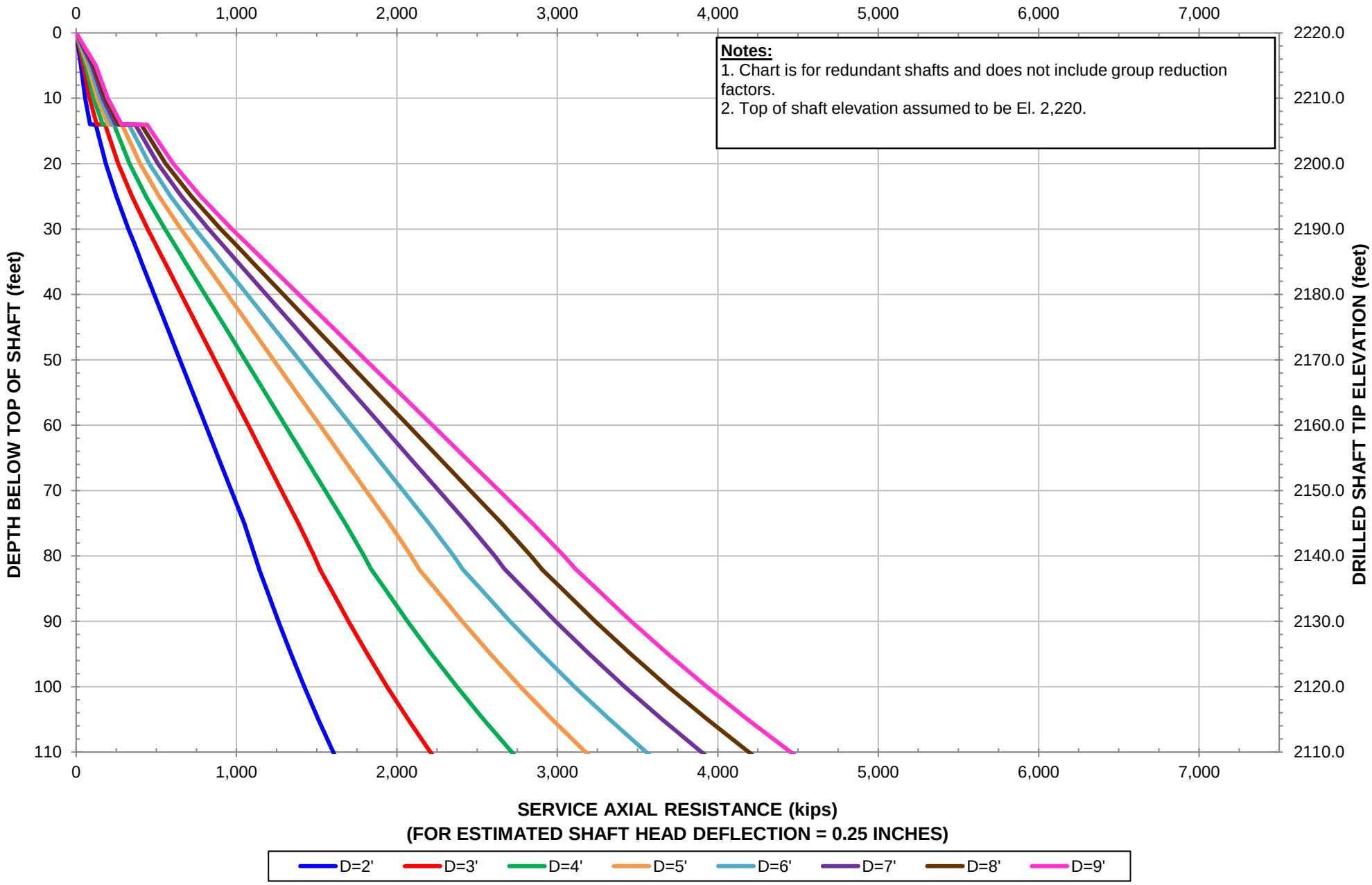
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road: I-10 to River: UPRR Bridge Pier 1, Abutments 1 and 2 - Preliminary Design



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

UPRR-3

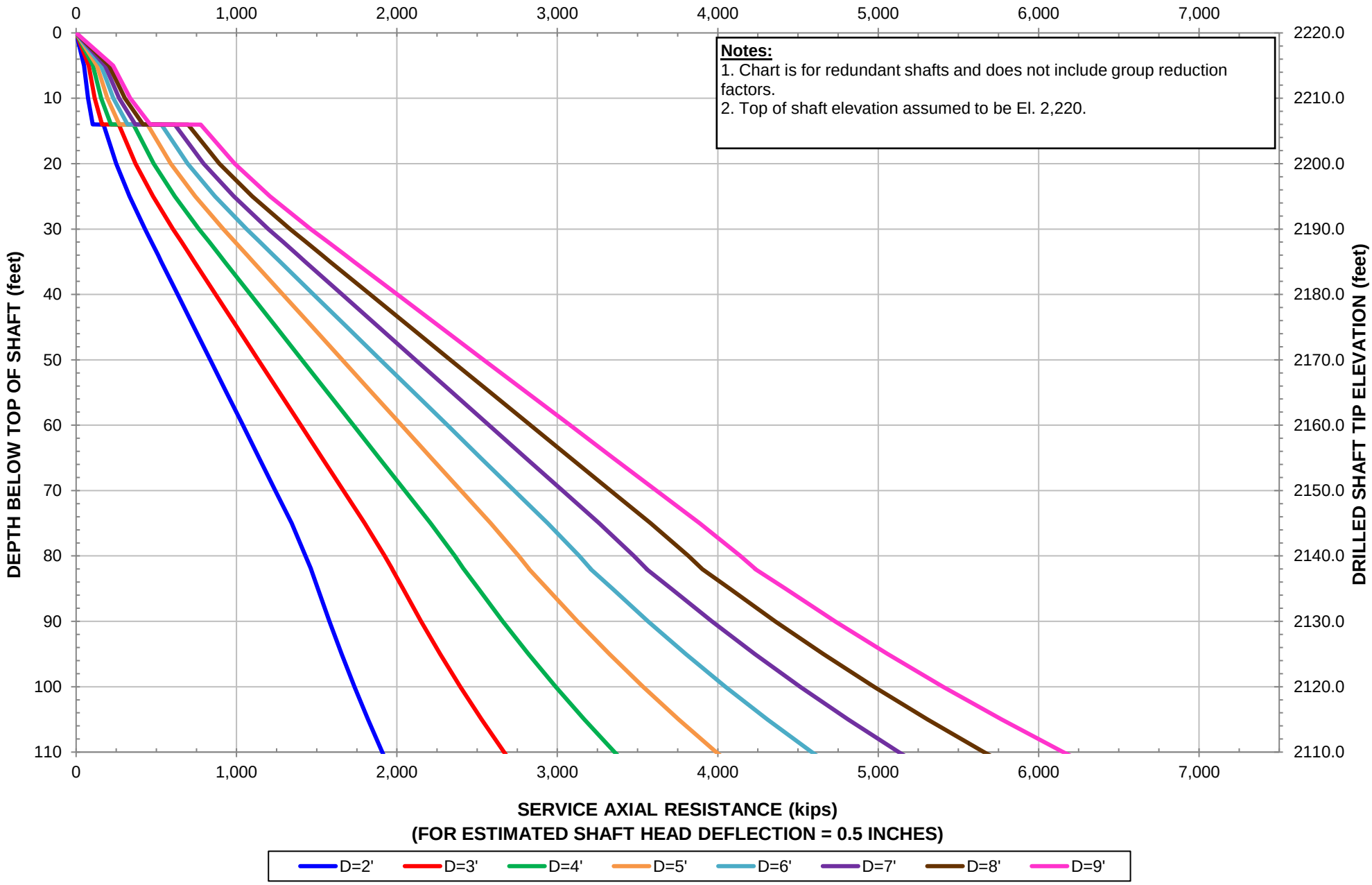
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road: I-10 to River: UPRR Bridge Pier 1, Abutments 1 and 2 - Preliminary Design



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

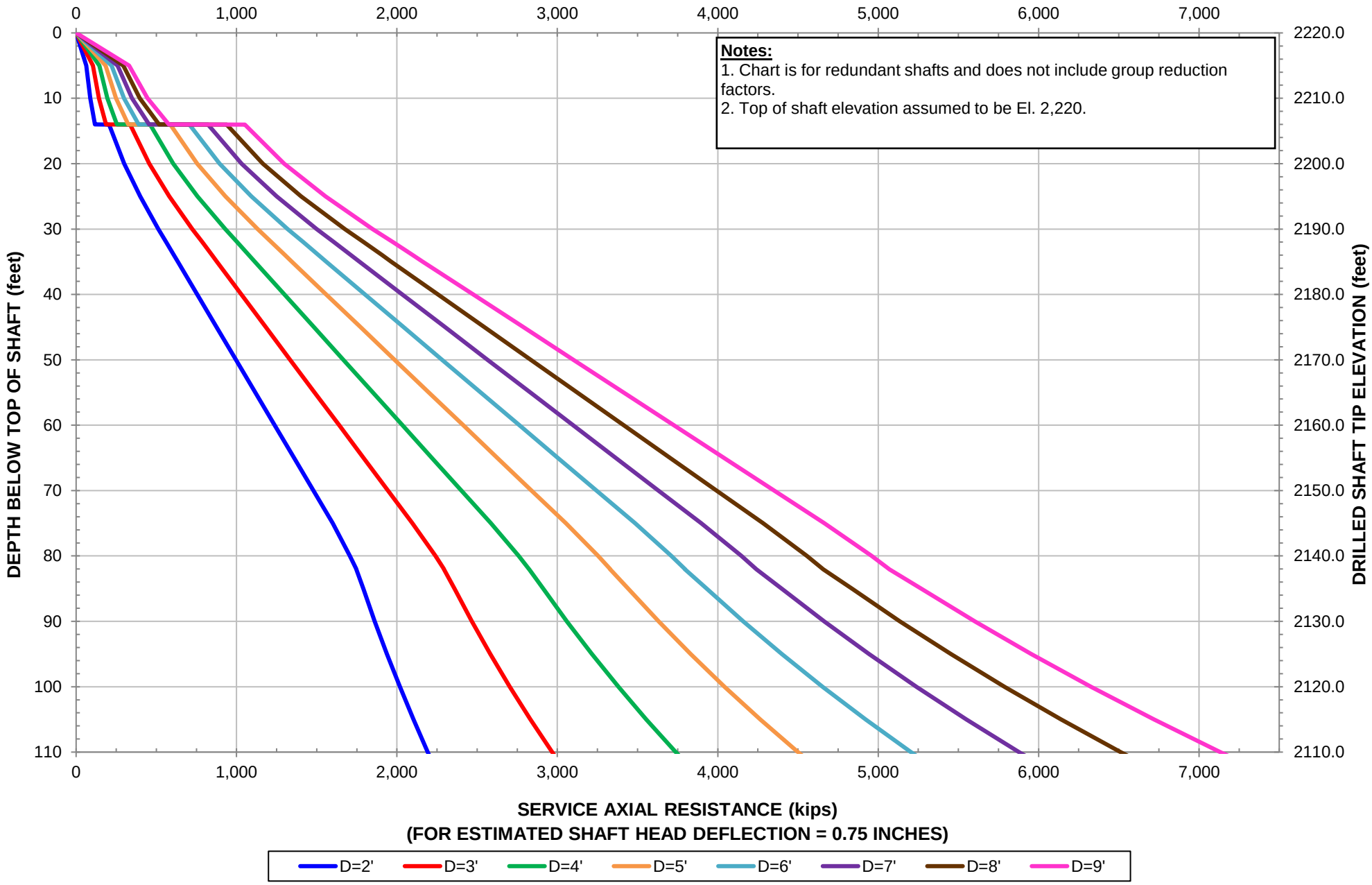
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road: I-10 to River: UPRR Bridge Pier 1, Abutments 1 and 2 - Preliminary Design



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Checked By: RMP
Approved By: RMP

GOLDER

UPRR-5

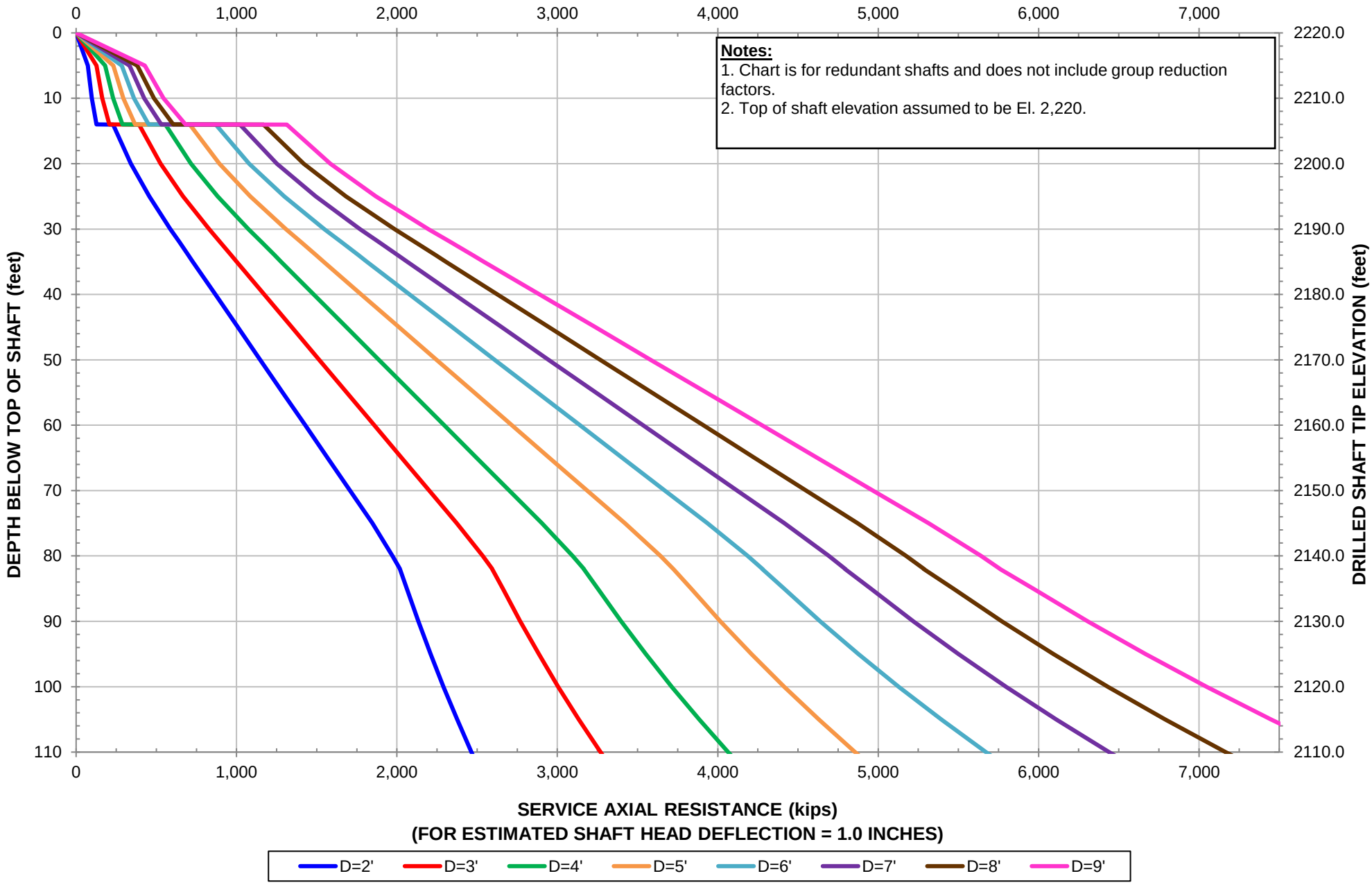
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road: I-10 to River: UPRR Bridge Pier 1, Abutments 1 and 2 - Preliminary Design



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

UPRR-6

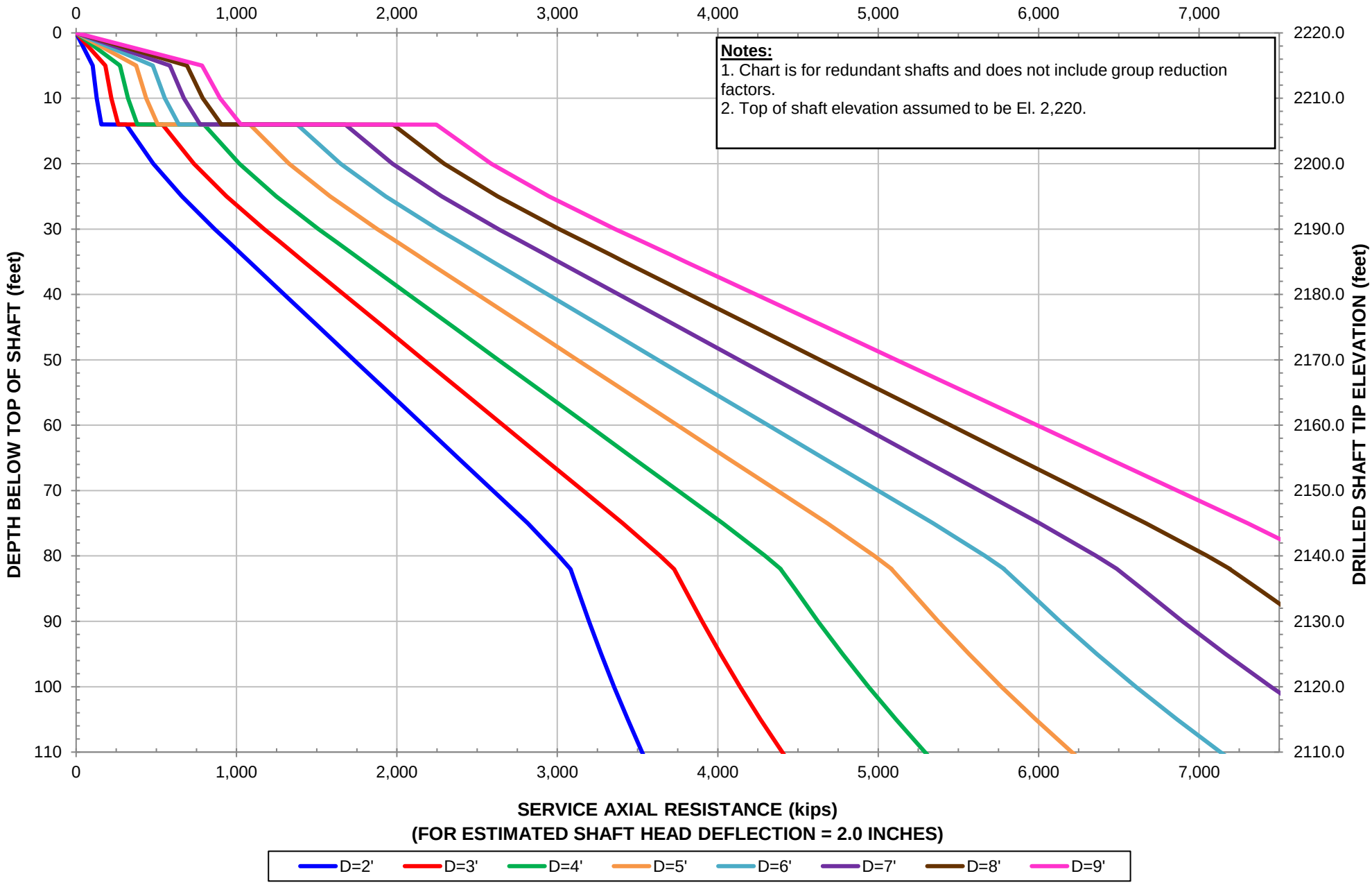
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road: I-10 to River: UPRR Bridge Pier 1, Abutments 1 and 2 - Preliminary Design



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

UPRR-7

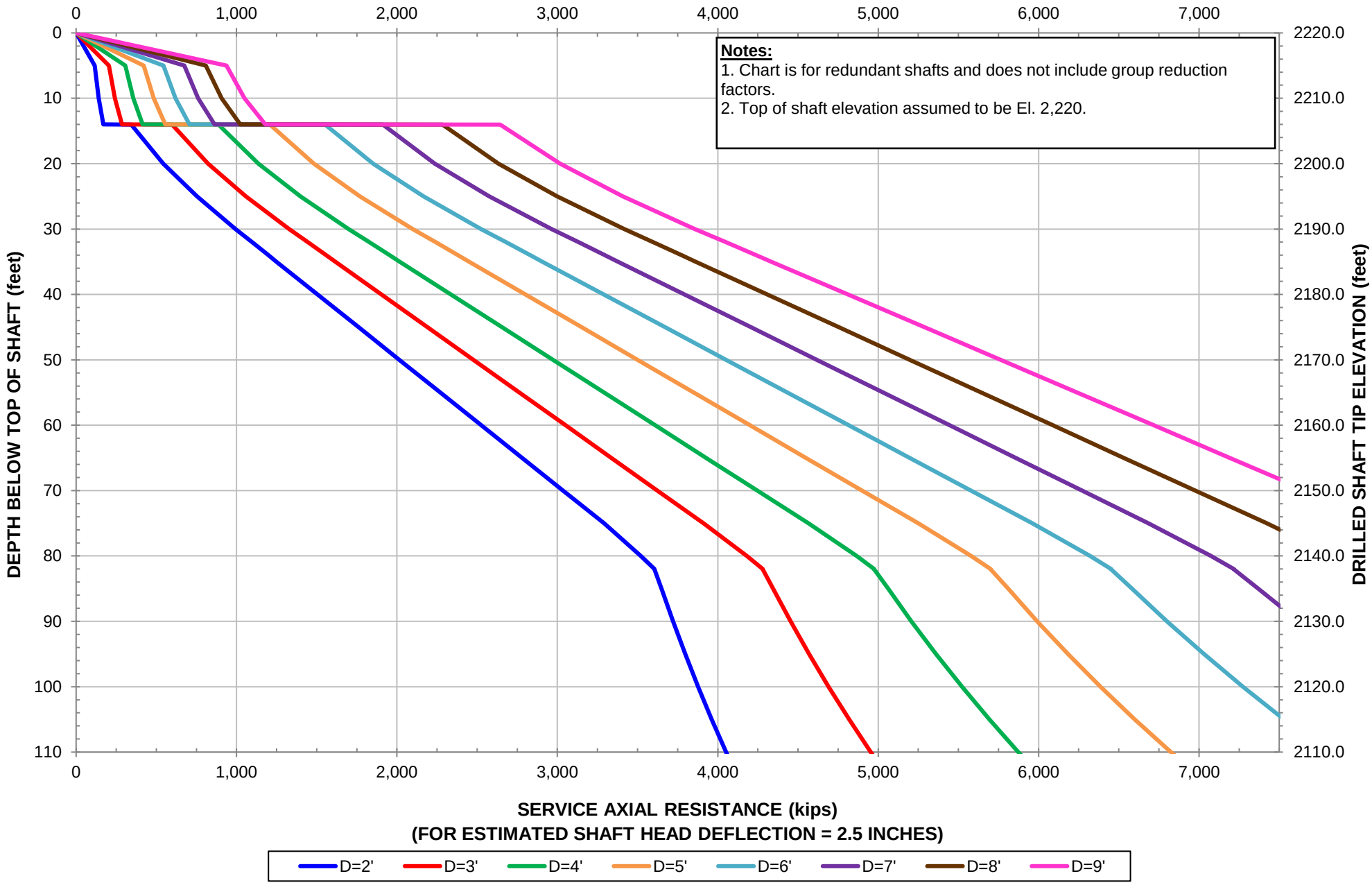
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road: I-10 to River: UPRR Bridge Pier 1, Abutments 1 and 2 - Preliminary Design



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

UPRR-8

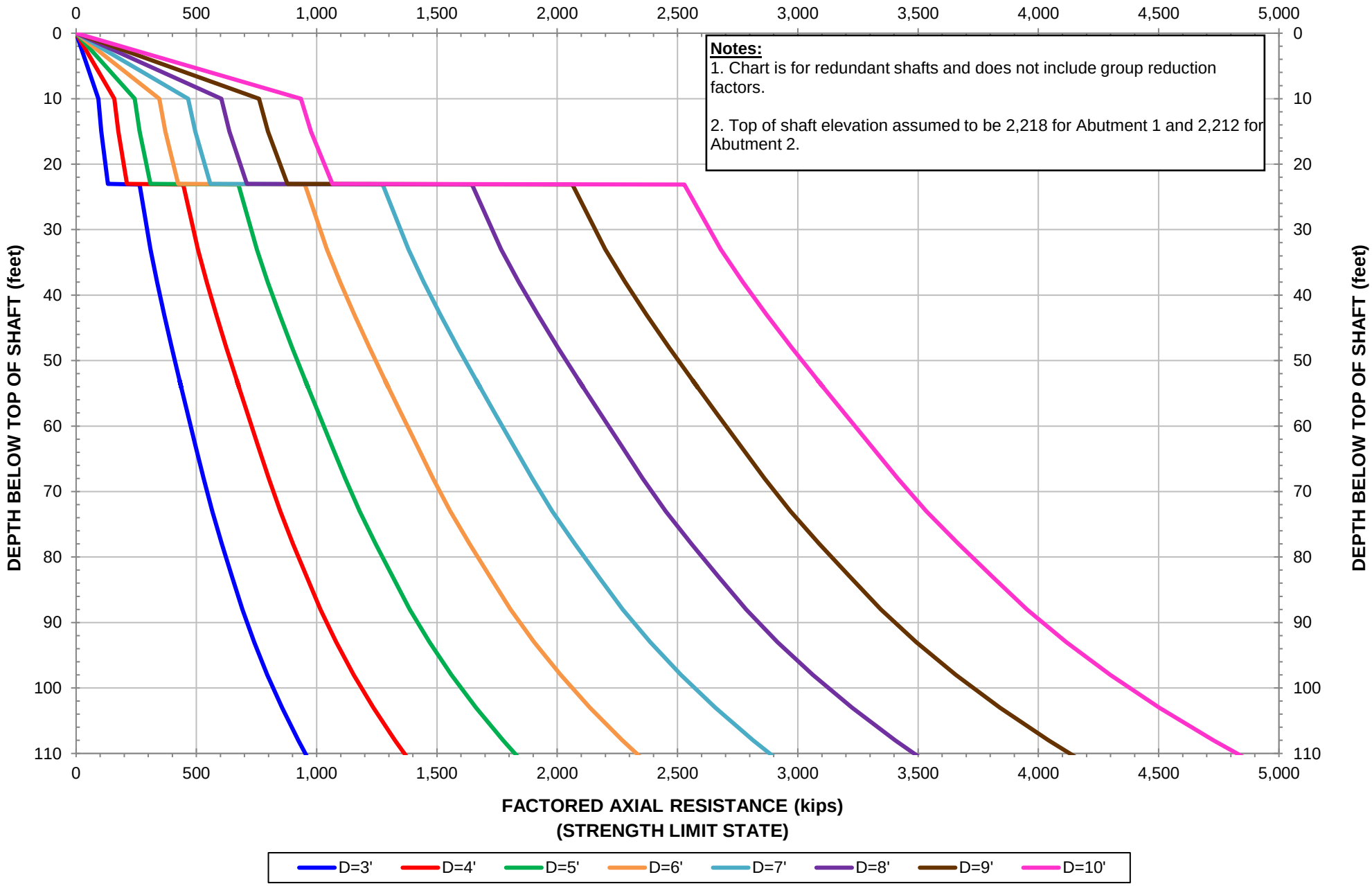
INITIAL

5/11/2020

19128078

FACTORED DRILLED SHAFT AXIAL RESISTANCE - STRENGTH I LIMIT STATE

Sunset Road - I-10 to River Road: Rillito Creek Abutments for 100-yr Flood - Preliminary



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

RCA-1

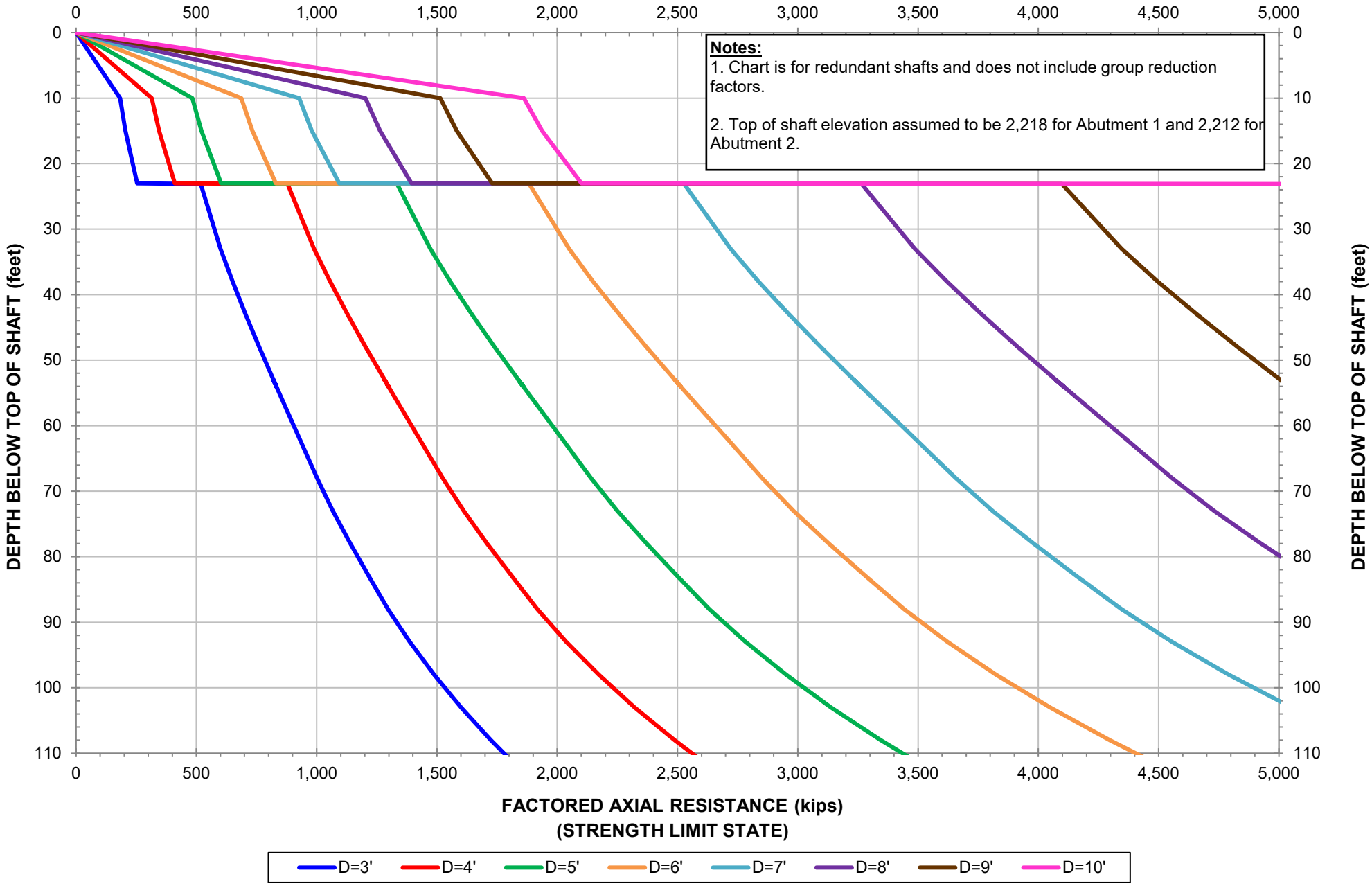
INITIAL

5/11/2020

19128078

FACTORED DRILLED SHAFT AXIAL RESISTANCE - EXTREME EVENT LIMIT STATE

Sunset Road - I-10 to River Road: Rillito Creek Abutments for 500-yr Flood - Preliminary



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

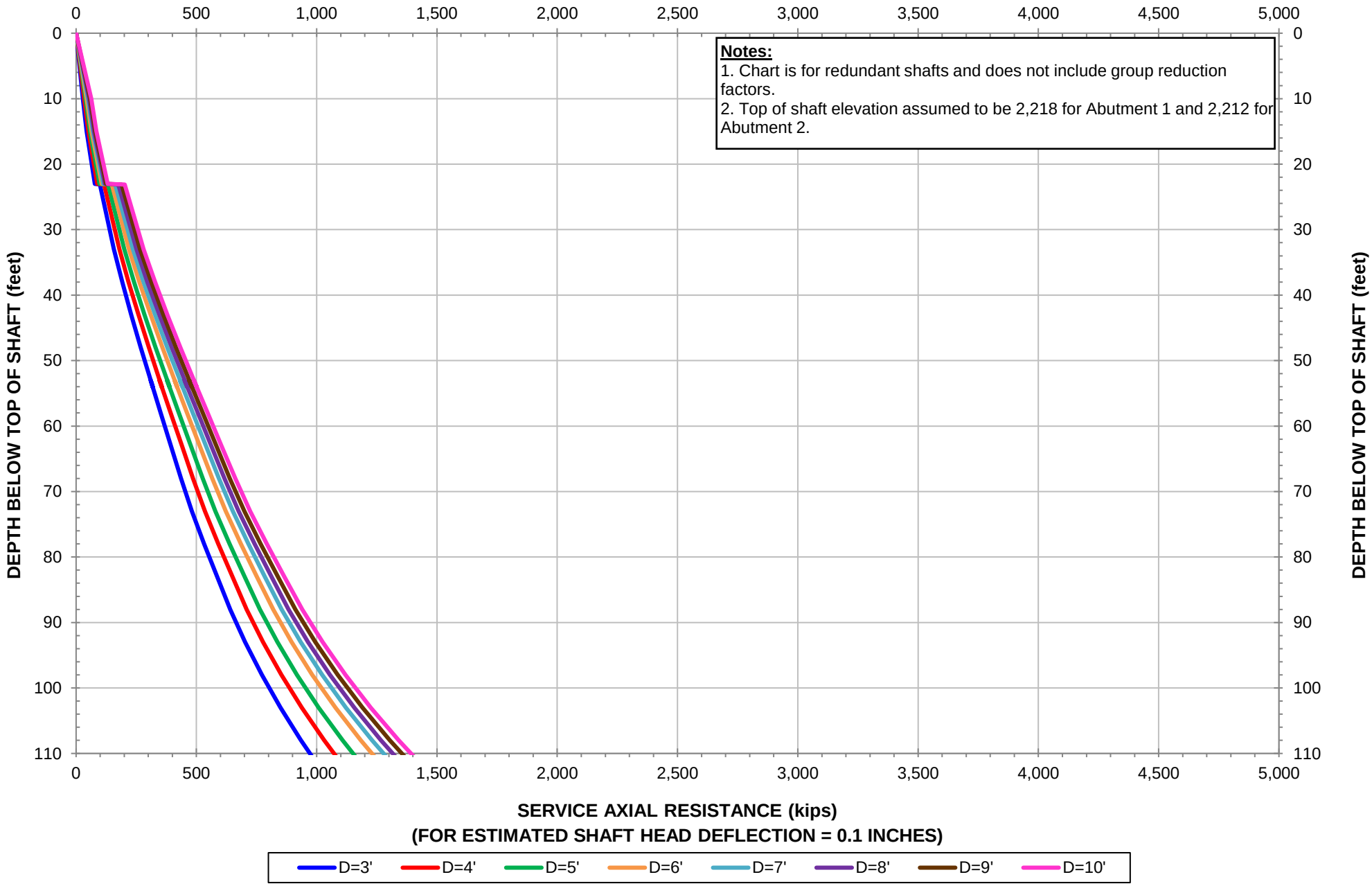
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road - I-10 to River Road: Rillito Creek Abutments for 100-yr Flood - Preliminary



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

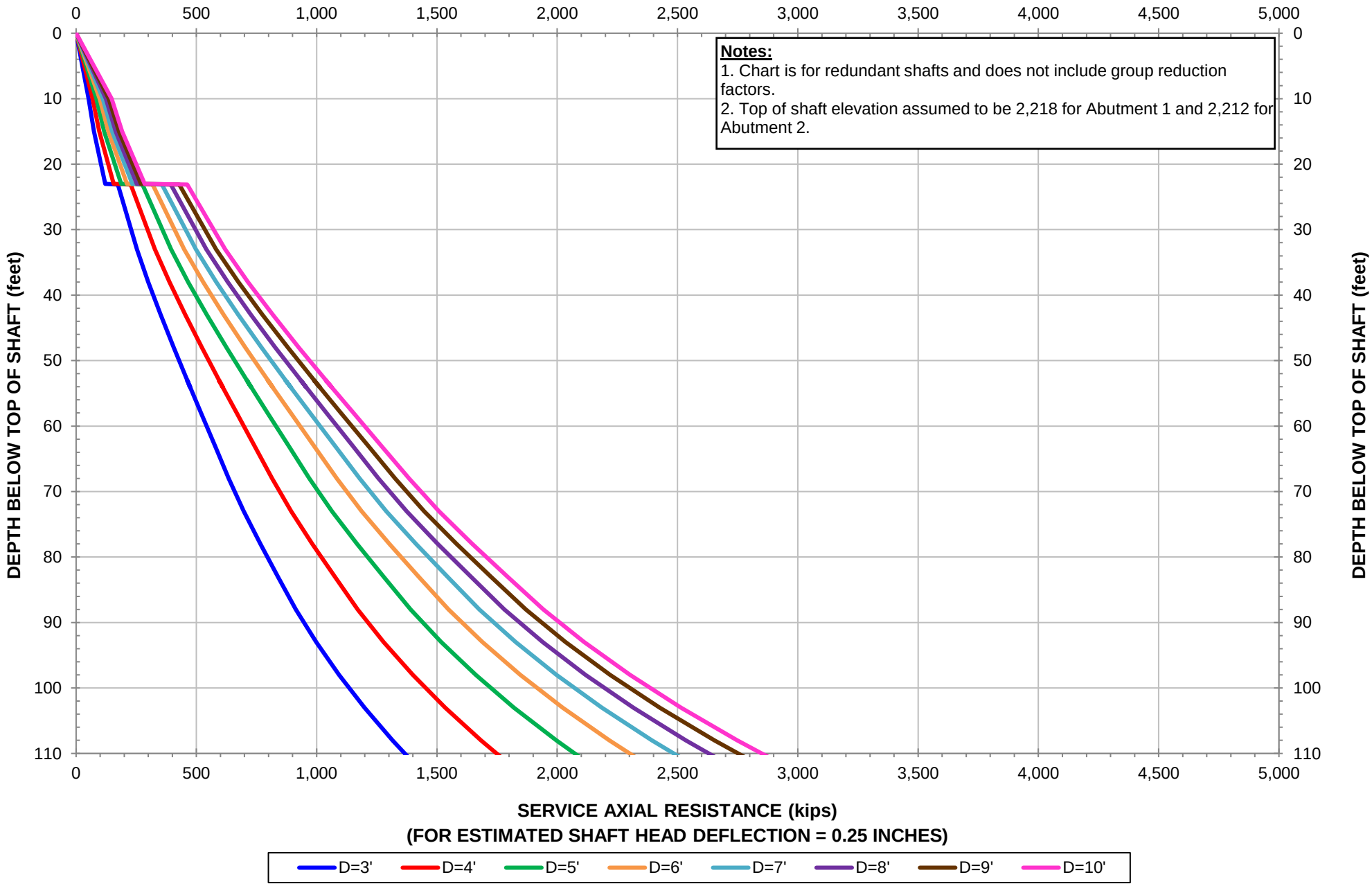
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road - I-10 to River Road: Rillito Creek Abutments for 100-yr Flood - Preliminary



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

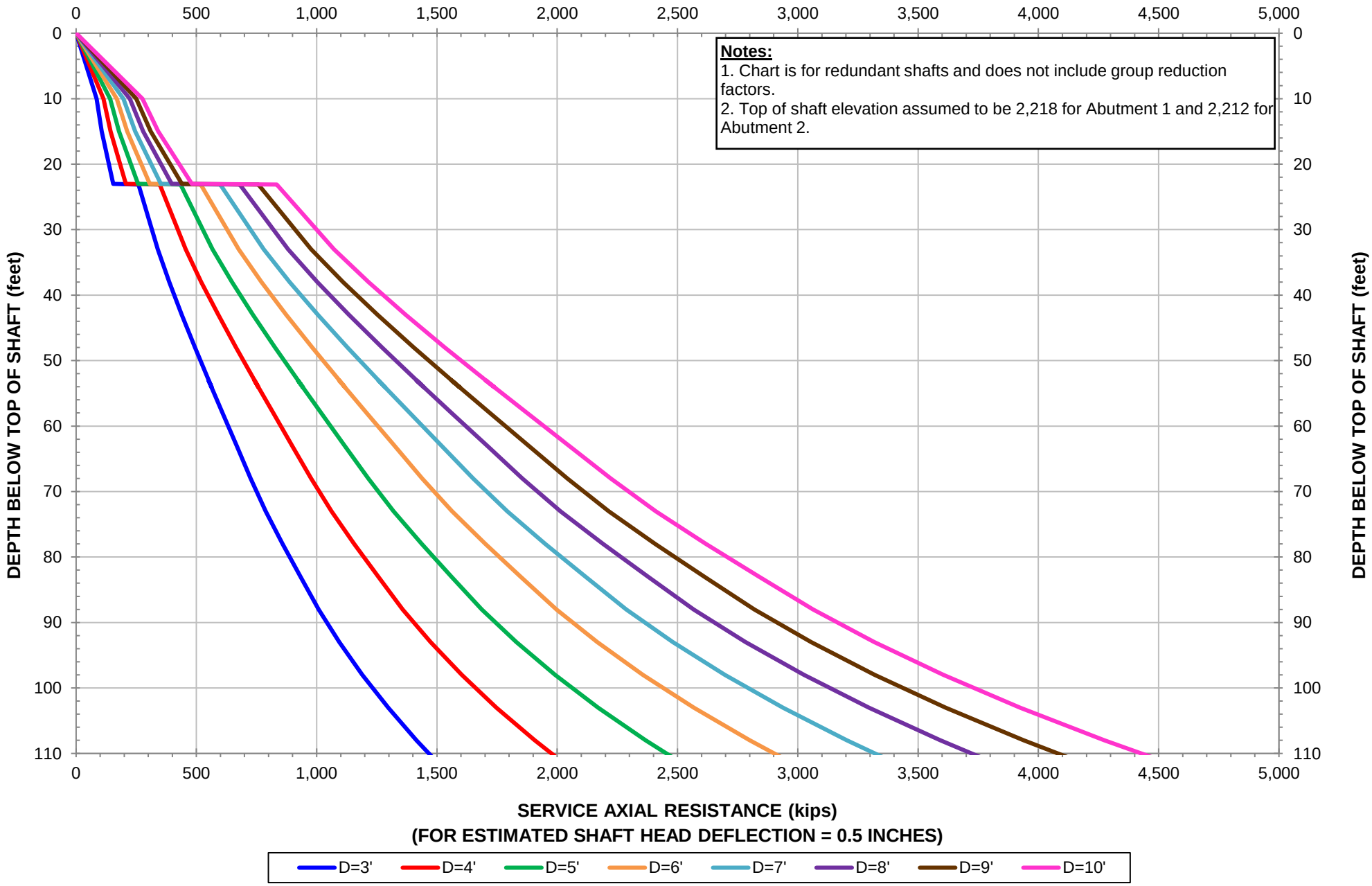
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road - I-10 to River Road: Rillito Creek Abutments for 100-yr Flood - Preliminary



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

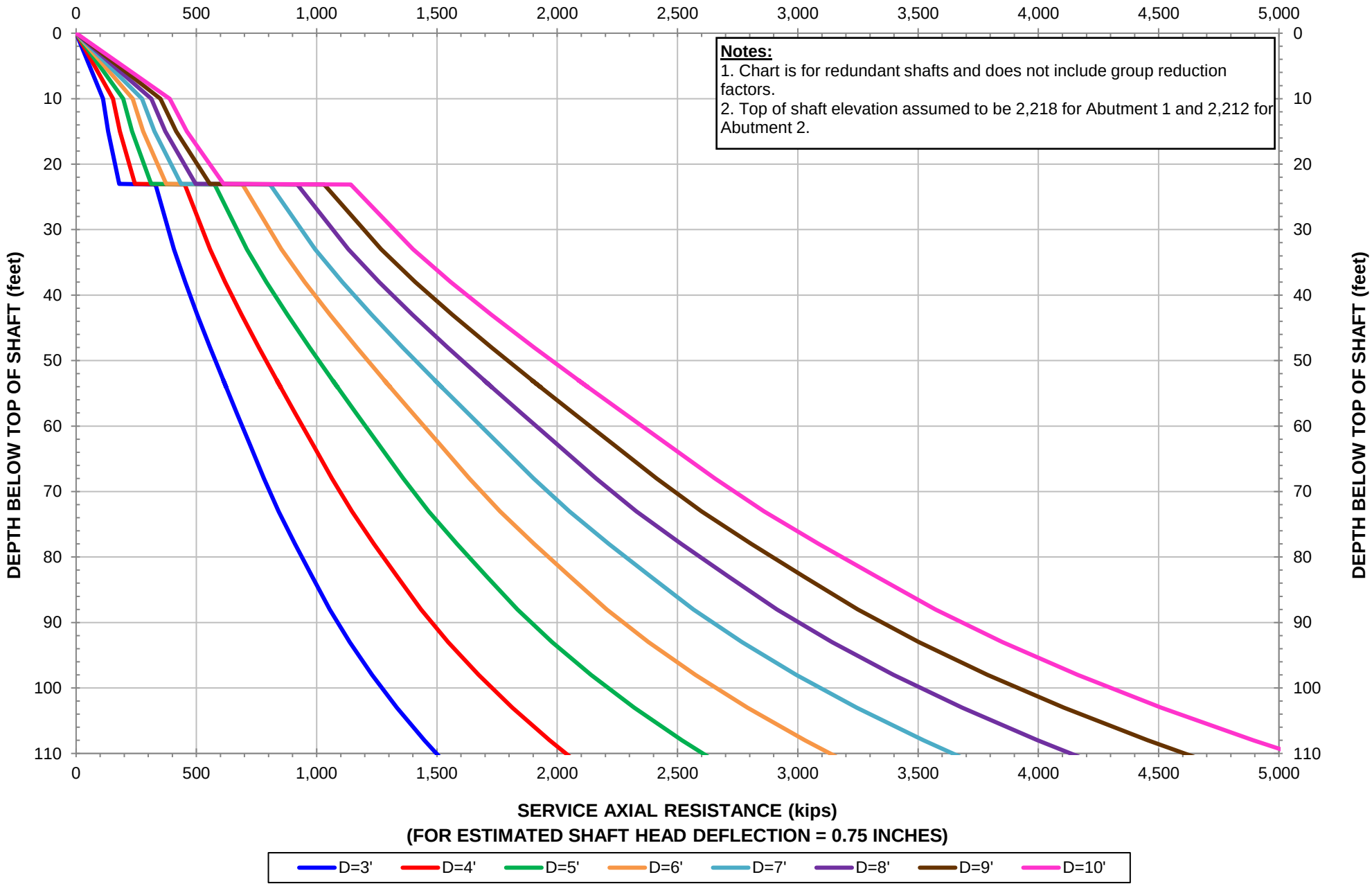
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road - I-10 to River Road: Rillito Creek Abutments for 100-yr Flood - Preliminary



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

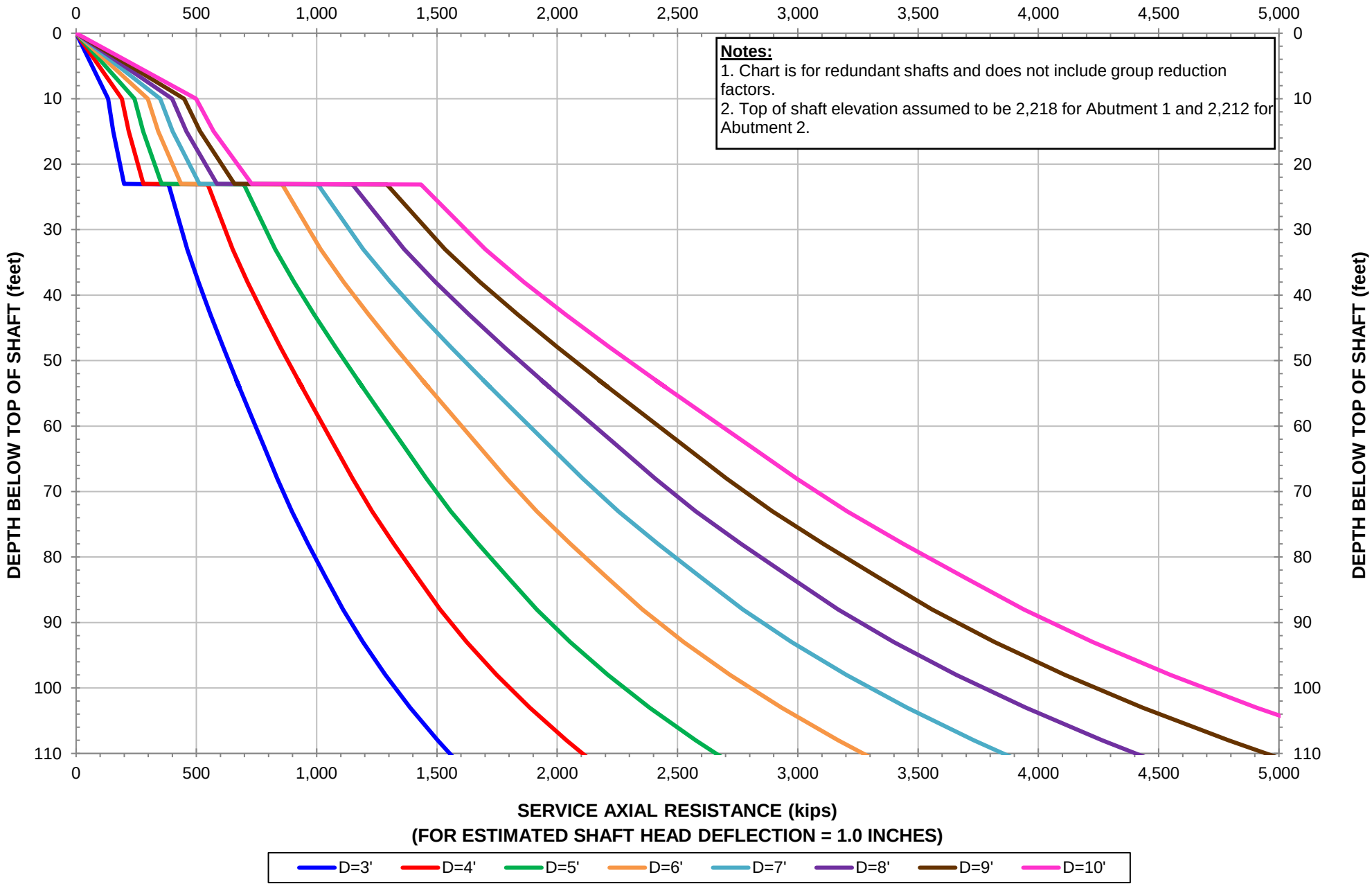
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road - I-10 to River Road: Rillito Creek Abutments for 100-yr Flood - Preliminary



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

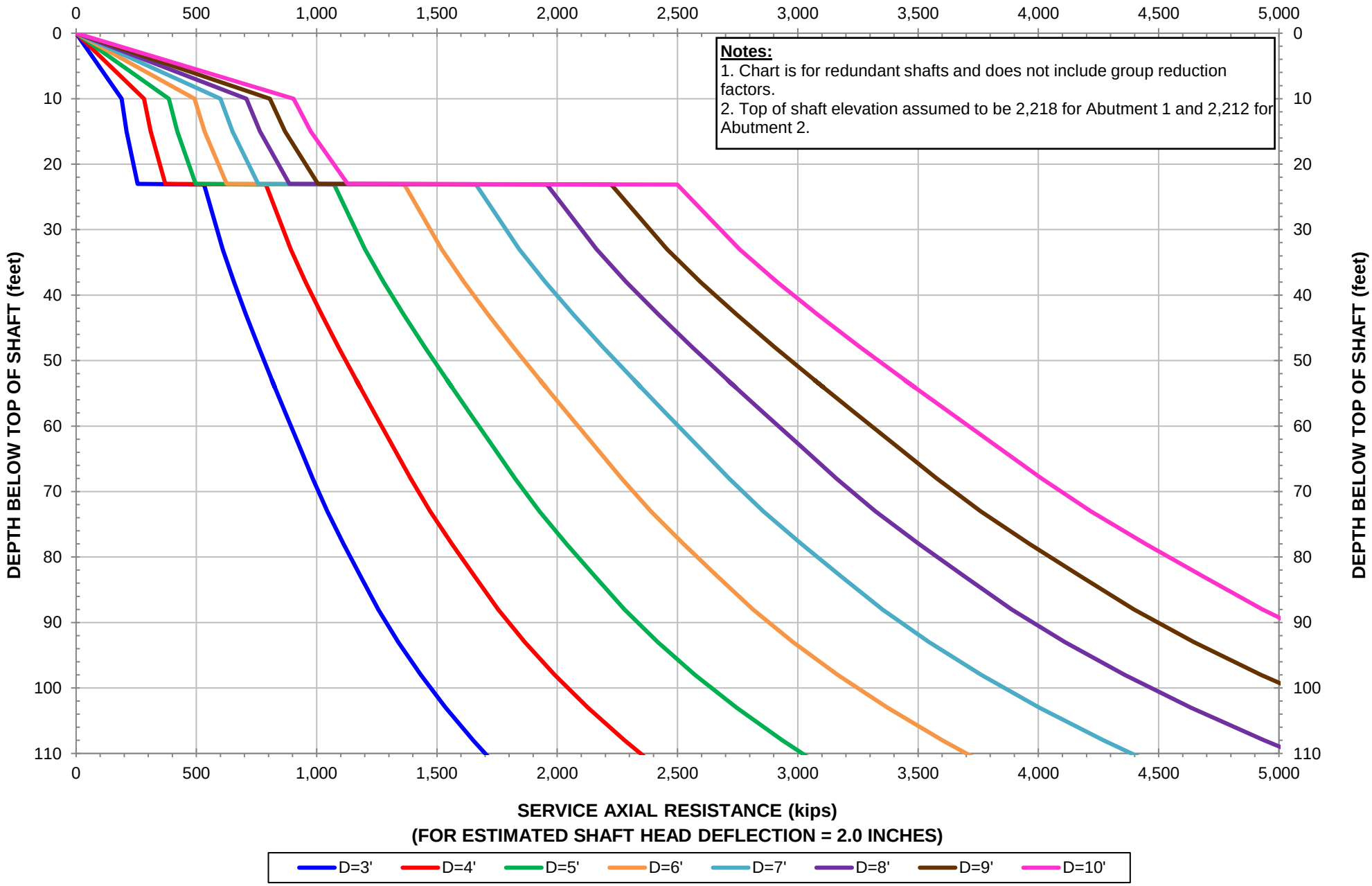
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road - I-10 to River Road: Rillito Creek Abutments for 100-yr Flood - Preliminary



Made By: KAR (Rev. 1)
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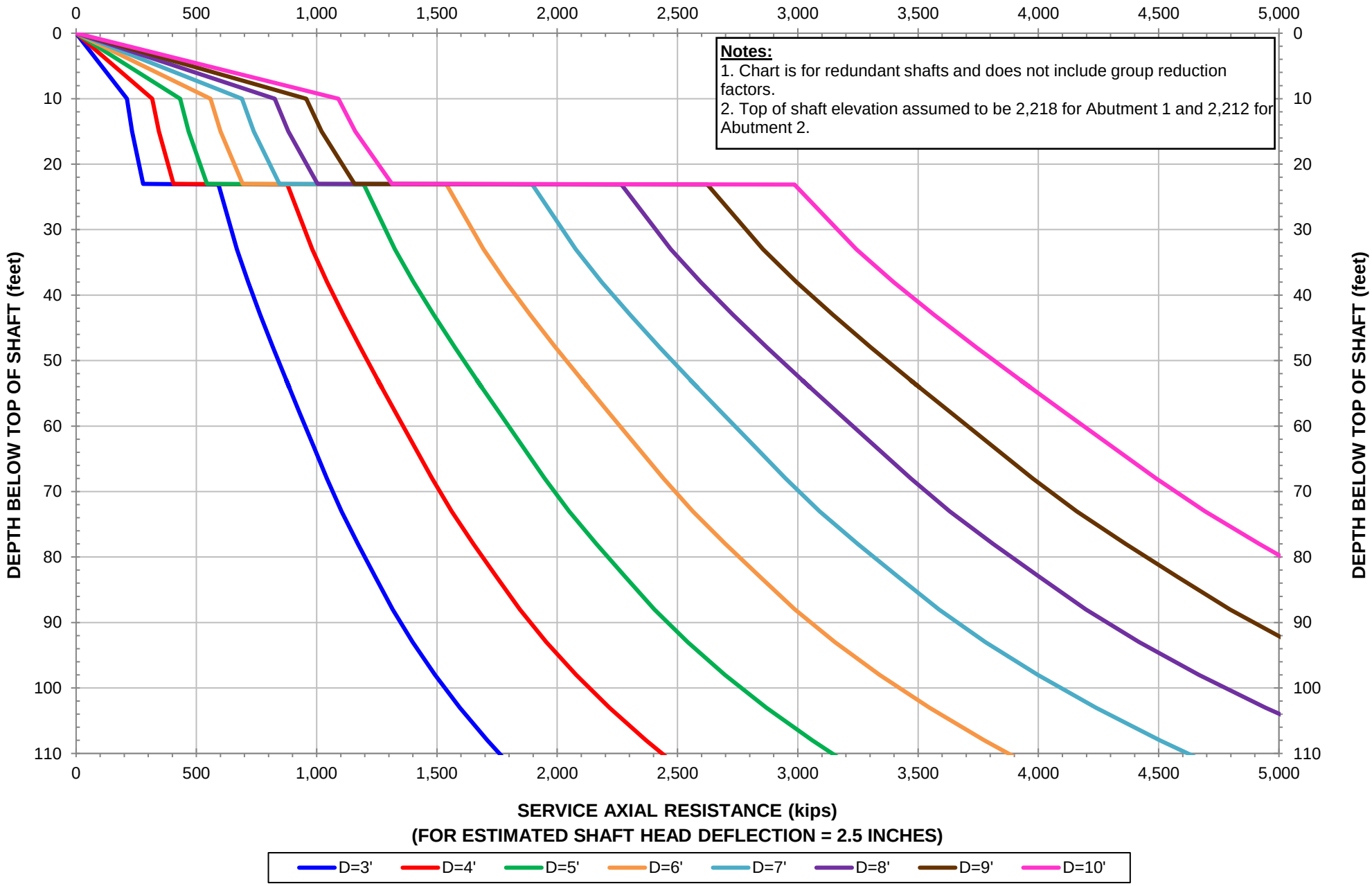
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road - I-10 to River Road: Rillito Creek Abutments for 100-yr Flood - Preliminary



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Checked By: RMP
Approved By: RMP

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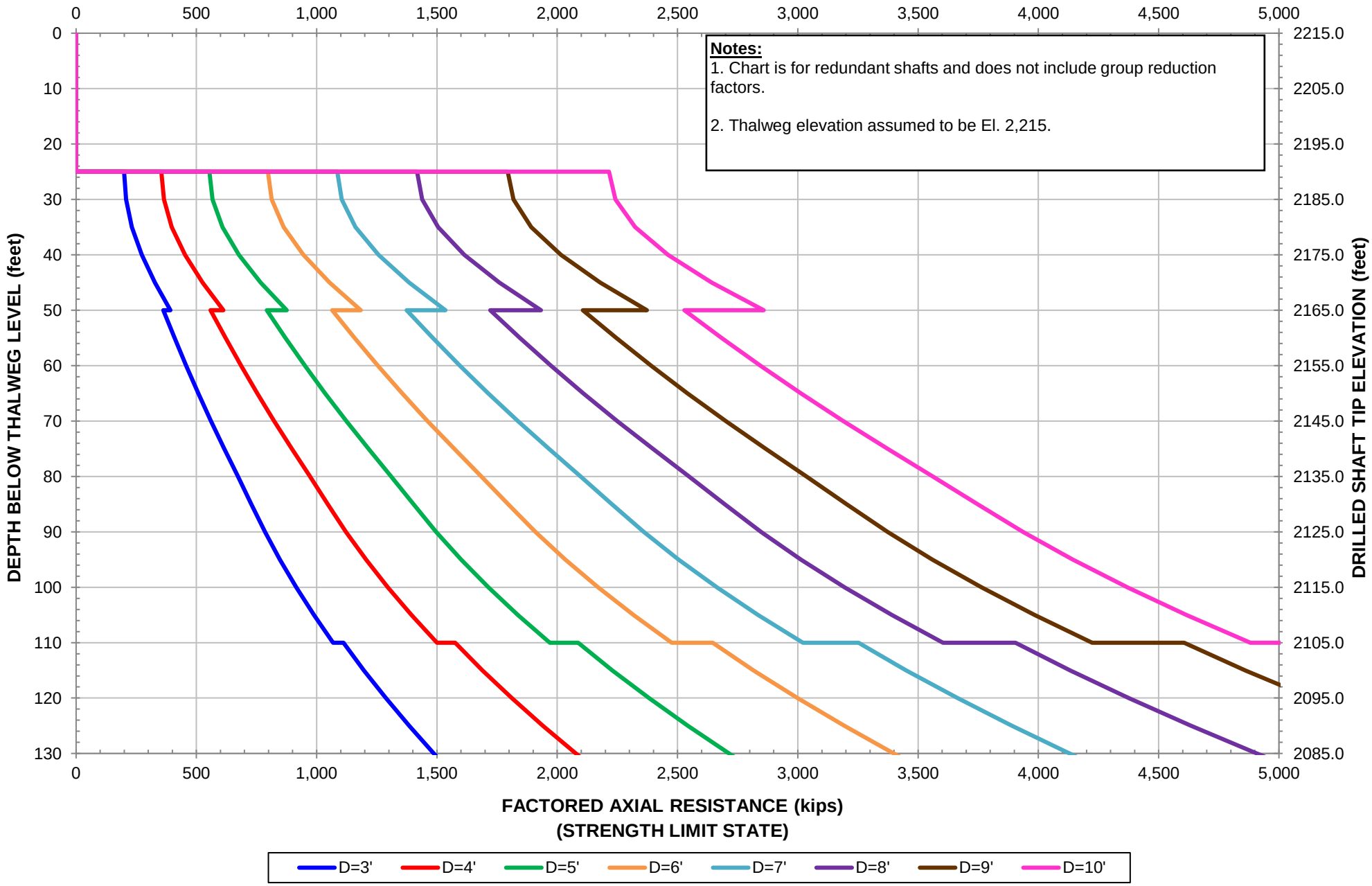
INITIAL

5/11/2020

19128078

FACTORED DRILLED SHAFT AXIAL RESISTANCE - STRENGTH I LIMIT STATE

Sunset Road - I-10 to River Road: Rillito Creek Bridge Piers for 100-yr Flood - Preliminary



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RCP-1

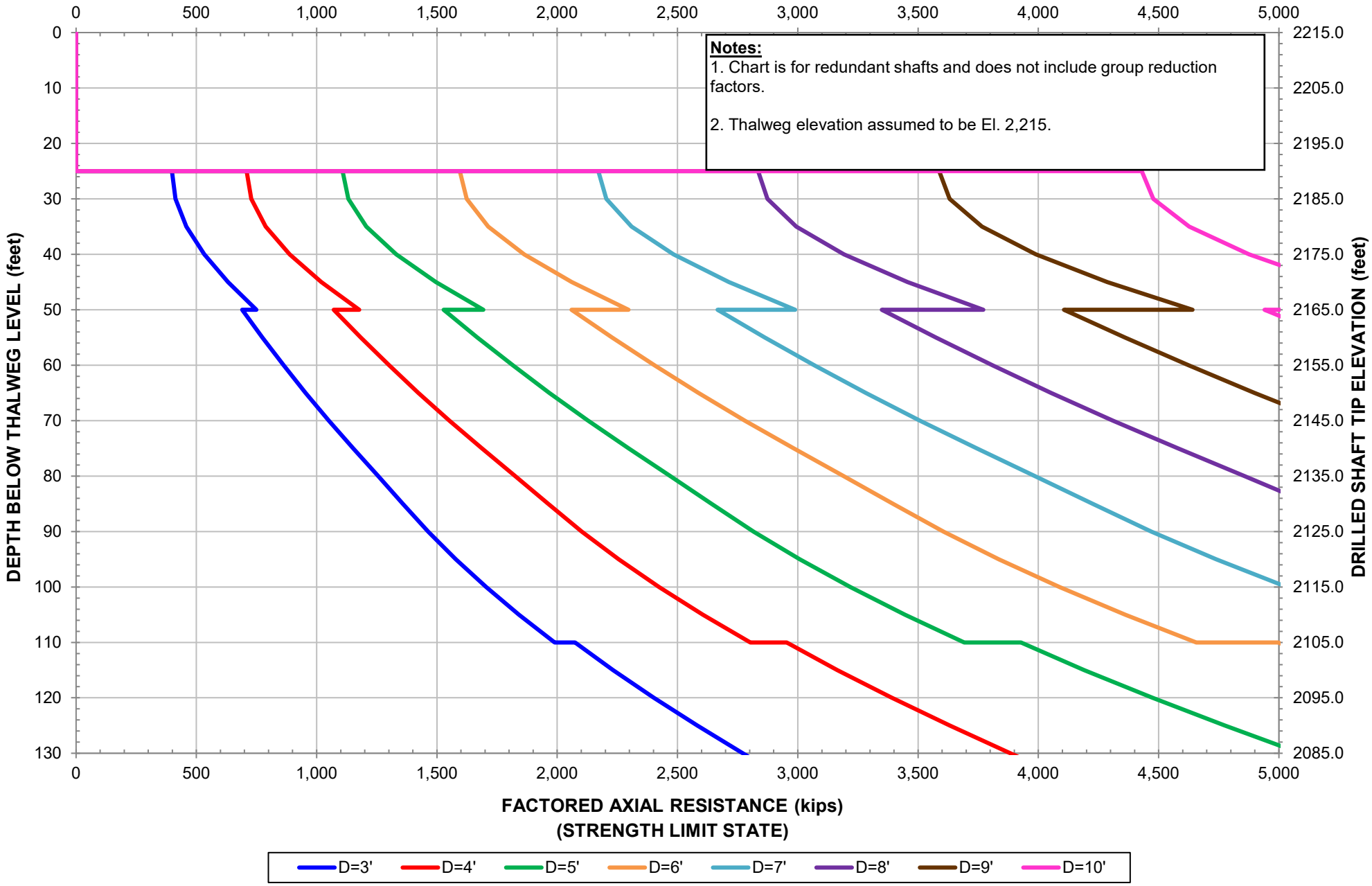
INITIAL

5/11/2020

19128078

FACTORED DRILLED SHAFT AXIAL RESISTANCE - EXTREME EVENT LIMIT STATE

Sunset Road - I-10 to River Road: Rillito Creek Bridge Piers for 500-yr Flood - Preliminary



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

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RCP-2

INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

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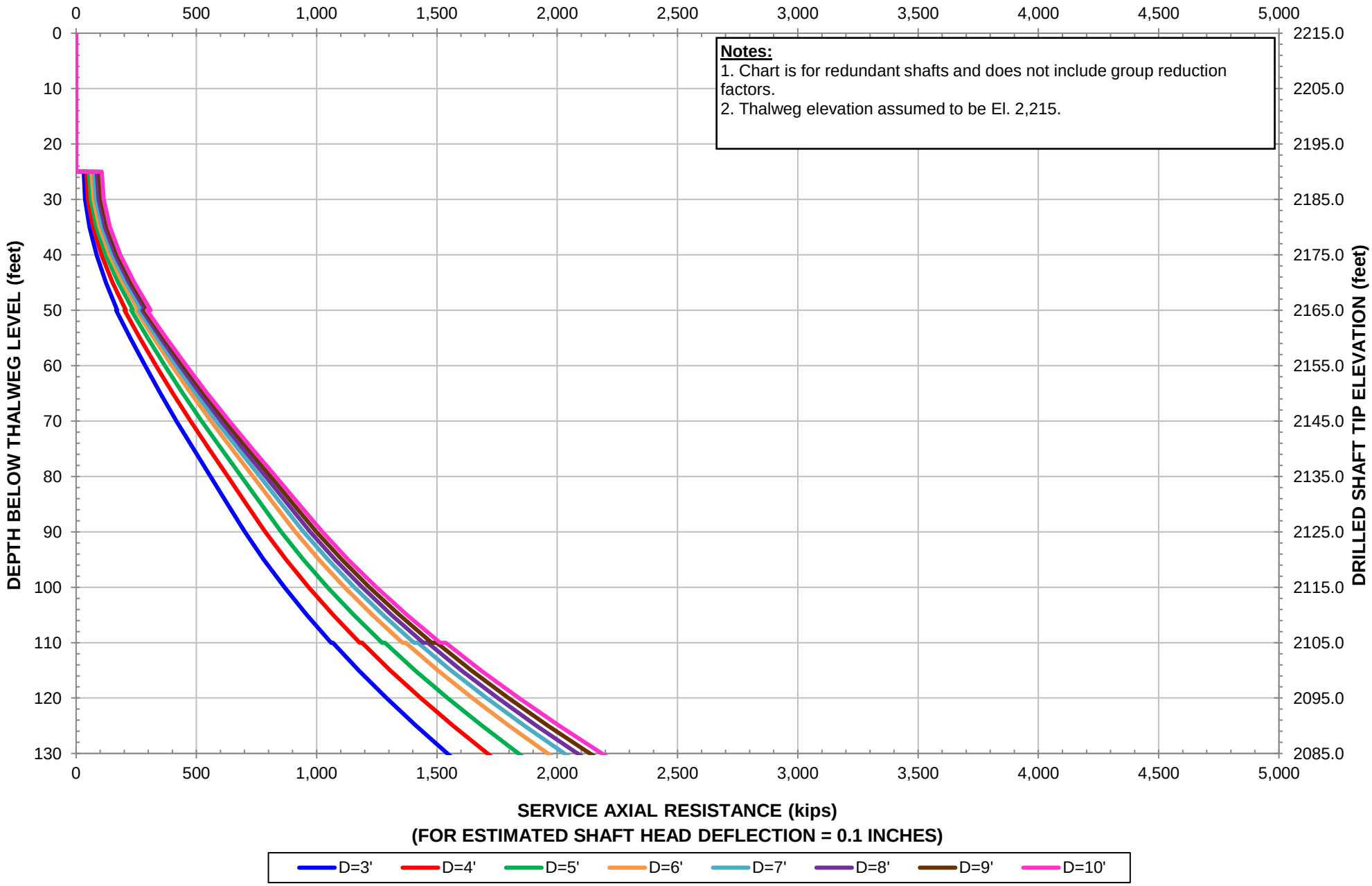
Sunset Road - I-10 to River Road: Rillito Creek Bridge Piers for 100-yr Flood - Preliminary



Made By: KAR (Rev. 1)
Checked By: RMP
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RCP-3

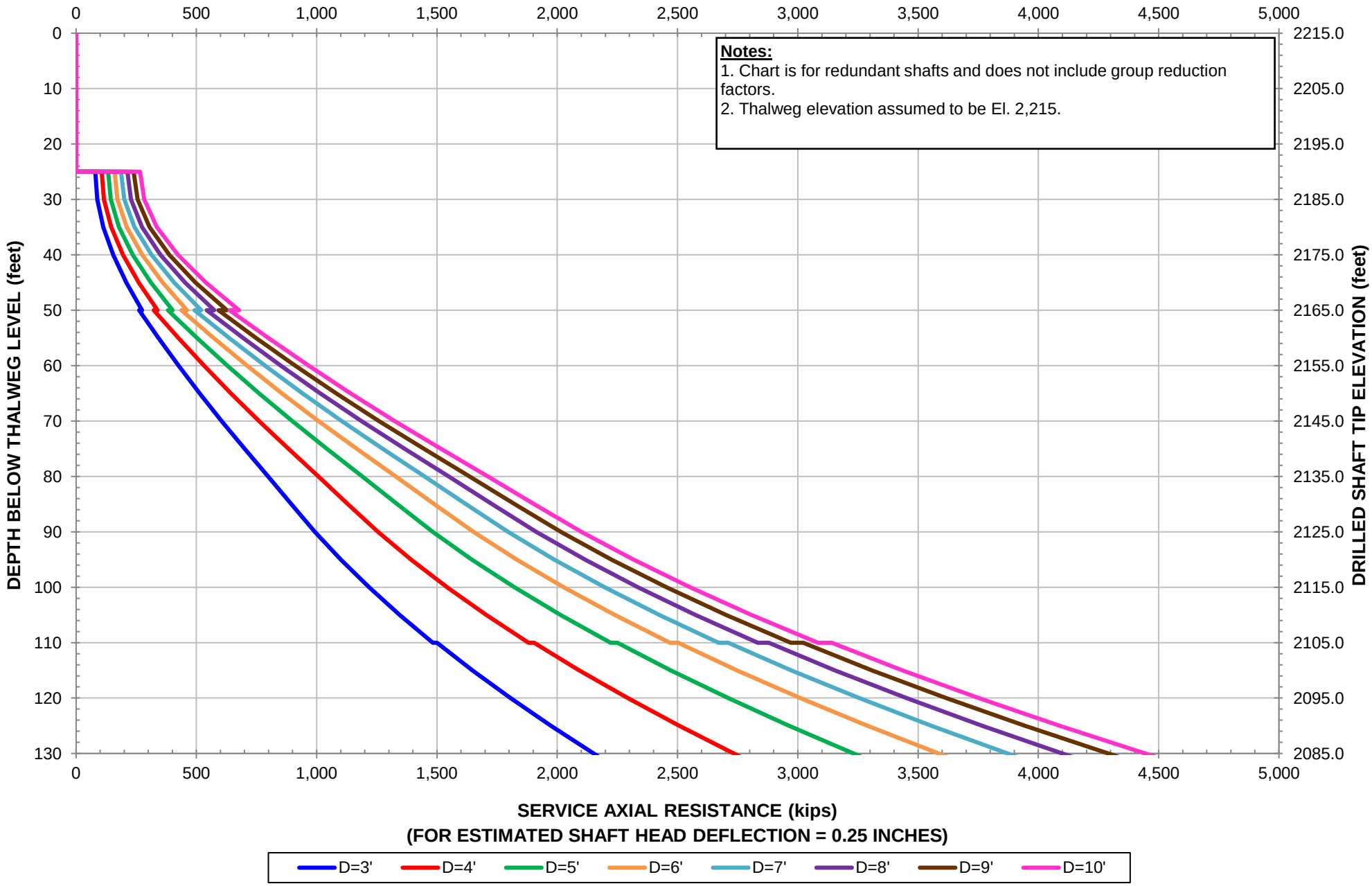
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road - I-10 to River Road: Rillito Creek Bridge Piers for 100-yr Flood - Preliminary



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Checked By: RMP
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GOLDER

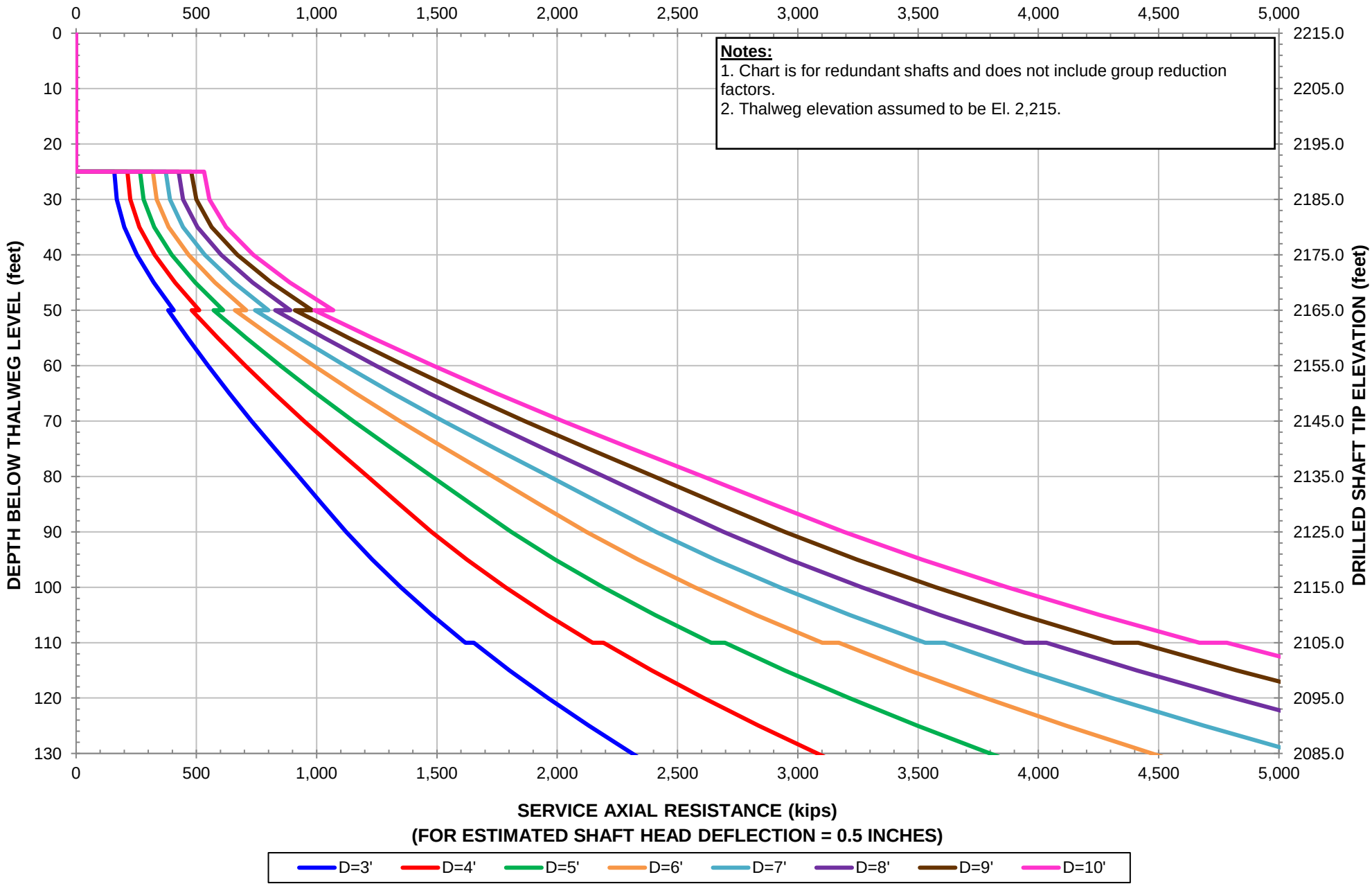
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road - I-10 to River Road: Rillito Creek Bridge Piers for 100-yr Flood - Preliminary



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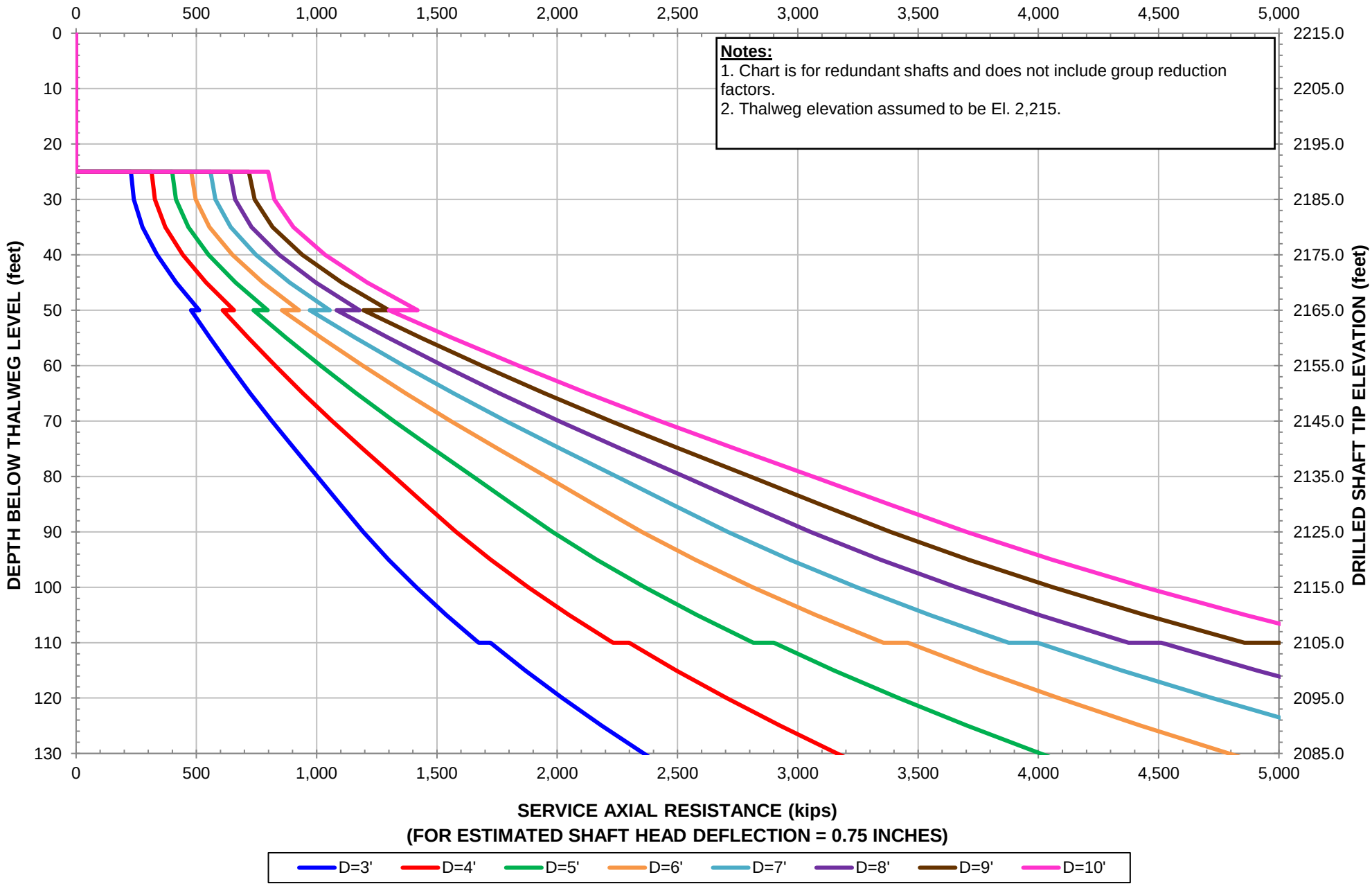
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road - I-10 to River Road: Rillito Creek Bridge Piers for 100-yr Flood - Preliminary



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5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

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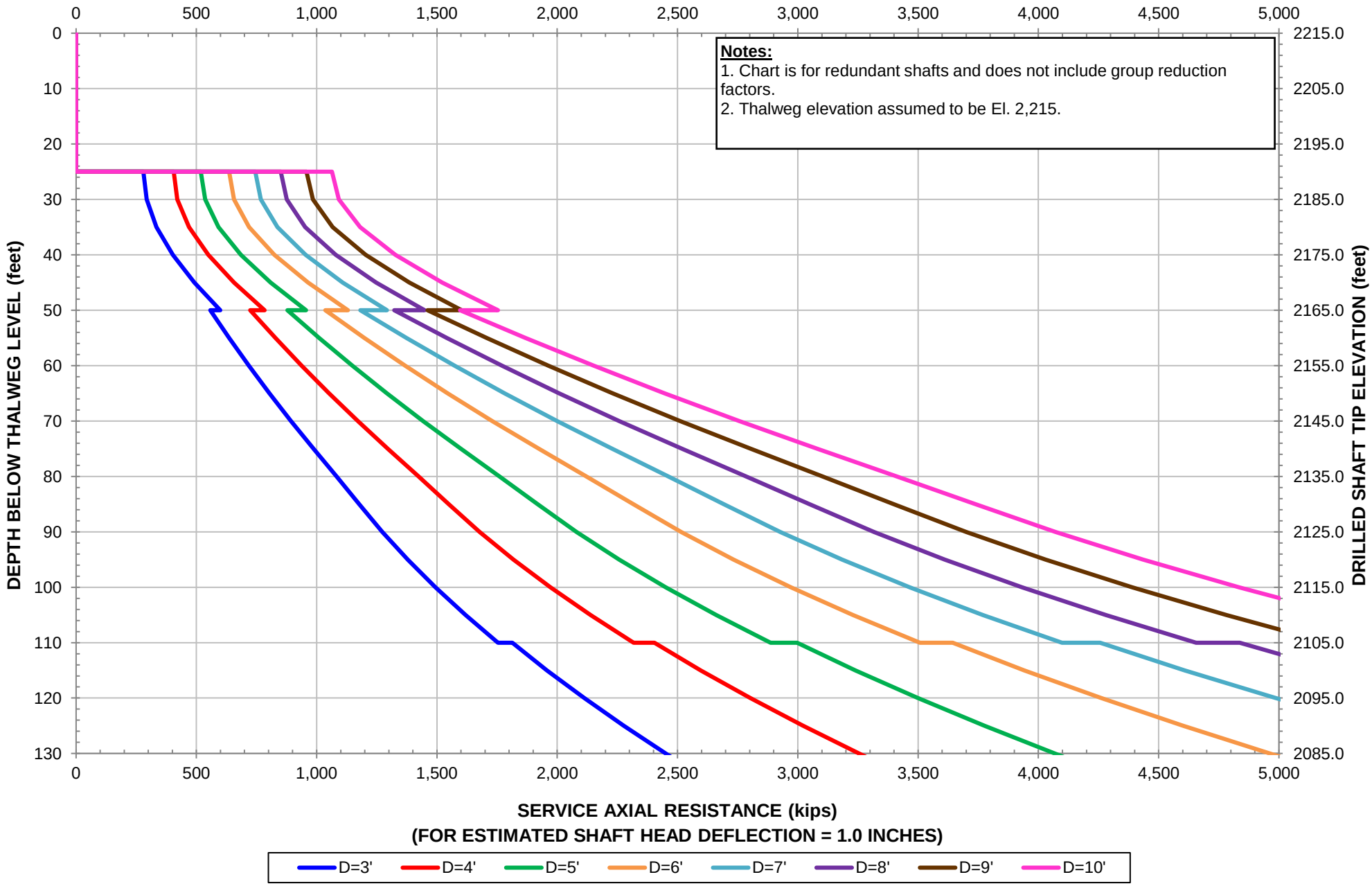

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Checked By: RMP
Approved By: RMP

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INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

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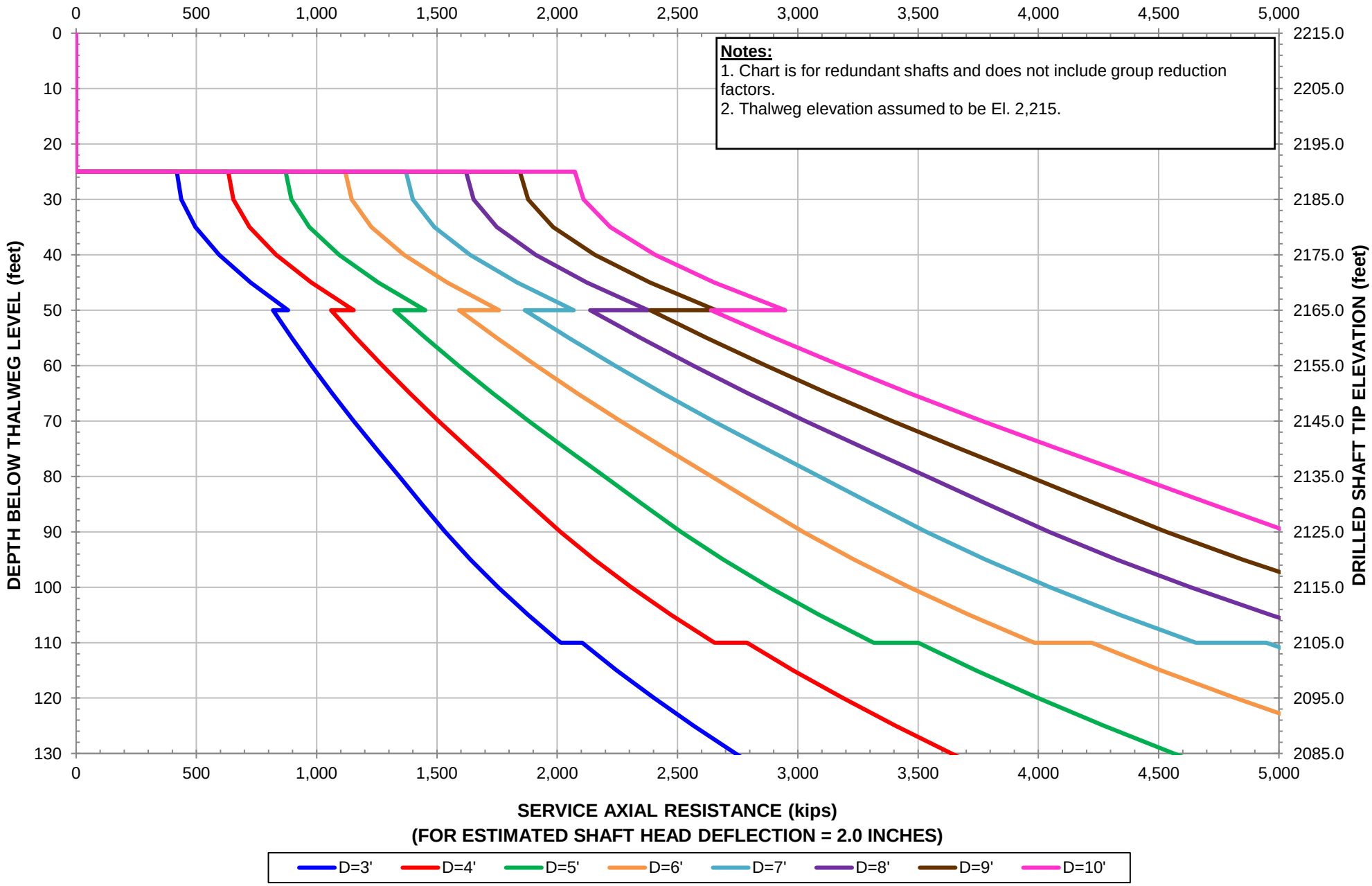

Made By: KAR (Rev. 1)
Checked By: RMP
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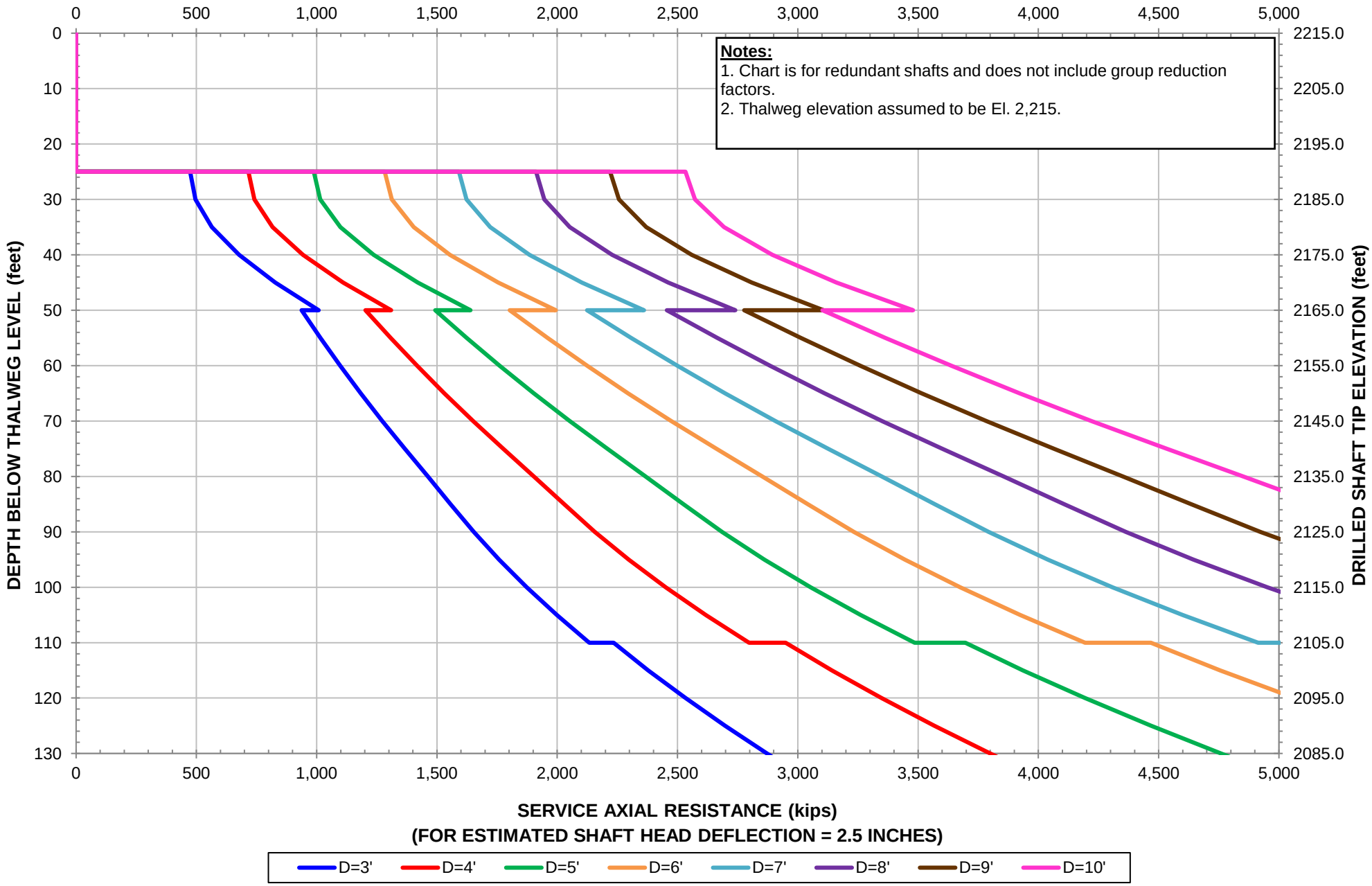
INITIAL

5/11/2020

FACTORED DRILLED SHAFT AXIAL RESISTANCE - SERVICE LIMIT STATE

19128078

Sunset Road - I-10 to River Road: Rillito Creek Bridge Piers for 100-yr Flood - Preliminary



Made By: KAR (Rev. 1)
Checked By: RMP
Approved By: RMP

GOLDER

APPENDIX D

Bearing Resistance Charts

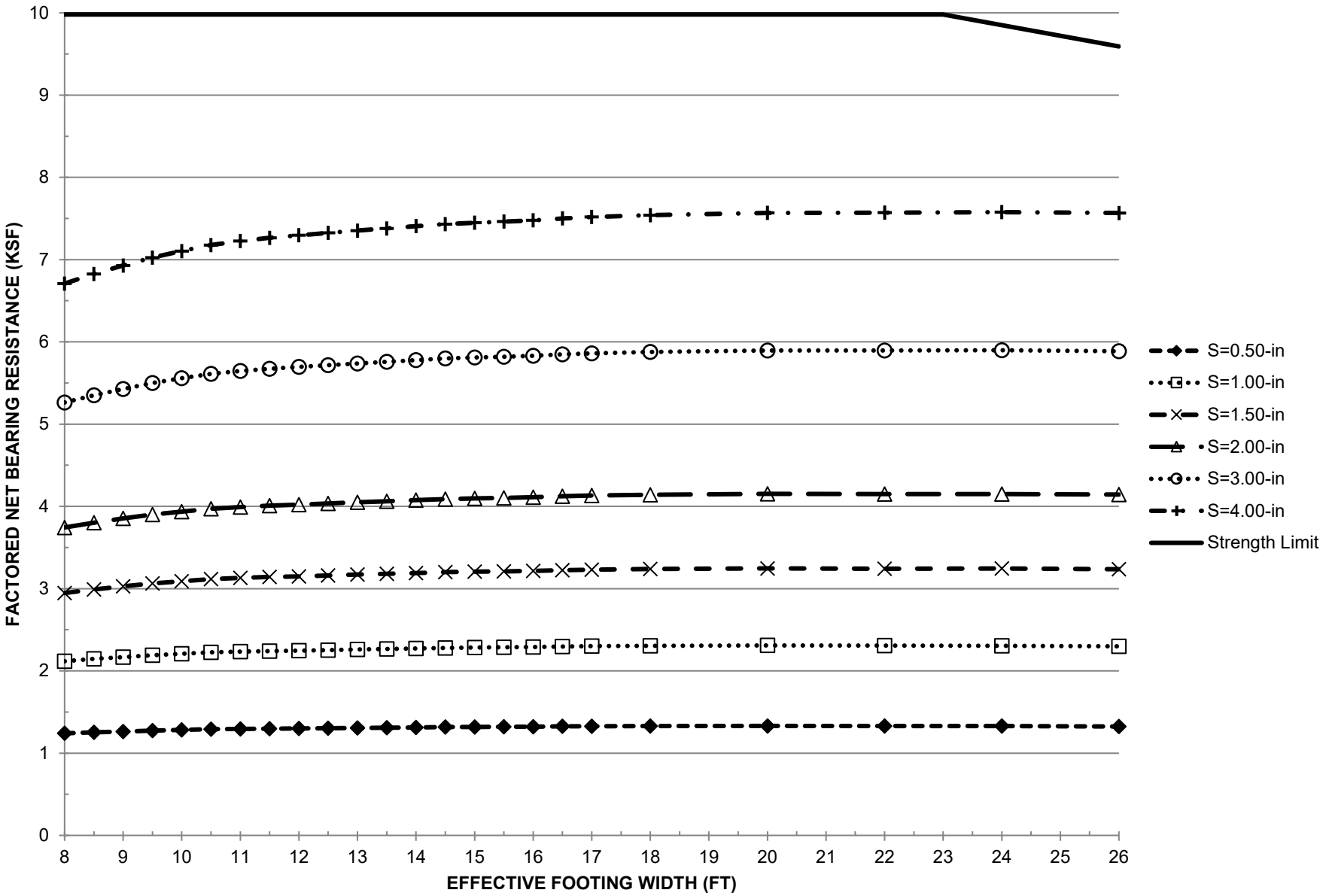
INITIAL

May 2020

FACTORED SPREAD FOOTING BEARING RESISTANCE - STRENGTH AND SERVICE LIMIT STATES

19128078

Sunset Road: I-10 to River - UPRR Bridge Footings and East Approach Walls (Df = 5')



Made By: RMP
Checked By: KR
Approved By: MLP

GOLDER

FIGURE D-1

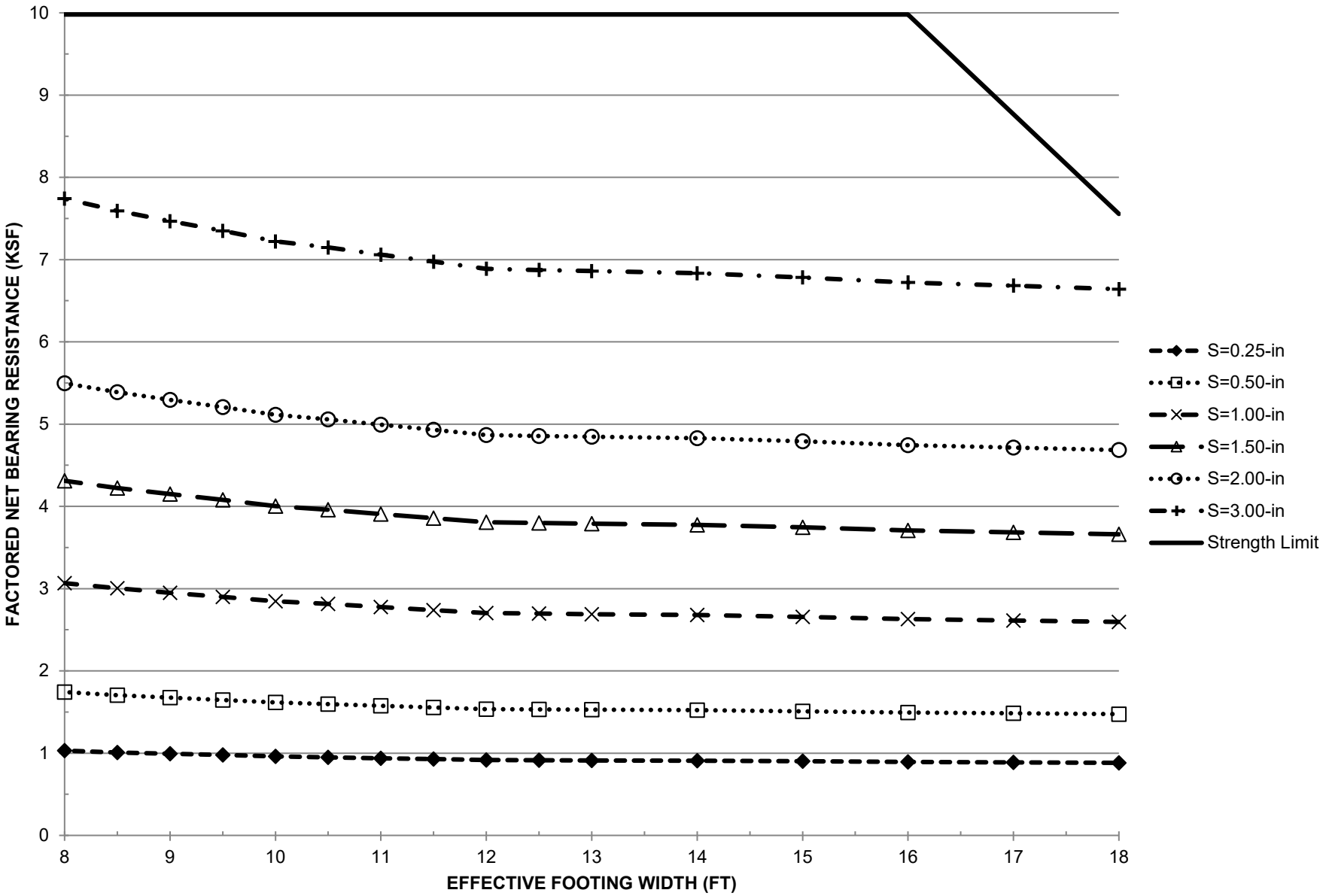
INITIAL

May 2020

FACTORED SPREAD FOOTING BEARING RESISTANCE - STRENGTH AND SERVICE LIMIT STATES

19128078

Sunset Road: I-10 to River - Rillito Creek Wingwalls (Df = 3', min)



Made By: RMP
Checked By: KR
Approved By: MLP

GOLDER

FIGURE D-2

APPENDIX E

Important Information About Your Geotechnical Report

Important Information about This

Geotechnical-Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

While you cannot eliminate all such risks, you can manage them. The following information is provided to help.

The Geoprofessional Business Association (GBA) has prepared this advisory to help you – assumedly a client representative – interpret and apply this geotechnical-engineering report as effectively as possible. In that way, you can benefit from a lowered exposure to problems associated with subsurface conditions at project sites and development of them that, for decades, have been a principal cause of construction delays, cost overruns, claims, and disputes. If you have questions or want more information about any of the issues discussed herein, contact your GBA-member geotechnical engineer. Active engagement in GBA exposes geotechnical engineers to a wide array of risk-confrontation techniques that can be of genuine benefit for everyone involved with a construction project.

Understand the Geotechnical-Engineering Services Provided for this Report

Geotechnical-engineering services typically include the planning, collection, interpretation, and analysis of exploratory data from widely spaced borings and/or test pits. Field data are combined with results from laboratory tests of soil and rock samples obtained from field exploration (if applicable), observations made during site reconnaissance, and historical information to form one or more models of the expected subsurface conditions beneath the site. Local geology and alterations of the site surface and subsurface by previous and proposed construction are also important considerations. Geotechnical engineers apply their engineering training, experience, and judgment to adapt the requirements of the prospective project to the subsurface model(s). Estimates are made of the subsurface conditions that will likely be exposed during construction as well as the expected performance of foundations and other structures being planned and/or affected by construction activities.

The culmination of these geotechnical-engineering services is typically a geotechnical-engineering report providing the data obtained, a discussion of the subsurface model(s), the engineering and geologic engineering assessments and analyses made, and the recommendations developed to satisfy the given requirements of the project. These reports may be titled investigations, explorations, studies, assessments, or evaluations. Regardless of the title used, the geotechnical-engineering report is an engineering interpretation of the subsurface conditions within the context of the project and does not represent a close examination, systematic inquiry, or thorough investigation of all site and subsurface conditions.

Geotechnical-Engineering Services are Performed for Specific Purposes, Persons, and Projects, and At Specific Times

Geotechnical engineers structure their services to meet the specific needs, goals, and risk management preferences of their clients. A geotechnical-engineering study conducted for a given civil engineer will not likely meet the needs of a civil-works constructor or even a different civil engineer. Because each geotechnical-engineering study is unique, each geotechnical-engineering report is unique, prepared *solely* for the client.

Likewise, geotechnical-engineering services are performed for a specific project and purpose. For example, it is unlikely that a geotechnical-engineering study for a refrigerated warehouse will be the same as one prepared for a parking garage; and a few borings drilled during a preliminary study to evaluate site feasibility will not be adequate to develop geotechnical design recommendations for the project.

Do not rely on this report if your geotechnical engineer prepared it:

- for a different client;
- for a different project or purpose;
- for a different site (that may or may not include all or a portion of the original site); or
- before important events occurred at the site or adjacent to it; e.g., man-made events like construction or environmental remediation, or natural events like floods, droughts, earthquakes, or groundwater fluctuations.

Note, too, the reliability of a geotechnical-engineering report can be affected by the passage of time, because of factors like changed subsurface conditions; new or modified codes, standards, or regulations; or new techniques or tools. *If you are the least bit uncertain* about the continued reliability of this report, contact your geotechnical engineer before applying the recommendations in it. A minor amount of additional testing or analysis after the passage of time – if any is required at all – could prevent major problems.

Read this Report in Full

Costly problems have occurred because those relying on a geotechnical-engineering report did not read the report in its entirety. Do not rely on an executive summary. Do not read selective elements only. *Read and refer to the report in full.*

You Need to Inform Your Geotechnical Engineer About Change

Your geotechnical engineer considered unique, project-specific factors when developing the scope of study behind this report and developing the confirmation-dependent recommendations the report conveys. Typical changes that could erode the reliability of this report include those that affect:

- the site's size or shape;
- the elevation, configuration, location, orientation, function or weight of the proposed structure and the desired performance criteria;
- the composition of the design team; or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project or site changes – even minor ones – and request an assessment of their impact. *The geotechnical engineer who prepared this report cannot accept*

responsibility or liability for problems that arise because the geotechnical engineer was not informed about developments the engineer otherwise would have considered.

Most of the "Findings" Related in This Report Are Professional Opinions

Before construction begins, geotechnical engineers explore a site's subsurface using various sampling and testing procedures. *Geotechnical engineers can observe actual subsurface conditions only at those specific locations where sampling and testing is performed.* The data derived from that sampling and testing were reviewed by your geotechnical engineer, who then applied professional judgement to form opinions about subsurface conditions throughout the site. Actual sitewide-subsurface conditions may differ – maybe significantly – from those indicated in this report. Confront that risk by retaining your geotechnical engineer to serve on the design team through project completion to obtain informed guidance quickly, whenever needed.

This Report's Recommendations Are Confirmation-Dependent

The recommendations included in this report – including any options or alternatives – are confirmation-dependent. In other words, they are not final, because the geotechnical engineer who developed them relied heavily on judgement and opinion to do so. Your geotechnical engineer can finalize the recommendations *only after observing actual subsurface conditions* exposed during construction. If through observation your geotechnical engineer confirms that the conditions assumed to exist actually do exist, the recommendations can be relied upon, assuming no other changes have occurred. *The geotechnical engineer who prepared this report cannot assume responsibility or liability for confirmation-dependent recommendations if you fail to retain that engineer to perform construction observation.*

This Report Could Be Misinterpreted

Other design professionals' misinterpretation of geotechnical-engineering reports has resulted in costly problems. Confront that risk by having your geotechnical engineer serve as a continuing member of the design team, to:

- confer with other design-team members;
- help develop specifications;
- review pertinent elements of other design professionals' plans and specifications; and
- be available whenever geotechnical-engineering guidance is needed.

You should also confront the risk of constructors misinterpreting this report. Do so by retaining your geotechnical engineer to participate in prebid and preconstruction conferences and to perform construction-phase observations.

Give Constructors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can shift unanticipated-subsurface-conditions liability to constructors by limiting the information they provide for bid preparation. To help prevent the costly, contentious problems this practice has caused, include the complete geotechnical-engineering report, along with any attachments or appendices, with your contract documents, *but be certain to note conspicuously that you've included the material for information purposes only.* To avoid misunderstanding, you may also want to note that "informational purposes" means constructors have no right to rely on the interpretations, opinions, conclusions, or recommendations in the report. Be certain that constructors know they may learn about specific project requirements, including options selected from the report, *only* from the design drawings and specifications. Remind constructors that they may perform their own studies if they want to, and *be sure to allow enough time* to permit them to do so. Only then might you be in a position to give constructors the information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions. Conducting prebid and preconstruction conferences can also be valuable in this respect.

Read Responsibility Provisions Closely

Some client representatives, design professionals, and constructors do not realize that geotechnical engineering is far less exact than other engineering disciplines. This happens in part because soil and rock on project sites are typically heterogeneous and not manufactured materials with well-defined engineering properties like steel and concrete. That lack of understanding has nurtured unrealistic expectations that have resulted in disappointments, delays, cost overruns, claims, and disputes. To confront that risk, geotechnical engineers commonly include explanatory provisions in their reports. Sometimes labeled "limitations," many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Geoenvironmental Concerns Are Not Covered

The personnel, equipment, and techniques used to perform an environmental study – e.g., a "phase-one" or "phase-two" environmental site assessment – differ significantly from those used to perform a geotechnical-engineering study. For that reason, a geotechnical-engineering report does not usually provide environmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated subsurface environmental problems have led to project failures.* If you have not obtained your own environmental information about the project site, ask your geotechnical consultant for a recommendation on how to find environmental risk-management guidance.

Obtain Professional Assistance to Deal with Moisture Infiltration and Mold

While your geotechnical engineer may have addressed groundwater, water infiltration, or similar issues in this report, the engineer's services were not designed, conducted, or intended to prevent migration of moisture – including water vapor – from the soil through building slabs and walls and into the building interior, where it can cause mold growth and material-performance deficiencies. Accordingly, ***proper implementation of the geotechnical engineer's recommendations will not of itself be sufficient to prevent moisture infiltration. Confront the risk of moisture infiltration*** by including building-envelope or mold specialists on the design team. ***Geotechnical engineers are not building-envelope or mold specialists.***

GEOPROFESSIONAL BUSINESS ASSOCIATION

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e-mail: info@geoprofessional.org www.geoprofessional.org

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