RAYMONDVILLE DRAIN PROJECT
ENGINEERING APPENDIX A1

ATTACHMENT F

GEOTECHNICAL REPORT – WILLACY COUNTY

GEOTECHNICAL INVESTIGATION
FOR
RAYMONDVILLE DRAIN

WILLACY COUNTY, TEXAS

Prepared For:
S&B Infrastructure

Prepared By:
L&G Engineering Laboratory, L.L.C.
[Texas Registered Engineering Firm F-6633]

L&G Project No. GL15007
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Draft – Existing Sub-Surface Conditions, Site Investigation, Prelim. Geo Boring Analysis, Prelim. Geo Engineering Analysis, Prelim. Construction Recs.
(See File Folders for Additional Info. Gradation, Sulfates, Deep Foundation Analysis & Global Stability Analysis)

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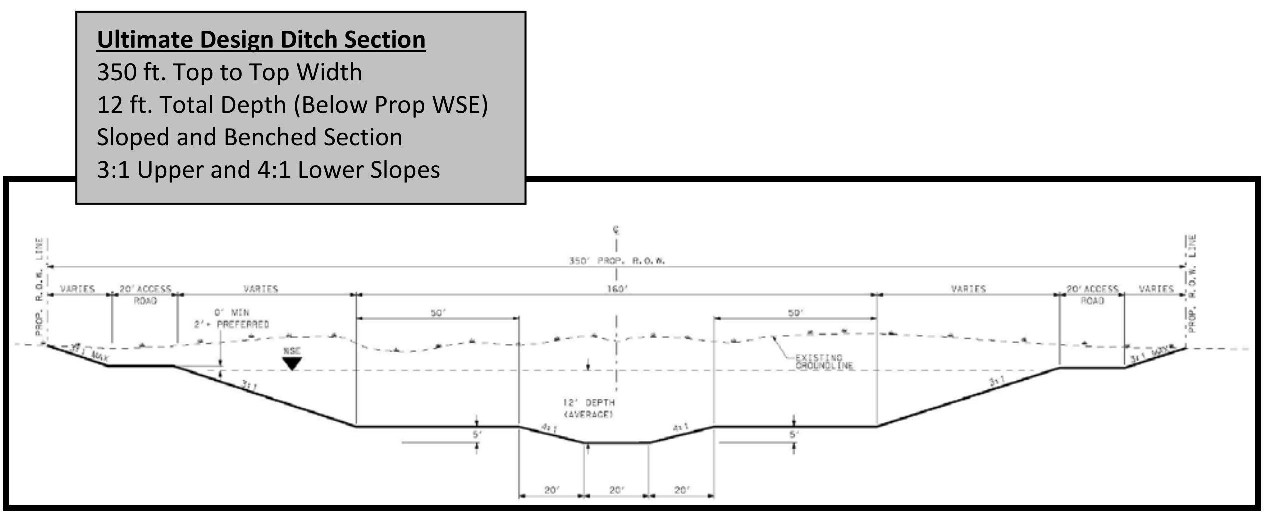
INTRODUCTION

L&G Engineering Laboratory, L.L.C. (L&G) was contracted by **S&B Infrastructure (S&B)** to perform a subsurface geotechnical investigation and engineering analysis for the proposed Raymondville Drain Project in Willacy County, Texas. This report addresses several design requirements including chemical properties (sulfate contents) of in-situ soils to determine the effects on concrete structures, as well as generalized slope/global stability analyses for ditch side slopes. In addition, this report addresses several aspects regarding the hydrology, geology, and physical properties of the existing subsurface soils, and provides construction recommendations for the proposed drainage improvements.

GENERAL PROJECT OVERVIEW

Project Description

L&G is pleased to submit this document presenting our findings as the result of a subsurface geotechnical exploration performed at the request of **S&B**. It is our understanding that the general project involves the widening of the existing Raymondville Drain. The projects begins at the Willacy County border line at County Rd. 5 (between SH186 and County Rd 2900 W) and meanders approximately 32 miles east ending at the intersection of State Highway 186 and the existing Raymondville Drain. Bridge crossings will also be constructed at several locations along the Raymondville Drain (TO BE UPDATED). A general location map showing the proposed Raymondville Drain Project can be found on Figure 1 in Appendix A.



Scope and Limitations of Investigation

This report has been prepared in accordance with accepted Geotechnical Engineering practices for the subject project site and the anticipated construction. No specific warranty program or other standards, except acceptable industry standards, were followed during the course of this investigation. This report is intended for use by **S&B** and their representatives. This report may not contain sufficient information for other parties or agencies for uses in determining construction means and methods.

The strata shown on the boring logs (included in Appendix B of this report) represent the in-situ soil conditions at the boring locations during exploration. These stratifications represent approximate boundaries between subsurface materials; their actual transition may be gradual. It should be noted that the exploratory borings were performed within the limits of the proposed construction as requested and agreed upon by **S&B** and **L&G**.

The purposes for this study are to:

1. explore the general existing subsurface conditions at the site
2. evaluate the relevant engineering properties of the subsurface materials
3. calculate strength parameters for the existing soil strata for structural evaluation
4. analyze chemical composition of in-situ soils (pH and sulfate concentrations)
5. conduct slope/global stability analyses for ditch side slopes
6. develop grain size gradation curves for soils (for future use in Scour Analysis)
7. provide general construction recommendations regarding all aspects of the project

The scope of this geotechnical engineering study does not include environmental assessment of the air, soil, rock or water conditions on or adjacent to the site. No environmental opinions are presented in this report.

EXISTING SOIL SURFACE & SUB-SURFACE CONDITIONS

Site Location / Description

The proposed alignment for the Raymondville Drain Project within Willacy County, Texas is within and around the vicinity of the Lasara, Raymondville and San Perlita, Texas (See Figure 1 in Appendix A). The projects begins at the Willacy County border line at County Rd. 5 (between SH186 and County Rd 2900 W) and meanders approximately 25 miles east getting to Access drive #4 then changing direction going south ending at the Main Floodwater Channel. The alignment crosses several tracts of existing agricultural lands, cultivated farmlands (small crops) and undeveloped acreages. In addition, it should be noted, much of the alignment remains within an existing Delta Lake Irrigation District right of way (ROW) existing ditch. The boring locations were drilled as close as possible to the locations specified by the Client as shown on Figure 2 in Appendix A. All final boring locations were surveyed by the Client to determine the exact coordinates for the borings (these are noted on the boring logs in Appendix B).

Geology

The Geologic Atlas of Texas, McAllen-Brownsville Sheet, dated 1976, indicates that the subject site is located within the *Beaumont Formation (Qb)* of the Pleistocene geological epoch (part of the Quaternary period), *Lissie Formation (undivided)*, and *Goliad Formation*. The description of the materials is as follows:

<u>Beaumont Formation</u> – "Mostly clay, silt, sand, and gravel; includes mainly stream channel, point bar, natural levee, and backswamp deposits; concretions and massive accumulations of calcium carbonate (caliche) and concretions of iron oxide and iron-manganese oxides in zone of weathering". The location of the formation referenced is in a lined overprint pattern which denotes the following: "areas of floodplain deposits consisting of mud veneer over meanderbelt sand, little grain preserved, grass covered"

<u>Beaumont Formation (Stippled Overprint)</u> – "The stippled overprint shows areas that are "Dominantly clay and mud of low permeability, high to very high shrink-swell potential, poor drainage, level to depresses relief, low shear strength, and high plasticity; geologic units include interdistributary muds, abandoned channel-fill muds, and fluvial overbank muds."

<u>Beaumont Formation (Lined Print)</u> – "The lined overprint shows areas of floodplain deposits consisting of mud veneer over meanderbelt sand, little grain preserved, grass covered"

<u>Lissie Formation</u> – "Clay, Silt, Sand, Gravel, and caliche; gray to brown to pale yellow; gravel mainly siliceous, locally cemented by and interbedded with sandy caliche; caliche massive to nodular; surface characterized by many undrained circular to irregular depressions, by relict dunes, and by stabilized northwest-trending longitudinal dunes"

<u>Goliad Formation</u> – "Clay, sand, sandstone, marl caliche, limestone, and conglomerate; clay, commonly light shades of pink and green, calcareous concretions; sand and sandstone, medium to very coarse grained, in part crossbedded, mostly quartz, some black and red chert; conglomerate, black chert and dark siliceous granules and pebbles in calcareous (caliche) matrix; sandstone and conglomerate locally well bedded; marl and limestone poorly bedded or massive; Tertiary vertebrate and reworked Cretaceous invertebrate fossils fairly common; thickness up to 600 feet. The strippled overprint shows areas of caliche, sand veneered with strong relict eolian grain"

Soil Survey Description

According to the Soil Survey of Willacy County, Texas, published by the United States Department of Agriculture (issued December 1982, soil maps current), the proposed Raymondville Drain ditch alignment encompasses several soil map units. These soils are described by the Soil Survey as the following (in order from most to least prevalent):

> **Hidalgo Sandy Clay Loam (0 to 1% slopes) (HoA) –** This deep, nearly level soil is on low rises on the middle coastal terrace. The surface is plane. Areas are broad and irregular in shape and range from 40 to 200 acres. Typically, the surface layer is grayish brown sandy clay loam about 14 inches tick. The subsoil, which extends to a depth of 42

inches, is sandy clay loam that is brown in the upper part and pale brown in the lower part and has many threads and films of calcium carbonate. The underlying material to a depth of 60 inches is very pale brown clay loam with many soft masses of calcim carbonate. This soil is moderately alkaline throughout. This soil is well drained. Surface runoff is slow. Permeability is moderate. Available water capacity is high. The erosion hazard is slight. The soil is easy to work and responds well to good management.

Lyford Sandy Clay Loam (Ly) – This nearly level soil is on drainageways of the low coastal terraces. The surface is plane. Slopes are less than 1 percent. Areas are irregularly shaped and range from 10 to 100 acres. Typically, the surface layer is neutral, dark grayish brown sandy clay loam about 12 inches thick. The subsoil, from 12 to 40 inches, is sandy clay loam that is mildly alkaline and brown in the upper part and moderately alkaline and brown, in the lower part. The underlying material to a depth of 60 inches is moderately alkaline, light brown clay loam, which has many soft masses and concretions of calcium carbonate. The soil is deep and moderately well drained. Surface runoff is slow. Permeability is moderate. Available water capacity is high. The erosion hazard is slight. A seasonal high water table is within 3 to 5 feet if the soil surface.

Racombes Sandy Clay Loam (Ra) – This nearly level soil is in drainageways of the middle stream terraces. The soil has plane to slightly concave slopes of less than 1 percent. Areas are irregularly rounded and range from 10 to 100 acres. Typically, the surface layers is mildly alkaline, dark gray sandy clay loam about 10 inches thick. The subsoil to a depth of 32 inches is mildly alkaline sandy clay loam that is dark gray in the upper part and dark grayish brown in the lower part. The lower part of the subsoil, from 32 to 44 inches, is moderately alkaline, brown clay loam. Below that to a depth of 60 inches is moderately alkaline, pink clay loam with many masses of calcium carbonate. This soil is deep and moderately well drained. It is rarely flooded. Surface runoff is slow. Permeability is moderate. Available water capacity is high. The soil is usually ponded for short periods after heavy rains unless surface drainage is provided in these areas. The erosion hazard is slight.

Raymondville Clay Loam (Rd) – This deep, nearly level soil is on slightly depressed flats of the middle stream terraces. The surface is plane to slightly concave, and slopes are less than 1 percent. Areas are broad and irregular and range from 10 to more than 600 acres. Typically, the surface layer is grayish brown clay loam about 16 inches thick. The subsoil, from 16 to 46 inches, is light brownish gray clay loam with many concretions of calcium carbonate. The underlying material to a depth of 60 inches is very pale brown clay loam. It has a few concretions of salt and calcium carbonate. The soil is moderately alkaline and calcareous throughout. This soil is moderately well drained. Surface runoff is slow. Permeability is slow. Available water capacity is moderate. The erosion hazard is slight. Surface water is common for a few days after heavy rains unless the areas provided with a drainage system.

Rainfall

The mean annual precipitation for this area of Willacy County is approximately 20-24 inches, as reported by the U.S. Department of Agriculture Soil Conservation Service. Our geotechnical investigation, performed in March – TO BE DETERMINED 2015 was conducted during a nondrought condition ("None" as noted by the National Weather Service and U.S. Drought Monitor). The National Oceanic and Atmospheric Administration (NOAA) reports for the subject date indicated that no significant rainfall observations (at least one inch) occurred prior to or during our exploration that could have had significant effects on any groundwater levels or moisture content of surface soils.

GEOTECHNICAL SITE INVESTIGATION

Soil Borings and Field/Laboratory Tests

Subsurface conditions at the site were evaluated through various depths of borings based on their required use in analysis. The overall breakdown of boring and corresponding depths is as follows

- Channel Borings –166 borings drilled at locations of proposed channel alignment (drilled to a depth of approximately thirty-five (35) feet below the existing top of natural ground). (CURRENT DRILLED 114 BORINGS)
- Structure Borings – 83 borings drilled at locations of proposed structures noted along the channel alignment (drilled to a depth of approximately seventy-five (75) feet below the existing top of natural ground). (CURRENT DRILLED 75 BORINGS)
- Weir Borings – 8 borings to be drilled at currently unidentified locations of proposed weirs along the channel alignment (to be drilled to a depth of approximately seventy (70) feet below the existing top of natural ground). (CURRENT DRILLED 0 BORINGS)

All exploratory borings were drilled at the approximate locations shown on Figure 2 in Appendix A. The soil borings were drilled and sampled in general accordance with American Society of Testing Materials Procedures (ASTM) D420, D1452, and D1586 using a truck mounted drilling rig (Simco 2800 HS (HT)).

Standard Penetration Testing (SPT) – Borings B-CH-# & B-W-#

As part of the drilling procedure, split barrel (spoon) and Standard Penetration Tests (SPT) were performed and recorded. Standard Penetration Test results are noted on the boring logs as blows per foot or twelve (12) inch increment. The sampler was advanced through three (3) consecutive six (6) inch increments; however, the first six inch increment is considered the seating drive, which eliminates the effect of cuttings or disturbances on the test result. The sum of the blows for the last two six (6) inch increments is considered the "standard penetration resistance value" or "field N-value". Where hard or very dense materials were encountered, the SPT was terminated and noted on the boring log when one of the following situations occurred:

1. *a total of 50 blows were applied on one six inch increment*
2. *a total of 100 blows were applied during the test*
3. *no observation of advancement of the sampler was detected during the application of 10 consecutive blows from the hammer*

As part of the sampling procedure, split spoon samples were collected through SPT sampling during the drilling process. Representative portions of the samples were identified, packaged, sealed in containers (to reduce moisture loss), and transported to our laboratory for subsequent testing. In the laboratory, each sample was evaluated and visually classified by a member of our Geotechnical Engineering staff. The properties of the strata were evaluated by a series of laboratory index tests (Tex-142-E, Laboratory Classification of Soils for Engineering Purposes and ASTM D 2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)). A summary of the laboratory data and their corresponding depths are presented on the boring logs in Appendix B.

Samples will be retained in our laboratory for 30 days after submittal of this report. Other arrangements may be provided at the request of the Client.

Texas Cone Penetration Testing (TCP) – Boring B-BRG-#

As part of the drilling procedure, Texas Cone Penetration (TCP) field tests were performed at various depth intervals for use in determination of soil strength parameters. TCP tests were executed in compliance with TxDOT test procedures (Tex-132-E, Texas Cone Penetration) and results were reported as blows per increment on the boring logs. A 170 pound hammer was used to drive the conical driving point through three (3) - six inch increments. The first six inch increment (or 12 blows, whichever was reached first), typically referred to as the seating drive, was not included in the blow count as per the test procedure. The number of blows required to drive the sampler through the subsequent two (2) - six inch increments were recorded as the TCP results (and were included on the boring logs in Appendix B). Where very dense or hard material was encountered (resulting in less than 6 inches of movement per 50 blows) the cone was driven for a minimum 100 blows, and the depth of penetration for the first and second 50 blows was recorded as the TCP results.

As part of the sampling procedure, auger samples were collected through general grab sampling during the drilling process (auger cuttings were collected at drilling intervals between TCP tests). Representative portions of the samples were identified, packaged, sealed in containers (to reduce moisture loss) and transported to our laboratory for subsequent testing. In the laboratory, each sample was evaluated and visually classified by a member of our Geotechnical Engineering staff. The properties of the strata were evaluated by a series of laboratory index tests (Tex-142-E, Laboratory Classification of Soils for Engineering Purposes and ASTM D 2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)). A summary of the laboratory data and their corresponding depths are presented on the boring logs in Appendix B.

Samples will be retained in our laboratory for 30 days after submittal of this report. Other arrangements may be provided at the request of the Client.

Subsurface Stratigraphy

TO BE COMPLETED

Water Strike Readings

TO BE COMPLETED – SEE ATTACHED DRILL LOG INFO

GEOTECHNICAL BORING ANALYSIS & TESTING

Moisture Content

The moisture content of a soil is defined as the ratio of the weight of the water in the sample to the dry weight of the soil sample. The moisture contents for the samples obtained as part of our geotechnical exploration were performed in compliance with ASTM procedure D2216. The results varied from xx percent to xx percent. Variance in percentages within the samples can be attributed to a multitude of issues including, range in depth, distance between samples, location of groundwater table and seasonal moisture zone. The variation could also be caused by differences in soil classifications, as some soils such as loose gravels and sands are made up of larger particles and thus exhibit more voids as a soil structure (higher capability to hold water than fine grained soils). Finer grained denser soils, though, due to high impermeability, may also exhibit high moisture contents in certain instances due to the slower movement of water through the soil structure. A comprehensive list of all the moisture contents by corresponding depth can be found on the boring logs.

Plasticity Index

The Plasticity Index (PI) is defined as the difference between the liquid limit and the plastic limit of a soil. These limits are commonly referred to as the Atterberg limits, which describe the consistency of soils with respect to their varying moisture contents. The liquid limit is defined as the moisture content at which soil begins to transition from a plastic to a liquid state and begins to behave as a liquid material by beginning to flow. The plastic limit refers to the water content of a soil at the point of transition from a semisolid to a plastic state where soil starts to exhibit plastic behavior. A soils behavior can be divided into four basic states: liquid, plastic, semisolid and solid. The plasticity index shows the range in which a soil acts in a plastic state. Experience has shown that the more plastic a soil is the more expansive and compressive it will act. The plasticity indices for the samples obtained as part of our geotechnical exploration were performed in compliance with ASTM procedure D4318. PI values for the borings performed for this report range from xx (xxx) to xx (xxx). A comprehensive list of all the plasticity indices by corresponding depth can be found on the boring logs.

Particle Size Analysis (Determination of Fines Content)

The standard grain size analysis is used to determine the relative proportions of different grain sizes as they are distributed along a range of different sized sieves. The minus 200 sieve analysis is used commonly as a tool for soil classification and identification using the Unified Soils Classification System. Results for this test are reported as a percentage of soil passing the No. 200 sieve, which has openings 0.075mm wide. This test is also used to determine the suitability of soil for construction purposes and to estimate probable seepage through soils. Generally a % -200 greater than 50% indicates a non-granular cohesive soil with large amounts of fines in the soil composition. The particle size analyses for the samples obtained as part of our geotechnical exploration were performed in compliance with ASTM procedure D1140. The % -200 values for the samples collected range from xx% (xx) to xx% (xx). A comprehensive list of all the fines contents by corresponding depth can be found on the boring logs.

Particle Size Analysis (Gradation Curves - D50 & D90)

Full standard gradation analysis is necessary to establish soil gradation curves. Standard gradation analysis involves two parts, the sieve analysis and the hydrometer analysis. The sieve analysis consists of stacking progressively finer sieves and passing a soil mass through. The sieve sizes correspond to different particle sizes within a soil. Hydrometer analyses are used primarily in fine grained soils but are also very useful in establishing the 'tail-end' of a gradation curve for soils having a mixture of coarse grained and fine grained soil constituents. The diameter of soil particles corresponding to 50% (D50) and 90% (D90) finer in the soil sample were derived from sieve and hydrometer analyses (establishment of particle-size distribution curve) for use in Hydraulic Scour Analysis. The results at structure locations are presented in Table 3:

Bridge Name (Crossing)	Bridge Borings (BRG)	*Sample Depth	D50 (mm)	D90 (mm)
CR 10 (County Line Rd.)	37, 38	20, 15	0.02, 0.04	0.18, 0.14
CR 15	39, 40	5, 20	0.13, 0.04	0.26, 0.17
CR 3000 W (1 - West Crossing)	41, 42	5, 20	0.13, 0.04	0.27, 0.16
CR 25	43, 44	5, 10	0.11, 0.09	0.25, 0.24
CR 30 (Roland Rd.)	45, 46	15, 25	0.01, 0.03	0.15, 0.09
CR 3000 W (2 - East Crossing)	46, 47	10, 5	0.03, 0.05	0.09, 0.12
FM 88	48, 49	10, 5	0.06, 0.07	0.22, 0.22
CR 40	50, 51	20, 10	0.04, 0.01	0.20, 0.17
CR 60 (Tamezville Rd.)	52, 53	10, 5	0.05, 0.09	0.24, 0.24
Cemetary Rd. (CR 65)	54, 55	15, 10	0.05, 0.06	0.24, 0.25
FM 1015	56, 57	5, 20	0.06, 0.13	0.23, 0.31
SH 186 (1 - West Crossing)	58, 59	25, 25	0.02, 0.04	0.17, 0.23
IDT Rd. (FM 105)	60, 61	5, 10	0.01, 0.00	0.22, 0.19
Access Drive #1	62, 63	15, 15	0.00, 0.00	0.18, 0.22
FM 1761	64, 65	20, 5	0.15, 0.02	0.19, 0.27
Weaver CR (FM 141)	66, 67	10, 5	0.00, 0.00	0.17, 0.18
Access Drive #2	68, 69	10, 20	0.00, 0.01	0.17, 0.23
Humphrey CR (Rancho Carlo Rd. - FM 156)	70, 71	5, 10	0.05, 0.01	0.19, 0.17
Spence CR	72, 73	10, 15	0.00, 0.00	0.18, 0.16
Lopez CR (Simon Gomez Rd.)	74, 75	25, 10	0.09, 0.05	0.20, 0.18
Ramirez CR	76, 77	20, 15	0.01, 0.06	0.15, 0.23
Access Drive #3	78, 79	10, 20	0.01, 0.01	0.18, 0.13
Missouri Pacific RR (at Bus. 77)	80, 81	20, 10	0.02, 0.00	0.19, 0.14
Business 77	81, 82	10, 20	0.00, 0.08	0.14, 0.22
US 77	83, 84, 85, 86, 87	20, 25, 10, 20, 20	0.12, 0.00, 0.06, 0.02, 0.03	0.26, 0.14, 0.21, 0.13, 0.19
Gonzalez CR	88, 89	5, 10	0.00, 0.00	0.10, 0.01
Cemetary CR (Co Rd 315 N)	90, 91	15, 20	0.00, 0.14	0.16, 0.25

Cantu CR (Co Rd 330 N)	92, 93	25, 10	0.06, 0.13	0.21, 0.25
Amaro CR (Co Rd 345 N)	94, 95	15, 10	0.01, 0.00	0.02, 0.02
Santa Margarita CR (Co Rd 360 N)	96, 97	10, 20	0.00, 0.16	0.19, 0.26
Garcia CR (Tiffen Rd.)	98, 99	5, 10	0.01, 0.01	0.19, 0.20
Correa Rd.	100, 101	20, 15	0.19, 0.09,	0.28, 0.22
Rodriguez CR (Shewmaker Rd.)	102, 103	5, 20	0.00, 0.22	0.22, 0.29
FM 2209 N	104, 105	5, 5	0.01, 0.00	0.23, 0.19
San Andreas CR	106, 107	20, 10	0.17, 0.2	0.28, 0.23
Access Drive #4	108, 109			
Control Structure Ray Drain South to MFC	110, 111			
SH 186 (2 - East Crossing) - Add	112A, 113A	15, 15	0.08, 0.05	0.20, 0.20
Main Floodwater Channel - Add	114A, 115A			

Table 3A – D50 & D90 Values for Scour Analysis (Bridge Borings)

**all depths are referenced from existing natural ground*

Channel Boring #	*Sample Depth (ft.)	D50 (mm)	D90 (mm)
B-CH-28	10.5	0.09	0.24
B-CH-29	0.5	0.01	0.2
B-CH-30	18.5	0.06	0.22
B-CH-31	10.5	0.08	0.22
B-CH-32	6.5	0.08	0.24
B-CH-33	6.5	0.03	0.21
B-CH-34	6.5	0.07	0.23
B-CH-35	0.5	0.15	0.26
B-CH-36	4.5	0	0.18
B-CH-37	6.5	0.08	0.25
B-CH-38	8.5	0.01	0.23
B-CH-39	4.5	0.08	0.25
B-CH-40	10.5	0	0.0165
B-CH-41	2.5	0.02	0.21
B-CH-42	4.5	0.05	0.21
B-CH-43	4.5	0.09	0.23
B-CH-44	23.5	0.01	0.2
B-CH-45	4.5	0.08	0.2
B-CH-46	13.5	0.04	0.24
B-CH-47	4.5	0.1	0.27
B-CH-48	10.5	0.01	0.24
B-CH-49	13.5	0.01	0.24
B-CH-50	23.5	0.01	0.17
B-CH-51	18.5	0.1	0.27
B-CH-52	13.5	0.15	0.26

B-CH-53	23.5	0.02	0.16
B-CH-54	23.5	0.07	0.25
B-CH-55			
B-CH-56	23.5	0.04	0.26
B-CH-57	18.5	0.01	0.26
B-CH-58	28.5	0.01	0.12
B-CH-59	2.5	0.1	0.24
B-CH-60			
B-CH-61	13.5	0.01	0.25
B-CH-62			
B-CH-63	18.5	0	0.23
B-CH-64	13.5	0.15	0.28
B-CH-65	28.5	0.06	0.25
B-CH-66	18.5	0.2	0.29
B-CH-67			
B-CH-68	33.5	0	0.17
B-CH-69	10.5	0	0.17
B-CH-70	18.5	0	0.23
B-CH-71	23.5	0.02	0.21
B-CH-72	23.5	0.1	0.26
B-CH-73	28.5	0.06	0.21
B-CH-74	28.5	0.07	0.26
B-CH-75	18.5	0.15	0.26
B-CH-76	18.5	0	0.04
B-CH-77	28.5	0.18	0.28
B-CH-78	33.5	0.19	0.28
B-CH-79	18.5	0.19	0.28
B-CH-80	23.5	0.19	0.28
B-CH-81			
B-CH-82	33.5	0.2	0.29
B-CH-83	28.5	0.1	0.28
B-CH-84			
B-CH-85	13.5	0	0.09
B-CH-86	18.5	0.04	0.12
B-CH-87	18.5	0.02	0.07
B-CH-88	13.5	0	0.08
B-CH-89	13.5	0.01	0.14
B-CH-90	13.5	0.04	0.16
B-CH-91	23.5	0.1	0.18
B-CH-92	23.5	0.03	0
B-CH-93	23.5	0.01	0.17
B-CH-94	13.5	0	0.063

B-CH-95	13.5	0	0.16
B-CH-96	23.5	0.01	0.18
B-CH-97	23.5	0	0.095
B-CH-98	18.5	0	0.15
B-CH-99	23.5	0.07	0.36
B-CH-100	28.5	0	0.15
B-CH-101	18.5	0	0.005
B-CH-102	28.5	0.03	0.17
B-CH-103	23.5	0.12	0.22
B-CH-104	28.5	0.03	0.22
B-CH-105	23.5	0.15	0.25
B-CH-106	23.5	0.06	0.21
B-CH-107	23.5	0.14	0.25
B-CH-108	23.5	0.18	0.29
B-CH-109	23.5	0.1	0.16
B-CH-110			
B-CH-111	23.5	0.15	0.25
B-CH-112	23.5	0.16	0.26
B-CH-113	23.5	0.17	0.27
B-CH-114	23.5	0.14	0.23
B-CH-115	23.5	0.05	0.18
B-CH-116	23.5	0.1	0.16
B-CH-117	23.5	0.03	0.09
B-CH-118	18.5	0.21	0.29
B-CH-119			
B-CH-120	13.5	0.17	0.27
B-CH-121	18.5	0.22	0.3
B-CH-122	23.5	0.22	0.3
B-CH-123	23.5	0.22	0.3
B-CH-124	23.5	0.21	0.29
B-CH-125	23.5	0.22	0.3
B-CH-126	18.5	0.09	0.22
B-CH-127	23.5	0.08	0.13
B-CH-128			
B-CH-129	23.5	0.01	0.018
B-CH-130	28.5	0.06	0.26
B-CH-131	28.5	0	0.02
B-CH-132	13.5	0.08	0.13
B-CH-133	23.5	0	0.0175
B-CH-134	18.5	0.07	0.14
B-CH-135	23.5	0.19	0.29
B-CH-136			

B-CH-137			
B-CH-138			
B-CH-139	23.5	0.23	0.35
B-CH-140			
B-CH-141	23.5	0.21	0.3

Table 3B – D50 & D90 Values for Scour Analysis (Channel Borings)

**all depths are referenced from existing natural ground*

In accordance with the TxDOT Geotechnical Manual (2006), **L&G** recommends D50 values be limited to 4 x 10^{-3} inches (0.10 millimeters) for this channel in cohesive material. In addition (and if required), it should be noted, the TxDOT Geotechnical Manual (2012) recommends Pier Scour utilize equations in HEC-18 with a reduction factor of 0.5 for soils with 11% or more clay.

Sulfate Content of Soil

The presence of high concentrations of water-soluble sulfates (SO_4) in soils can be detrimental to concrete structures in direct contact. Concrete exposed to these sulfate rich soils (buried concrete structures, foundations, slabs-on-grade) are highly vulnerable to deterioration typically in the form of expansion, extensive cracking and spalling. In the long-term, sulfates causing micro-cracks in concrete structures can form areas of additional ettringite (calcium sulfoaluminate) formation that can potentially penetrate the structures and lead to weakening of the cement paste and structure as a whole. In order to detect levels of water-soluble sulfates in the soils, we performed testing on these soils in accordance with Tex-145-E (Determining Sulfate Content in Soils – Colorimetric Method). To ensure we got an accurate reading with regard to the water levels impacting the soils, we performed these tests at various depths at the locations of structure borings. The location specific results for sulfate content are presented in Table 4.

Bridge Name (Crossing)	Bridge Boring #	Sulfate Content (ppm)	Sulfate Resistant Conc. Recommended
CR 10 (County Line Rd.)	37, 38	1260/780	**Y**
CR 15	39, 40	5880/780	**Y**
CR 3000 W (1 - West Crossing)	41, 42	820/1900	**Y**
CR 25	43, 44	420/660	**N**
CR 30 (Roland Rd.)	45, 46	380/120	**Y**
CR 3000 W (2 - East Crossing)	46, 47	120/2600	**Y**
FM 88	48, 49	500/440	**N**
CR 40	50, 51	1080/2960	**Y**
CR 60 (Tamezville Rd.)	52, 53	1600/1120	**Y**
Cemetary Rd. (CR 65)	54, 55	500/1240	**Y**
FM 1015	56, 57	620/760	**N**
SH 186 (1 - West Crossing)	58, 59	2100/160	**Y**
IDT Rd. (FM 105)	60, 61	3180/3700	**Y**
Access Drive #1	62, 63	1700/1820	**Y**

FM 1761	64, 65	332/440	**N**
Weaver CR (FM 141)	66, 67	780/1300	**Y**
Access Drive #2	68, 69	2100/1360	**Y**
Humphrey CR (Rancho Carlo Rd. - FM 156)	70, 71	1520/1680	**Y**
Spence CR	72, 73	560/840	**N**
Lopez CR (Simon Gomez Rd.)	74, 75	100/600	**N**
Ramirez CR	76, 77	140/420	**N**
Access Drive #3	78, 79	900/140	**N**
Missouri Pacific RR (at Bus. 77)	80, 81	900/1000	**Y**
Business 77	81, 82	1000/1640	**Y**
US 77	83, 84, 85, 86, 87	500-1080	**Y**
Gonzalez CR	88, 89	500/3260	**Y**
Cemetary CR (Co Rd 315 N)	90, 91	1480/<100	**N**
Cantu CR (Co Rd 330 N)	92, 93	<100/720	**N**
Amaro CR (Co Rd 345 N)	94, 95	400/<100	**N**
Santa Margarita CR (Co Rd 360 N)	96, 97	3580/180	**Y**
Garcia CR (Tiffen Rd.)	98, 99	1200/400	**Y**
Correa Rd.	100, 101	420/540	**N**
Rodriguez CR (Shewmaker Rd.)	102, 103	440/580	**N**
FM 2209 N	104, 105	360/1340	**Y**
San Andreas CR	106, 107	120/100	**N**
Access Drive #4	108, 109		
Control Structure Ray Drain South to MFC	110, 111		
SH 186 (2 - East Crossing) - Add	112A, 113A	120/100	**N**
Main Floodwater Channel - Add	114A, 115A		

Table 4 – Summary of Sulfate Contents

**all depths are referenced from existing natural ground*

It should be noted, Texas Department of Transportation (TxDOT) Pharr District Master General Notes specifies the use of Sulfate Resistant Concrete when sulfate concentrations in the soil are greater than 1000 ppm. Based on these results, **L&G** recommends the specific use of Sulfate Resistant Concrete for the foundation elements of the structures noted in the table.

GEOTECHNICAL ENGINEERING ANALYSES

L&G was tasked to provide a geotechnical report including shallow deep foundation analysis for bridge locations (point bearing and skin friction models for development of foundation capacity curves) and overall global (slope) stability for channel.

Deep Foundation Analysis (Bridge) (Capacity Curves)

Texas Cone Penetration (TCP) test results were used to calculate foundation capacity curves for various deep foundation options. Deep foundation options for use on this project could include square prestressed concrete piling or reinforced concrete drilled shafts. We have provided design curves for the most common and widely used sizes of the two (square piling – 16 and 18 inch & drilled shafts – 36 inch diameter). If alternate foundation types or sizes are required for the project, **L&G** can provide alternate curves as needed. The foundation capacities include the effects of point bearing and skin friction to account for total foundation capacity. Depths of proposed embankment fill at structural abutments were discounted in terms of skin friction and no additional disregard depth was taken in analysis below the proposed embankment. A disregard depth equal to approximately 5 feet was incorporated into the capacity curves to discount the skin friction contribution of the upper most strata layer due to high potential for shrink and swell of the material (may shrink away from the foundation due to climatic events) and scour. Any additional disregarded or discounted lengths utilized through analysis were based on site specific information and are included in the site specific analysis in Appendix C.

Capacity curves were generated through the Texas Department of Transportation (TxDOT) WINCORE software program (version 3.1). Through the program, curves were developed based on geometry of foundation elements, bearing capacities of founding layers and skin friction of in-situ soil strata. The provided capacity curves can be utilized for future development using the proposed piling or drilled shaft size and design load to determine the required tip elevations of deep foundations (utilizing the provided capacity curves will give general/approximate foundation tip elevations for verification of in-depth foundation design).

It is imperative for designers to note that the depth of foundation determined by way of the foundation capacity curves provided is a generalized model and the minimum necessary. True foundation tip elevations should be verified with engineering judgment and modified based on each individualistic case. Foundation tip elevations determined utilizing foundation capacity curves provided should only be used to verify and supplement an in-depth foundation design. Foundation Capacity Curves are included in Appendix C.

Slope / Global Stability Analysis (Channel Slopes)

It is the understanding of **L&G** that Raymondville Drain will include an ultimate proposed channel cross section as denoted by the Client and provided in the 'Project Description' section of this report.

This report includes complete Global Stability Analysis as the means to evaluate channel side slope geometry with regard to existing top strata (proposed slope sections), section geometry and underlying foundation soils. The Factor of Safety requirements utilized in this analysis are referenced from the 2012 TxDOT Geotechnical Manual. For this project, we will utilize the threshold value of FS = 1.3 for all analyses.

The limit equilibrium method of analysis is the most commonly used method of analyzing the overall stability of both natural and manmade slopes as well as retaining wall structures. The fundamental principles behind this method are that the soil mass above a potential failure surface acts as a rigid body, and the shear strength of the material is fully engaged at all points along the surface at the moment of initial movement. A failure criterion is adopted and the conditions for static equilibrium are applied to analyze the problem. This method of analysis assumes that no strain takes place until the failure condition is reached. The results of the analyses are expressed in terms of a safety factor in the form of a ratio of the available shear strength along the potential failure surface to the shear stress required to maintain equilibrium of the failure mass under the applied loads. This method has traditionally been used in the analysis of man-made earth structures such as embankments, levees and retaining wall structures.

The Global Stability Analyses of the channel side slope sections (slopes) was performed using ***GSTABL with STEDwin*** Version 7 software program. Analyses were performed using the Modified Bishop Method of slices for circular surfaces (random surfaces were not investigated in this report). It should be noted that the possibility of undetected anomalies in the soil, such as remnants of previous sliding, tension cracks or water-bearing seams of sand, could potentially alter or negate the findings of the stability analysis. Through the utilization of the GSTABL software program, conservative modeling techniques, and engineering judgment we present what we believe are the most accurate factors of safety.

Input parameters such as shear strength (cohesion and angle of friction) were correlated from the results of the SPT testing and laboratory soil classification testing (unit weight was assumed based on material properties from laboratory tests). Both short-term (undrained) and long-term (drained) conditions were analyzed in accordance with the TxDOT Geotechnical Manual. Correlations for undrained parameters were based on correlation equations of Stroud (1974), Bowles (1988) and Teng (1962). Correlations for drained parameters were based on correlation equations of Holtz & Kovacks (1981), Bjerrum and Simons (1960) and Gibson (1953). It should be noted; only total shear strengths of soils were input into the GSTABL models for the short-term (undrained) condition, as opposed to individual cohesions and friction angles to maintain consistency with the strength correlations. In addition it should be noted, a minimum residual cohesion value of 50 pounds per square foot (psf) was incorporated into the long-term (drained) condition models.

The geometric model of the Channel Slopes utilized for analysis consisted of maximum channel heights per each section limits assumed at all boring locations at each location for a worst case analysis. Traffic surcharge loading was incorporated into the modeling considered equivalent to two (2) feet of soil (approximately 250 psf) placed atop the channel slopes (to model an access road atop the channel). Piezometric surfaces (groundwater surfaces) were modeled at depths noted in boring logs. The models were analyzed as follows (See <u>Appendix E</u> for Global Stability Runs):

GENERAL CONSIDERATIONS DURING CONSTRUCTION

L&G recommends drain ditches be constructed in accordance with details shown on plans and approved working drawings, and to the pertinent requirements of the following TxDOT 2014 Standard Specification Items: Item 110 “Excavation”, and Item 132 “Embankment.” Excavate to the lines and grades shown on the plans or as directed. Provide slopes, benching, bracing, pumping, and bailing as necessary to maintain the stability and safety of excavations up to 5 feet deep. Excavations deeper than 5 feet shall conform to OSHA requirements for trench protection or temporary special shoring requirements. Any excavation activity should be observed by **L&G** representatives to document existing conditions and proposed embankment preparation.

Drainage / Dewatering Recommendations

Drainage is one of the most important aspects to be addressed to ensure the successful performance of any structure. Positive surface drainage should be implemented prior to, during, and maintained after construction to prevent water ponding at or adjacent to the embankments under construction. If water is present at the construction area, **L&G** recommends that dewatering techniques be used (bailing, point wells, pumping wells, cofferdam structures, or other approved methods) to ensure proper construction of the channel embankments.

Channel Side Slope Recommendations

L&G recommends utilizing 3(horizontal) to 1(vertical) slopes or flatter for the banks of the drainage channels, where possible. Slopes steeper than our typical recommended 3:1 may have the potential to cause problems with erosion, minor slope stability (in the form of surface sloughing), and general maintenance of the slopes. If steeper slopes become a requirement of this project, **L&G** should be notified to provide updated Slope Stability modeling and calculations. The construction of the channel slopes should include the installation of vegetation to assist in reducing erosion, preventing slough failures, and increasing the general slope stability. In the areas of anticipated inlet/outlet structures, as well as any other areas where turbulent or rapid flows may occur (at channel bends or turns), we recommend the use of additional erosion protection such as concrete riprap, rock riprap, geotextiles, or hydraulic energy dissipaters to minimize erosion.

Erosion Protection of Inlet & Outlet Structures

Erosion protection is essential in prolonging the life of the proposed drainage structures due to the higher velocities and water forces caused by these structures. Though no locations investigated noted highly erosive materials, we recommend general good practice measures to counteract any potential problems with future erosion. **L&G** recommends utilizing multiple erosion protection measures at channel entrance and exit locations (culverts, pipes, etc.):

- **L&G** recommends general good practice measures such as good embedment and compaction of supporting soils surrounding these structures to help ensure stability.
- **L&G** recommends that if concrete box culverts or pipes are utilized they include concrete headwalls, wingwalls and riprap at inlet/outlet points with two (2) foot

minimum toe walls along all structures for enhanced stability and protection of culvert/pipe bedding and subgrade.

- **L&G** recommends that any circular pipe inlet points to the channel provide a concrete splash-pad (or outlet to concrete riprap or flexible erosion protection system) to avoid localized erosion points.
- **L&G** recommends utilizing flexible erosion protection on the channel side slopes such as rock riprap (in accordance with Article 432.3 of the TxDOT Standard Specifications) at inlet/outlet locations (alternatively erosion protection measures such as articulated block or rigid erosion protection systems (concrete riprap) may be utilized). In areas where bank protection will not (or cannot) be used, vegetation of earthen slopes and topsoil should be utilized as a minimum to reduce erosion problems.

Deep Foundation Recommendations (Drilled Shafts & Piling)

Drilled Shafts

If Drilled Shafts are utilized as the deep foundation alternative on this project, **L&G** recommends all Drilled Shaft construction be in accordance with the requirements of TxDOT 2014 'Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges,' Item 416 – Drilled Shaft Foundations. The Contractor shall utilize an excavation method that is suitable to field conditions and that will result in a stable excavation. **L&G** further recommends that prior to construction a Drilling Construction Plan / Procedure be provided by the Contractor (to the Engineer of Record) to ensure adequate planning and procedures based on the soil conditions. In terms of concrete, we recommend special attention be made to minimum / maximum slump of concrete required for drilled shafts (and requirements of slump retentions). If differing site conditions (unanticipated or unusual strata) are encountered during construction, **L&G** shall be contacted to provide review and possible re-analysis if required.

Piling

If Piling is utilized as the deep foundation alternative on this project, **L&G** recommends all Piling be provided in accordance with the requirements of TxDOT 2014 'Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges,' Item 409 – Prestressed Concrete Piling. In addition, we further recommend that any Piling be constructed as denoted in TxDOT Prestressed Concrete Piling (CP) Standard (and as such should be included with the final plan set for this project). Pile installation and driving shall be in accordance with the requirements of TxDOT 2014 'Standard Specifications,' Item 404 – Driving Piling. If hard soils are encountered at any of the structure sites, the use of pilot holes and / or jetting of Piling may be necessary in order to advance Piling to required penetrations. If utilized, pilot holes and jetting shall be performed in accordance with the requirements of TxDOT Item 404 and shall only be performed as necessary to satisfy advancement of the Piling (without compromising the load carrying capacity of foundation). If any damage (cracking or spalling) is noted during Pile installation, all operations shall cease immediately and cause of distress shall be determined (no subsequent Pile driving shall occur until necessary modifications have been made to Pile driving operation or installation method). If differing site conditions (unanticipated or unusual strata) are encountered during construction, **L&G** shall be contacted to provide review and possible re-analysis if required.

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8. TxDOT, 2004, “TxDOT Pharr District Master General Notes” (Updated 01-2012).

9. United Stated Army Corps of Engineers – EM 1110-1-1904 “Settlement Analysis”

10. United Stated Army Corps of Engineers – EM 1110-1-1905 “Bearing Capacity of Soils”

11. United Facilities Criteria (UFC), “Soils & Geology Procedures for Foundation Design of Building and Other Structures”, UFC 3-220-03FA, (January 2004).

APPENDIX A – FIGURES

APPENDIX B – BORING LOGS & GRADATIONS

APPENDIX C – DEEP FOUNDATION CAPACITY

APPENDIX D – GLOBAL STABILITY ANALYSIS