Initial Pavement Design Report

Sunset Road
Interstate 10 to River Rd

Prepared for:

PIMA COUNTY
TRANSPORTATION

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PCDOT Project No. 4SRRIV

CONSOR Project No. 2019-023

Golder Associates Inc. Project No. 19128078

August 2020

Distribution List

1 electronic copy CONSOR

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1.0 INTRODUCTION

This report presents the results of Golder Associates Inc.'s (Golder) geotechnical and pavement 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. 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.

From a pavement design perspective, the project will consist of flexible pavement sections on River Road and Sunset Road until approximately 300 feet from the UPRR and I-10 bridges where a rigid pavement section will be used to tie in to the I-10 frontage roads. There are two through-lanes in each direction throughout the project. This project includes some re-work of the pavement from Phase 1 to tie in with the new embankment and to accommodate driveways for proposed development and to address changes to drainage configuration.

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 and pavement record drawings
- A field investigation consisting of three boreholes drilled for characterizing the pavement subgrade on River Road

- Three asphalt cores paired with the boreholes to confirm the thickness of the existing pavement on River Road
- Laboratory testing of representative material samples
- Preparation of a pavement design in accordance with Pima County design methodology using data collected by Golder
- Identification of any geotechnical issues or hazards that may critically impact pavements or limit design options
- Preparation of this report summarizing the results and recommendations for the pavement study

The geotechnical portions of our scope of services for the project are described in the Initial Preliminary Geotechnical Report under separate cover (Golder 2020). This report includes a discussion of the regional geology and site conditions; the investigation program for bridges, walls, and embankments; and additional recommendations.

1.3 Pavement Design Standards

The design of the flexible pavements presented in this report is in accordance with the 2013 Pima County Roadway Design Manual (PCRDM, PCDOT 2016). Pima County's procedures are generally consistent with the Arizona Department of Transportation Pavement Design Manual (ADOT 2017) with modifications for local adjustments to R-Value correlation procedures and coefficients used in the design process. Golder's designs assume the use of the Pima Association of Governments Standard Specifications (PAG 2014). Asphalt mixes should be the latest approved mixes by PAG.

2.0 SITE INVESTIGATION

The only location where pavement subgrade explorations were performed is along River Road where the new Sunset Alignment will tie it. This is the only location where the proposed finished grade is within 5 feet of existing grade. In all other locations on Phase 2, the pavement subgrade will consist of at least 5 feet of imported fill.

2.1 Geotechnical Exploration Program

Golder conducted a field program consisting of three pavement boreholes in the existing right lane of eastbound (EB) River Road. At each location, a 10-inch diameter pavement core was collected and the thickness of existing asphaltic concrete (AC) and aggregate base (AB) was documented. Investigation locations are shown in Figure A-2 in Appendix A. Golder's borehole logs are included in Appendix A.

Southlands Engineering, LLC drilled all pavement cores and boreholes on April 21, 2020. 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 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 or in ring sample tubes. Bulk samples of auger cuttings were collected as well. Selected samples were transported to ATEK in Tucson for geotechnical testing.

Golder geotechnical personnel were present throughout the field investigation program to observe the drilling and coring 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)”.

A summary of investigation locations is provided in Table 1. Planned borehole locations were surveyed by EEC and Golder measured any field offset from surveyed locations to report the approximate final coordinates.

Table 1: Summary of Boreholes

Borehole No.	Northing (feet)	Easting (feet)	Existing Ground Elevation (feet)	Depth (feet)
BH-06	478,860	971,043	2229.5	6.5
BH-07	478,553	971,443	2235.8	21.5
BH-08	478,257	971,993	2236.0	6.5

2.1.1 Pavement Coring Results

The record drawing for River Road from Orange Grove Road to Shannon Road (Johnson – Brittain & Associates 2008) indicates that the pavement section for River Road consists of 4 inches of AC over 11 inches of AB in the vicinity of this project. The pavement coring results compared quite closely to this as indicated in Table 2. Photos of the asphalt cores are provided as Figure 1.

Table 2: Pavement Coring Results

Location ID	Station (feet)	Offset (feet)	AC Thickness (inches)	AB Thickness (inches)
PC-06	52+91	30 Right	4	11
PC-07	57+87	30 Right	5	11
PC-08	64+10	30 Right	4	11

Figure 1: Pavement Core Results

2.2 Relevant Geotechnical Investigations by Others

2.2.1 Sunset Road Phase 1

NCS Consultants, LLC (NCS) conducted a geotechnical investigation on Sunset Road west of I-10 (NCS 2015). Their investigation included nine boreholes that were used for pavement subgrade characterization. They addressed the high standard deviation of the tested and correlated R-Values by providing recommendations for three different design R-Values: 20, 25, and 30. The lab data and correlated R-Values associated with these boreholes are summarized in Table 3.

Table 3: Summary of Relevant NCS Pavement Lab Data

Borehole	Sample Depth (feet)	PI (%)	Passing #200 (%)	USCS	ADOT Correlated R-Value	Pima County Correlated R-Value	Tested R-Value
B-08	0-10	8	68	CL	28.6	16.8	
B-11	0-10	NP	45	SM	53.7	35.7	
P-02	0-10	8	66	CL	29.4	17.3	
PE-03	0-10	6	68	CL-ML	30.9	18.4	
PE-04	0-10	9	77	CL	24.3	13.8	34

Notes:
PI = Plasticity index
% = Percent

2.2.2 River Road

Terracon Consultants Western, Inc. (Terracon) performed a geotechnical investigation for the River Road – Shannon to Thornydale project (Terracon 1995). They drilled several boreholes near the proposed intersection with Sunset Road. The exact borehole locations were difficult to determine given the coarse scale of the location plan and lack of coordinates, but the closest and most relevant boreholes are B-8 to B-11. Laboratory index data and correlated R-Values from these boreholes are summarized in Table 4. A collapse test was conducted at Borehole B-9 under an inundation load of 1,000 psf. The sample exhibited a hydro-collapse settlement of approximately 8.5 percent.

Table 4: Summary of Relevant Terracon Pavement Lab Data

Borehole	Sample Depth (feet)	PI (%)	Passing #200 (%)	USCS	ADOT Correlated R-Value	Pima County Correlated R-Value	Tested R-Value
B-8	0	NP	26.8	SM	69.1	48.3	
B-9	2	NP	24.7	SM	71.1	50.0	
B-10	1	NP	25.7	SM	70.1	49.2	
B-11	2	NP	21.6	SM	74.2	52.7	59

Notes:
PI = Plasticity index
% = Percent

2.3 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 5. 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 5: 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)

3.0 SITE CONDITIONS AND GEOTECHNICAL DATA

3.1 Subsurface Conditions

The pavement boreholes were drilled primarily in the engineered fill supporting the approaches to the bridge over Camino de la Tierra; however, BH-07 encountered native material at a depth of approximately 18 feet. The fill material was compact to dense clayey sand (SC), although the SPT blow counts in Borehole BH-07 indicated loose material at a depth of 15 feet. The native material encountered at the bottom of borehole BH-07 was compact poorly graded sand with silt (SP-SM).

The native material observed by Golder in BH-07 matches reasonably well with the Terracon data set. There was low variation in the percent fines and PI for their dataset indicating the soil unit underlying the River Road embankment fill is relatively consistent. The index testing for the fill material did not match well with the native soil results from NCS, Terracon, or Golder indicating that the fill was likely borrow from an offsite source, possibly one of the nearby material pits.

3.2 Geologic Hazards

3.2.1 Hydro-collapsible Soil

A detailed discussion of hydro-collapsible soil is provided in the geotechnical report (Golder 2020). One additional collapse test was performed in Borehole BH-07 that indicated less than 1.5 percent collapse at 4 kilopounds per square foot of normal pressure, which is considered a “slight” degree of collapse potential. The risk of hydro-collapse in properly compacted embankment fill with good surface drainage is assessed to be minimal. Hydro-collapse potential of native soil beneath the Sunset Road embankments is discussed in the geotechnical report, but the relatively low embankment heights expected along River Road and between River Road and the Rillito Creek Bridge will impose relatively low ground pressure on the native subgrade, indicating low collapse potential. The primary area of concern is between the UPRR and Rillito Creek Bridges, where embankment loads are significant.

3.2.2 Expansive Soils

Swelling soils may result in uplift of pavements or poor ride quality. Table 10.4.6.3-1 of AASHTO (2017), reproduced here as Table 6, provides criteria for identifying potentially expansive soils. Golder did not encounter any high plasticity clay soil that rates as marginal or high accordingly to these criteria. Accordingly, no additional testing or mitigation is required regarding potentially expansive soils.

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

Notes:
% = Percent

3.3 R-Value Analysis

Golder collected bulk samples from the three boreholes drilled on River Road. The results of laboratory index testing and R-Value testing are summarized in Table 7.

Table 7: Summary of Phase 2 R-Value Testing

Borehole	Sample Depth (feet)	PI (%)	Passing #200 (%)	USCS	ADOT Correlated R-Value	Pima County Correlated R-Value	Tested R-Value
BH-06	0-5	11	35	SC	40.1	25.2	
BH-07	0-5	8	32	SC	47.0	30.4	27
BH-08	0-5	9	30	SC	46.5	30.0	27

Notes:
PI = Plasticity index
% = Percent

The PCRDM references ADOT procedures for analyzing correlated and tested R-Values to determine a design and construction control R-Value. The only difference is that the County's correlation equation is used in place of ADOT's. However, this procedure is not applicable to this project for several reasons.

As noted above, the majority of the project will be constructed on at least 5 feet of imported fill, so the design R-Value for these locations will be controlled by the subgrade acceptance criteria applied to the borrow. The nearby I-10: Ruthrauff Road Traffic Interchange project is currently under construction and consists of a significant quantity of imported fill. The design R-Value for the I-10 mainline, I-10 frontage roads, and ramps is 25, and the design R-Value for Ruthrauff Road is 20. Golder recommends assuming an R-Value of 25 for design for this project based on this information and Golder's experience on PCDOT pavement design projects in the area and we have used this value for design.

Although the NCS report utilized a range of R-Values for providing pavement recommendations, the final pavement sections constructed for Phase 1 appear to match the pavement sections designed with an R-Value of 25 contained in the NCS Report. The material on River Road exceeds the correlated R-Value of 25 as well based on Golder's test results, and the native material tested by Terracon has a substantially higher R-Value. Accordingly, if on-site material is available for use as borrow, it will likely meet the subgrade acceptance requirements.

4.0 TRAFFIC DATA

Traffic data was provided in the project's Initial Traffic Engineering Report traffic report by Kittelson and Associates, Inc. (Kittelson 2020). A summary of available average daily traffic (ADT) data and the corresponding growth rates is summarized in Table 8. The table also includes the project ADT at an assumed construction year of 2025.

Table 8: Summary of ADT and Growth Rate Data

Roadway Segment	ADT 1	ADT 1 Year	ADT 2	ADT 2 Year	Annual Growth Rate (%)	ADT in Year 2025
Sunset Road West (South) of EB Frontage	5,700	2019	22,000	2045	5.33	7,784
Sunset East (North) of WB Frontage	5,700	2019	18,000	2045	4.52	7,431
River Road	18,582	2016	23,000	2045	0.74	19,857

Notes:
% = Percent

The method used to compute the 18-kip equivalent single axle loadings (ESALS) for pavement design purposes is provided in the ADOT Pavement Design Manual (2017). The methods include tables for estimating the percentages of vehicle classes in the absence of vehicle classification data. Golder utilized these tables since no vehicle classification data is provided in the Kittelson report. Kittelson recommended assuming four percent trucks (percentage is relative to ADT), and recommended using three percent medium trucks, and one percent heavy trucks which Golder assumed to correspond to three percent single trailer units, and one percent multi-trailer units or “combos”.

Following the guidance in the manual, we selected Truck Traffic Classification (TTC) AZ-6 from Table A-1 of the reference. Truck Load Factors were taken from Tables A-5 and A-6 of the reference for flexible and rigid pavements, respectively. The recommended cluster for “Principal Arterial (Other)” in urban environments is 2/3 which means that both cluster 2 and 3 must be evaluated and the one producing the higher ESAL value should be used. Golder found that cluster 2 produced the higher traffic loading. The resulting ESAL Values are included in Table 9. Calculation sheets based on a template provided by ADOT are included in Appendix C.

Table 9: Computed Design Lane ESAL Values

Roadway Segment	Pavement Type	ADOT Cluster	TTC	Design Lane ESALS
Sunset Road West (South) of EB Frontage	Flexible	2	AZ-6	1,434,124
	Rigid	2	AZ-6	1,782,406
Sunset East (North) of WB Frontage	Flexible	2	AZ-6	1,256,908
	Rigid	2	AZ-6	1,562,153
River Road	Flexible	2	AZ-6	2,293,859

4.1 Comparison with NCS Phase 1 Traffic Loading

The final NCS report indicated the traffic loading for Sunset Road was 1,853,000 ESALS, which is higher than the 1,434,124 computed by Golder. Based on discussions with Kittelson (Ladron 2020), there is not a significant difference between the ADT values and growth rates used in the Phase 1 and Phase 2 projects.

We speculate that the difference is related to two factors: that the report was issued prior to the issuance of the 2017 ADOT pavement design manual, and that they may have utilized a higher truck percentage for the Phase 1 study. Since the 1989 ADOT manual (ADOT 1989) was still in effect when NCS issued their report, they would have used truck loading factors from that manual, which include an escalation factor with time for heavy truck load factors. The 2017 manual does not use variable truck loading factors.

A check calculation was performed using the ADOT simplified method described in Appendix A of the 1989 manual, which provides truck load equivalency factors of 0.8, 1.0, and 1.2 for corresponding truck volume categories of light, medium, and heavy. Using this method, a truck load equivalency factor of 1.2 and 3.5 percent truck volume is required to obtain an ESAL value of approximately 1.8 million. The truck percentage is quite close to the value provided by Kittelson. The weighted average of the truck load factors used in the 2017 procedure is 0.63, which is close to the light truck volume category of the simplified method, which appears to be the primary difference between Golder's and NCS' analyses. The 2017 procedure is assessed to be a better representation of the pavement loading condition, since the truck volume, at 4 percent of the total, is judged to be light and comprised of few heavy trucks.

Based on discussions with CONSOR (Glock 2020) and comments received for the draft report, Golder opted to use the ESAL values we computed for pavement design rather than the value used by NCS for Phase 1.

5.0 PAVEMENT DESIGN

5.1 Basis of Comparison of Structural Section Alternatives

Golder considered standard AC over AB pavement sections for the flexible pavement analysis, and plain jointed Portland cement concrete (PCCP) for the rigid pavement sections. Estimates of initial construction cost are used to compare pavement structural section alternatives that meet the minimum requirements. The costs are based on unit prices from the draft DCR Cost Estimate. These costs are meant only to compare the relative construction cost of the alternative pavement sections evaluated. CONSOR and the County should independently develop costs for the purposes of compiling an overall construction cost estimate. The unit prices selected for this evaluation are:

- AC (PAG Mix No. 1): \$3.83/square yard-inch (yd^2-in)
- AC (PAG Mix No. 2): \$6.02/ yd^2-in
- AB: \$0.89/yd^2-in

The AC costs are based:

- AC (PAG No. 1): \$70.00/ton
- AC (PAG No. 2): \$110.00/ton

The cost for AB of \$0.89/yd^2-in is equivalent to \$32.00 per cubic yard (yd^3).

Only the minimum rigid pavement structural section was analyzed, so no cost comparison was performed for alterative rigid pavement structural sections.

5.2 Flexible Pavement Design

Golder performed pavement design according to the PCRDM and the ADOT Pavement Design Manual.

5.2.1 Design Parameters

The flexible pavement design parameters used to develop the 20-year design life pavement sections for the project are shown in Table 10.

Table 10: Flexible Pavement Design Parameters

Location	Flexible Pavement Design Parameter					
	W_{18}	Z_R	S_0	P_O	P_T	ΔPSI
Sunset Road West (South) of EB Frontage	1,435,000	-1.645	0.35	4.2	2.8	1.4
Sunset East (North) of WB Frontage	1,257,000	-1.645	0.35	4.2	2.8	1.4
River Road	2,294,000	-1.645	0.35	4.2	2.8	1.4

Notes:
W_{18} = 18-kip ESALs applied to the pavement during the design life in the design lane.
Z_R = Standard normal random variable corresponding to level of reliability values on page 3-43 of the PCRDM. A Level of Reliability of 95 percent is assigned to Sunset Road and River Road based on their classification as a principal arterial.
S_0 = Standard error as given by the PCRDM.
P_O = The initial design serviceability index, computed from required P_T and ΔPSI values from PCRDM.
P_T = The design terminal serviceability index, from PCRDM.
ΔPSI = P_O - P_T; this is the change from the present serviceability index over the 20-year design period, given on the PCRDM

In addition to these parameters, a resilient modulus (M_R) of 10,837 pounds per square inch (psi) was used throughout the project. This value is derived from the design R-Value of 25 presented in Section 3.3.

The structural coefficients for AC, and AB used for design are 0.44, and 0.12, respectively, as given in Section 3.13 of the PCRDM (PCDOT 2016). A drainage coefficient of 0.92 was assigned based on the PCRDM which corresponds to fair drainage conditions with the seasonal variation factor for the Tucson area of 1.7 according to Table 2-4 of the ADOT Pavement Design Manual (2017).

5.2.2 Required Pavement Structural Number

The required pavement structural number for each roadway segment was computed based on the design parameters above and the traffic volumes. The minimum required structural number for arterials is 2.64 based on page 3-44 of the PCRDM, but this value did not govern the design for this project.

5.2.3 Alternative Pavement Structural Sections

Table 11 provides a summary of the alternative flexible pavement sections considered for this project. Golder recommends using alternative Pavement Section Number 2 for each of the roadway segments. The PCRDM recommends a ratio of AB to AC of between 1.1:1 and 1.75:1. Several alternatives evaluated by Golder were marginally outside these ratios, however we believe they should still be considered valid alternatives since the component lift thicknesses remain within the range that is practical and economical to compact with typical construction equipment. The recommended pavement sections are summarized in Section 5.5. Pavement design calculations sheets are included in Appendix D.

Table 11: Evaluation of Alternative Flexible Pavement Structural Sections

Location	Pavement Section No.	PAG 1 AC (in)	PAG 2 AC (in)	AB (in)	Total Section Thickness (in)	Required Structural No.	Provided Structural No.	Initial Pavement Construction Cost ($/yd^2)
Sunset Road West (South) of EB Frontage	1	3.0	3.0	6	12.0 [A]	3.31	3.36	34.89
	2	3.0	2.5	8	13.5	3.31	3.38	33.66
Sunset East (North) of WB Frontage	1	3.0	2.5	7	12.5	3.23	3.26	32.77
	2	3.0	2.0	9	14.0 [A]	3.23	3.28	31.54
River Road	1	4.0	2.0	8	14.0	3.60	3.60	34.48
	2	3.5	2.0	10	15.5 [A]	3.60	3.62	34.35

Notes:
In = Inch
$/yd^2 = Dollars per square yard
A – Ratio of AB to AC marginally outside PCRDM recommended ratios of 1.1:1 to 1.75:1

5.3 Rigid Pavement Design

PCCP is required within approximately 300 feet of the I-10 bridge on the west side of the project, and within approximately 300 feet of the UPRR bridge on the east side of the project. Golder performed a rigid pavement design using the procedures in the ADOT Pavement Manual. We analyzed the minimum recommended pavement section of 9 inches of plain jointed PCCP using the ESAL loading and relevant inputs listed in Table 9 and Table 10 and found that the minimum section is adequate. The rigid pavement design calculation sheet and supporting documentation is provided in Appendix D.

5.4 Subgrade Acceptance

The design R-Value of 25 is also the construction control R-value. The recommended subgrade acceptance chart is provided as Figure 2.

Most of the pavement on the project will be constructed on imported fill. Borrow placed within three feet of finished subgrade shall give an X value of 100 or less when the PI and the percent passing the No. 200 sieve (Minus 200) are entered into the following equation:

$$X = (\text{Minus } 200) + [2.83\ (PI)].$$

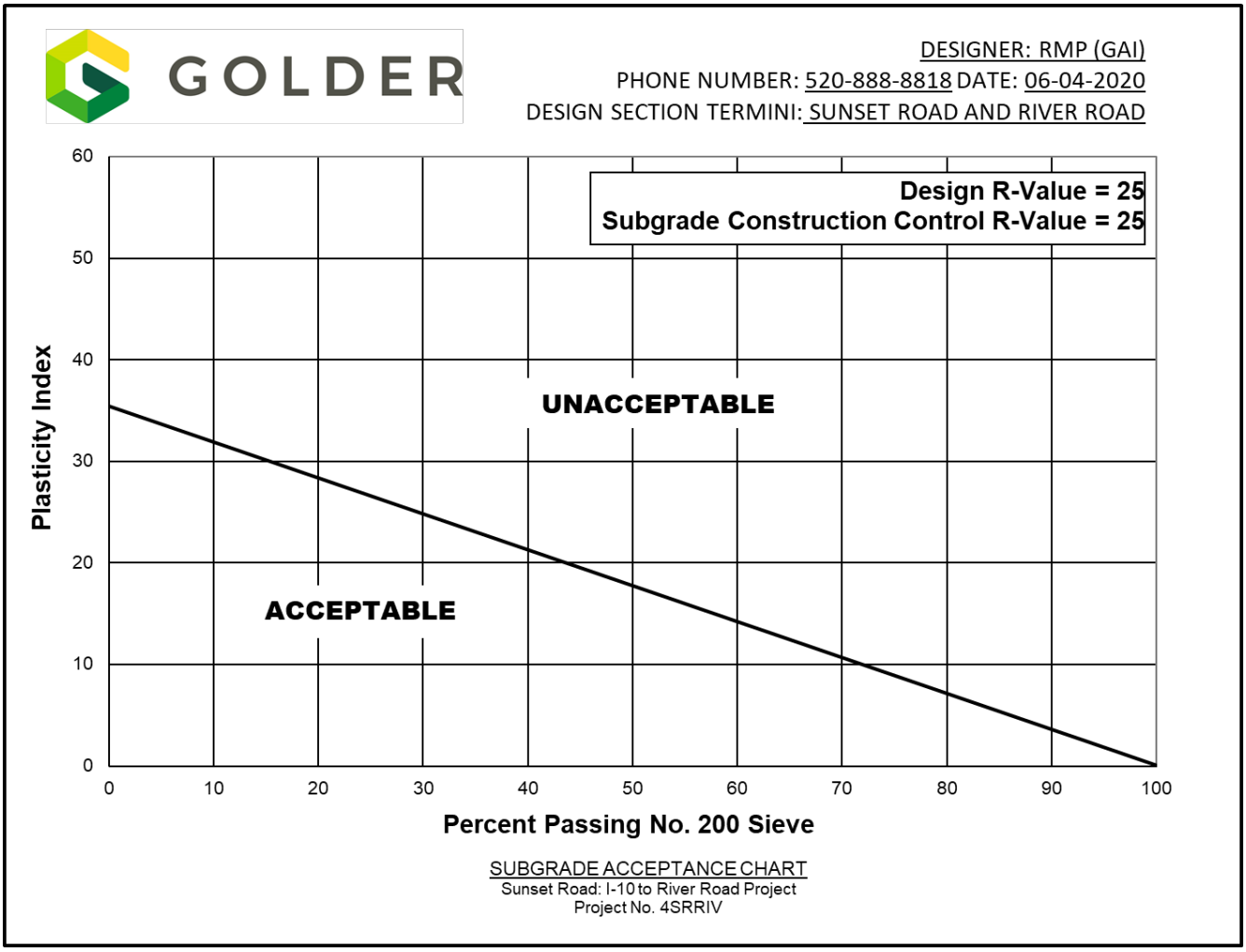

Figure 2: Initial Subgrade Acceptance Chart

5.5 Summary of Recommended Pavement Sections

Golder recommends the following pavement sections for the project (components listed from the bottom to the top of the section):

Sunset Road West (South) of EB Frontage – Flexible Section

- 8 inches of AB
- 3.0 inches of PAG No. 1
- Tack Coat
- 2.5 inches of PAG No. 2

Sunset Road East (North) of WB Frontage – Flexible Section

- 9 inches of AB
- 3.0 inches of PAG No. 1
- Tack Coat
- 2.0 inches of PAG No. 2

Sunset Road – Rigid Section

- 4 inches of AB
- 9 inches of plain jointed PCCP

River Road

- 10 inches of AB
- 3.5 inches of PAG No. 1
- Tack coat
- 2 inches of PAG No. 2

6.0 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

Golder Associates Inc.

Randy Post, PE
Senior Geotechnical Engineer

Michael L. Pegnam, PE
Associate/Geotechnical Practice Leader

RMP/MLP/rm

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https://golderassociates.sharepoint.com/sites/113372/project files/6 deliverables/006 pavement report/rev 0/19128078-r-006-rev0-20200803.docx

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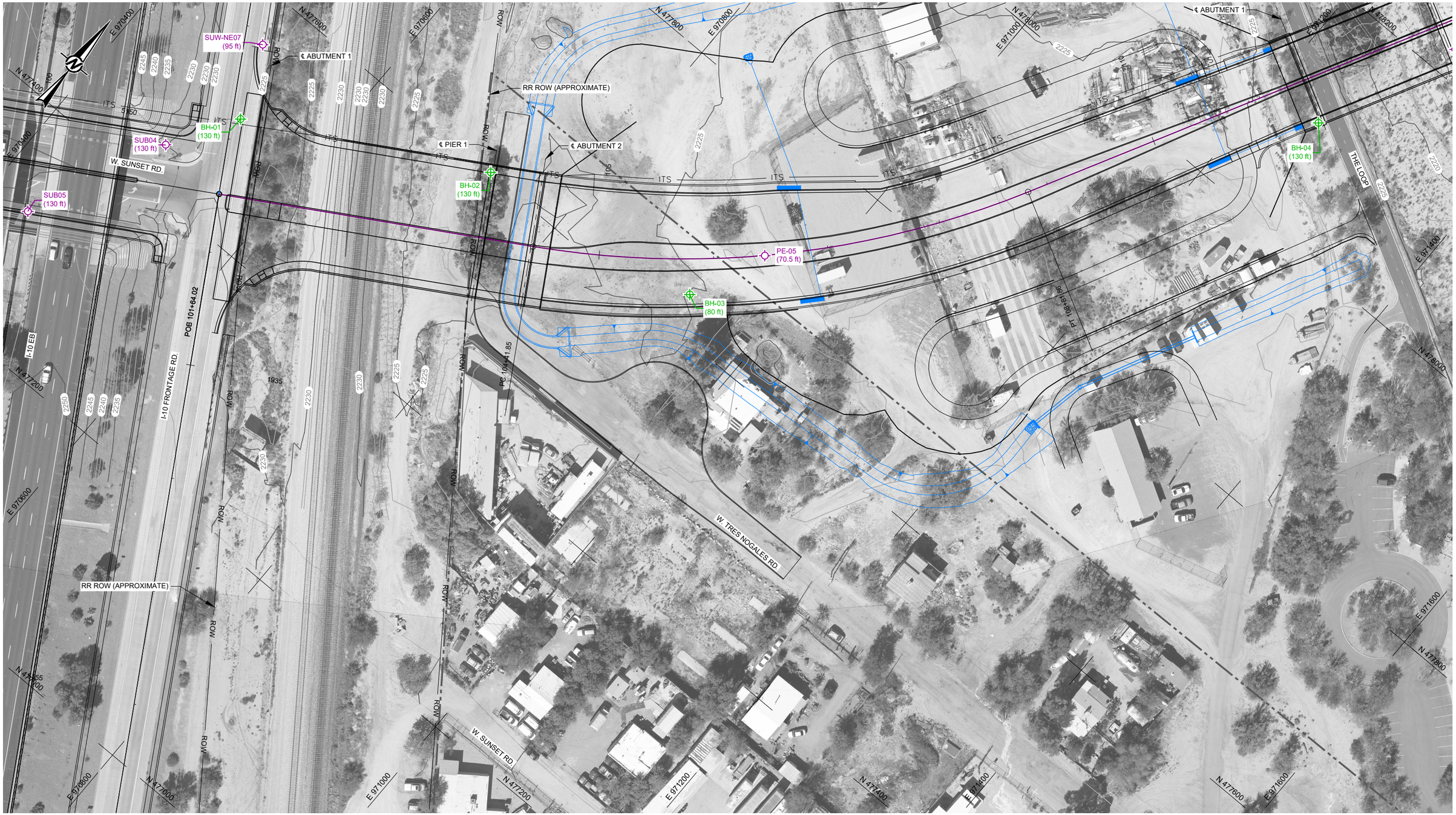
APPENDIX A

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

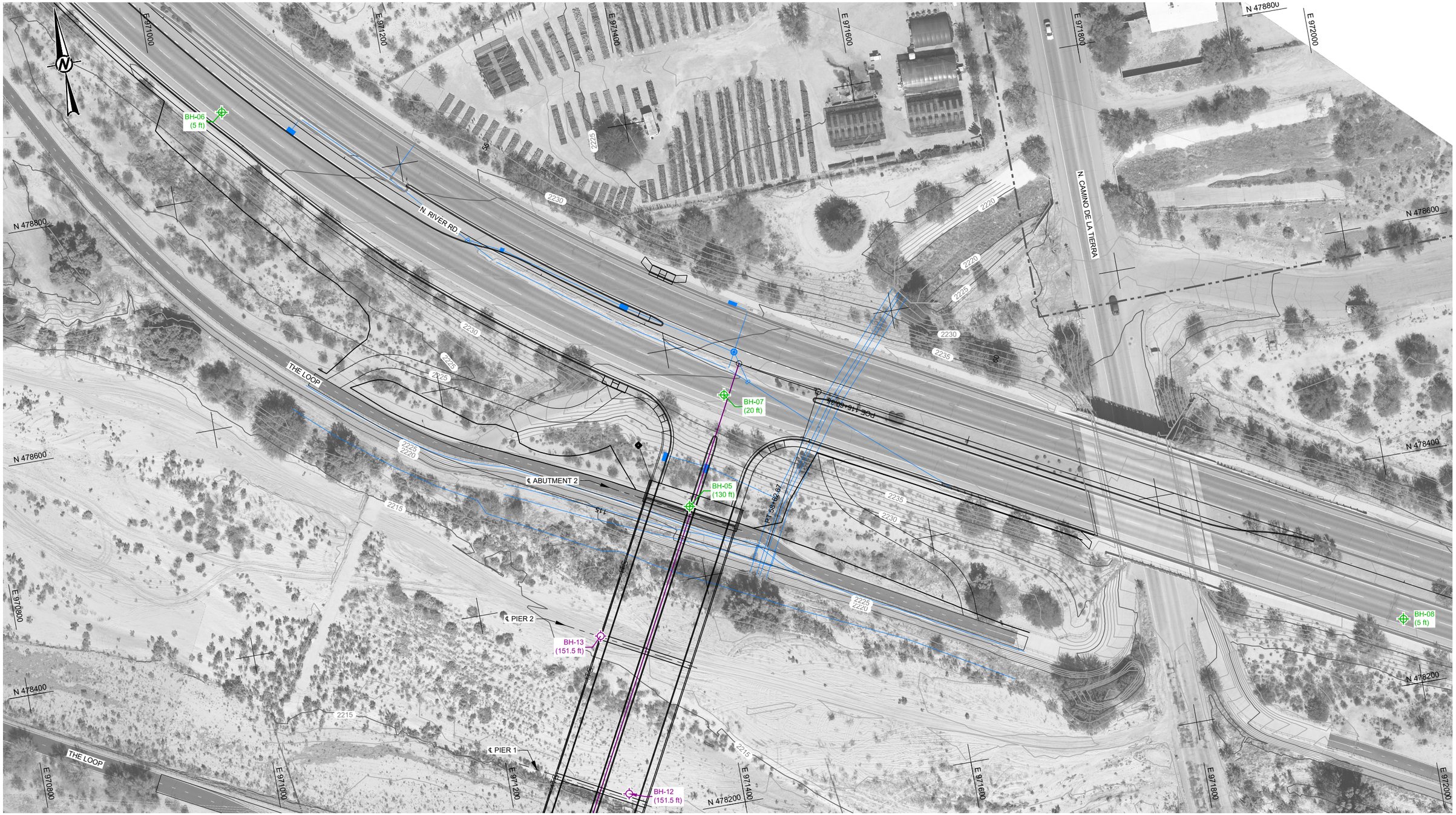
PROJECT
SUNSET ROAD
GEOTECHNICAL INVESTIGATION

TITLE
GEOTECHNICAL INVESTIGATION PLAN (1 OF 2)

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

Path: \\tucson\cadd\STRUCTURAL_GRACE\Sunset Rd\99_PROJECTS\19128078_Geotech\0101_Logistics\02_PRODUCTION\DWGs\ | File Name: 19128078_0101_FIG_A01.dwg | Last Edited By: jediaz Date: 2020-05-08 Time:9:08:14 AM | Printed By: nlocascio Date: 2020-07-29 Time:1:16:49 PM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



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

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
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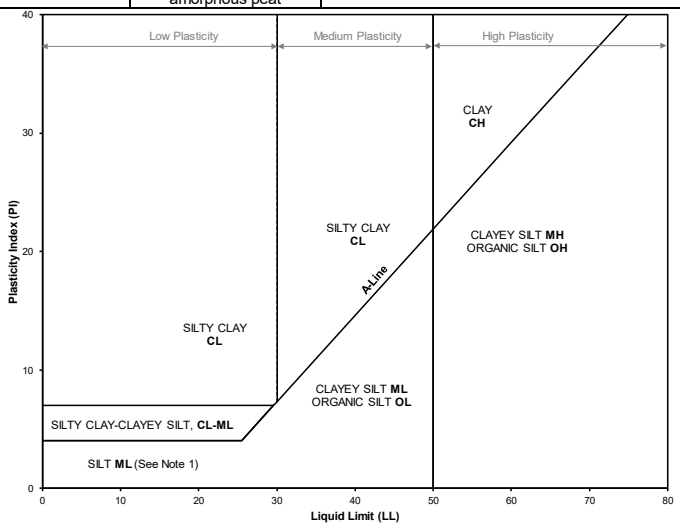
METHOD OF SOIL CLASSIFICATION

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.

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-06

CLIENT:	Structural Grace	DATE:	April 21, 2020	ELEVATION:	2229.5 ft (Ground)
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

DRILL RIG: CME-75

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

MATERIAL PROFILE: DESCRIPTION	USCS	STRATA PLOT	ELEV. / DEPTH (ft)	SAMPLES: NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING
Asphalt			0.0	PC-06					PC-06
Aggregate Base	GP-GM		2229.2 / 0.3						
FILL - (SC) Clayey sand, fine to medium, subrounded, some low plasticity fines, trace fine subrounded to subangular gravel; brown, no HCL reaction, trace presence of roots; non-cohesive, moist, dense, Embankment Fill.	SC		2228.5 / 1.0	BH-06	MCGS	100	22-27	49	Bulk_BH-06
			2223.0	SPT-02	SS	100	12-14-19	33	

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

End of hole at 6.5 ft.

Backfilled with clean sand to bottom of AC layer and finished with PermaPatch

DEPTH SCALE: 1:131

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	ELEVATION:	2235.8 ft (Ground)
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.

MATERIAL PROFILE: DESCRIPTION	USCS	ELEV. / DEPTH (ft)	SAMPLE NUMBER	TYPE	REC %	BLOWS	N-VALUE	ADDITIONAL LAB TESTING
Asphalt		0.0	PC-07					PC-07
Aggregate Base	GP-GM	2235.4 / 0.4						
FILL - (SC) Clayey sand, fine to medium, subrounded, some low plasticity fines, trace fine to medium subrounded to subangular gravel; brown, trace presence of roots; non-cohesive, moist, loose to dense, Embankment Fill.	SC	2234.8 / 1.0	SPT-04	SS	100	21-17-15	32	Bulk_BH-07
			MC-02	MC	100	22-40	62	
			SPT-03	SS	100	10-12-13	25	
			SPT-04	SS	89	3-2-3	5	
(SP-SM) Poorly graded sand with silt, medium to coarse, poorly graded, subrounded, few fine to coarse subrounded to subangular gravel, few non plastic fines; light brown and light gray; non-cohesive, moist, compact, Native Soil.	SP-SM	2217.5 / 18.2	SPT-05	SS	100	7-8-9	17	
End of hole at 21.5 ft.		2214.3						

Backfilled with clean sand to bottom of AC layer and finished with PermaPatch

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

GROUNDWATER OBSERVATIONS:

ADDITIONAL OBSERVATIONS:

DEPTH SCALE: 1:131

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	ELEVATION:	2236.0 ft (Ground)
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

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
	Asphalt			0.0	PC-08					PC-08		
	Aggregate Base	GP-GM		2235.6 / 0.3								
1	FILL - (SC) Clayey sand, fine to medium, subrounded, some low plasticity fines, few fine subrounded to subangular gravel; brown, trace presence of roots; non-cohesive, moist, compact, Embankment Fill.	SC		2235.0 / 1.0								
2												
3					Bulk_BH-08	GS	100	23-15-15	30	Bulk_BH-08		
4					SPT-01	SS						
5												
6				2229.5	SPT-02	SS	67	7-6-7	13			
7	End of hole at 6.5 ft.											
8	Backfilled with clean sand to bottom of AC layer and finished with PermaPatch											
9												
10												
11												
12												
13												
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15												
16												
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22												
23												
24												
25												

DEPTH SCALE: 1:131

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	**PROJECT NO:**	200063
LOCATION:	Request 2 - 19128078 - Sunset Rd.: I-10 to River Rd.	**WORK ORDER NO:**	2010187
DATE SAMPLED:	5/13/2020	**REVIEWED BY:**	Michael Connolly

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

Bulk, BH-06 @ 0.5'-5.0'	SC	24	13	11	100	100	100	100	100	100	100	100	99	98	96	94	90	88	84	74	67	59	44	35	1
Bulk, BH-07 @ 0.5'-5.0'	SC	22	14	8	100	100	100	100	100	100	100	99	98	96	93	92	87	85	80	70	64	56	42	32	2
SPT, BH-07 @ 5.0'-5.0'	SC	25	14	11	100	100	100	100	100	100	100	99	99	98	97	96	93	92	89	81	76	68	52	40	3
SPT, SPT-05 @ 20.0'-21.5'	SP-SM	NV	NP	NP	100	100	100	100	100	100	100	98	95	94	90	86	71	66	49	31	25	20	13	8.9	4
Bulk, BH-08 @ 0.5'-5.0'	SC	24	15	9	100	100	100	100	100	100	100	100	99	97	92	89	81	79	71	61	56	51	40	30	5

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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atek ENGINEERING CONSULTANTS

PROJECT: Golder Associates 2020 On-Call
LOCATION: Request 2 - 19128078 - Sunset Rd.: I-10 to River Rd.
SAMPLE DATE: 5/13/2019

PROJECT: 200063
WORK ORDER: 2010187
REVIEWED BY: M. Connolly

MOISTURE CONTENT OF SOIL -- ASTM D 2216

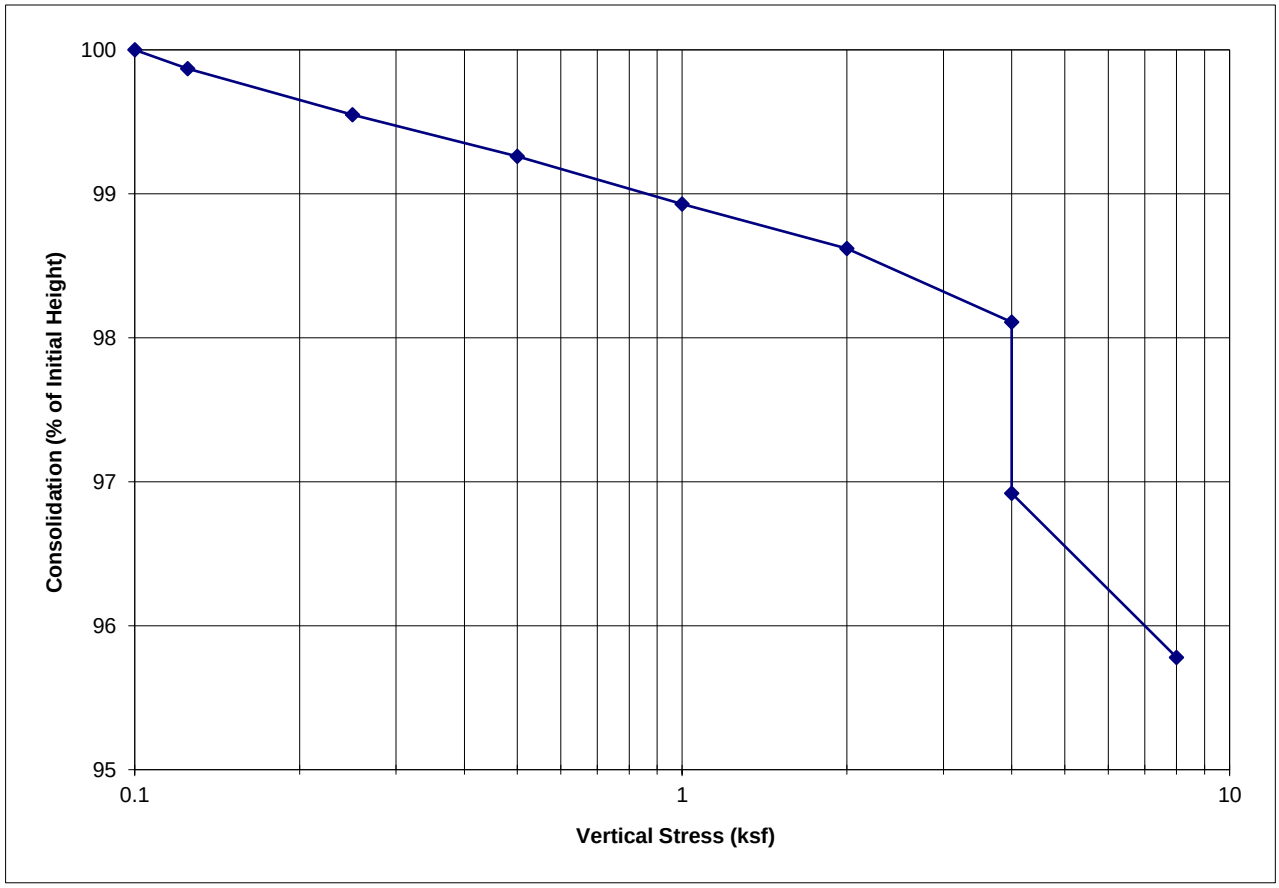
LAB #	SAMPLE SOURCE	MOISTURE WET WEIGHT (g)	MOISTURE DRY WEIGHT (g)	MOISTURE MOISTURE CONTENT
1	Bulk BH-06 @ 0.5'-5.0"	688.0	630.5	9.1%
2	Bulk BH-07 @ 0.5'-5.0"	790.8	731.8	8.1%
3	SPT BH-07 @ 5.0'-6.0"	1,733.7	1,586.7	9.3%
4	SPT-05 @ 2.0'-21.5"	923.6	899.8	2.6%
5	BH-08 @ 0.5'-5.0"	890.1	847.7	5.0%

atek ENGINEERING CONSULTANTS

Project:	Golder Associates 2020 On-Call	**Project Number:**	200063
Project Location:	Request 2 - 19128078 - Sunset Rd.: I-10 to River Rd.	**Work Order Number:**	2010187
Client:	Golder	**Lab Number:**	3
Material:	Native	**Date Sampled:**	05/13/20
Sample Source:	STP B-BH-07 @ 5.0'-6.0'	**Reviewed by:**	M. Connolly
Sample Prep:	In-Situ		

One-Dimensional Swell or Collapse Properties of Soils (ASTM D4546)

Initial Volume (cu.in)	4.60	Final Volume (cu.in)	4.41
Initial Moisture Content	9.3%	Final Moisture Content	11.4%
Initial Dry Density(pcf)	120.4	Final Dry Density(pcf)	125.6
Initial Degree of Saturation	66%	Final Degree of Saturation	96%
Initial Void Ratio	0.4	Final Void Ratio	0.3
Estimated Specific Gravity	2.65	Saturated at	4 ksf



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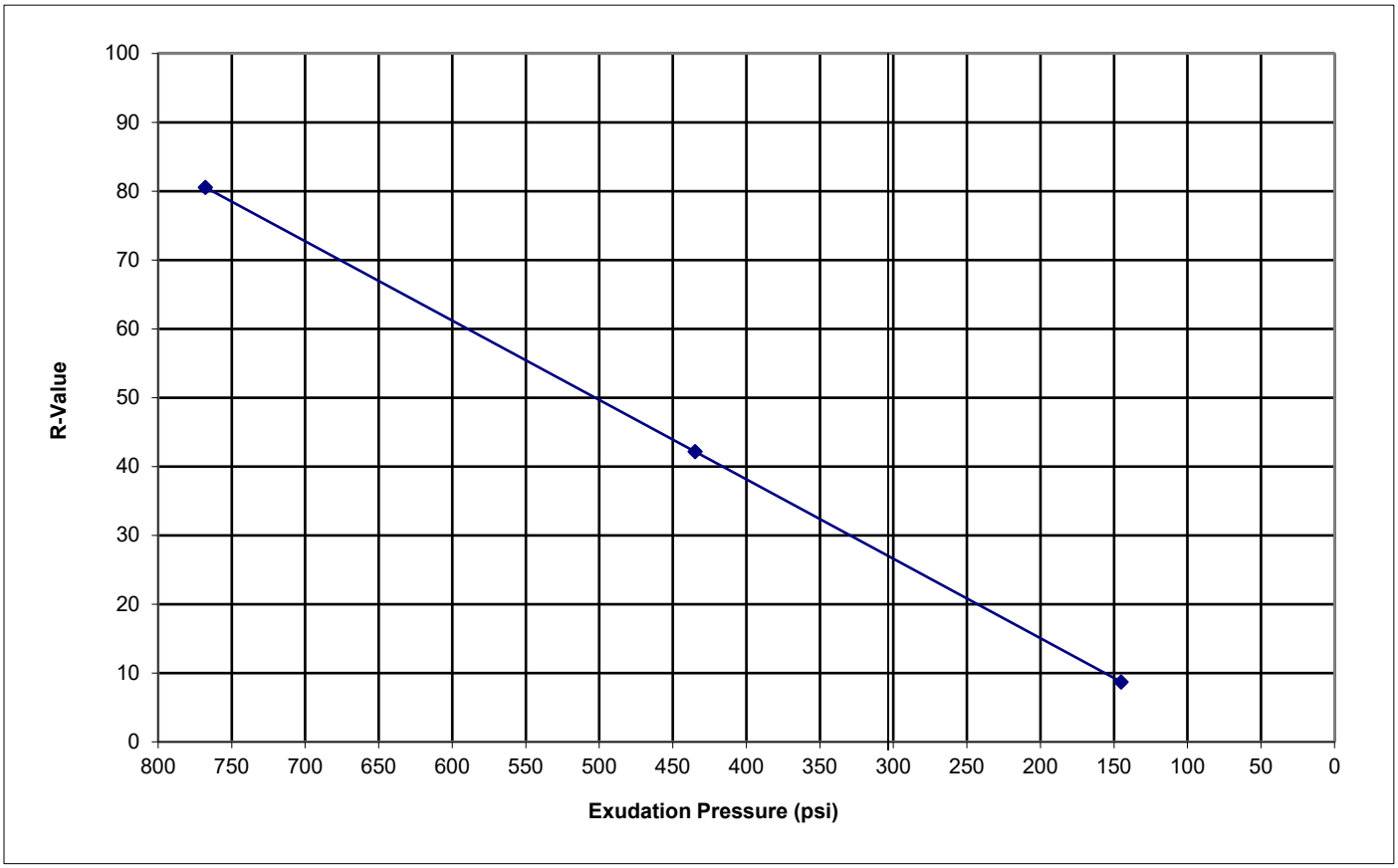
PROJECT: Atek Job #200063; WO #2010187
LOCATION: Phoenix, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: BH-07 (0.5-5.0')

JOB NO: 19-2011-1087
WORK ORDER NO: 234
LAB NO: 20-0916
DATE SAMPLED: 05/13/20

RESISTANCE R-VALUE AND EXPANSION PRESSURE OF COMPACTED SOILS (ASTM D2844)

SPECIMEN ID	A	B	C
Moisture Content	10.0%	8.3%	7.4%
Compaction Pressure (psi)	50	175	225
Specimen Height (inches)	2.44	2.32	2.49
Dry Density (pcf)	128.3	134.1	126.8
Horiz. Pres. @ 1000lbs (psi)	57.0	30.0	13.0
Horiz. Pres. @ 2000lbs (psi)	133.0	68.0	25.0
Displacement	5.00	3.87	3.26
Expansion Pressure (psi)	0.3	0.7	0.0
Exudation Pressure (psi)	145	435	768
R Value	9	42	81



R Value at 300 PSI = 27

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3630 E Wier Ave.
Phoenix, AZ 85040

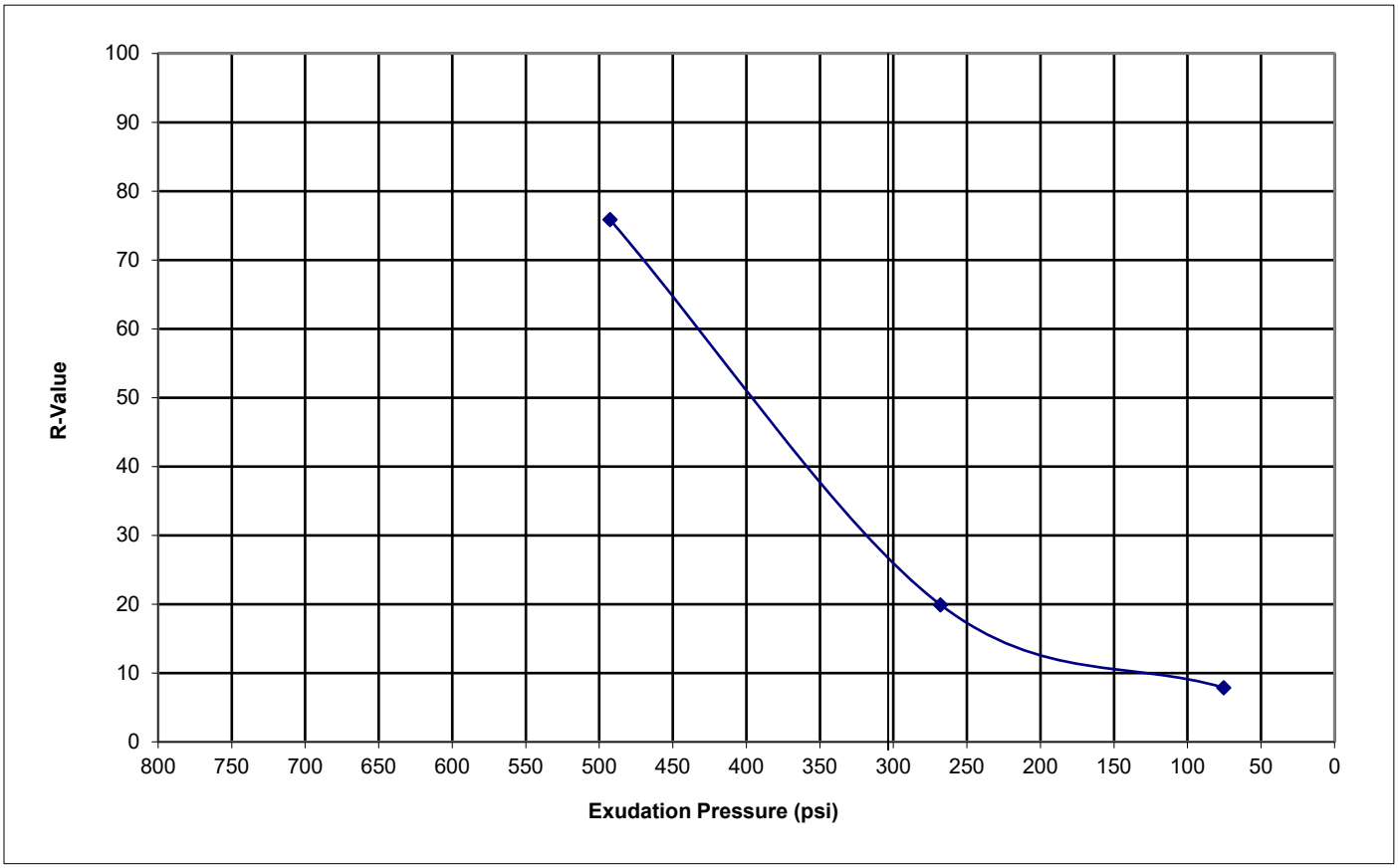
REVIEWED BY Robert Kostelny

PROJECT: Atek Job #200063; WO #2010187
LOCATION: Phoenix, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: BH-08 (0.5-5.0')

JOB NO: 19-2011-1087
WORK ORDER NO: 234
LAB NO: 20-0917
DATE SAMPLED: 05/13/20

RESISTANCE R-VALUE AND EXPANSION PRESSURE OF COMPACTED SOILS (ASTM D2844)

SPECIMEN ID	A	B	C
Moisture Content	7.5%	8.8%	9.7%
Compaction Pressure (psi)	175	100	50
Specimen Height (inches)	2.38	2.45	2.45
Dry Density (pcf)	130.9	126.4	125.6
Horiz. Pres. @ 1000lbs (psi)	15.0	46.0	58.0
Horiz. Pres. @ 2000lbs (psi)	29.0	110.0	135.0
Displacement	3.20	4.57	5.42
Expansion Pressure (psi)	0.0	0.0	0.0
Exudation Pressure (psi)	493	268	75
R Value	76	20	8



R Value at 300 PSI = 27

Wood Environment & Infrastructure Solutions, Inc.
3630 E Wier Ave.
Phoenix, AZ 85040

REVIEWED BY Robert Kostelny

APPENDIX C

ESAL Derivation Calculations

GOLDER

Pavement Design Traffic Loading Derivations

Date:	8/3/2020	**Rev:**	1	**Made by:**	RMP
Project No.:	19128078			**Checked by:**	JAV
Roadway:	All - Flexible Case			**Reviewed by:**	
Project Short Title:	Sunset Road: I-10 to River Road				

Spreadsheet Version 1.0

1.0 PURPOSE

To derive traffic loads for pavement design purposes using ADOT methods.

2.0 REFERENCES

1. ADOT. 2017. Pavement Design Manual. Roadway Engineering Group, Pavement Design Section. September 29, 2017.

3.0 PROBLEM STATEMENT

This spreadsheet allows you to package one or more sets of traffic loading data into an easy to review format. It then transfers this data into the ADOT format ESAL Spreadsheet.

4.0 ASSUMPTIONS

1. Assumes new construction, widening, etc. As opposed to rehabilitation (this primarily affects lane distribution factor).
2. Assumes all loading configurations to be analyzed are for either rigid or flexible pavement design, you can't mix and match.

5.0 CALCULATIONS

Some relevant reference information used for this analysis is included in Section 7.0.

5.1 General Inputs

Pavement Type	Flexible	This spreadsheet assumes you are looking at all rigid pavement or all flexible. If you have both, run the analysis twice.
TRACS	N/A	The ADOT TRACS No. (if applicable). You can just enter "N/A" otherwise.

5.2 AADT and Growth Factor Simplfication

Use this section to reduce two-way AADT data and growth rate information to plug into the ADOT spreadsheet. You can either start with two AADT values/years and compute the growth factor (and project it to a design year), or start with one AADT/year and a given growth factor and compute the design year AADT. Just hide the one you don't need.

GOLDER

Pavement Design Traffic Loading Derivations

Date:	8/3/2020	**Rev:**	1	**Made by:**	RMP
Project No.:	19128078			**Checked by:**	JAV
Roadway:	All - Flexible Case			**Reviewed by:**	
Project Short Title:	Sunset Road: I-10 to River Road				

Table 1: AADT Growth Rate Working Area - Given Two AADT Values

Roadway / Case	AADT1	AADT2	Year 1	Year 2	Compount Annual Growth Rate	Year 3	AADT3
Sunset West (South) of EB Frontage	5,700	22,000	2019	2045	5.33%	2025	7,784
Sunset East (North) of WB Frontage	5,700	18,000	2019	2045	4.52%	2025	7,431
River Road	18,582	23,000	2016	2045	0.74%	2025	19,857

5.3 Inputs for ADOT ESAL Spreadsheet

This spreadsheet will report results for up to 4 different traffic loading cases. Just enter the data in Table 2 and (and 3 if desired), and the ADOT ESAL spreadsheet will be populated with the proper data. The ADOT spreadsheet has been modified to accept the inputs the here, but unless noted in green, the actual formulas/functionality has not been modified.

GOLDER

Pavement Design Traffic Loading Derivations

Date:	8/3/2020	**Rev:**	1	**Made by:**	RMP
Project No.:	19128078			**Checked by:**	JAV
Roadway:	All - Flexible Case			**Reviewed by:**	
Project Short Title:	Sunset Road: I-10 to River Road				

Table 2: Inputs for ADOT Worksheet

Parameter	ESAL Case 1	ESAL Case 2	ESAL Case 3	ESAL Case 4
Route	Sunset Rd.	Sunset Rd.	River Rd.	Sunset Rd.
Case Name / Description	Sunset West (South) of EB Frontage	Sunset East (North) of WB Frontage	Widening for Turn Lanes at Sunset	Sunset West (South) of EB Frontage [Match NCS]
Begin Milepost/Sta.				
End Milepost/Sta.				
Functional Class.	Principal Arterial (Other)	Principal Arterial (Other)	Principal Arterial (Other)	Principal Arterial (Other)
Rural / Urban	Urban	Urban	Urban	Urban
Recommended Cluster Number	2/3*	2/3*	2/3*	2/3*
Cluster Number	2	2	2	2
Vehicle Class Distribution Method	ADOT Tables	ADOT Tables	ADOT Tables	ADOT Tables
Avg. Daily Trucks - Singles				
Avg. Daily Trucks - Combos				
Percent Trucks - Singles (of AADT)	3.00%	3.00%	3.00%	5.29%
Percent Trucks - Combos (of AADT)	1.00%	1.00%	1.00%	1.32%
Directional Distribution Factor (D_D)	0.5	0.5	0.5	0.5
Number of Lanes	2	2	2	2
Build Year	2025	2025	2025	2025
Build Year AADT	7,784	7,431	19,857	7,784
Growth Rate (%)	5.33%	4.52%	0.74%	5.33%
Design Life (Years)	20	20	20	20

* Designer to evaluate Cluster 2 and 3. Final design should be based on the cluster that results in the most ESAL's.

5.4 Vehicle Classification Worksheet

If you want to use actual vehicle classification data instead of the built-in ADOT tables, you can use the following section to reduce data and develop the design percentages to use.

GOLDER

Pavement Design Traffic Loading Derivations

Date:	8/3/2020	**Rev:**	1	**Made by:**	RMP
Project No.:	19128078			**Checked by:**	JAV
Roadway:	All - Flexible Case			**Reviewed by:**	
Project Short Title:	Sunset Road: I-10 to River Road				

6.0 RESULTS AND CONCLUSIONS

The resulting ESAL values for each case are presented in Table 4.

Table 4: Computed Design Lane ESAL Values

Design Case	18-kip Design ESALS
Sunset Rd. - Sunset West (South) of EB Frontage (ESAL Case 1)	1,434,124
Sunset Rd. - Sunset East (North) of WB Frontage (ESAL Case 2)	1,256,908
River Rd. - Widening for Turn Lanes at Sunset (ESAL Case 3)	2,293,859
Sunset Rd. - Sunset West (South) of EB Frontage [Match NCS] (ESAL Case 4)	1,853,000

GOLDER

Pavement Design Traffic Loading Derivations

Date:	8/3/2020	**Rev:**	1	**Made by:**	RMP
Project No.:	19128078			**Checked by:**	JAV
Roadway:	All - Flexible Case			**Reviewed by:**	
Project Short Title:	Sunset Road: I-10 to River Road				

7.0 REFERENCE INFORMATION

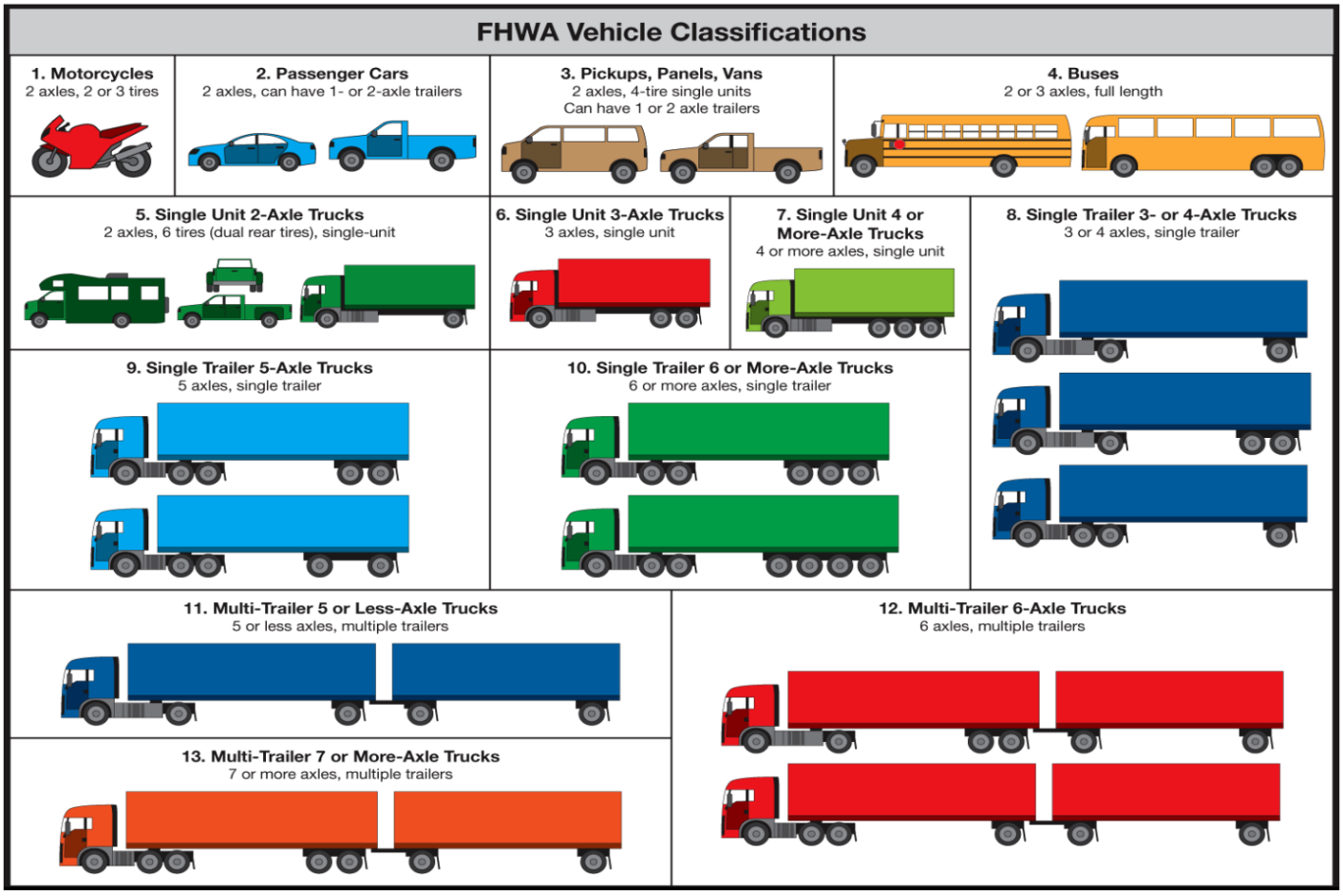


Figure 1: FHWA Vehicle Classifications

ESAL Calculation Worksheet

ESAL Case 1: **Sunset West (South) of EB Frontage**

TRACS:	N/A		Project No.	19128078		Project Name:	Sunset Road: I-10 to River Road		
Route:	Sunset Rd.	BMP:	0.00	Design Life (years):	20.0	Functional Class:	Principal Arterial (Other)		
		EMP:	0.00	Growth Rate (%):	5.33	Pavement Type:	Flexible	Cluster Number:	2

						Percent Trucks					
				Truck Volumes		(% of total AADT)		(% of total AADTT)			
				Singles	Combos	Singles	Combos	Singles	Combos	TTC	Vehicle Class. Dist. Method
Present AADT	2025	7,784	Data Year	0	0	3.00%	1.00%	75%	25%	AZ-5	ADOT Tables
Future AADT	2025	7,784	Build Year					Select appropriate TTC from Table A-1 using % Combos Above			

	2	3	4	5	6	7	8	9	10	11	12	
Vehicle Class	1---3	4	5	6	7	8	9	10	11	12	13	Total
Distribution (%)	N/A	5.30	46.30	5.70	0.70	16.10	24.10	1.10	0.30	0.10	0.30	100.0
Class Volume (daily)	7,473	17	144	18	2	50	75	3	1	0	1	7784
Growth Factor (G)	34.24	34.24	34.24	34.24	34.24	34.24	34.24	34.24	34.24	34.24	34.24	
Class Volume (total)	93,398,208	206,254	1,801,807	221,821	27,241	626,546	937,874	42,808	11,675	3,892	11,675	
Truck Load Factor (T_{LF})	0.0008	1.06	0.39	0.96	0.61	0.91	1.34	1.53	1.96	1.33	3.5	
Class ESAL's	74719	218630	702705	212948	16617	570157	1256751	65495	22883	5176	40862	3,186,941

Total Number of Trucks	3,891,592
Directional Distribution Factor (D_D)	0.50
Lane Distribution Factor (D_L)	0.90
Design ESAL's	1,434,124

BMP - beginning mile point

EMP - ending mile point

light grey cells are caculated but should be confirmed by user

user input information/data

light blue cells generally come from ADOTs MPD published sources

New formulas by RMP of Golder

GOLDER

ESAL Calculation Worksheet

ESAL Case 2: **Sunset East (North) of WB Frontage**

TRACS:	N/A		Project No.	19128078		Project Name:	Sunset Road: I-10 to River Road		
Route:	Sunset Rd.	BMP:	0.00	Design Life (years):	20.0	Functional Class:	Principal Arterial (Other)		
		EMP:	0.00	Growth Rate (%):	4.52	Pavement Type:	Flexible	Cluster Number:	2

				Truck Volumes		Percent Trucks (% of total AADT)		Percent Trucks (% of total AADTT)			
				Singles	Combos	Singles	Combos	Singles	Combos	TTC	Vehicle Class. Dist. Method
Present AADT	2025	7,431	Data Year	0	0	3.00%	1.00%	75%	25%	AZ-5	ADOT Tables
Future AADT	2025	7,431	Build Year					Select appropriate TTC from Table A-1 using % Combos Above			

	2	3	4	5	6	7	8	9	10	11	12	
Vehicle Class	1---3	4	5	6	7	8	9	10	11	12	13	Total
Distribution (%)	N/A	5.30	46.30	5.70	0.70	16.10	24.10	1.10	0.30	0.10	0.30	100.0
Class Volume (daily)	7,134	16	138	17	2	48	72	3	1	0	1	7431
Growth Factor (G)	31.44	31.44	31.44	31.44	31.44	31.44	31.44	31.44	31.44	31.44	31.44	
Class Volume (total)	81,856,933	180,767	1,579,157	194,410	23,875	549,124	821,980	37,518	10,232	3,411	10,232	
Truck Load Factor (T_{LF})	0.0008	1.06	0.39	0.96	0.61	0.91	1.34	1.53	1.96	1.33	3.5	
Class ESAL's	65486	191613	615871	186634	14564	499702	1101453	57402	20055	4536	35812	2,793,129

Total Number of Trucks	3,410,706
Directional Distribution Factor (D_D)	0.50
Lane Distribution Factor (D_L)	0.90
Design ESAL's	1,256,908

BMP - beginning mile point

EMP - ending mile point

light grey cells are caculated but should be confirmed by user

user input information/data

light blue cells generally come from ADOTs MPD published sources

New formulas by RMP of Golder

GOLDER

ESAL Calculation Worksheet

ESAL Case 3: **Widening for Turn Lanes at Sunset**

TRACS:	N/A		Project No.	19128078		Project Name:	Sunset Road: I-10 to River Road		
Route:	River Rd.	BMP:	0.00	Design Life (years):	20.0	Functional Class:	Principal Arterial (Other)		
		EMP:	0.00	Growth Rate (%):	0.74	Pavement Type:	Flexible	Cluster Number:	2

				Truck Volumes		Percent Trucks (% of total AADT)		Percent Trucks (% of total AADTT)			
				Singles	Combos	Singles	Combos	Singles	Combos	TTC	Vehicle Class. Dist. Method
Present AADT	2025	19,857	Data Year	0	0	3.00%	1.00%	75%	25%	AZ-5	ADOT Tables
Future AADT	2025	19,857	Build Year					Select appropriate TTC from Table A-1 using % Combos Above			

	2	3	4	5	6	7	8	9	10	11	12	
Vehicle Class	1---3	4	5	6	7	8	9	10	11	12	13	Total
Distribution (%)	N/A	5.30	46.30	5.70	0.70	16.10	24.10	1.10	0.30	0.10	0.30	100.0
Class Volume (daily)	19,063	42	368	45	6	128	191	9	2	1	2	19857
Growth Factor (G)	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47	21.47	
Class Volume (total)	149,389,000	329,901	2,881,963	354,799	43,572	1,002,151	1,500,115	68,470	18,674	6,225	18,674	
Truck Load Factor (T_{LF})	0.0008	1.06	0.39	0.96	0.61	0.91	1.34	1.53	1.96	1.33	3.5	
Class ESAL's	119511	349695	1123965	340607	26579	911958	2010153	104759	36600	8279	65358	5,097,464

Total Number of Trucks	6,224,542
Directional Distribution Factor (D_D)	0.50
Lane Distribution Factor (D_L)	0.90
Design ESAL's	2,293,859

BMP - beginning mile point

EMP - ending mile point

light grey cells are caculated but should be confirmed by user

user input information/data

light blue cells generally come from ADOTs MPD published sources

New formulas by RMP of Golder

GOLDER

ESAL Calculation Worksheet

ESAL Case 4: **Sunset West (South) of EB Frontage [Match NCS]**

TRACS:	N/A		Project No.	19128078		Project Name:	Sunset Road: I-10 to River Road		
Route:	Sunset Rd.	BMP:	0.00	Design Life (years):	20.0	Functional Class:	Principal Arterial (Other)		
		EMP:	0.00	Growth Rate (%):	5.33	Pavement Type:	Flexible	Cluster Number:	2

				Truck Volumes		Percent Trucks (% of total AADT)		Percent Trucks (% of total AADTT)			
				Singles	Combos	Singles	Combos	Singles	Combos	TTC	Vehicle Class. Dist. Method
Present AADT	2025	7,784	Data Year	0	0	5.29%	1.32%	80%	20%	AZ-6	ADOT Tables
Future AADT	2025	7,784	Build Year					Select appropriate TTC from Table A-1 using % Combos Above			

	2	3	4	5	6	7	8	9	10	11	12	
Vehicle Class	1---3	4	5	6	7	8	9	10	11	12	13	Total
Distribution (%)	N/A	7.80	65.80	4.40	0.20	11.70	9.10	0.70	0.20	0.00	0.10	100.0
Class Volume (daily)	7,270	40	338	23	1	60	47	4	1	0	1	7784
Growth Factor (G)	34.24	34.24	34.24	34.24	34.24	34.24	34.24	34.24	34.24	34.24	34.24	
Class Volume (total)	90,861,883	501,378	4,229,569	282,828	12,856	752,066	584,940	44,995	12,856	-	6,428	
Truck Load Factor (T_{LF})	0.0008	1.06	0.39	0.96	0.61	0.91	1.34	1.53	1.96	1.33	3.5	
Class ESAL's	72690	531460	1649532	271515	7842	684380	783820	68843	25197	0	22498	4,117,778

Total Number of Trucks	6,427,917
Directional Distribution Factor (D_D)	0.50
Lane Distribution Factor (D_L)	0.90
Design ESAL's	1,853,000

BMP - beginning mile point

EMP - ending mile point

light grey cells are caculated but should be confirmed by user

user input information/data

light blue cells generally come from ADOTs MPD published sources

New formulas by RMP of Golder

GOLDER

GOLDER

Pavement Design Traffic Loading Derivations

Date:	8/3/2020	**Rev:**	1	**Made by:**	RMP
Project No.:	19128078			**Checked by:**	JAV
Roadway:	All - Rigid Case			**Reviewed by:**	
Project Short Title:	Sunset Road: I-10 to River Road				

Spreadsheet Version 1.0

1.0 PURPOSE

To derive traffic loads for pavement design purposes using ADOT methods.

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3.0 PROBLEM STATEMENT

This spreadsheet allows you to package one or more sets of traffic loading data into an easy to review format. It then transfers this data into the ADOT format ESAL Spreadsheet.

4.0 ASSUMPTIONS

1. Assumes new construction, widening, etc. As opposed to rehabilitation (this primarily affects lane distribution factor).
2. Assumes all loading configurations to be analyzed are for either rigid or flexible pavement design, you can't mix and match.

5.0 CALCULATIONS

Some relevant reference information used for this analysis is included in Section 7.0.

5.1 General Inputs

Pavement Type	Rigid	This spreadsheet assumes you are looking at all rigid pavement or all flexible. If you have both, run the analysis twice.
TRACS	N/A	The ADOT TRACS No. (if applicable). You can just enter "N/A" otherwise.

5.2 AADT and Growth Factor Simplfication

Use this section to reduce two-way AADT data and growth rate information to plug into the ADOT spreadsheet. You can either start with two AADT values/years and compute the growth factor (and project it to a design year), or start with one AADT/year and a given growth factor and compute the design year AADT. Just hide the one you don't need.

GOLDER

Pavement Design Traffic Loading Derivations

Date:	8/3/2020	**Rev:**	1	**Made by:**	RMP
Project No.:	19128078			**Checked by:**	JAV
Roadway:	All - Rigid Case			**Reviewed by:**	
Project Short Title:	Sunset Road: I-10 to River Road				

Table 1: AADT Growth Rate Working Area - Given Two AADT Values

Roadway / Case	AADT1	AADT2	Year 1	Year 2	Compount Annual Growth Rate	Year 3	AADT3
Sunset West (South) of EB Frontage	5,700	22,000	2019	2045	5.33%	2025	7,784
Sunset East (North) of WB Frontage	5,700	18,000	2019	2045	4.52%	2025	7,431

5.3 Inputs for ADOT ESAL Spreadsheet

This spreadsheet will report results for up to 4 different traffic loading cases. Just enter the data in Table 2 and (and 3 if desired), and the ADOT ESAL spreadsheet will be populated with the proper data. The ADOT spreadsheet has been modified to accept the inputs the here, but unless noted in green, the actual formulas/functionality has not been modified.

GOLDER

Pavement Design Traffic Loading Derivations

Date:	8/3/2020	**Rev:**	1	**Made by:**	RMP
Project No.:	19128078			**Checked by:**	JAV
Roadway:	All - Rigid Case			**Reviewed by:**	
Project Short Title:	Sunset Road: I-10 to River Road				

Table 2: Inputs for ADOT Worksheet

Parameter	ESAL Case 1	ESAL Case 2	ESAL Case 3	ESAL Case 4
Route	Sunset Rd.	Sunset Rd.		
Case Name / Description	Sunset West (South) of EB Frontage	Sunset East (North) of WB Frontage		
Begin Milepost/Sta.				
End Milepost/Sta.				
Functional Class.	Principal Arterial (Other)	Principal Arterial (Other)		
Rural / Urban	Urban	Urban		
Recommended Cluster Number	2/3*	2/3*		
Cluster Number	2	2		
Vehicle Class Distribution Method	ADOT Tables	ADOT Tables		
Avg. Daily Trucks - Singles				
Avg. Daily Trucks - Combos				
Percent Trucks - Singles (of AADT)	3.00%	3.00%		
Percent Trucks - Combos (of AADT)	1.00%	1.00%		
Directional Distribution Factor (D_D)	0.5	0.5		
Number of Lanes	2	2		
Build Year	2025	2025		
Build Year AADT	7,784	7,431		
Growth Rate (%)	5.33%	4.52%		
Design Life (Years)	20	20		

* Designer to evaluate Cluster 2 and 3. Final design should be based on the cluster that results in the most ESAL's.

5.4 Vehicle Classification Worksheet

If you want to use actual vehicle classification data instead of the built-in ADOT tables, you can use the following section to reduce data and develop the design percentages to use.

GOLDER

Pavement Design Traffic Loading Derivations

Date:	8/3/2020	**Rev:**	1	**Made by:**	RMP
Project No.:	19128078			**Checked by:**	JAV
Roadway:	All - Rigid Case			**Reviewed by:**	
Project Short Title:	Sunset Road: I-10 to River Road				

6.0 RESULTS AND CONCLUSIONS

The resulting ESAL values for each case are presented in Table 4.

Table 4: Computed Design Lane ESAL Values

Design Case	18-kip Design ESALS
Sunset Rd. - Sunset West (South) of EB Frontage (ESAL Case 1)	1,782,406
Sunset Rd. - Sunset East (North) of WB Frontage (ESAL Case 2)	1,562,153

GOLDER

Pavement Design Traffic Loading Derivations

Date:	8/3/2020	**Rev:**	1	**Made by:**	RMP
Project No.:	19128078			**Checked by:**	JAV
Roadway:	All - Rigid Case			**Reviewed by:**	
Project Short Title:	Sunset Road: I-10 to River Road				

7.0 REFERENCE INFORMATION

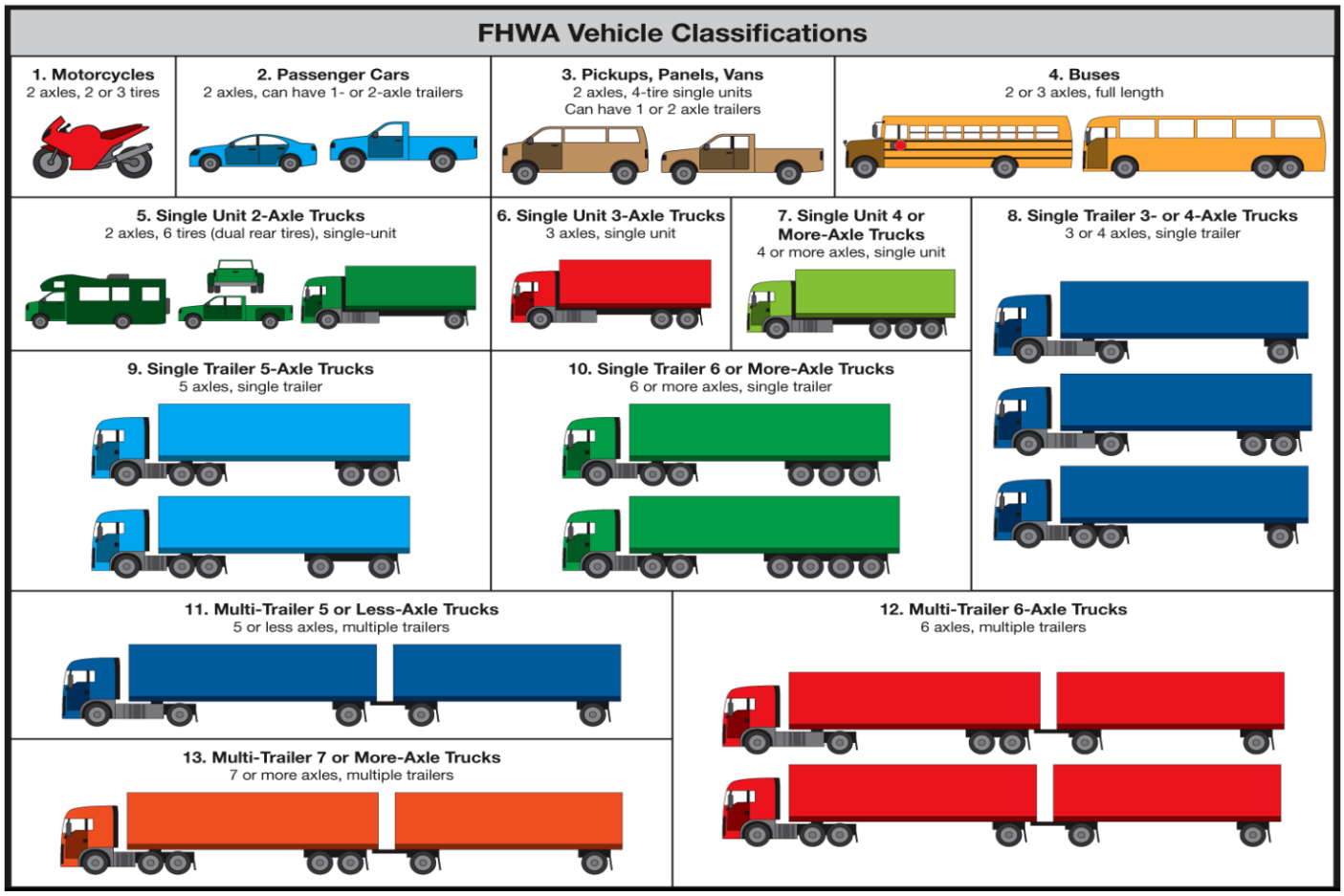


Figure 1: FHWA Vehicle Classifications

ESAL Calculation Worksheet

ESAL Case 1: **Sunset West (South) of EB Frontage**

TRACS:	N/A		Project No.	19128078		Project Name:	Sunset Road: I-10 to River Road		
Route:	Sunset Rd.	BMP:	0.00	Design Life (years):	20.0	Functional Class:	Principal Arterial (Other)		
		EMP:	0.00	Growth Rate (%):	5.33	Pavement Type:	Rigid	Cluster Number:	2

						Percent Trucks						
				Truck Volumes		(% of total AADT)		(% of total AADTT)				
				Singles	Combos	Singles	Combos	Singles	Combos	TTC	Vehicle Class. Dist. Method	
Present AADT	2025	7,784	Data Year	0	0	3.00%	1.00%	75%	25%	AZ-5	ADOT Tables	
Future AADT	2025	7,784	Build Year					Select appropriate TTC from Table A-1 using % Combos Above				

	2	3	4	5	6	7	8	9	10	11	12	
Vehicle Class	1---3	4	5	6	7	8	9	10	11	12	13	Total
Distribution (%)	N/A	5.30	46.30	5.70	0.70	16.10	24.10	1.10	0.30	0.10	0.30	100.0
Class Volume (daily)	7,473	17	144	18	2	50	75	3	1	0	1	7784
Growth Factor (G)	34.24	34.24	34.24	34.24	34.24	34.24	34.24	34.24	34.24	34.24	34.24	
Class Volume (total)	93,398,208	206,254	1,801,807	221,821	27,241	626,546	937,874	42,808	11,675	3,892	11,675	
Truck Load Factor (T_{LF})	0.0008	1.26	0.36	1.31	0.85	1	1.96	2.46	1.9	1.19	5.74	
Class ESAL's	74719	259881	648651	290585	23155	626546	1838232	105306	22182	4631	67013	3,960,901

Total Number of Trucks	3,891,592
Directional Distribution Factor (D_D)	0.50
Lane Distribution Factor (D_L)	0.90
Design ESAL's	1,782,406

BMP - beginning mile point

EMP - ending mile point

light grey cells are caculated but should be confirmed by user

user input information/data

light blue cells generally come from ADOTs MPD published sources

New formulas by RMP of Golder

GOLDER

ESAL Calculation Worksheet

ESAL Case 2: **Sunset East (North) of WB Frontage**

TRACS:	N/A		Project No.	19128078		Project Name:	Sunset Road: I-10 to River Road		
Route:	Sunset Rd.	BMP:	0.00	Design Life (years):	20.0	Functional Class:	Principal Arterial (Other)		
		EMP:	0.00	Growth Rate (%):	4.52	Pavement Type:	Rigid	Cluster Number:	2

						Percent Trucks						
				Truck Volumes		(% of total AADT)		(% of total AADTT)				
				Singles	Combos	Singles	Combos	Singles	Combos	TTC	Vehicle Class. Dist. Method	
Present AADT	2025	7,431	Data Year	0	0	3.00%	1.00%	75%	25%	AZ-5	ADOT Tables	
Future AADT	2025	7,431	Build Year					Select appropriate TTC from Table A-1 using % Combos Above				

	2	3	4	5	6	7	8	9	10	11	12	
Vehicle Class	1---3	4	5	6	7	8	9	10	11	12	13	Total
Distribution (%)	N/A	5.30	46.30	5.70	0.70	16.10	24.10	1.10	0.30	0.10	0.30	100.0
Class Volume (daily)	7,134	16	138	17	2	48	72	3	1	0	1	7431
Growth Factor (G)	31.44	31.44	31.44	31.44	31.44	31.44	31.44	31.44	31.44	31.44	31.44	
Class Volume (total)	81,856,933	180,767	1,579,157	194,410	23,875	549,124	821,980	37,518	10,232	3,411	10,232	
Truck Load Factor (T_{LF})	0.0008	1.26	0.36	1.31	0.85	1	1.96	2.46	1.9	1.19	5.74	
Class ESAL's	65486	227767	568496	254677	20294	549124	1611081	92294	19441	4059	58732	3,471,450

Total Number of Trucks	3,410,706
Directional Distribution Factor (D_D)	0.50
Lane Distribution Factor (D_L)	0.90
Design ESAL's	1,562,153

BMP - beginning mile point

EMP - ending mile point

light grey cells are caculated but should be confirmed by user

user input information/data

light blue cells generally come from ADOTs MPD published sources

New formulas by RMP of Golder

GOLDER

APPENDIX D

Pavement Design Calculations

Sunset Road: I-10 to River Road
Sunset Road - Flexible Pavement - West (South) of EB I-10 Frontage, Alt. 1

AASHTO Flexible Pavement Design Process

21-Jul-20	Made By:	R. Post
	Chkd By:	J. Velarde

ESAL's (W-18) **1,435,000** Flexible 18-kip Equivalent Single Axle Loads

Level of Reliability (R) **95.00 %**
Zr = -1.645 Table 202.02-1 (page 83)

Standard Error (So) **0.35** Pima County RDM P. 3-43

Serviceability Index: **Po =** **4.2** Pima County RDM P. 3-43
Pt = **2.8**
Delta-PSI = 1.4

Resilient Modulus (Mr) **10,837** psi with R value of: **25**

Seasonal Variation Factor **1.7** ADOT Manual
Quality of Base Drainage Number **3** <=

Excellent:	1
Good:	2
Fair:	3
Poor:	4
Very Poor:	5

Base Drainage Coefficient, m2 = 0.92 Pima County RDM P. 3-44

Structural Number Required, SN_{reqd} = **3.31**

Layer (Surfacing - Base) Thicknesses:

			Layer Coefficients
PAG No. 1 =	D1=3.00	inches	a1 = 0.44
PAG No. 2 =	D2=3.00	inches	a2 = 0.44
Cement/Bituminous Base =	D3=0.00	inches	a3 = 0.28
Cement/Lime Subgrade =	D4=0.00	inches	a4 = 0.23
Aggregate Base =	D5=6.00	inches	a5 = 0.12

Total Section Thickness = 12.0 inches

Structural Number Provided, SN = **3.36**

PAVEMENT SECTION IS SUFFICIENT
101.48% of that required

Pavement Unit Costs

PAG No. 1 =	$3.83	/Sq. Yd./in. of thickness
PAG No. 2 =	$6.02	/Sq. Yd./in. of thickness
Cement/Bituminous Base =		/Sq. Yd./in. of thickness
Cement/Lime Subgrade =		/Sq. Yd./in. of thickness
Aggregate Base =	$0.89	/Sq. Yd./in. of thickness

Pavement Section Costs	
Initial	($/SY)
$34.89	
Life-Cycle	($/SY)
-	

GOLDER

Sunset Road: I-10 to River Road
Sunset Road - Flexible Pavement - West (South) of EB I-10 Frontage, Alt. 2

AASHTO Flexible Pavement Design Process

21-Jul-20	Made By:	R. Post
	Chkd By:	J. Velarde

ESAL's (W-18) **1,435,000** Flexible 18-kip Equivalent Single Axle Loads

Level of Reliability (R) **95.00 %**
Zr = -1.645 Table 202.02-1 (page 83)

Standard Error (So) **0.35** Pima County RDM P. 3-43

Serviceability Index: **Po =** **4.2** Pima County RDM P. 3-43
Pt = **2.8**
Delta-PSI = 1.4

Resilient Modulus (Mr) **10,837** psi with R value of: **25**

Seasonal Variation Factor **1.7** ADOT Manual
Quality of Base Drainage Number **3** <=

Excellent:	1
Good:	2
Fair:	3
Poor:	4
Very Poor:	5

Base Drainage Coefficient, m2 = 0.92 Pima County RDM P. 3-44

Structural Number Required, SN_{reqd} = **3.31**

Layer (Surfacing - Base) Thicknesses:

			Layer Coefficients
PAG No. 1 =	D1=3.00	inches	a1 = 0.44
PAG No. 2 =	D2=2.50	inches	a2 = 0.44
Cement/Bituminous Base =	D3=0.00	inches	a3 = 0.28
Cement/Lime Subgrade =	D4=0.00	inches	a4 = 0.23
Aggregate Base =	D5=8.00	inches	a5 = 0.12

Total Section Thickness = 13.5 inches

Structural Number Provided, SN = **3.38**

PAVEMENT SECTION IS SUFFICIENT
102.08% of that required

Pavement Unit Costs

PAG No. 1 =	$3.83	/Sq. Yd./in. of thickness
PAG No. 2 =	$6.02	/Sq. Yd./in. of thickness
Cement/Bituminous Base =		/Sq. Yd./in. of thickness
Cement/Lime Subgrade =		/Sq. Yd./in. of thickness
Aggregate Base =	$0.89	/Sq. Yd./in. of thickness

Pavement Section Costs	
Initial	($/SY)
$33.66	
Life-Cycle	($/SY)
-	

GOLDER

Sunset Road: I-10 to River Road
Sunset Road - Flexible Pavement - East (North) of WB I-10 Frontage, Alt. 1

AASHTO Flexible Pavement Design Process

21-Jul-20	Made By:	R. Post
	Chkd By:	J. Velarde

ESAL's (W-18)		**1,257,000**	Flexible 18-kip Equivalent Single Axle Loads
Level of Reliability (R)		**95.00 %**	
	Zr =	-1.645	Table 202.02-1 (page 83)
Standard Error (So)		**0.35**	Pima County RDM P. 3-43
Serviceability Index:	**Po =**	**4.2**	Pima County RDM P. 3-43
	Pt =	**2.8**	
	Delta-PSI =	1.4	
Resilient Modulus (Mr)		**10,837**	psi with R value of: **25**
Seasonal Variation Factor		**1.7**	ADOT Manual
Quality of Base Drainage Number		**3**	<=
	Base Drainage Coefficient, m2 =	0.92	Pima County RDM P. 3-44

Excellent:	1
Good:	2
Fair:	3
Poor:	4
Very Poor:	5

Structural Number Required, SN_{reqd} = **3.23**

Layer (Surfacing - Base) Thicknesses:

			Layer Coefficients
PAG No. 1 =	D1=3.00	inches	a1 = 0.44
PAG No. 2 =	D2=2.50	inches	a2 = 0.44
Cement/Bituminous Base =	D3=0.00	inches	a3 = 0.28
Cement/Lime Subgrade =	D4=0.00	inches	a4 = 0.23
Aggregate Base =	D5=7.00	inches	a5 = 0.12
Total Section Thickness =	12.5	inches	

Structural Number Provided, SN = **3.26**

PAVEMENT SECTION IS SUFFICIENT
100.81% of that required

Pavement Unit Costs

PAG No. 1 =	$3.83	/Sq. Yd./in. of thickness
PAG No. 2 =	$6.02	/Sq. Yd./in. of thickness
Cement/Bituminous Base =		/Sq. Yd./in. of thickness
Cement/Lime Subgrade =		/Sq. Yd./in. of thickness
Aggregate Base =	$0.89	/Sq. Yd./in. of thickness

Pavement Section Costs	
Initial	($/SY)
	$32.77
Life-Cycle	($/SY)
	-

GOLDER

Sunset Road: I-10 to River Road
Sunset Road - Flexible Pavement - East (North) of WB I-10 Frontage, Alt. 2

AASHTO Flexible Pavement Design Process

21-Jul-20	Made By:	R. Post
	Chkd By:	J. Velarde

ESAL's (W-18)		**1,257,000**	Flexible 18-kip Equivalent Single Axle Loads
Level of Reliability (R)		**95.00 %**	
	Zr =	-1.645	Table 202.02-1 (page 83)
Standard Error (So)		**0.35**	Pima County RDM P. 3-43
Serviceability Index:	**Po =**	**4.2**	Pima County RDM P. 3-43
	Pt =	**2.8**	
	Delta-PSI =	1.4	
Resilient Modulus (Mr)		**10,837**	psi with R value of: **25**
Seasonal Variation Factor		**1.7**	ADOT Manual
Quality of Base Drainage Number		**3**	<=
	Base Drainage Coefficient, m2 =	0.92	Pima County RDM P. 3-44

Excellent:	1
Good:	2
Fair:	3
Poor:	4
Very Poor:	5

Structural Number Required, SN_{reqd} = **3.23**

Layer (Surfacing - Base) Thicknesses:

			Layer Coefficients
PAG No. 1 =	D1=3.00	inches	a1 = 0.44
PAG No. 2 =	D2=2.00	inches	a2 = 0.44
Cement/Bituminous Base =	D3=0.00	inches	a3 = 0.28
Cement/Lime Subgrade =	D4=0.00	inches	a4 = 0.23
Aggregate Base =	D5=9.00	inches	a5 = 0.12
Total Section Thickness =	14.0	inches	

Structural Number Provided, SN = **3.28**

PAVEMENT SECTION IS SUFFICIENT
101.43% of that required

Pavement Unit Costs

PAG No. 1 =	$3.83	/Sq. Yd./in. of thickness
PAG No. 2 =	$6.02	/Sq. Yd./in. of thickness
Cement/Bituminous Base =		/Sq. Yd./in. of thickness
Cement/Lime Subgrade =		/Sq. Yd./in. of thickness
Aggregate Base =	$0.89	/Sq. Yd./in. of thickness

Pavement Section Costs
Initial ($/SY)
$31.54
Life-Cycle ($/SY)
-

GOLDER

Sunset Road: I-10 to River Road
River Road - Flexible Pavement, Alt. 1

AASHTO Flexible Pavement Design Process

21-Jul-20	Made By:	R. Post
	Chkd By:	J. Velarde

ESAL's (W-18)		**2,294,000**	Flexible 18-kip Equivalent Single Axle Loads
Level of Reliability (R)		**95.00 %**	
	Zr =	-1.645	Table 202.02-1 (page 83)
Standard Error (So)		**0.35**	Pima County RDM P. 3-43
Serviceability Index:	**Po =**	**4.2**	Pima County RDM P. 3-43
	Pt =	**2.8**	
	Delta-PSI =	1.4	
Resilient Modulus (Mr)		**10,837**	psi with R value of: **25**
Seasonal Variation Factor		**1.7**	ADOT Manual
Quality of Base Drainage Number		**3**	<=
	Base Drainage Coefficient, m2 =	0.92	Pima County RDM P. 3-44

Excellent:	1
Good:	2
Fair:	3
Poor:	4
Very Poor:	5

Structural Number Required, SN_{reqd} = **3.60**

Layer (Surfacing - Base) Thicknesses:

			Layer Coefficients
PAG No. 1 =	D1=4.00	inches	a1 = 0.44
PAG No. 2 =	D2=2.00	inches	a2 = 0.44
Cement/Bituminous Base =	D3=0.00	inches	a3 = 0.28
Cement/Lime Subgrade =	D4=0.00	inches	a4 = 0.23
Aggregate Base =	D5=8.00	inches	a5 = 0.12
Total Section Thickness =	14.0	inches	

Structural Number Provided, SN = **3.60**

PAVEMENT SECTION IS SUFFICIENT
100.02% of that required

Pavement Unit Costs

PAG No. 1 =	$3.83	/Sq. Yd./in. of thickness
PAG No. 2 =	$6.02	/Sq. Yd./in. of thickness
Cement/Bituminous Base =		/Sq. Yd./in. of thickness
Cement/Lime Subgrade =		/Sq. Yd./in. of thickness
Aggregate Base =	$0.89	/Sq. Yd./in. of thickness

Pavement Section Costs	
Initial	($/SY)
	$34.48
Life-Cycle	($/SY)
	-

GOLDER

Sunset Road: I-10 to River Road
River Road - Flexible Pavement, Alt. 2

AASHTO Flexible Pavement Design Process

21-Jul-20	Made By:	R. Post
	Chkd By:	J. Velarde

ESAL's (W-18)		**2,294,000**	Flexible 18-kip Equivalent Single Axle Loads
Level of Reliability (R)		**95.00 %**	
	Zr =	-1.645	Table 202.02-1 (page 83)
Standard Error (So)		**0.35**	Pima County RDM P. 3-43
Serviceability Index:	**Po =**	**4.2**	Pima County RDM P. 3-43
	Pt =	**2.8**	
	Delta-PSI =	1.4	
Resilient Modulus (Mr)		**10,837**	psi with R value of: **25**
Seasonal Variation Factor		**1.7**	ADOT Manual
Quality of Base Drainage Number		**3**	<=
	Base Drainage Coefficient, m2 =	0.92	Pima County RDM P. 3-44

Excellent:	1
Good:	2
Fair:	3
Poor:	4
Very Poor:	5

Structural Number Required, SN_{reqd} = **3.60**

Layer (Surfacing - Base) Thicknesses:

			Layer Coefficients
PAG No. 1 =	D1=3.50	inches	a1 = 0.44
PAG No. 2 =	D2=2.00	inches	a2 = 0.44
Cement/Bituminous Base =	D3=0.00	inches	a3 = 0.28
Cement/Lime Subgrade =	D4=0.00	inches	a4 = 0.23
Aggregate Base =	D5=10.00	inches	a5 = 0.12
Total Section Thickness =	15.5	inches	

Structural Number Provided, SN = **3.62**

PAVEMENT SECTION IS SUFFICIENT
100.57% of that required

Pavement Unit Costs

PAG No. 1 =	$3.83	/Sq. Yd./in. of thickness
PAG No. 2 =	$6.02	/Sq. Yd./in. of thickness
Cement/Bituminous Base =		/Sq. Yd./in. of thickness
Cement/Lime Subgrade =		/Sq. Yd./in. of thickness
Aggregate Base =	$0.89	/Sq. Yd./in. of thickness

Pavement Section Costs	
Initial	($/SY)
	$34.35
Life-Cycle	($/SY)
	-

GOLDER

Sunset Road: I-10 to River Road
Sunset Road - Rigid Pavement

AASHTO Rigid Pavement Design Process

21-Jul-20	Made By:	R. Post
	Chkd By:	J. Velarde

ESAL's (W-18)	**1,783,000**	Rigid 18-kip Equivalent Single Axle Loads
Level of Reliability (R)	**95.00 %**	
Zr =	-1.645	Table 2-1
Standard Error (So)	**0.25**	ADOT Standard Number
Average Modulus of Rupture (S'c)	**670**	psi - ADOT Standard
Modulus of Elasticity (Ec)	**4,000,000**	psi - ADOT Standard
Serviceability Index: Po =	**4.2**	Table 2-2
Pt =	**2.8**	
Resilient Modulus (Mr)	**10,837**	psi with R value of: **25**
Modulus of Subgrade Reaction (k)=	**559**	pci
Base Material Type =	**Aggregate Base**	
Composite Modulus of Subgrade Reaction (k_∞)=	**559**	pci - Corrected using Figure 2-7
Loss of Support (LS)=	**0.75**	Table 2-9
Design Modulus of Subgrade Reaction (k_{corr})=	**250**	pci - Corrected using Figure 2-6
Seasonal Variation Factor	**1.7**	
Quality of Base Drainage Number	**3**	<=
Base Drainage Coefficient (Cd)	0.92	

Excellent:	1
Good:	2
Fair:	3
Poor:	4
Very Poor:	5

Load Transfer Coefficient (J Factor)	**3.9**	Table 2-8

Layer (Surfacing - Base) Thicknesses:

Plain Jointed (No Dowels) =	9.00	inches
Jointed Reinforced (Dowels) =	0.00	inches
Continuously Reinforced =	0.00	inches
Asphaltic Concrete Base =	0.00	inches
Aggregate Base =	4.00	inches

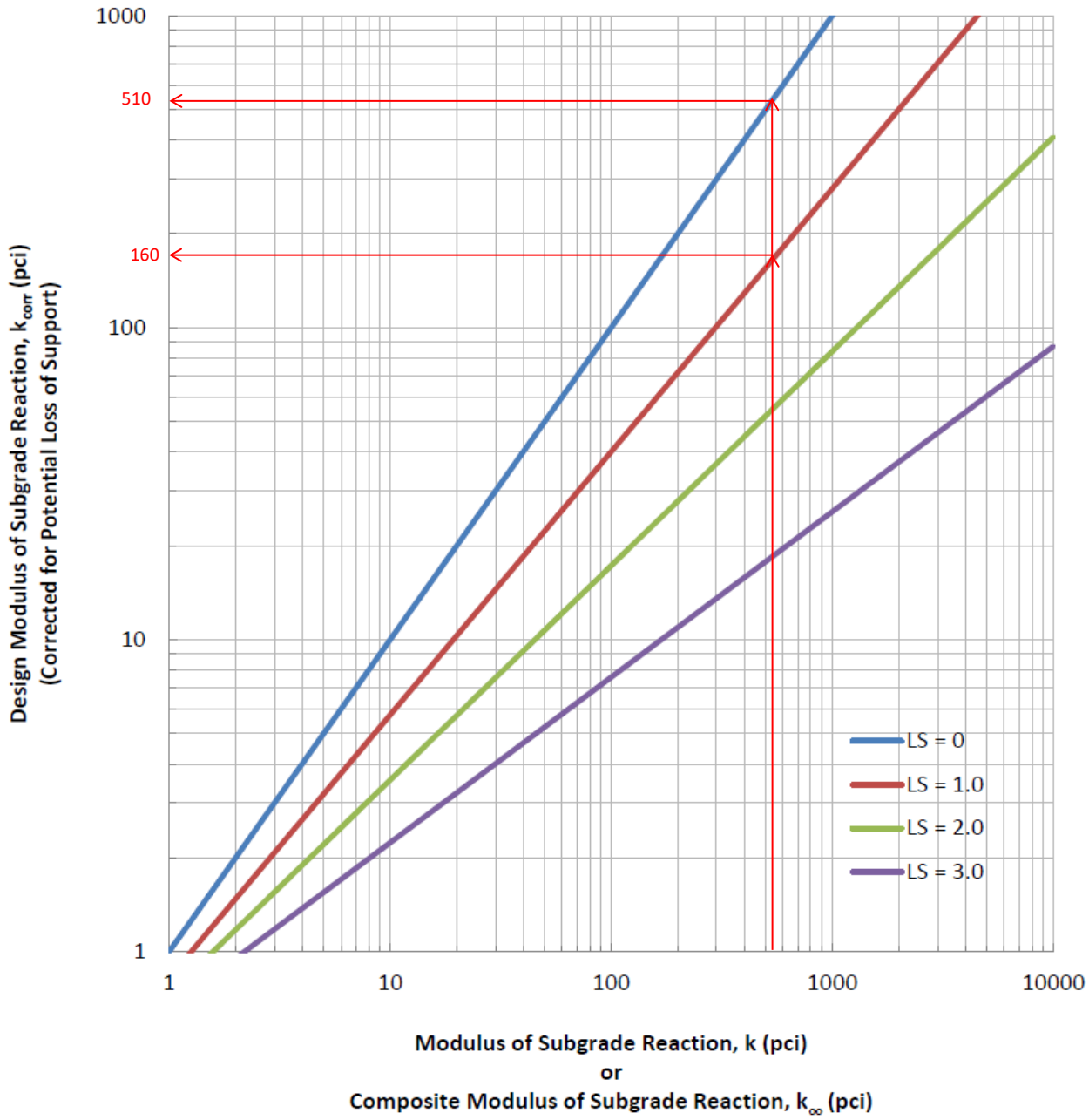
PAVEMENT SECTION IS SUFFICIENT
100.92% of that required

Pavement Unit Costs

Plain Jointed (No Dowels) =	-	/Sq. Yd./in. of thickness
Jointed Reinforced (Dowels) =	-	/Sq. Yd./in. of thickness
Continuously Reinforced =	-	/Sq. Yd./in. of thickness
Asphaltic Concrete Base =	-	/Sq. Yd./in. of thickness
Aggregate Base =	-	/Sq. Yd./in. of thickness

Pavement Section Costs
Initial ($/SY)
0.00
Life-Cycle ($/SY)
-

GOLDER


1000
510
160
100
10
1
1
10
100
1000
10000
Design Modulus of Subgrade Reaction, k_{corr} (pci)
(Corrected for Potential Loss of Support)
Modulus of Subgrade Reaction, k (pci)
or
Composite Modulus of Subgrade Reaction, k_{∞} (pci)
LS = 0
LS = 1.0
LS = 2.0
LS = 3.0

GOLDER

Example:

D_{SB} = 6 inches

E_{SB} = 20,000 psi

M_R = 7,000 psi

Solution: k_∞ = 400 pci

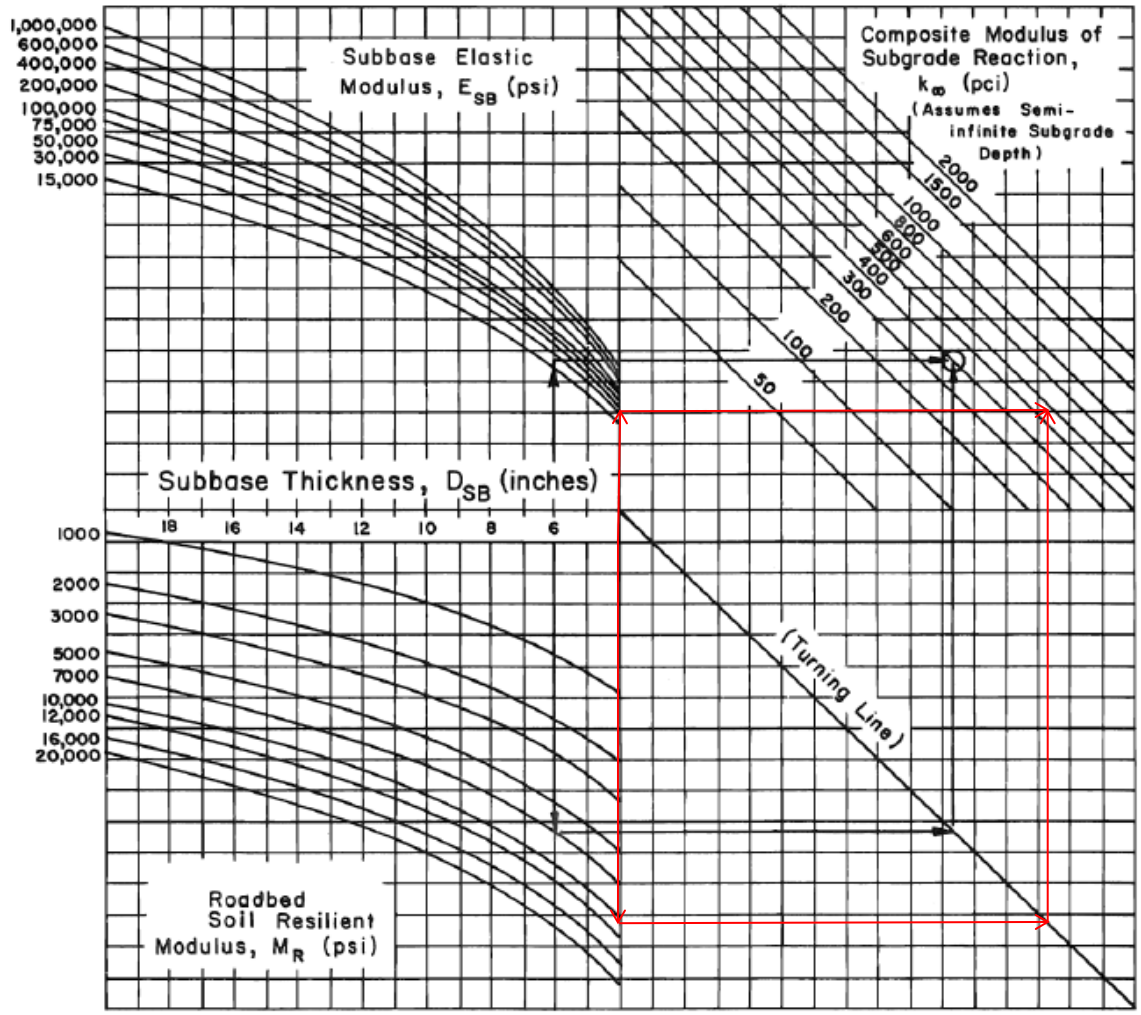


Figure 2-7 Composite Modulus of Subgrade Reaction (k_∞)

(Chart for estimating composite modulus of subgrade reaction, k_∞, assuming a semi-infinite subgrade depth. For practical purposes, a semi-infinite depth is considered to be greater than 10 feet below the surface of the subgrade.)

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APPENDIX E

Important Information About Your Geotechnical Engineering 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.***

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