SUBSURFACE EXPLORATION & GEOTECHNICAL EVALUATION

Sparrow Pond Stability Study

Arlington County, Virginia

Prepared for:
Versar, Inc.

And

Arlington County Department of Public Works

RK&K Commission No. 16068.003
March 19, 2018
REVISED June 12, 2018

Eric M. Klein, P.E., D.GE
Senior Manager, Geotechnical

Jason Varounis, P.E.
Associate, Geotechnical

Prepared by:
RUMMEL, KLEPPER & KAHL, LLP
700 East Pratt Street, Suite 500
Baltimore, Maryland 21202

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1 INTRODUCTION

In accordance with our proposal dated February 1, 2017, Rummel, Klepper & Kahl, LLP (RK&K) has completed the Subsurface Exploration and Geotechnical Engineering Evaluation for the Sparrow Pond Stability Study in Arlington County, Virginia.

This is a revised submission to the original report submitted on March 19, 2018. The revision is in response to comments received from Arlington County Department of Environmental Resources on April 27, 2018.

The purpose of this study was to determine the subsurface conditions at the project site and to evaluate those conditions with respect to geotechnical engineering considerations for the proposed construction. The specific scope of our services on this project consisted of exploring the subsurface conditions using soil borings, groundwater monitoring wells, laboratory testing, evaluating the conditions encountered, developing geotechnical recommendations, and submitting our findings in a report. Based on this geotechnical study, recommendations are provided for slope stability of the existing embankment, jack and bore for the proposed pipes, and other geotechnical concerns.

Also included in this report are descriptions of the field and laboratory testing on which this report is based. The results of this work are contained in the Appendix of this Report.

2 SITE AND PROJECT DESCRIPTION

2.1 SITE DESCRIPTION

The project site is located along Four Mile Run in Arlington County, Virginia as shown in Figure A-1 in Appendix A. Parallel to the north bank of the Four Mile Run are two trails: Washington and Old Dominion (WOD) Trail and Four Mile Run (FMR) Trail. The WOD trail is located on top of the historic railroad embankment and the FMR trail is located at the toe of the embankment on the south side. Sparrow Pond is located on the north side of the WOD trail. The existing pond was constructed in 2001 as part of the wetland enhancement project. Figures A-2a and A-2b in Appendix A shows the site topography and cross-sections through the trails and bodies of water. The 100-year flood is at EL 147.65 in Four Mile Run and EL152.65 in Sparrow Pond.

The area around Sparrow Pond is heavily wooded. The trails and Four Mile Run exist in a larger valley with residential developments on either side. Both trails are asphalt-paved and approximately 8-ft wide. The WOD Trail is near EL 158. The existing slope from WOD Trail to the existing bottom of Sparrow Pond is near EL 150, and is 2.5(H):1(V). The embankment slope from WOD Trail to FMR Trail, near EL 145, is 2.0(H):1(V). The existing slope from FMR Trail to the stream level is relatively flat before a sudden drop-off into the water. The existing Four Mile Run stream elevation is near EL138.

There are several known overhead and buried utilities within the project area. High voltage power lines run in between and parallel to the trails. A reinforced concrete sanitary sewer pipe runs along the north bank of Four Mile Run. Communications lines run underneath WOD Trail. There is a visible stone box culvert perpendicular to the trails at the west end of Sparrow Pond that connects the two bodies of water.

2.2 PROJECT DESCRIPTION

The proposed construction will include grading and design retrofit to Sparrow Pond. The pond will be re-graded, and earthwork will be performed at the toe of the north slope to the WOD Trail. The maximum depth of excavation will be about 5-ft. Figure A-2b in Appendix A shows cross sections of the existing and proposed ground surface lines perpendicular to the trail. The construction will also consist of installing a riser structure within the pond and two 30-inch diameter reinforced concrete pipes (RCP) from the riser structure in the pond which will outfall into the Four Mile Run. The top of the riser structure will be located at EL 150. The section of the new pipes under the WOD trail embankment will be jack and bored into place with the remaining sections along the south end will be installed in open cut trenches. The pipes will have approximate invert at EL144.0 in Sparrow Pond and the outfall invert at EL142.5 in Four Mile Run. The existing box culvert structure west of the proposed new pipes will be left in place.

3 FIELD AND LABORATORY WORK

3.1 FIELD EXPLORATION

The subsurface exploration consisted of drilling 6 Standard Penetration Test (SPT) borings on December 27, 2017 through January 2, 2018. The test borings were drilled by DMY, Inc. of Sterling, Virginia, under contract to RK&K. The borings were drilled using a CME 55 track-mounted drill rig equipped with an automatic hammer. Ground surface elevations of the borings were estimated from the plans. Table 3.1 summarizes the locations and depths of the borings. Boring locations are shown in Figure A-2a in Appendix A.

Table 3.1 – Summary of Borings

Boring No.	Location	Northing	Easting	G.S. EL	Depth (ft)
B-1	Pond 1 West	7000059	11877031	152	28.6
B-2	WOD Trail West	6999986	11877021	159	30.0
B-3	FMR Trail West	6999954	11877014	146	19.0
B-4	FMR Trail West	6999914	11877003	144	14.0
B-5	WOD Trail East	6999940	11877222	157	28.0
B-6	FMR Trail East	6999868	11877199	143	16.0

Northing / Easting – NAD83, Virginia State Plane, US Survey Feet
G.S. EL – Existing Ground Surface Elevation

3.2 SOIL SAMPLING

Soil samples were obtained at 2.5-ft intervals for the first 20-ft and at 5.0-ft intervals thereafter. In general, the SPT consists of advancing a 2-inch outside diameter sampling spoon 18-inches by driving it with a 140-pound hammer falling 30-inches. The values reported on the boring logs reflect the hammer blows required to advance the spoon three successive increments of 6-inches. The first 6-inch increment is considered as seating, and the sum of the number of blows for the second and third increments is the "N" value.

The soils were classified in general accordance with the Unified Soil Classification System (USCS). The USCS graphical and letter symbols are shown on the Summary of Boring Data, Figure A-3 in Appendix A. An RK&K field engineer on-site recorded the classifications, observations, water and cave in depths, and field sampling information on the Test Boring Logs contained in Appendix B. Descriptions of the soil classification systems and sampling procedures are also included in Appendix B.

3.3 ROCK SAMPLING

Bedrock was sampled using an NQ diamond bit with a double tube, swivel type barrel, which provides a 2-inch diameter core. The core description, core recovery, the Rock Quality Designation (RQD), and other pertinent information were recorded on the Test Boring Logs and on the Summary of Boring Data. The RQD value reflects the quality and fracture spacing of the rock and is defined as the sum of the length of rock pieces greater than 4-inches divided by the total core run length. The percentage of core recovery and RQD values provide an understanding of the physical and engineering properties of the rock. Descriptions of the rock classification system and sampling procedures are also included in Appendix B.

3.4 GROUNDWATER MONITORING

Observation wells were installed in borings B-2, B-3 and B-4 upon the completion of drilling to monitor groundwater levels within the project area. The project monitoring wells consisted of a 2-inch outer diameter Schedule 40 PVC pipe with a 0.020-inch slotted screen. 10-feet of well screen was placed from the bottom of the boring with riser casing thereafter to the surface. Packed gravel or sand was installed in the borehole annulus. Above the screened interval, the monitoring well was sealed with bentonite and then grouted. The monitoring wells were capped with water-tight plugs and protected with steel flush-mount casings.

Electronic data loggers were installed to monitor groundwater levels in the wells for a period of approximately two months from January, 2018 to March, 2018. Groundwater data is contained in Appendix D.

3.5 HYDRAULIC CONDUCTIVITY TESTING

RK&K performed three slug tests in monitoring well B-2 on January 10, 2018. The tests consisted of submerging a slug completely into groundwater, waiting for the displaced level within the well to equalize, removing the slug, and then waiting for the level to return to normal. The water level within the well was monitored throughout the test using an electronic data logger. The two processes produce a falling-head and then rising-head response within the well, and the results are used to determine the hydraulic conductivity of the soil within the well's screened interval. The results and interpretations of the slug tests are contained in Appendix D.

3.6 LABORATORY TESTING

The laboratory testing consisted of determining the natural moisture content, grain-size distribution, and Atterberg limits for selected soil samples. The results of the classification testing are summarized in Table 3.2. Natural moisture content results are shown on the Test Boring Logs in Appendix B. Grain-size distribution graphs and Atterberg Limits are included in Appendix C.

Table 3.2 – Summary of Laboratory Classification Test Results

Boring No./ Sample No.	Depth (ft)	NMC (%)	LL	PL	% Fines	USCS
B-1 / S-2	2.5 – 4.0	12.2	Not Tested		24.4	--
B-1 / S-3	5.0 – 6.5	16.3	27	20	41.0	SC-SM
B-2 / S-6	13.5 – 15.0	22.0	27	22	41.5	SM
B-3 / S-2	3.5 – 5.0	15.4	24	20	22.7	SC-SM
B-4 / S-2	3.5 – 5.0	19.4	28	24	29.1	SM
B-5 / S-1	1.0 – 2.5	20.2	Not Tested		25.0	--
B-5 / S-5	11.0 – 12.5	27.3	54	35	41.4	SM
B-6 / S-4	8.5 – 10.0	14.6	NV	NP	48.6	SM

USCS: Unified Soil Classification System **% Fines:** Passing No. 200 Sieve **NP**: Non-Plastic
NV: No Value **NMC:** Natural Moisture Content **LL:** Liquid Limit **PL:** Plastic Limit

4 SUBSURFACE CONDITIONS

4.1 GEOLOGY

According to the Physiographic Map of Virginia Counties, 2000, the project site is located in the Outer Piedmont subprovince that is characterized by a broad upland with low to moderate slopes. Natural soils in this region are residual soils, which have formed in place by the weathering of the parent bedrock. Residual soils typically form a profile characterized by a change from soil to decomposed rock to rock with increasing depths below the ground surface

According to the Geologic Map Database of the Washington DC Area, 2001, the project area is mapped within the Indian Formation of the Cambrian period and consists of poorly to well foliated metasedimentary mélange of quartz within a medium grained quartz-plagioclase-muscovite-biotite-chlorite-garnet matrix.

4.2 SUBSURFACE CONDITIONS

The Summary of Boring Data and the Test Boring Logs in Appendices A and B, respectively, provide details related to the subsurface conditions encountered in the various borings. Soil classifications presented in uppercase letters are based on laboratory test results; classifications in lowercase represent classifications based on visual/manual methods. The stratification lines shown on the Summary of Boring Data and Test Boring Logs represent approximate transitions between material types. In situ, strata changes could occur gradually or at slightly different levels. Also, the borings depict conditions at particular locations and at the particular times indicated. Some conditions, particularly groundwater conditions between borings, could vary from the conditions encountered at the particular boring locations.

Topsoil: Boring B-4 encountered topsoil to a depth of 3.5-ft.

Bituminous Concrete: Borings B-2 and B-5 performed directly through the trail encountered 5-in of bituminous concrete and 2-in of graded aggregate base.

Fill: Borings B-1, B-2 and B-5 in the upper trail and pond area encountered Fill ranging in depth from 8-ft to 16-ft below the existing ground surface. Fill material typically consisted of very loose to medium dense Sand with varying percentages of Silt, Clay. The SPT-N values typically ranged from 4 blows per foot (bpf) to 22-bpf and averaged 8-bpf. The moisture contents ranged from 3.5-percent to 22.0-percent and averaged 13.7-percent. The liquid limit for the two samples tested in this stratum was 27, and the plastic limit ranged from 20 to 22.

Table 4.1 summarizes the depth of FILL material encountered in the borings.

Table 4.1 – Summary of FILL Depths

Boring No.	Ground Surface Elevation	Thickness of FILL (ft)	Bottom of FILL Elevation
B-1	152	8.0	144.0
B-2	159	16.0	143.0
B-5	157	8.5	148.5

The borings encountered the following three natural soil strata:

Stratum I – Residual Soil (Coarse-Grained): Stratum I was encountered underneath surficial material and extended to depths ranging from 11.0-ft to 23.5-ft below the existing ground surface. Stratum I consisted of loose to very dense, coarse to fine SAND with varying percentages of Gravel, Silt and Clay [SC-SM, SM, sp, gp]. Cobbles were frequently encountered while drilling through this stratum. SPT N-values typically ranged from 5-bpf to 42-bpf and averaged 19-bpf. Gravel and cobbles likely exaggerated some of the SPT results. The natural moisture content ranged from 11.2-percent to 27.7-percent and averaged 16.6-percent. The liquid limit ranged from non-viscous (NV) to 54, and the plastic limit ranged from 20 to non-plastic (NP).

Stratum II – Completely Weathered Rock (CWR): Stratum II was encountered underneath Stratum I and extended to depths ranging from 23-ft below the existing ground surface to the end of boring. Stratum II consisted of coarse to fine SAND with varying percentages of gravel-sized Rock Fragments and Silt. The natural moisture content for one sample was 9.6-percent. Atterberg limits were not tested for this stratum.

Completely Weathered Rock (CWR) is defined in this report as residual material that retains the relict rock structure of the parent bedrock and exhibits SPT N-values consistently in excess of 60-bpf and less than 50-blows/inch or auger refusal.

Auger refusal may result from hard cemented soil, soft weathered rock, coarse gravel or boulders, thin rock seams, or the upper surface of sound continuous rock and is also dependent of the type of drilling machine used during the exploration. There is a wide range of torque and crowd within the typical types of drilling machines utilized in geotechnical exploration. Refusal encountered with a relatively light duty drill rig may be penetrated with a more powerful machine. Rock coring techniques are required to determine the character and continuity of the material below the refusal elevation. Table 4.2 summarizes the locations and depths of auger refusal encountered.

Table 4.2 – Summary of Auger Refusal		
Boring No.	**Depth (ft)**	**Elevation**
B-1	23.6	128.4
B-2	30.0	129.0
B-3	19.0	127.0
B-4	14.0	130.0
B-5	28.0	129.0
B-6	16.0	127.0

Stratum III – Bedrock: Bedrock was sampled only in boring B-1 and was encountered underneath Stratum II. Bedrock consisted of medium to fine grained, closely fractured, very hard, metasedimentary MELANGE. The recovery was 100-percent, and the Rock Quality Designation (RQD) was 60-percent.

4.3 GROUNDWATER

Groundwater was encountered in the borings during drilling. It is generally desirable to allow test borings to remain open for at least 24 hours after the completion of drilling and the removal of the drill tools and casing from the borehole. The purpose of this procedure is to allow the groundwater level in each borehole to recover from the effects of the test drilling. In clay soils, the length of time may extend several days before the groundwater level recovers to the pre-drilling elevation. It was necessary to backfill some of the borings immediately after the completion of drilling due to traffic, safety and/or logistic concerns. Groundwater data is summarized on Table 4.3.

In addition to groundwater levels, the depth to the bottom of each borehole was measured to determine the susceptibility of the borehole to collapse or cave. This information provides the contractor with information regarding the "stand-up" time of the soil, or the ability of the sides of an excavation to remain vertical or near vertical during trench excavation.

Table 4.3 – Summary of Borehole Groundwater and Cave Data

Boring No.	Surface Elevation	Groundwater		Cave	
		Depth (ft)	Elevation	Depth (ft)	Elevation
B-1	152	0.3	151.7	11.0	141.0
B-2	159	17.7**	141.3**	Observation wells installed	
B-3	146	5.7**	140.3**		
B-4	144	4.4**	139.6**		
B-5	157	Dry*	Dry*	16.0*	141.0*
B-6	143	6.0	137.0	10.0	133.0

* Reading immediately after drilling, borehole grouted upon completion
** Average based on observation well data. See Appendix D.

4.4 HYDRAULIC CONDUCTIVITY

Slug test data from monitoring well B-2 was used to determine the hydraulic conductivity of groundwater flow through soil in the project site. The slug testing procedure is described in Section 3.5 of this Report. The well screened interval spanned elevations 129 to 139 and included within Stratum I: Residual Soil (Coarse Grained) and Stratum II: Completely Weathered Rock.

The Hvorslev method was used to determine the hydraulic conductivity based on the slug test results. Details about the method are included in a graph in Appendix D or this Report. The hydraulic conductivity was determined to be 12 in/hr. This is consistent with the typical properties of a fine to medium sand.

5 EVALUATIONS AND RECOMMENDATIONS

The following recommendations have been developed on the basis of the previously described project characteristics and subsurface conditions. If there are any significant changes to the project characteristics or if significantly different subsurface conditions are encountered during construction, RK&K should be consulted so that the recommendations of this report can be reviewed.

5.1 SLOPE FAILURE MECHANISMS

Slope failures are generally caused when activating forces from the top of a hill or embankment exceed the resisting forces. These activating forces are usually the weight of the soil and water at the top of the hill. The resisting forces include the weight of any soil at the toe of the slope and the internal shear strength of the soil in the slope.

The ratio of the resisting forces divided by the activating forces is called the Factor of Safety (FS). When FS = 1, the slope is on the verge of failure. AASHTO recommends a minimum FS ≥ 1.3 for slopes that do not support a structural element.

Soil is composed of solid particles of matter and empty spaces called pores or voids. These voids between the soil particles often contain water and air. If moderate water is present in the pores between the soil particles the surface tension of the water will contribute to increasing the shear strength of the soil. However, if the pore spaces between the soil particles are completely filled with water, the soil is said to be saturated. A saturated soil will become very heavy, and the pore water pressure will decrease the effective shear strength of the soil mass.

Water content can, therefore, increase or decrease the stability of a slope. By saturating the soils at the top of a slope, the activating forces increase, and by saturating the soils at the bottom of a slope, the resisting shear strength of the soils are reduced.

We performed slope stability analyses of the existing WOD trail embankment to evaluate the slope with the proposed regrading of the pond and the 100-year flood elevation on both sides of the embankment.

5.2 SLOPE STABILITY ANALYSIS

To assess the stability of slopes, analyses using the software Slope/W and the Morgenstern Price method were performed on two cross sections of the WOD trail embankment. Figure A-2b in

Appendix A shows the cross sections at stations 11+33 and 13+30. Both the slopes from WOD trail to the pond and to FMR trail were analyzed at each station. No change is proposed for the southern face of the embankment towards the FMR trail, and both existing and proposed conditions were analyzed for the north slope towards the pond.

Groundwater conditions were modeled conservatively at the 100-year flood elevation in both the pond and stream. Table 5.1 summarizes the slope analysis results for the proposed conditions. Graphical output from the Slope/W software is included in Appendix D.

Table 5.1 – Summary of Slope Stability Results

Station – Direction - Condition	Factor of Safety
11+33 - South Toward Stream - No Change	1.33 (Fig D-3a)
11+33 - North Toward Pond - Existing	1.92 (Fig D-3b)
11+33 - North Toward Pond - Proposed	1.87 (Fig D-3c)
13+30 - South Toward Stream - No Change	1.30 (Fig D-3d)
13+30 - North Toward Pond - Existing	2.04 (Fig D-3e)
13+30 - North Toward Pond - Proposed	1.27** (Fig D-3f)
13+30 - North Toward Pond – 2(H):1(V)	1.46 (Fig D-3g)

**This does not satisfy the minimum allowable factor of safety for slope stability. Recommend the proposed grade be limited to 2(H):1(V)

For global stability, a minimum Factor of Safety (FS) of 1.30 is required for all permanent embankment slopes in accordance with VA DEQ Stormwater Design Specification Appendix A, Earthen Embankment, March 2011. Based on the analyses, the FS of the slope after the proposed construction will be 1.3 or higher in all areas EXCEPT Sta. 13+30 Toward Pond. The proposed grading inside the pond at STA 13+30 has a break in the slope with the upper portion proposed to be approximately 1(H):1(V). We recommend that the slope be graded to no steeper than 2(H):1(V) to achieve the desired FS>1.30.

5.2.1 Seepage Analysis

A steady-state groundwater seepage analysis was performed for the WOD Trail embankment at Station 11+33 and 13+30. The embankment fill was assumed to be homogeneous for the seepage analysis. GMS Seep 2D software was used to evaluate seepage using finite element methods. Surface water was modeled conservatively; at the highest riser elevation in Sparrow pond and at the lowest encountered elevation near Four Mile Run so as to generate the maximum groundwater gradient. Hydrologic soil properties were determined directly from slug testing and from correlations based on soil laboratory testing. Table 5.2 summarizes the modeled hydrologic soil properties.

Table 5.2 – Summary of Hydrologic Soil Properties

Soil Stratum	Hydraulic Conductivity (ft/s)
FILL*	5.79 X 10^{-06}
Stratum I**: Residual Soil	2.78 X 10^{-04}
Stratum II**: Completely Weathered Rock	2.78 X 10^{-04}
Stratum III: Bedrock	10^{-20} (impermeable)

* Determined from correlation with laboratory testing results
** Determined from slug testing results
Conductivity was modeled equally is all directions

The potential for soil piping at the toe of the embankment is expressed as a factor of safety (FS); the ratio of the critical gradient based on the soil unit weight compared to the maximum estimated gradient in the upward direction from the seepage analysis. A FS of 3.0 or greater indicates that piping is unlikely and no seepage protection is recommended. Based on the analysis, Figure D-4a and D-4b at STA 11+33, the phreatic surface does not intersect the toe of slope indicating the ground water will not express out on the slope face. Figure D-4c and D-4d at STA 13+30 shows the phreatic surface at the toe of slope. The maximum gradient at the toe of slope is less than 0.1 at STA 11+30 and less than 0.3 at STA 13+30. The critical gradient is 1.0, indicating the FS against piping will be greater than 3.0.

5.3 JACK AND BORE

Based on the results of the subsurface exploration and the proposed invert elevation of the pipes, the jack and bore operations will likely encounter Fill and Stratum I: Coarse-Grained Soil. The proposed invert elevations of the jack and bore pipes will be within 15-ft of the encountered bedrock. Table 4.2 in Section 4 of this Report summarizes the depth and elevation of auger refusal encountered in the borings.

For this application, the jack and bore techniques are dependent on the soil overburden above the proposed jack and bore crown. Insufficient cover during jack and bore operations could cause heave or subsidence of the soils. This would be reflected at the surface as cracking, upheaval or depressions in the trail pavement.

In accordance with Virginia Department of Transportation Special Provision for Jack and Bore, SP302-000120-00, November 2016, minimum pipe cover should be the greater of 5-ft or three-times the pipe outside diameter. Based on our experience with jack and bore and review of available literature and previous VDOT projects, we recommend a minimum pipe cover of 5-ft or two-times the pipe outside diameter, whichever is greater. Based on the proposed pipe elevations and site topography, this coverage does not exist for the full length of the pipes. Underneath WOD Trail there is about 13-ft of cover. This will provide adequate cover over the pipes. Between the southern toe of the embankment and southern limit of the pipe at the stream's edge, about 100-ft in length, there is an estimated maximum 18-in of cover. This is not adequate cover for jack and bore operations, so cut and cover techniques will be needed here.

We recommend the pipes be installed using jack and bore method through the WOD Trail embankment and the remainder of the pipe sections south of the embankment should be installed in an open cut trench due to insufficient cover, and lower cost.

Jack and boring may require full length shielding (bore liners) and positive face boring techniques to prevent caving and loss of ground. Surface settlements due to jack and bore operations are mainly a result of loss of ground during tunneling and dewatering operations. The extent of these settlements are dependent on the type and strength of the ground, groundwater conditions, size and depth of the pipe, equipment capabilities, and the skill of the contractor in operating and steering the machine.

All jack and bore operations should be inspected by a geotechnical technician on a full-time basis under the supervision of a geotechnical engineer licensed in the Commonwealth of Virginia.

Support of excavation (SOE) will likely be required for the jacking and receiving pits. Based on the soils encountered in the subsurface exploration, sheet piles may not be feasible at the site due to the presence of very dense CWR at shallow depths. A drilled-in soldier pile and lagging wall will be an alternate support of excavation. The design of the support of excavation is the responsibility of the Contractor.

5.3.1 Open Cut Trench

An alternative method will be to install the proposed pipes in an open cut trench for the entire length of the pipes. Based on the invert elevation of the proposed pipes the section of the pipe under the WOD trail will require an approximately 18-ft deep trench. Recommendation for temporary cut slopes for the trench excavation are provided in Section 5.4 of this report. An open cut trench for the entire length of the pipes will require temporarily shutting down both the WOD trail and the FMR trail for an extended period. The width of the excavation will be about 60-ft to provide a side slope that complies with OSHA. Otherwise, a SOE would be needed.

5.4 TEMPORARY CUT SLOPES

Construction safety is the responsibility of the contractor. To guide planning, it can be assumed that the soils are Category C in accordance with OSHA 29 CFR 1926 and 1.5(H):1(V) temporary slopes can be used. The actual stability of the excavations should be evaluated by the contractor in accordance with OSHA regulations.

5.5 DEWATERING AND DRAINAGE

The borings encountered static groundwater at elevations ranging from 137 to 141. This is within the limits of the anticipated depth of excavations and within the proposed jack and bore alignment. Therefore, is likely that groundwater will be encountered during excavation for the proposed pipe installation.

We anticipate groundwater will be encountered in the jack and bore alignment, jacking pit, or during open cut trench construction. Appropriate dewatering should be performed so that construction will be performed in a relatively dry condition. Dewatering should be able to be completed with conventional ditching, sumps, and pumps.

Groundwater was monitored during the winter months. The evaluation of seasonal variations would require a monitoring period of at least one full year. Groundwater is relatively low during the winter months; therefore, the groundwater elevation may be higher than reported in the boring logs.

The actual dewatering plan is the responsibility of the Contractor. Sediment laden water should not be allowed to flow into any watercourse, adjacent drainageway, or over land without first filtering through an approved desilting device. The site drainage should also be such that the runoff onto adjacent properties and into waterways is controlled properly. Flash flooding is a risk, and the contractor should submit a plan to protect his equipment and the constructed work in the event the site is flooded.

6 BASIS OF RECOMMENDATIONS

This report has been prepared to present the geotechnical conditions at the site and to provide geotechnical recommendations regarding the proposed construction. Adequate recommendations have been provided to serve as a basis for design and preparation of plans and specifications. The opinions, conclusions and recommendations contained in this report are based upon our professional judgment and generally accepted principles of geotechnical engineering. Inherent to these are the assumptions that the earthwork and foundation construction should be monitored and tested by an engineering technician acting under the guidance of a geotechnical engineer licensed in the Commonwealth of Virginia.

These analyses and recommendations are, of necessity, based on the information available at the time of the actual writing of the report and on the site conditions, surface and subsurface, that existed at the time the exploratory borings were drilled. Further, assumptions have been made regarding the limited exploratory borings, in relation to both the lateral extent of the site conditions and to the depth.

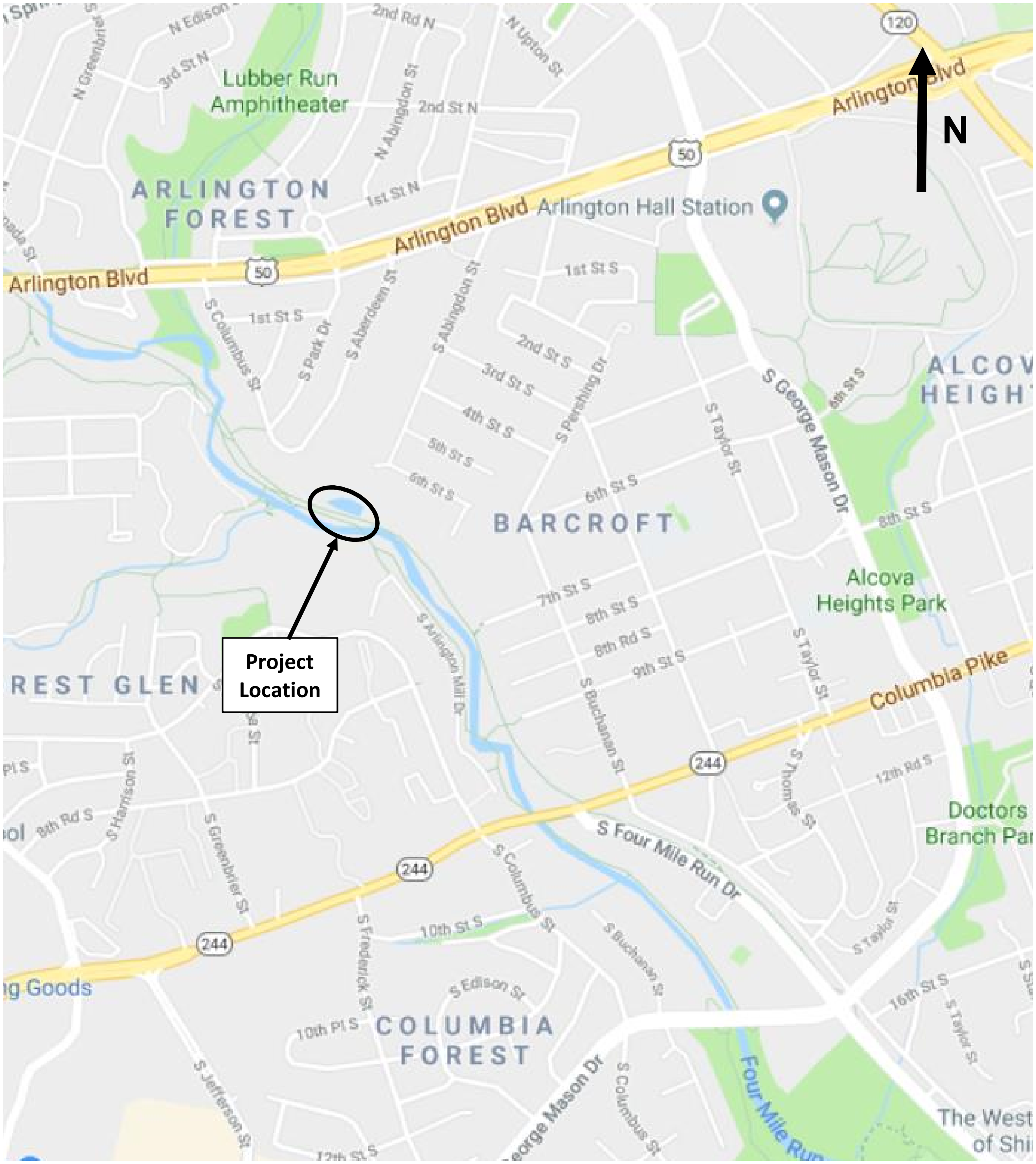
The nature and extent of variations between borings may not become evident until construction. If variations from the anticipated conditions are encountered, it may be necessary to revise the recommendations in this report.

Our professional services have been performed in accordance with generally accepted engineering principles and practices; no other warranty, expressed or implied, is made. RK&K assumes no responsibility for interpretations made by others on the work performed by RK&K.

We recommend that this report be made available in its entirety to contractors for informational purposes only. The boring logs and laboratory test data contained in this report represent an integral part of this report and incorrect interpretation of the data may occur if the attachments are separated from the text. The project plans or specifications should include the following note:

> *A geotechnical report has been prepared for this project by Rummel, Klepper & Kahl, LLP. This report is for informational purposes only and shall not be considered as part of the contract documents. The opinions and conclusions of RK&K represent our interpretation of the subsurface conditions and the planned construction at the time of the report preparation. The data in this report may not be adequate for contractors estimating purposes.*

Appendix A



MAP DATA 2018, GOOGLE

1000 ft

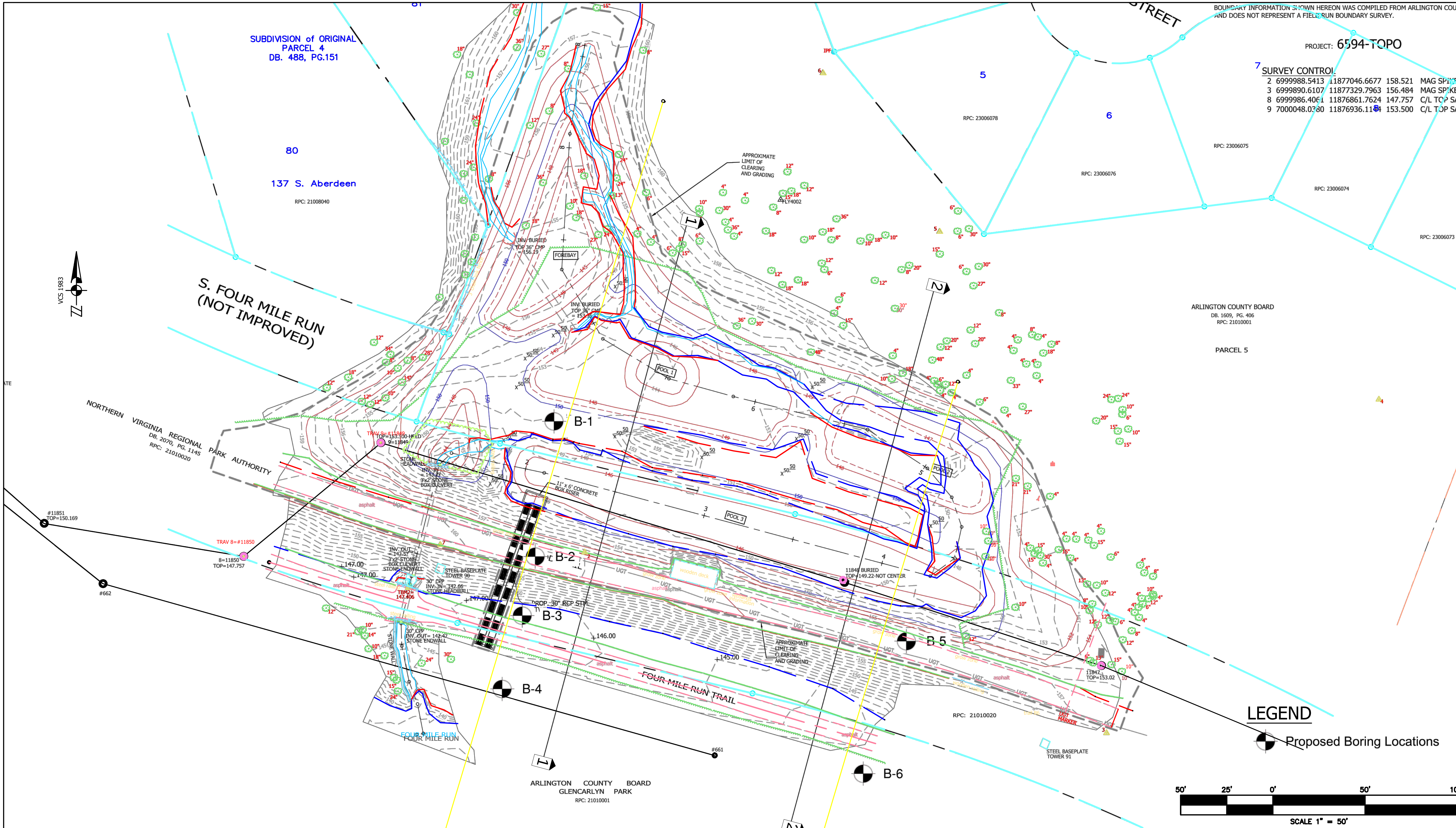
RK&K
700 East Pratt Street, Suite 500
Baltimore, Maryland 21202
(410) 728-2900

Sparrow Pond Stability Study

Site Vicinity Map

Figure No: **A-1**

DRAWN BY:	APPROVED BY:	SCALE:	DATE:	COMM. NO.
JJV	BBS	NTS	February, 2018	16068.000.RKK.003



Rummel, Klepper & Kahl, LLP

Engineers | Construction Managers | Planners | Scientist

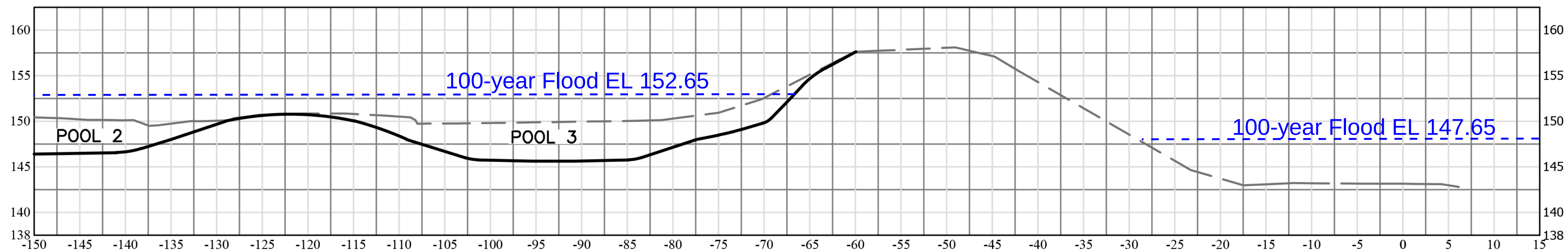
700 East Pratt Street, Suite 500
Baltimore, Maryland 21202-4919
410.728.2900

SPARROW POND – STABILITY STUDY
BORING LOCATION PLAN

FIGURE NO.	A–2a
COMMISSION. NO.	16068.002
SHEET NO.	01 OF 01

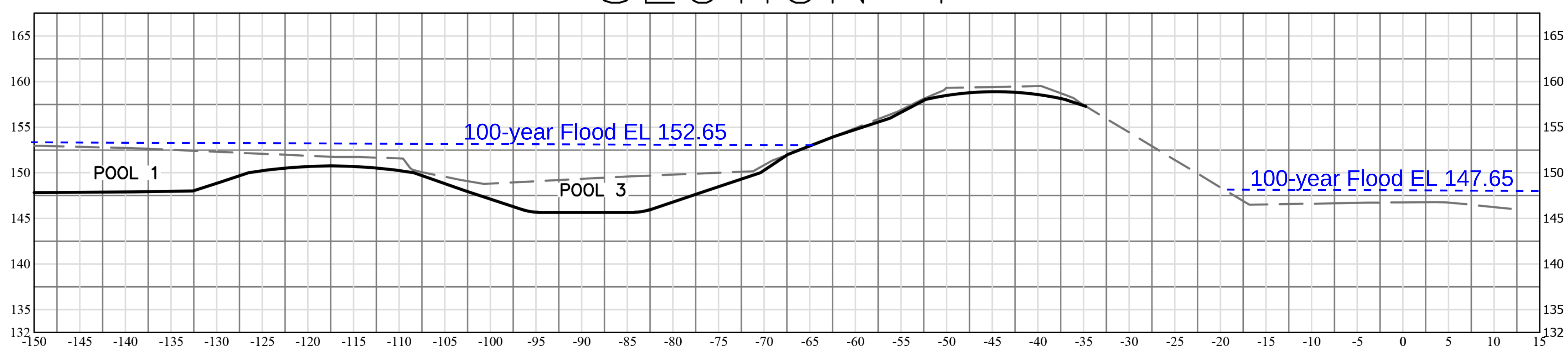
DRAWN BY	APPROVED BY	SCALE	DATE
TR	EMK	AS SHOWN	02/2018

SECTION 2'



13+29.87

SECTION 1'



11+33.15

LEGEND

PROPOSED GRADE

EXISTING GRADE

RK&K
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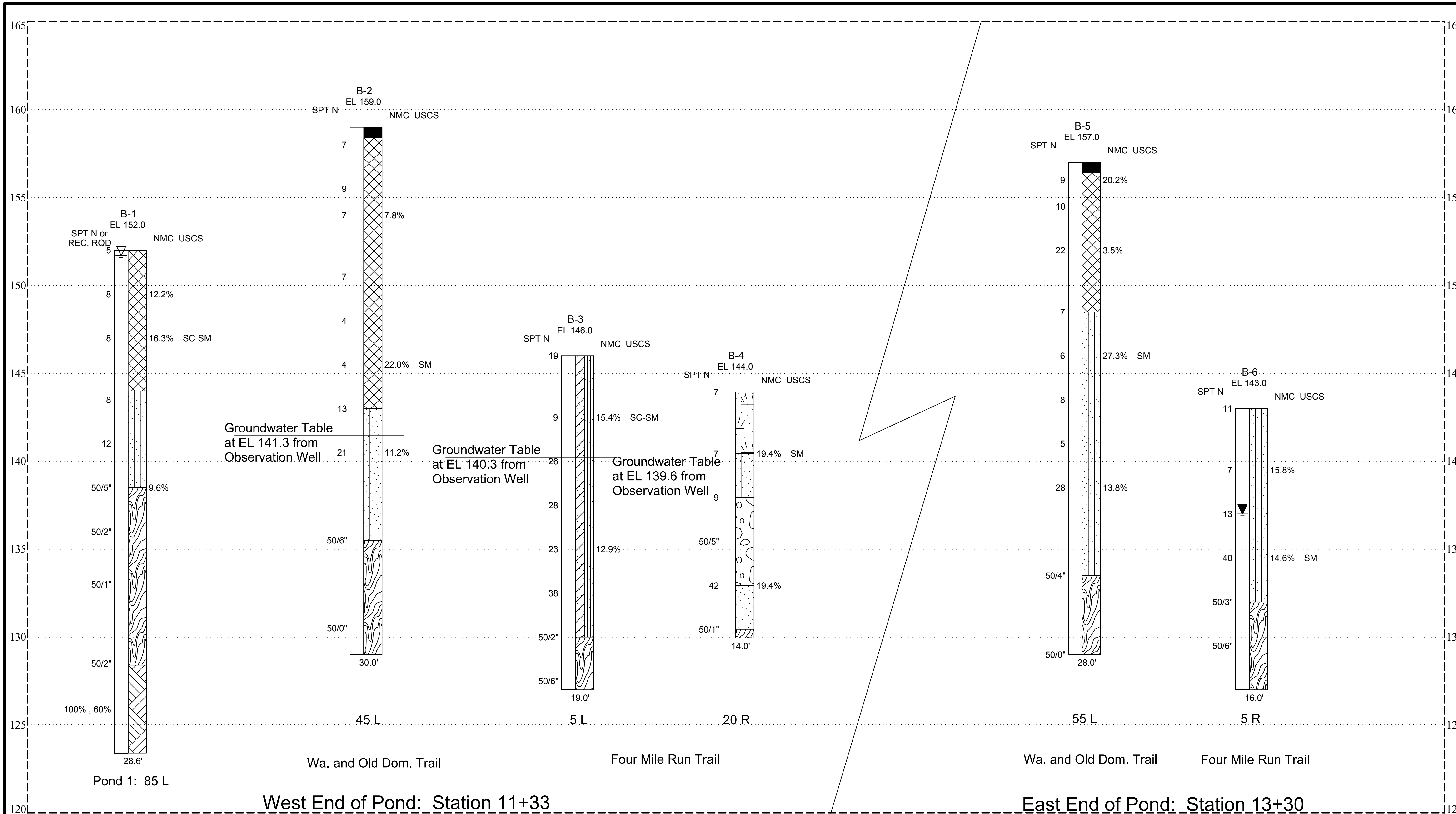
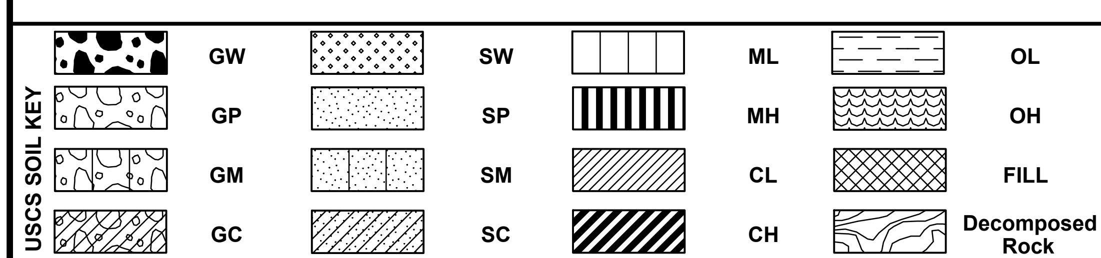
700 East Pratt Street, Suite 500
Baltimore, Maryland 21202-4919
410.728.2900

SPARROW POND – STABILITY STUDY
CROSS SECTIONS

FIGURE NO.	COMMISSION. NO.	DRAWN BY	APPROVED BY	SCALE	DATE	SHEET NO.
A–2b	16068.002	TR	EMK	AS SHOWN	02/2018	01 OF 01





Rummel, Klepper & Kahl, LLP
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700 East Pratt Street, Suite 500
Baltimore, MD 21202
(410) 728-2900

Title: **Summary of Boring Data**

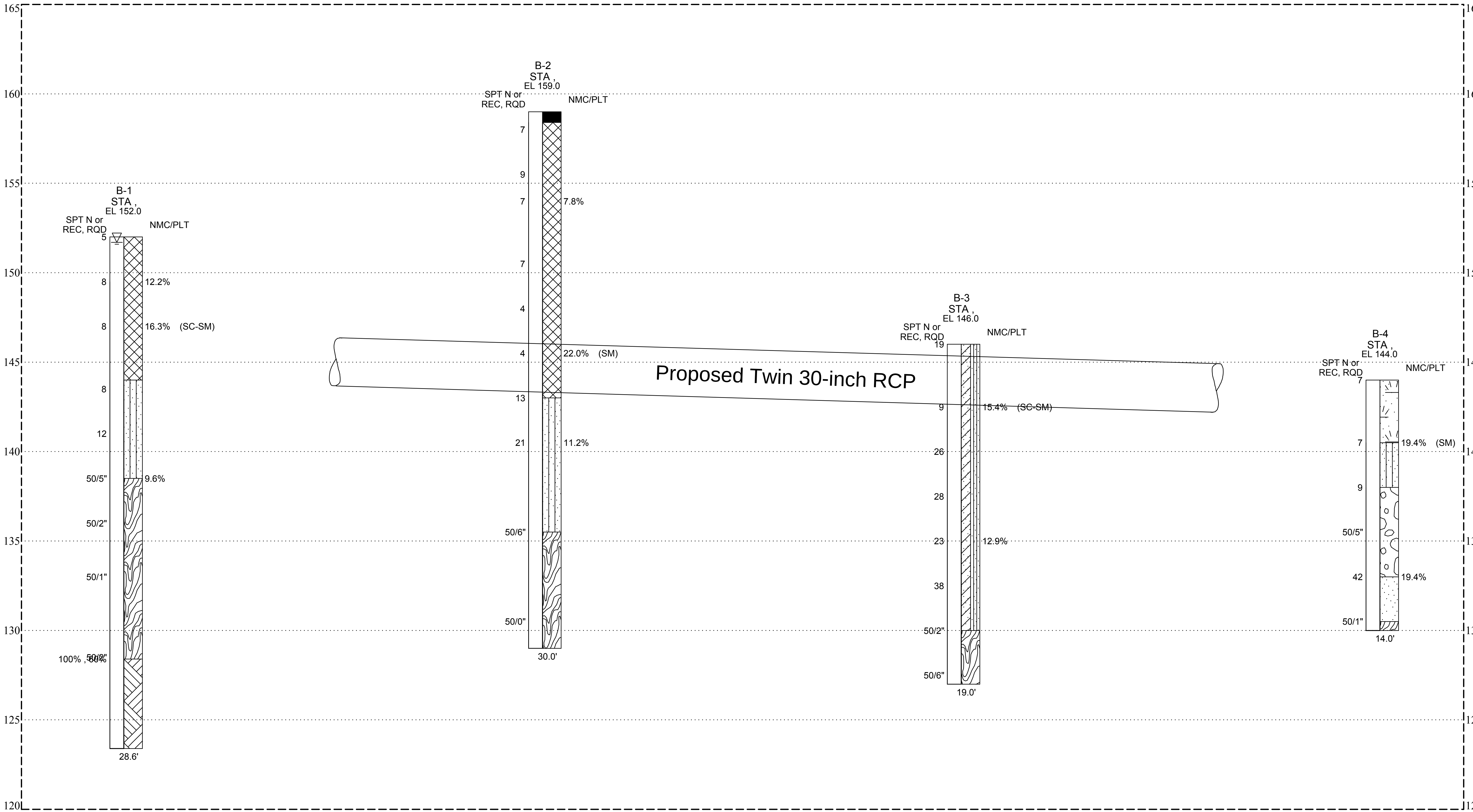
Sparrow Pond Stability Study

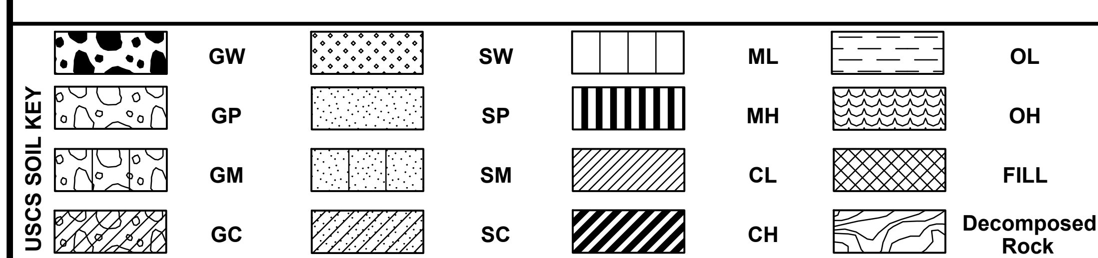
Drawn: JJV	Approved: BBS	Date: 01/30/18

Figure No. **A-3**

Comm. No. 16068.003

RKK FENCE - USCS (DEFAULT) 16068 SPARROW POND.GPJ RKK_CURRENT.GDT 01/30/18





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Baltimore, MD 21202
(410) 728-2900

Title: **Summary of Boring Data**

Proposed Twin 30-inch RCP

Figure No. **A-4**

Drawn: BBS | Approved: EMK | Date: 3/16/18 | Comm. No. 16068.003

RKK FENCE - USCS WITH STATION/OFFSET 16068 SPARROW POND.GPJ RKK_CURRENT.GDT 3/16/18

Appendix B

TEST BORING LOG

RK&K

PROJECT: Sparrow Pond

SITE: Arlington County , Virginia

DRILLING CO.: DMY **RIG/HAMMER:** CME-55 Tracked / Auto

COMMISSION NO.:	16068.003
NORTH:	7000059
EAST:	11877031
ELEVATION:	152 - ft
START DATE:	12/27/2017
END DATE:	12/27/2017
DRILLER:	Miguel
LOGGED BY:	JV

GROUNDWATER DATA (ft)

Date	Time	Water	Casing	Cave-In
12/28/2018	8:15:00 AM	0.3		11.0

EQUIPMENT	CASING	SAMPLER	CORE
TYPE	HSA	S	NQ
SIZE, ID (in)	3.25	1.375	2
HAMMER WT. (lb)		140	-
HAMMER FALL (in)		30	-

SAMPLE NUMBER	SAMPLE TYPE	SAMPLE RECOVERY (in)	BLOWS/6" (% RQD)	NMC/ Frac. Freq.	LIQUID LIMIT	PLASTICITY INDEX	DEPTH	ELEV. / DEPTH	GRAPHIC	DESCRIPTION AND CLASSIFICATION (moisture, density, color, proportions, etc.)	NOTES:
S-1	S	4	2 2 3							FILL Sampled As: Moist, Loose, Brown and Grey, Coarse to Fine SAND, Some Silt, Trace Clay, Trace Roots	
S-2	S	9	4 5 3	12.2%						Sample S-2: No Roots, Micaceous	
S-3	S	18	3 4 4	16.3%	27	7	5				
								EL 144.0 / 8.0			Drill through cobbles
S-4	S	0	7 3 5				10			Moist, Loose, Grey, Coarse to Fine SAND, Little Silt, Micaceous (sm) Sample S-4: No Recovery	
S-5	S	0	8 5 7							Sample S-5: No Recovery	
								EL 138.5 / 13.5			
S-6	S	5	50/5"	9.6%			15			COMPLETELY WEATHERED ROCK Sampled As: Moist, Grey, Coarse to Fine SAND, Some Rock Fragments, Trace Silt	Water on split spoon sampler
S-7	S	2	50/2"								
S-8	S	1	50/1"				20				
								EL 128.4 / 23.6			
S-9	S	2	50/2"							Medium to Fine Grained, Closely Fractured, Very Hard, Metasedementary MELANGE, No Foliation, 45-Degree Fractures	Auger refusal at 23.6-ft, switch to NQ2 coring
R-1	RC	60	60%				25				
								EL 123.4 / 28.6		Bottom of Boring @ 28.6 ft	Backfilled with auguer cuttings on 12-28-2018
							30				

SAMPLE IDENTIFICATION	DRILLING METHOD
- S - SPLIT SPOON	HSA - HOLLOW STEM AUGERS
- T - THIN WALL TUBE	SSA - SOLID STEM AUGERS
- SS - 3" SPLIT SPOON	DC - DRIVING CASING
- D - DENISON	MD - MUD DRILLING
- RC - ROCK CORE	HA - HAND AUGER

BLOWS/FT	DENSITY
0-4	VERY LOOSE
5-10	LOOSE
11-30	MEDIUM DENSE
31-50	DENSE
OVER 50	VERY DENSE

BLOWS/FT	CONSISTENCY
0-2	VERY SOFT
3-4	SOFT
5-8	MEDIUM STIFF
9-15	STIFF
16-30	VERY STIFF
OVER 30	HARD

SAMPLE PROPORTIONS (PERCENT)	
TRACE	1 TO 10
LITTLE	11 TO 20
SOME	21 TO 35
AND	36 TO 50

RKK NORTH/EAST (DEFAULT) 16068 SPARROW POND.GPJ RKK_CURRENT.GDT 01/30/18

TEST BORING LOG

RK&K

PROJECT: Sparrow Pond

SITE: Arlington County , Virginia

DRILLING CO.: DMY **RIG/HAMMER:** CME-55 Tracked / Auto

COMMISSION NO.:	16068.003
NORTH:	6999986
EAST:	11877021
ELEVATION:	159 - ft
START DATE:	12/29/2017
END DATE:	12/29/2017
DRILLER:	Miguel
LOGGED BY:	JV

GROUNDWATER DATA (ft)

Date	Time	Water	Casing	Cave-In

EQUIPMENT	CASING	SAMPLER	CORE
TYPE	HSA	S	
SIZE, ID (in)	3.25	1.375	
HAMMER WT. (lb)		140	-
HAMMER FALL (in)		30	-

SAMPLE NUMBER	SAMPLE TYPE	SAMPLE RECOVERY (in)	BLOWS/6" (% RQD)	NMC/ Frac. Freq.	LIQUID LIMIT	PLASTICITY INDEX	DEPTH	ELEV. / DEPTH	DESCRIPTION AND CLASSIFICATION (moisture, density, color, proportions, etc.)	NOTES:
								EL 158.4 / 0.6	5-in Bituminous Concrete, 2-in Graded Aggregate Base	
S-1	S	8	4 3 4						FILL Sampled As: Moist, Loose, Brown, Coarse to Fine SAND, Some Silt, Trace Clay, Micaceous	
S-2	S	16	3 4 5							
S-3	S	14	6 4 3	7.8%			5		Sample S-3: Trace Fine Gravel	
S-4	S	6	5 4 3				10			
S-5	S	18	2 2 2						Sample S-5: Very Loose, Some Silt	
S-6	S	16	3 2 2	22%	27	5	15		Sample S-6: Very Loose, and SILT	
S-7	S	16	6 7 6					EL 143.0 / 16.0	Moist, Medium Dense, Tan, Coarse to Fine SAND, Little Coarse to Fine Gravel, Little Silt (sm)	
S-8	S	14	11 8 13	11.2%			20		Sample S-8: Wet, Some Gravel	
S-9	S	9	20 50/6"				25	EL 135.5 / 23.5	COMPLETELY WEATHERED ROCK Sampled As: Moist, Grey, Coarse to Fine SAND, Some Rock Fragments, Trace Silt	
S-10	S	0	50/0"				30	EL 129.0 / 30.0	Bottom of Boring @ 30.0 ft	Auger refusal at 30.0-ft 2-in diameter monitoring well installed with 10-ft screen

SAMPLE IDENTIFICATION	DRILLING METHOD
- S - SPLIT SPOON	HSA - HOLLOW STEM AUGERS
- T - THIN WALL TUBE	SSA - SOLID STEM AUGERS
- SS - 3" SPLIT SPOON	DC - DRIVING CASING
- D - DENISON	MD - MUD DRILLING
- RC - ROCK CORE	HA - HAND AUGER

BLOWS/FT	DENSITY
0-4	VERY LOOSE
5-10	LOOSE
11-30	MEDIUM DENSE
31-50	DENSE
OVER 50	VERY DENSE

BLOWS/FT	CONSISTENCY
0-2	VERY SOFT
3-4	SOFT
5-8	MEDIUM STIFF
9-15	STIFF
16-30	VERY STIFF
OVER 30	HARD

SAMPLE PROPORTIONS (PERCENT)	
TRACE	1 TO 10
LITTLE	11 TO 20
SOME	21 TO 35
AND	36 TO 50

TEST BORING LOG

RK&K

PROJECT: Sparrow Pond

SITE: Arlington County , Virginia

DRILLING CO.: DMY **RIG/HAMMER:** CME-55 Tracked / Auto

COMMISSION NO.:	16068.003
NORTH:	6999954
EAST:	11877014
ELEVATION:	146 - ft
START DATE:	12/28/2017
END DATE:	12/28/2017
DRILLER:	Miguel
LOGGED BY:	JV

GROUNDWATER DATA (ft)

Date	Time	Water	Casing	Cave-In

EQUIPMENT	CASING	SAMPLER	CORE
TYPE	HSA	S	
SIZE, ID (in)	3.25	1.375	
HAMMER WT. (lb)		140	-
HAMMER FALL (in)		30	-

SAMPLE NUMBER	SAMPLE TYPE	SAMPLE RECOVERY (in)	BLOWS/6" (% RQD)	NMC/ Frac. Freq.	LIQUID LIMIT	PLASTICITY INDEX	DEPTH	ELEV. / DEPTH	GRAPHIC	DESCRIPTION AND CLASSIFICATION (moisture, density, color, proportions, etc.)	NOTES:
S-1	S	18	7 7 12							Moist, Medium Dense, Brown and Grey, Coarse to Fine SAND, Little Coarse to Fine Gravel , Some Silt, Trace Clay, Micaceous (SC-SM)	Drill through cobbles
S-2	S	18	7 5 4	15.4%	24	4	5			Sample S-2: Loose, Some Silt	
S-3	S	15	4 13 13							Sample S-3: And SILT	
S-4	S	2	11 16 12							Sample S-4: And GRAVEL	Drill through cobbles
S-5	S	18	10 11 12	12.9%			10			Sample S-5: No Gravel	
S-6	S	18	17 17 21				15			Sample S-6: Dense, No Gravel	
S-7	S	6	28 50/2"					EL 130.0 / 16.0		COMPLETELY WEATHERED ROCK Sampled As: Dry, Grey, ROCK FRAGMENTS	
S-8	S	2	50/6"					EL 127.0 / 19.0		Bottom of Boring @ 19.0 ft	Auger refusal at 19.0-ft
							20				2-in diameter monitoring well installed with 10-ft screen. The first attempt at well installation failed, and the boring was backfilled with auger cuttings upon completion. A second boring was drilled at 5-ft offset. No samples were taken, refusal was encountered at the same depth, and the well was installed successfully.
							25				
							30				

SAMPLE IDENTIFICATION	DRILLING METHOD	BLOWS/FT	DENSITY	BLOWS/FT	CONSISTENCY	SAMPLE PROPORTIONS (PERCENT)	
- S - SPLIT SPOON	HSA - HOLLOW STEM AUGERS	0-4	VERY LOOSE	0-2	VERY SOFT	TRACE	1 TO 10
- T - THIN WALL TUBE	SSA - SOLID STEM AUGERS	5-10	LOOSE	3-4	SOFT	LITTLE	11 TO 20
- SS - 3" SPLIT SPOON	DC - DRIVING CASING	11-30	MEDIUM DENSE	5-8	MEDIUM STIFF	SOME	21 TO 35
- D - DENISON	MD - MUD DRILLING	31-50	DENSE	9-15	STIFF	AND	36 TO 50
- RC - ROCK CORE	HA - HAND AUGER	OVER 50	VERY DENSE	16-30	VERY STIFF		
				OVER 30	HARD		

RKK NORTH/EAST (DEFAULT) 16068 SPARROW POND.GPJ RKK_CURRENT.GDT 01/30/18

TEST BORING LOG

PROJECT: Sparrow Pond
SITE: Arlington County , Virginia
DRILLING CO.: DMY **RIG/HAMMER:** CME-55 Tracked / Auto

COMMISSION NO.:	16068.003
NORTH:	6999914
EAST:	11877003
ELEVATION:	144 - ft
START DATE:	12/28/2017
END DATE:	12/28/2017
DRILLER:	Miguel
LOGGED BY:	JV

GROUNDWATER DATA (ft)

Date	Time	Water	Casing	Cave-In

EQUIPMENT	CASING	SAMPLER	CORE
TYPE	HSA	S	
SIZE, ID (in)	3.25	1.375	
HAMMER WT. (lb)		140	-
HAMMER FALL (in)		30	-

SAMPLE NUMBER	SAMPLE TYPE	SAMPLE RECOVERY (in)	BLOWS/6" (% RQD)	LABORATORY TEST RESULTS NMC/ Frac. Freq.	LIQUID LIMIT	PLASTICITY INDEX	DEPTH	ELEV. / DEPTH	GRAPHIC	DESCRIPTION AND CLASSIFICATION (moisture, density, color, proportions, etc.)	NOTES:
S-1	S	6	1 2 5							Topsoil	
S-2	S	18	3 3 4	19.4%	28	4	5	EL 140.5 / 3.5		Moist, Loose, Brown, Coarse to FIne SAND, Some Silt, Trace Fine Gravel Trace Roots (SM)	
S-3	S	2	5 5 4					EL 138.0 / 6.0		Moist, Loose, Grey and Brown, Coarse GRAVEL and ROOTS (gp)	
S-4	S	2	50/5"							Sample S-4: Very Dense, No Roots	Drill through cobbles
S-5	S	18	16 18 24	19.4%			10	EL 133.0 / 11.0		Moist, Dense, Grey, Coarse to Fine SAND, Trace Silt, Micaceous (sp)	
S-6	S	1	50/1"					EL 130.5 / 13.5		COMPLETELY WEATHERED ROCK Sampled As: ROCK FRAGMENTS	Auger refusal at 14.0-ft
							15	EL 130.0 / 14.0		Bottom of Boring @ 14.0 ft	2-in diameter monitoring well installed with 10-ft screen.
							20				
							25				
							30				

SAMPLE IDENTIFICATION	DRILLING METHOD	BLOWS/FT	DENSITY	BLOWS/FT	CONSISTENCY	SAMPLE PROPORTIONS (PERCENT)	
- S - SPLIT SPOON	HSA - HOLLOW STEM AUGERS	0-4	VERY LOOSE	0-2	VERY SOFT	TRACE	1 TO 10
- T - THIN WALL TUBE	SSA - SOLID STEM AUGERS	5-10	LOOSE	3-4	SOFT	LITTLE	11 TO 20
- SS - 3" SPLIT SPOON	DC - DRIVING CASING	11-30	MEDIUM DENSE	5-8	MEDIUM STIFF	SOME	21 TO 35
- D - DENISON	MD - MUD DRILLING	31-50	DENSE	9-15	STIFF	AND	36 TO 50
- RC - ROCK CORE	HA - HAND AUGER	OVER 50	VERY DENSE	16-30	VERY STIFF		
				OVER 30	HARD		

RKK NORTH/EAST (DEFAULT) 16068 SPARROW POND.GPJ RKK_CURRENT.GDT 01/30/18

TEST BORING LOG

RK&K

PROJECT: Sparrow Pond

SITE: Arlington County , Virginia

DRILLING CO.: DMY **RIG/HAMMER:** CME-55 Tracked / Auto

COMMISSION NO.:	16068.003
NORTH:	6999940
EAST:	11877222
ELEVATION:	157 - ft
START DATE:	1/2/2018
END DATE:	1/2/2018
DRILLER:	Miguel
LOGGED BY:	ACR

GROUNDWATER DATA (ft)

Date	Time	Water	Casing	Cave-In
1/2/2018	11:20:00 AM	Dry		16.0

EQUIPMENT	CASING	SAMPLER	CORE
TYPE	HSA	S	
SIZE, ID (in)	3.25	1.375	
HAMMER WT. (lb)		140	-
HAMMER FALL (in)		30	-

SAMPLE NUMBER	SAMPLE TYPE	SAMPLE RECOVERY (in)	BLOWS/6" (% RQD)	NMC/ Frac. Freq.	LIQUID LIMIT	PLASTICITY INDEX	DEPTH	ELEV. / DEPTH	GRAPHIC	DESCRIPTION AND CLASSIFICATION (moisture, density, color, proportions, etc.)	NOTES:
								EL 156.4 / 0.6		5-in Bituminous Concrete, 2-in Graded Aggregate Base	
S-1	S	8	7 4 5	20.2%						FILL Sampled As: Moist, Loose, Brown, Coarse to Fine SAND, Some Silt, Little Coarse to Fine Gravel	
S-2	S	2	5 4 6							Sample S-2: Grey, Some Rubble, Trace Gravel, Trace Silt	
S-3	S	2	9 5 17	3.5%			5			Sample S-2: Medium Dense, Grey, And GRAVEL, Trace Silt	
S-4	S	14	4 4 3					EL 148.5 / 8.5		Moist, Loose, Brown, Coarse to Fine SAND, Some Silt, Micaceous (SM)	
							10				
S-5	S	7	2 3 3	27.3%	54	19					
S-6	S	14	3 4 4							Sample S-6: Little Silt	
							15				
S-7	S	18	2 2 3							Sample S-7: Wet	
S-8	S	18	7 18 10	13.8%						Sample S-8: Wet, Medium Dense, Grey and Brown, Trace Rock Fragments	
							20				
S-9	S	12	15 18 50/4"					EL 133.5 / 23.5		COMPLETELY WEATHERED ROCK Sampled As: Moist, Grey, Coarse to Fine SAND, Little Silt, Micaceous	Water on split spoon sampler
							25				
S-10		0	50/0"					EL 129.0 / 28.0		Bottom of Boring @ 28.0 ft	Auger refusal at 28.0-ft Backfilled with cement grout and patched with bituminous concrete upon completion
							30				

SAMPLE IDENTIFICATION	DRILLING METHOD
- S - SPLIT SPOON	HSA - HOLLOW STEM AUGERS
- T - THIN WALL TUBE	SSA - SOLID STEM AUGERS
- SS - 3" SPLIT SPOON	DC - DRIVING CASING
- D - DENISON	MD - MUD DRILLING
- RC - ROCK CORE	HA - HAND AUGER

BLOWS/FT	DENSITY
0-4	VERY LOOSE
5-10	LOOSE
11-30	MEDIUM DENSE
31-50	DENSE
OVER 50	VERY DENSE

BLOWS/FT	CONSISTENCY
0-2	VERY SOFT
3-4	SOFT
5-8	MEDIUM STIFF
9-15	STIFF
16-30	VERY STIFF
OVER 30	HARD

SAMPLE PROPORTIONS (PERCENT)	
TRACE	1 TO 10
LITTLE	11 TO 20
SOME	21 TO 35
AND	36 TO 50

TEST BORING LOG

RK&K

PROJECT: Sparrow Pond

SITE: Arlington County , Virginia

DRILLING CO.: DMY **RIG/HAMMER:** CME-55 Tracked / Auto

COMMISSION NO.:	16068.003
NORTH:	6999868
EAST:	11877199
ELEVATION:	143 - ft
START DATE:	12/28/2017
END DATE:	12/28/2017
DRILLER:	Miguel
LOGGED BY:	JV

GROUNDWATER DATA (ft)

Date	Time	Water	Casing	Cave-In
12/28/2018	10:00:00 AM	Dry		10.5
12/29/2018	8:00:00 AM	6.0		10.0

EQUIPMENT	CASING	SAMPLER	CORE
TYPE	HSA	S	
SIZE, ID (in)	3.25	1.375	
HAMMER WT. (lb)		140	-
HAMMER FALL (in)		30	-

SAMPLE NUMBER	SAMPLE TYPE	SAMPLE RECOVERY (in)	BLOWS/6" (% RQD)	LABORATORY TEST RESULTS: NMC/ Frac. Freq.	LIQUID LIMIT	PLASTICITY INDEX	DEPTH	ELEV. / DEPTH	GRAPHIC	DESCRIPTION AND CLASSIFICATION (moisture, density, color, proportions, etc.)	NOTES:
S-1	S	6	3 5 6							Moist, Medium Dense, Brown, Coarse to Fine SAND, And Silt, Trace Coarse to Fine Gravel (SM)	Drill through cobbles
S-2	S	10	3 4 3	15.8%			5			Sample S-2: Loose, No Gravel Observed	
S-3	S	10	6 7 6				▼			Sample S-3: Micaceous, No Gravel Observed	
S-4	S	18	5 12 28	14.6%	NP	NP	10			Sample S-4: Dense, Brown and Grey, Micaceous, No Gravel Observed	
S-5	S	6	30 35 50/3"					EL 132.0 / 11.0		COMPLETELY WEATHERED ROCK Sampled As: Moist, Grey, Coarse to Fine SAND, Some Rock Fragments, Little Silt, Micaceous	
S-6	S	0	36 50/6"				15				
								EL 127.0 / 16.0		Bottom of Boring @ 16.0 ft	Auger refusal at 16.0-ft Backfilled with auguer cuttings on 12-29-2018
							20				
							25				
							30				

SAMPLE IDENTIFICATION	DRILLING METHOD
- S - SPLIT SPOON	HSA - HOLLOW STEM AUGERS
- T - THIN WALL TUBE	SSA - SOLID STEM AUGERS
- SS - 3" SPLIT SPOON	DC - DRIVING CASING
- D - DENISON	MD - MUD DRILLING
- RC - ROCK CORE	HA - HAND AUGER

BLOWS/FT	DENSITY	BLOWS/FT	CONSISTENCY
0-4	VERY LOOSE	0-2	VERY SOFT
5-10	LOOSE	3-4	SOFT
11-30	MEDIUM DENSE	5-8	MEDIUM STIFF
31-50	DENSE	9-15	STIFF
OVER 50	VERY DENSE	16-30	VERY STIFF
		OVER 30	HARD

SAMPLE PROPORTIONS (PERCENT)	
TRACE	1 TO 10
LITTLE	11 TO 20
SOME	21 TO 35
AND	36 TO 50

RKK NORTH/EAST (DEFAULT) 16068 SPARROW POND.GPJ RKK_CURRENT.GDT 01/30/18

FIELD CLASSIFICATION SYSTEM FOR SOIL EXPLORATION

COHESIONLESS SOILS (Silt, Sand, Gravel, and Combinations)

Density

Very Loose	4 blows/ft or less
Loose	5 to 10 blows/ft
Medium Dense	11 to 30 blows/ft
Dense	31 to 50 blows/ft
Very Dense	51 blows/ft or more

Relative Proportions

Descriptive Term	Percent
Trace	1 to 10
Little	11 to 20
Some	21 to 35
And	35 to 50

Particle Size Identification

Boulders		12 inches diameter or more
Cobbles		3 to 12 inch diameter
Gravel	Coarse:	3/4 to 3 inch diameter
	Fine:	1/4 to 3/4 inch diameter
Sand	Coarse:	2 mm to 1/4 inch (diameter of pencil lead)
	Medium:	0.425 to 2 mm (diameter of broom straw)
	Fine:	0.075 to 0.425 mm (diameter of human hair)
Silt		0.005 to 0.075 mm (Cannot see particles)

COHESIVE SOILS (Clay, Silt, and Combinations)

Consistency

Very Soft	2 blows/ft or less
Soft	3 to 4 blows/ft
Medium Stiff	5 to 8 blows/ft
Stiff	9 to 15 blows/ft
Very Stiff	16 to 30 blows/ft
Hard	31 blows/ft or more
Hard	31 blows/ft or more

Plasticity

Degree of Plasticity	Plasticity Index
No to Slight	0 - 4
Slight	5 - 7
Medium	8 - 22
High to Very High	over 22
High to Very High	over 22

Soil Classifications on Test Boring Logs are made by visual-manual inspection of samples. Soil classification symbols using lower case letters are based on a visual-manual classification. Soil classification symbols using upper case letters are based on laboratory testing.

Standard Penetration Test

Driving a 2.0-inch OD, 1 3/8-inch ID sampler a distance of 1.0-foot into undisturbed soil with a 140-lb hammer free falling a distance of 30.0-inches. It is required to drive the spoon 6.0-inches to seat into undisturbed soil, then perform the test. The number of hammer blows for seating and making the test are recorded each 6.0-inches of penetration on the Test boring Log (Example 6-8-9, 8+9=17 blows/ft). (ASTM D-1586)

Strata Changes

In the column "Soil Descriptions" on the Test Boring Logs, the horizontal lines represent strata changes. A solid line represents an actually observed change, a dashed line represents an estimated change.

Ground Water

Observations were made at the time indicated. Porosity of soil strata, weather conditions, site topography, etc. may cause changes in the water levels indicated on the Test Boring Log.

RK&K
700 East Pratt Street, Suite 500
Baltimore, Maryland 21202
(410) 728-2900

Title:			Figure No:
FIELD CLASSIFICATION SYSTEM FOR SOIL EXPLORATION			B-1
Drawn: JJV	Approved: SAB	Date: October, 2017	Comm No: General

FIELD CLASSIFICATION SYSTEM FOR ROCK EXPLORATION

Rock Penetrated by Split Spoon Sampler: A transitional material between soil and rock retains the relic structure of the parent rock and exhibits penetration resistance between 60 blows/ft and 100 blows/ 2-inches of penetration

RQD: Rock Quality Designation: Ratio of the core lengths greater than 4-inches to the total length of the run. Applies only to sound, fresh, unweathered rock.

Recovery	Description	RQD	Description of Rock Quality	Approximate General Tunneler's Description
< 40%	Incompetent	0 - 25	Very Poor	Crushed
40-70	Competent	25 - 50	Poor	Shattered, very blocky and seamy
70-90	Fairly Continuous	50 - 75	Fair	Blocky and seamy
90-100	Continuous	75 - 90	Good	Massive, moderately jointed
		90 - 100	Excellent	Intact Rock

FIELD HARDNESS

(A measure of resistance to scratching or abrasion.)

Very Hard

Cannot be scratched with knife or geologist's pick. Breaking of hand specimens requires hard blows of geologist's pick. Typical UCC > 28- ksi

Hard

Can be scratched with knife or geologist's pick only with difficulty. Hard blow of a hammer required to detach hand specimen. Typical UCC: 14 to 28- ksi

Medium Hard

Can be scratched with knife or geologist's pick. Gouges or grooves of 1/4-inch deep can be excavated by hard blow of point of a geologist's pick. Hand specimens can be detached by moderate blow. Typical UCC: 10.5 to 14- ksi

Medium

Can be grooved or gouged 1/16-inch deep by firm pressure on knife or geologist's pick point. Can be excavated in small chips to pieces about 1-inch maximum size by hard blows of the point of a geologist's pick. Typical UCC: 7 to 10.5- ksi

Soft

Can be gouged or grooved readily with knife or pick point. Can be excavated in chips and pieces several inches in size by moderate blows of a geologist's pick point. Small thin pieces can be broken by finger pressure. Typical UCC: 3.5 to 7- ksi

Very Soft

Can be carved with knife. Can be excavated with point of pick. Pieces 1-inch or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail. Typical UCC: 140 to 3,500- psi

ROCK FRACTURE FREQUENCY

Description	Spacing Between Fractures
Extremely Fractured	< 1-in
Moderately Fractured	1 to 4-in
Slightly Fractured	4 to 8-in
Sound	> 8-in

NOTE: Fracture frequency terms are generalized to describe the average condition of the rock obtained from the core run. Portions of the rock within the run described may vary from the generalized descriptions. Where a core break appears to be due to drilling and not to natural causes, it has not been considered as a break for accessing fracture frequency. Frequency shown on the Test Boring Logs represents conditions of core as removed from the core barrel.

WEATHERING

(The action of the elements in altering the color, texture, and composition of the

Very Slightly

Rock generally fresh, joints stained, some joints may contain thin clay coatings, crystals in broken face show bright. Rock rings under hammer if crystalline.

Slightly

Rock generally fresh, joints stained, and discoloration extends into rock up to 1-inch. Joints may contain clay. In granitoid rocks, some occasional feldspar crystals are dull and discolored. Crystalline rocks ring under hammer.

Moderately

Significant portions of rock show discoloration and weathering effects. In granitoid rocks, most feldspars are dull and discolored; some may be decomposed to clay. Rock has dull sound under hammer and has a significant loss of strength compared with fresh rock.

Severely

All rock except quartz discolored or stained. Rock "fabric" clear and evident but reduced in strength to strong soil. In granitoid rocks, all feldspars kaolinized to some extent. Some fragments of strong rock usually left.

Very Severely

All rock except quartz discolored or stained. Rock "fabric" discernible, but mass effectively reduced to "soil" with only fragments of strong rock remaining.

Completely

All rock completely altered to soil-like material.

JOINTS, BEDDING AND FOLIATION

Joints	Bedding and Foliation	Spacing
	Fissile	< 0.25-in
Very Close	Very Thin	< 2-in
Close	Thin	2-in to 1-ft
Moderately Close	Medium	1 to 3-ft
Wide	Thick	3 to 10-ft
Very Wide	Very Thick	> 10-ft

NOTE: Refers to perpendicular distance between discontinuities.

Attitude	Angle (Degrees)
Vertical	0 to 5
Steep or High Angle	5 to 35
Moderately Dipping	35 to 55
Shallow to Low Angle	55 to 85
Horizontal	85 to 90

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Title: FIELD CLASSIFICATION SYSTEM FOR ROCK EXPLORATION			Figure No: B-2
Drawn: JJV	Approved: EMK	Date: August, 2015	Comm No: General

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

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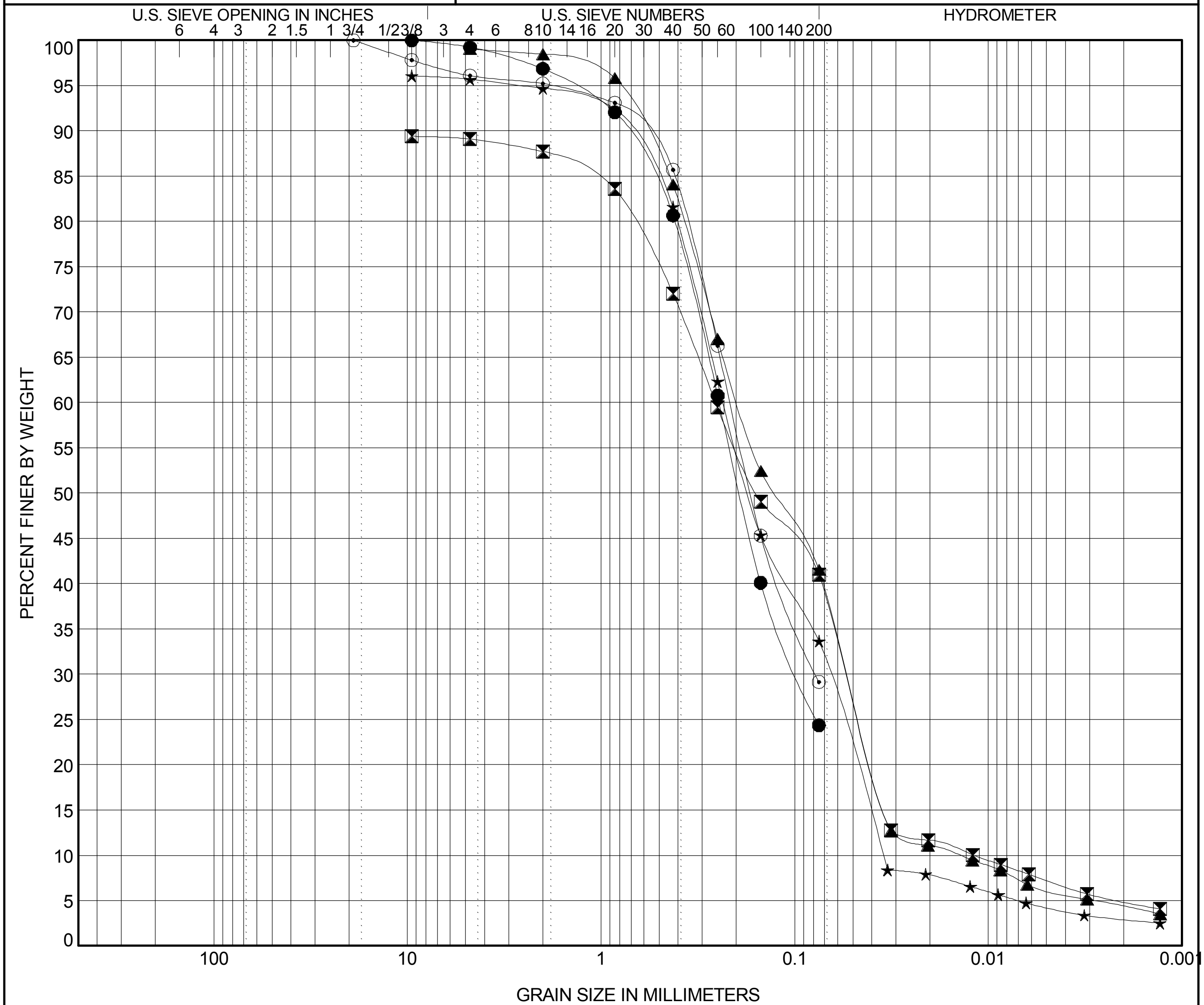
Title:			Figure No:
UNIFIED SOIL CLASSIFICATION SYSTEM			B-3
Drawn: JJV	Approved: SAB	Date: October, 2017	Comm No: General

Appendix C

PROJECT NAME: Sparrow Pond
PROJECT NO.: 03.03336.01
LOCATION: Arlington, VA
CLIENT: RK&K

GRAIN SIZE DISTRIBUTION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

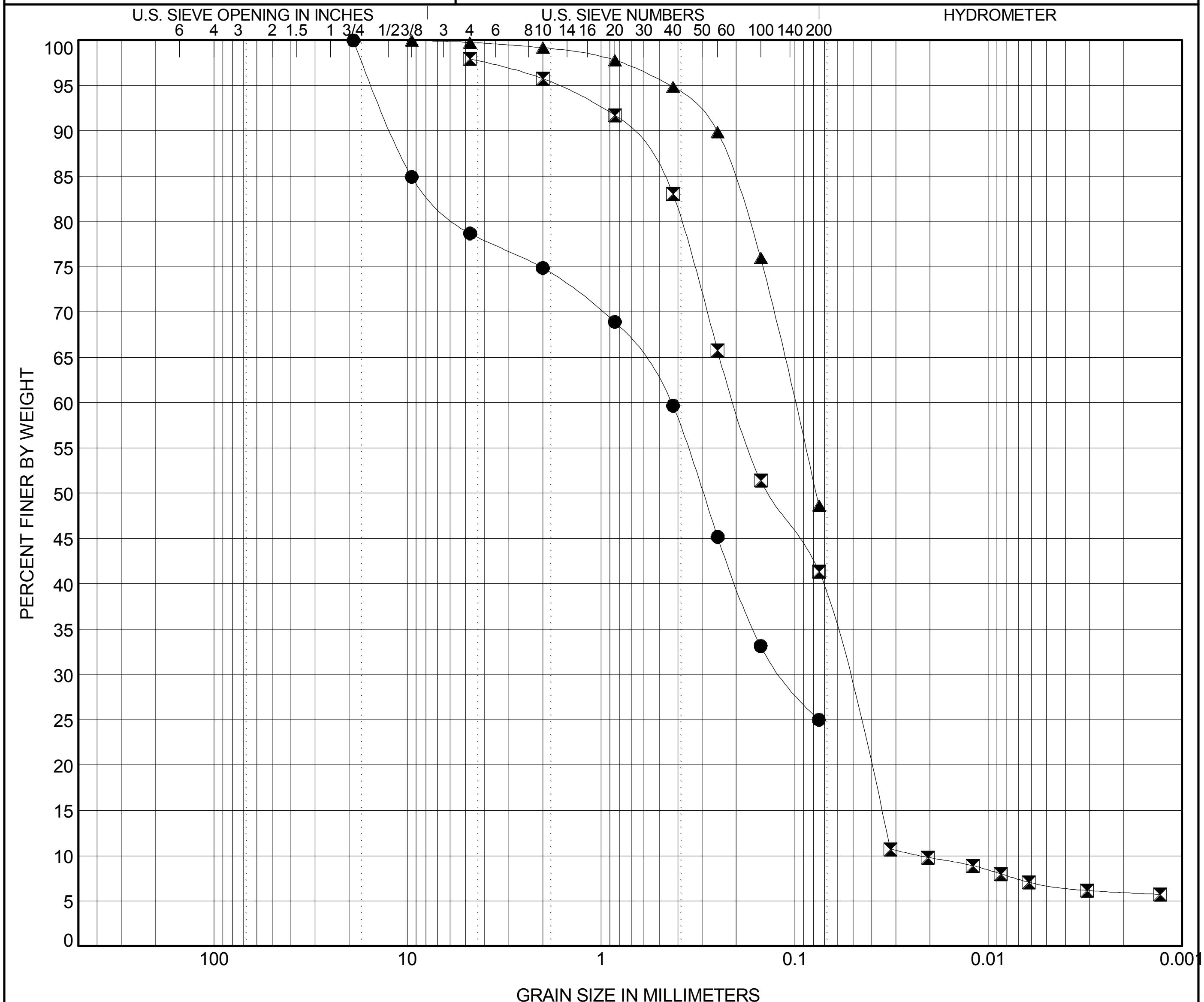
SAMPLE	DEPTH (FT)	SAMPLE DESCRIPTION	LL	PL	PI
● **B-1-S-2**	**2.5-4.0**				
⧗ **B-1-S-3**	**5.0-6.5**	Gray, Silty, Clayey Sand (**SC-SM**)	**27**	**20**	**7**
▲ **B-2-S-6**	**13.5-15.0**	Brown, Silty Sand (**SM**)	**27**	**22**	**5**
★ **B-3-S-2**	**3.5-5.0**	Gray, Silty, Clayey Sand (**SC-SM**)	**24**	**20**	**4**
⊙ **B-4-S-2**	**3.5-5.0**	Brown, Silty Sand (**SM**)	**28**	**24**	**4**

	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● **B-1-S-2**	**9.5**	**0.245**	**0.096**		**0.8**	**74.9**	**24.4**	
⧗ **B-1-S-3**		**0.256**	**0.054**	**0.012**		**48.1**	**33.8**	**7.2**
▲ **B-2-S-6**		**0.195**	**0.053**	**0.014**		**57.5**	**35.3**	**6.2**
★ **B-3-S-2**		**0.233**	**0.067**	**0.035**		**62.1**	**29.4**	**4.3**
⊙ **B-4-S-2**	**19**	**0.215**	**0.078**		**3.9**	**67.0**	**29.1**	

GRAIN SIZE 1/16/18

PROJECT NAME: Sparrow Pond
PROJECT NO.: 03.03336.01
LOCATION: Arlington, VA
CLIENT: RK&K

GRAIN SIZE DISTRIBUTION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

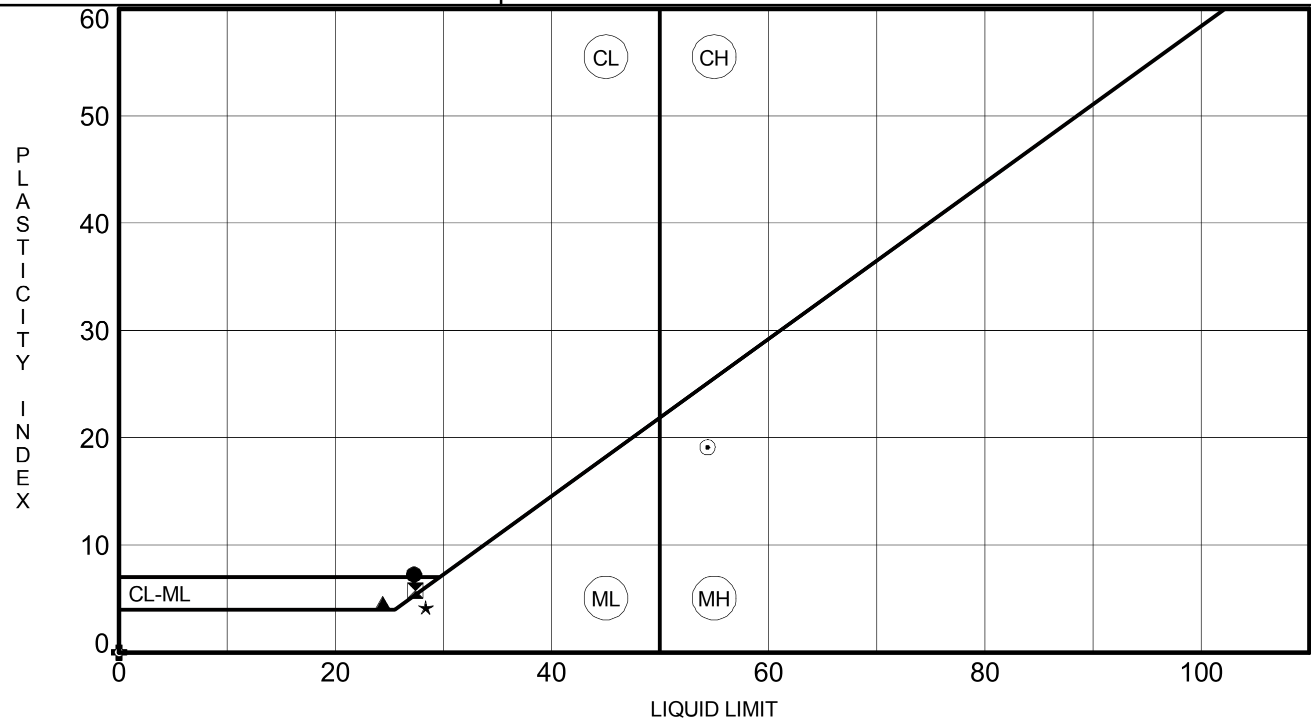
	SAMPLE	DEPTH (FT)	SAMPLE DESCRIPTION	LL	PL	PI
●	**B-5-S-1**	**1.0-2.5**				
⧗	**B-5-S-5**	**11.0-12.5**	Brown, Silty Sand (**SM**)	**54**	**35**	**19**
▲	**B-6-S-4**	**8.5-10.0**	Brown, Silty Sand (**SM**)	**NP**	**NP**	**NP**

		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**B-5-S-1**	**19**	**0.435**	**0.115**		**21.3**	**53.7**	**25.0**	
⧗	**B-5-S-5**		**0.204**	**0.055**	**0.022**		**56.6**	**34.6**	**6.8**
▲	**B-6-S-4**	**9.5**	**0.1**			**0.2**	**51.1**	**48.6**	

GRAIN SIZE 1/16/18

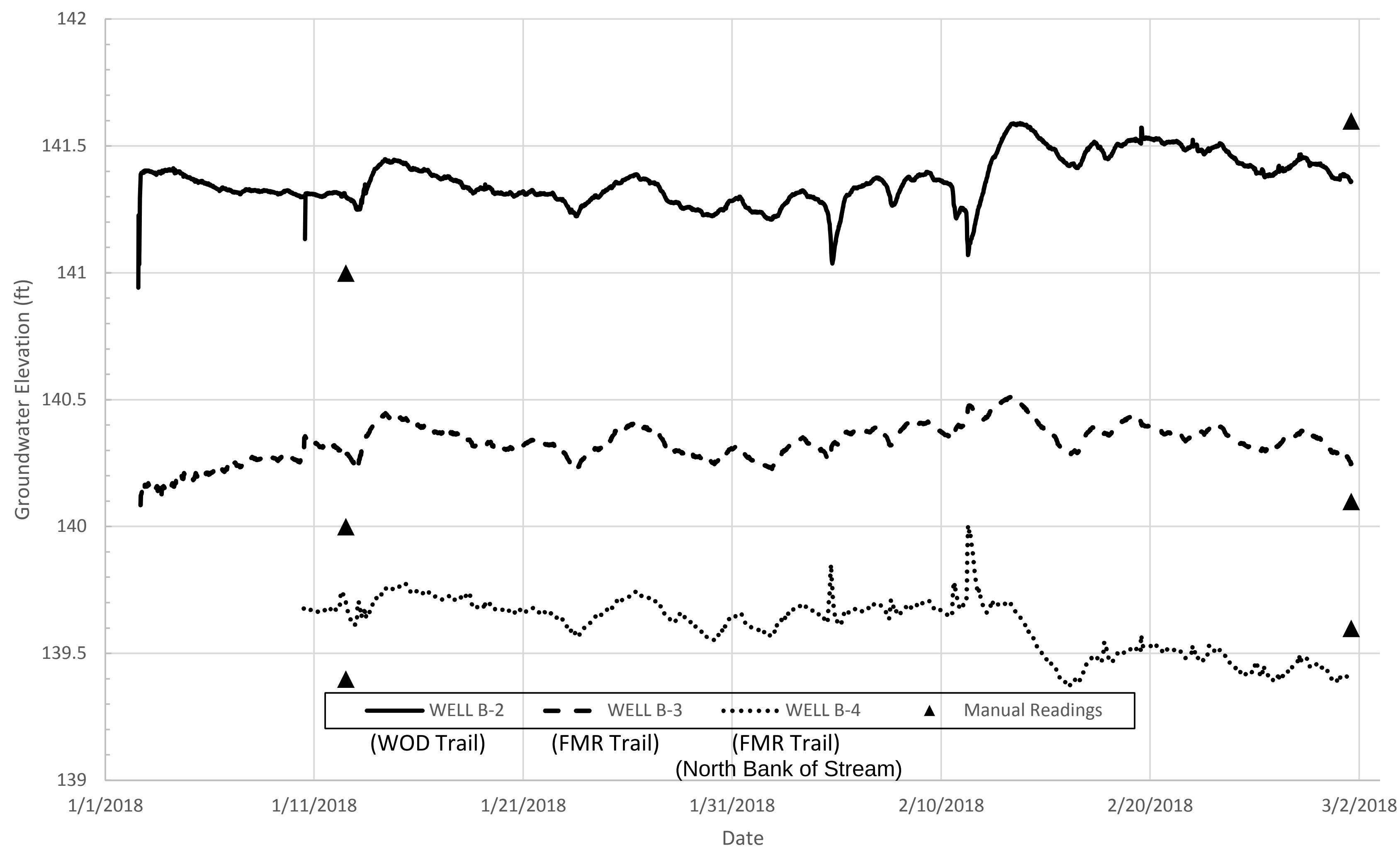
PROJECT NAME: Sparrow Pond
PROJECT NO.: 03.03336.01
LOCATION: Arlington, VA
CLIENT: RK&K

ATTERBERG LIMITS RESULTS ASTM D4318



SAMPLE	DEPTH (FT)	LL	PL	PI	Fines	SAMPLE DESCRIPTION
● **B-1-S-3**	**5.0-6.5**	**27**	**20**	**7**	**41.0**	Gray, Silty, Clayey Sand (**SC-SM**)
⧗ **B-2-S-6**	**13.5-15.0**	**27**	**22**	**5**	**41.5**	Brown, Silty Sand (**SM**)
▲ **B-3-S-2**	**3.5-5.0**	**24**	**20**	**4**	**33.7**	Gray, Silty, Clayey Sand (**SC-SM**)
★ **B-4-S-2**	**3.5-5.0**	**28**	**24**	**4**	**29.1**	Brown, Silty Sand (**SM**)
⊙ **B-5-S-5**	**11.0-12.5**	**54**	**35**	**19**	**41.4**	Brown, Silty Sand (**SM**)
✪ **B-6-S-4**	**8.5-10.0**	**NP**	**NP**	**NP**	**48.6**	Brown, Silty Sand (**SM**)

Appendix D



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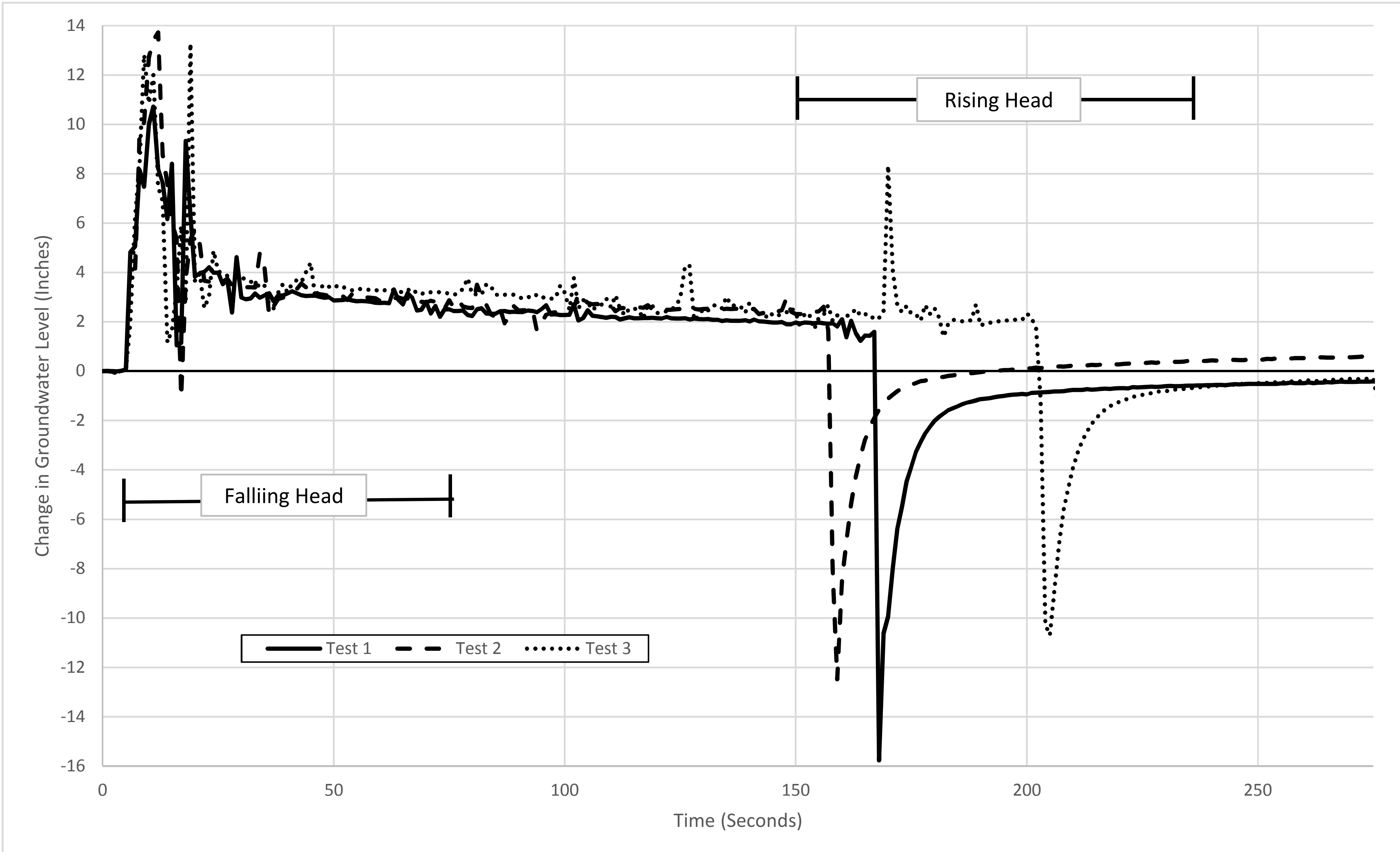
Sparrow Pond Stability Study

Groundwater Monitoring Well Hydrograph

Figure: D-1

DRAWN BY:	APPROVED BY:	SCALE:	DATE:	COMM. NO.
JJV	BBS	NTS	March, 2018	16068.000.RKK.003



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Sparrow Pond Stability Study

Well #2 Slug Test Data

Figure: **D-2a**

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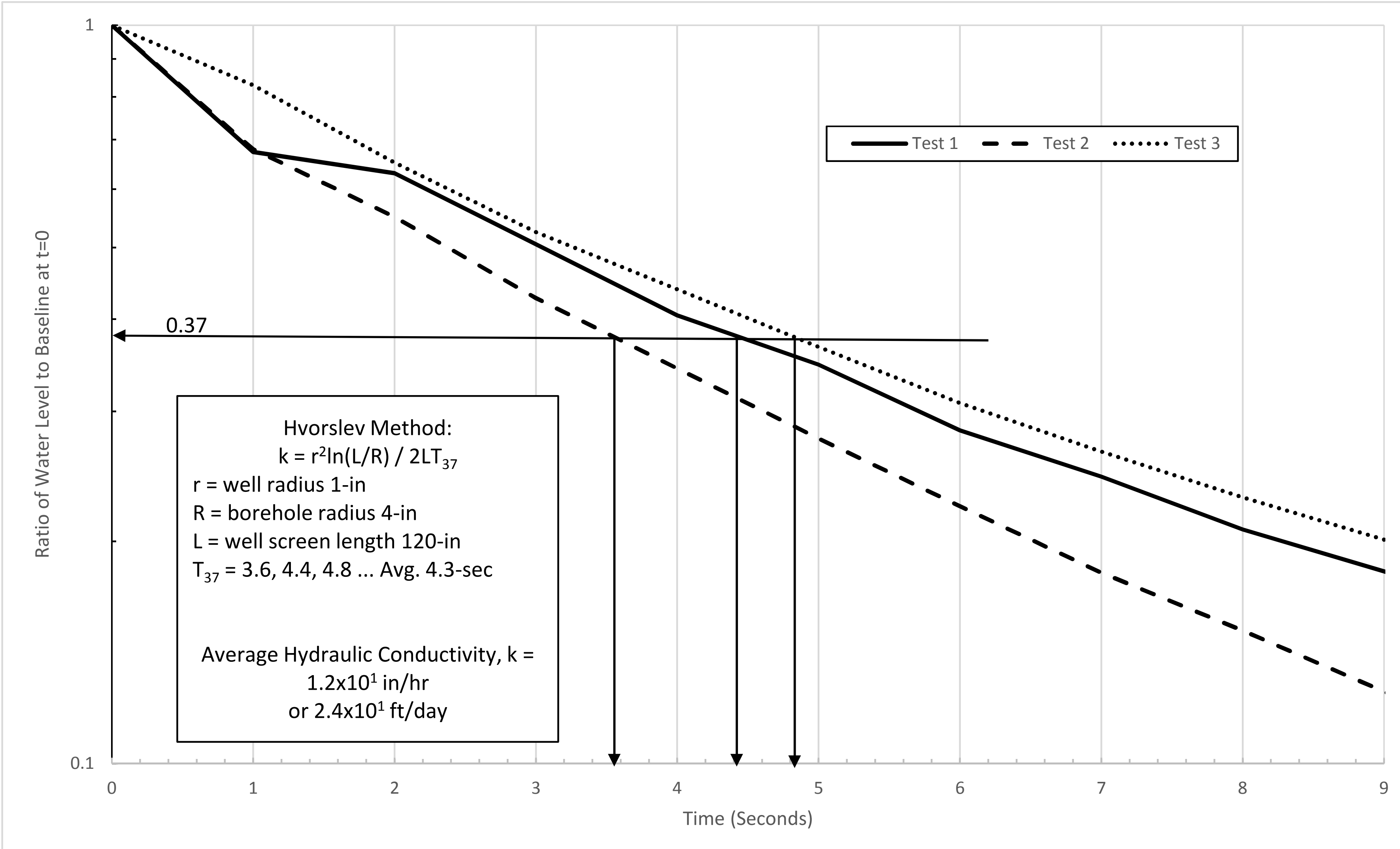
JJV	BBS	NTS	February, 2018	16068.000.RKK.003



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Well #2 Slug Test: Rising Head Test Semilog Chart

Figure:

D-2b

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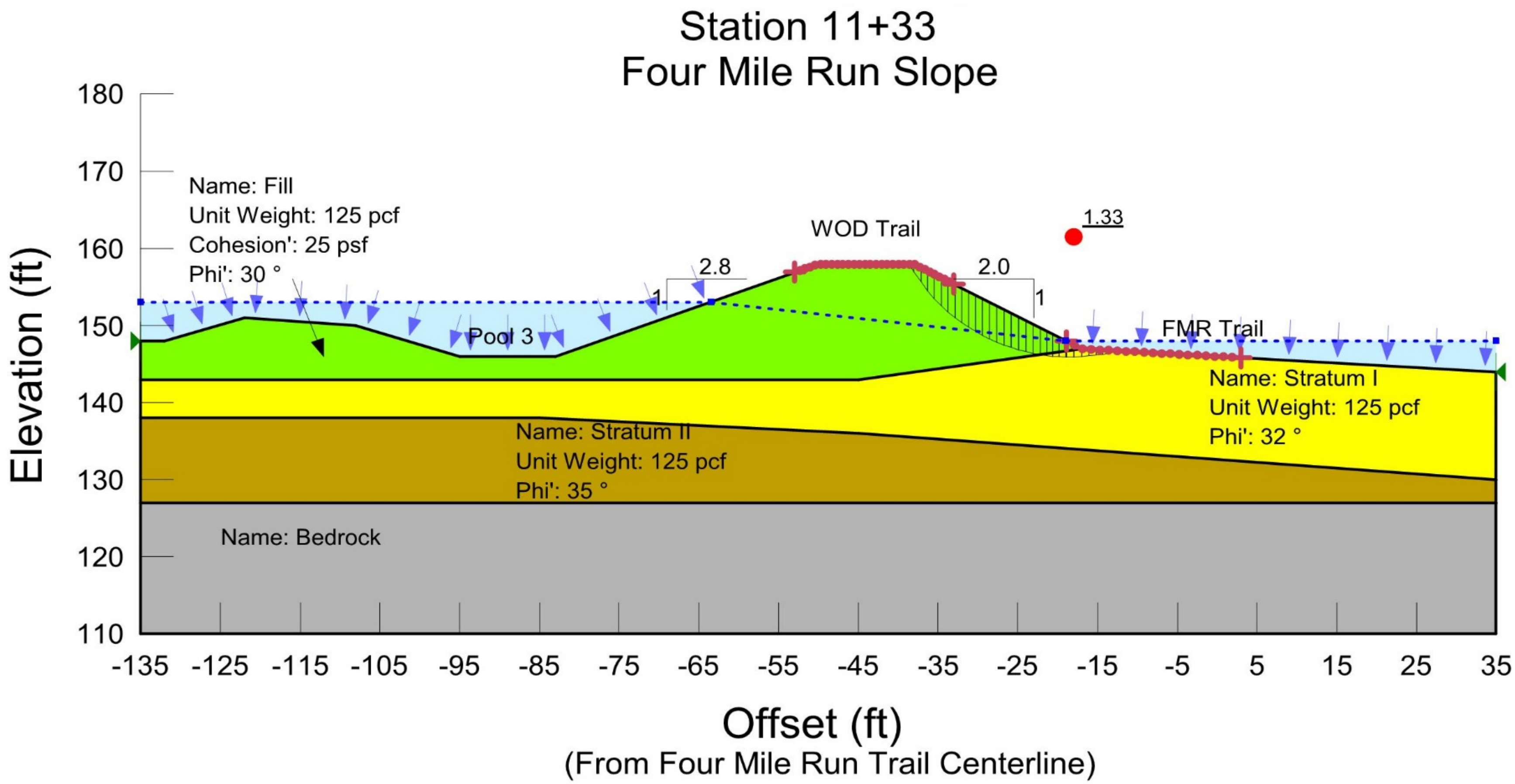

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Sparrow Pond Stability Study

Global Stability Analysis

Figure: D-3a

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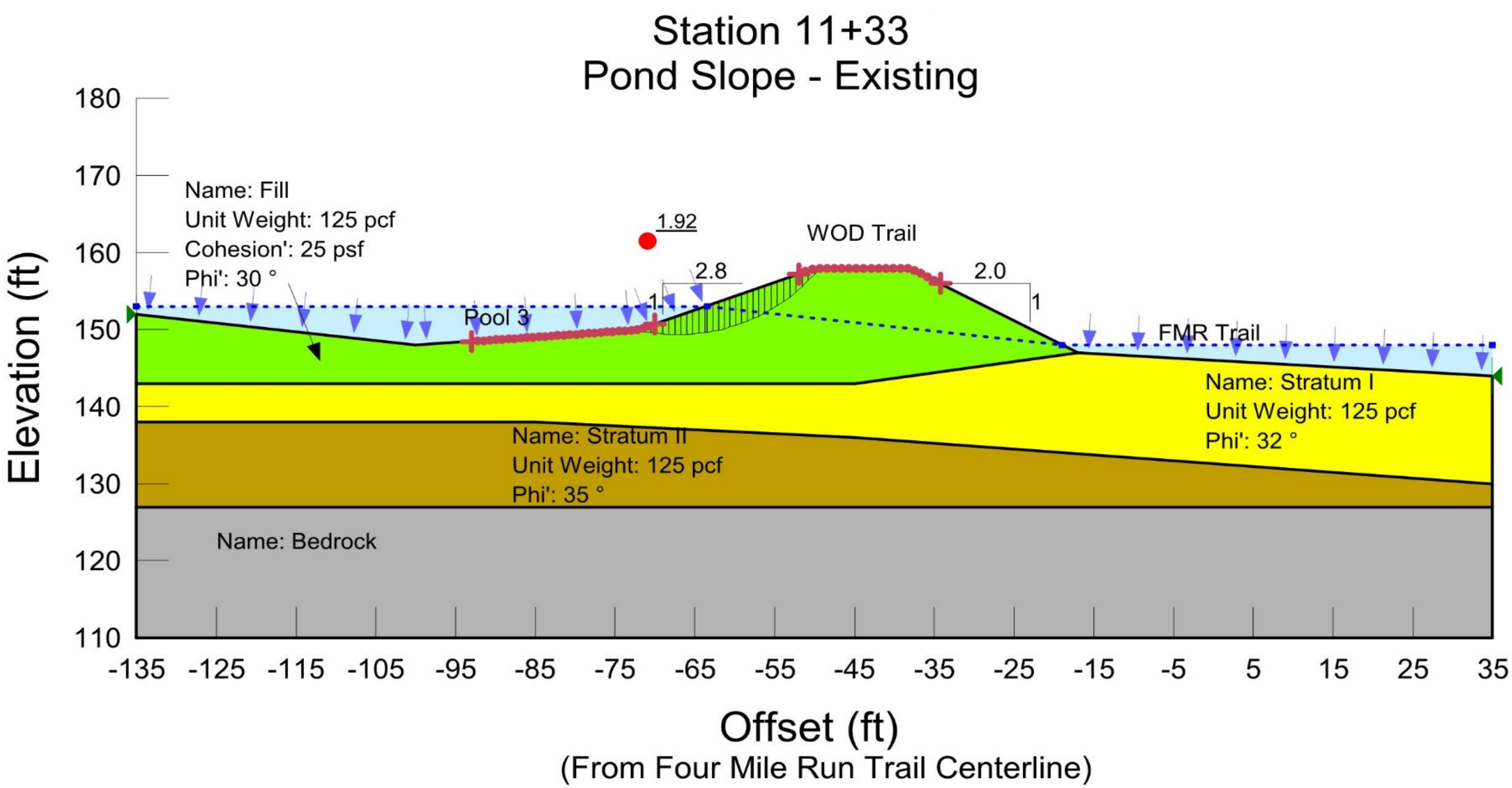

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Global Stability Analysis

Figure: D-3b

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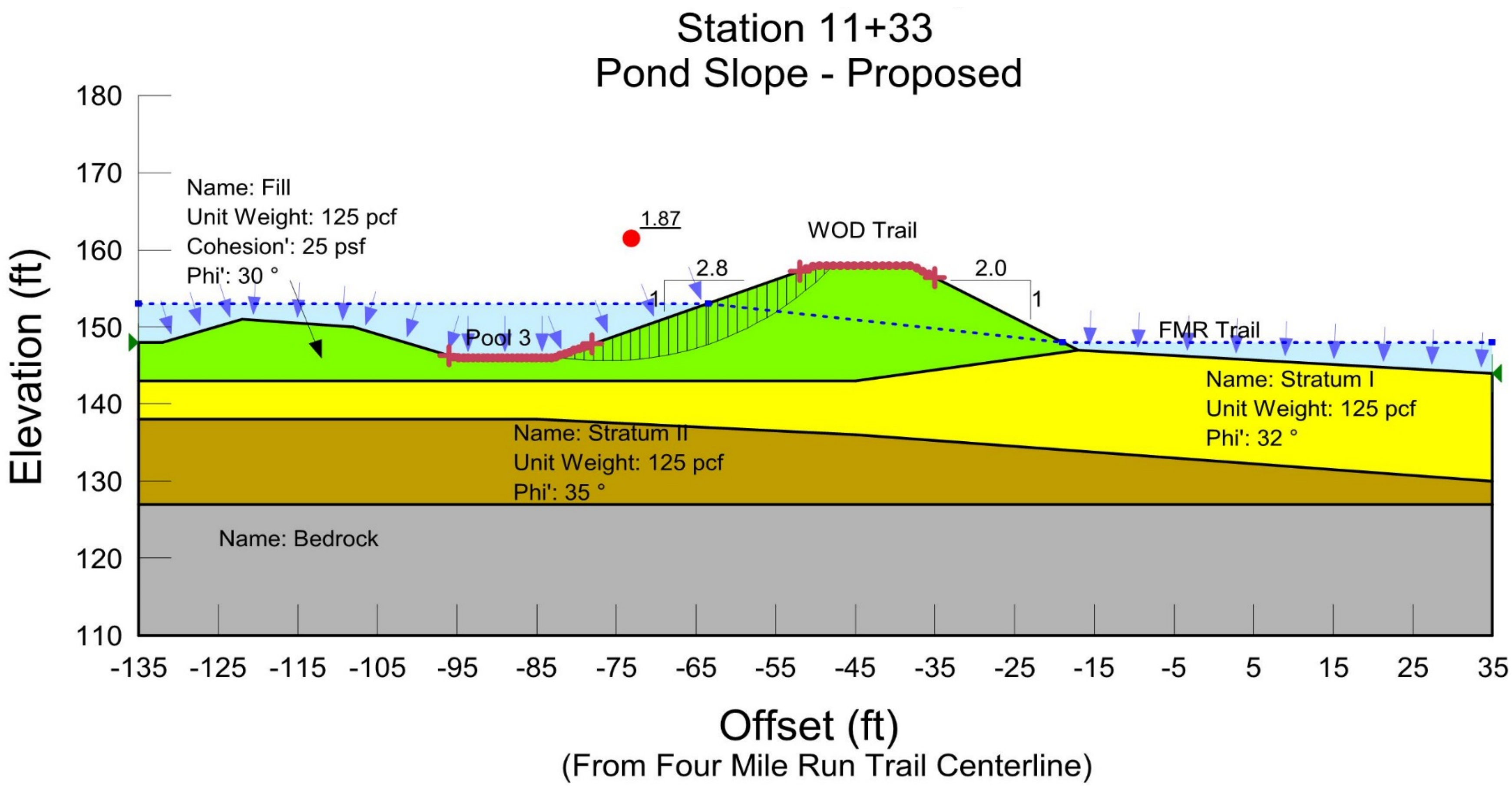

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Global Stability Analysis

Figure: **D-3c**

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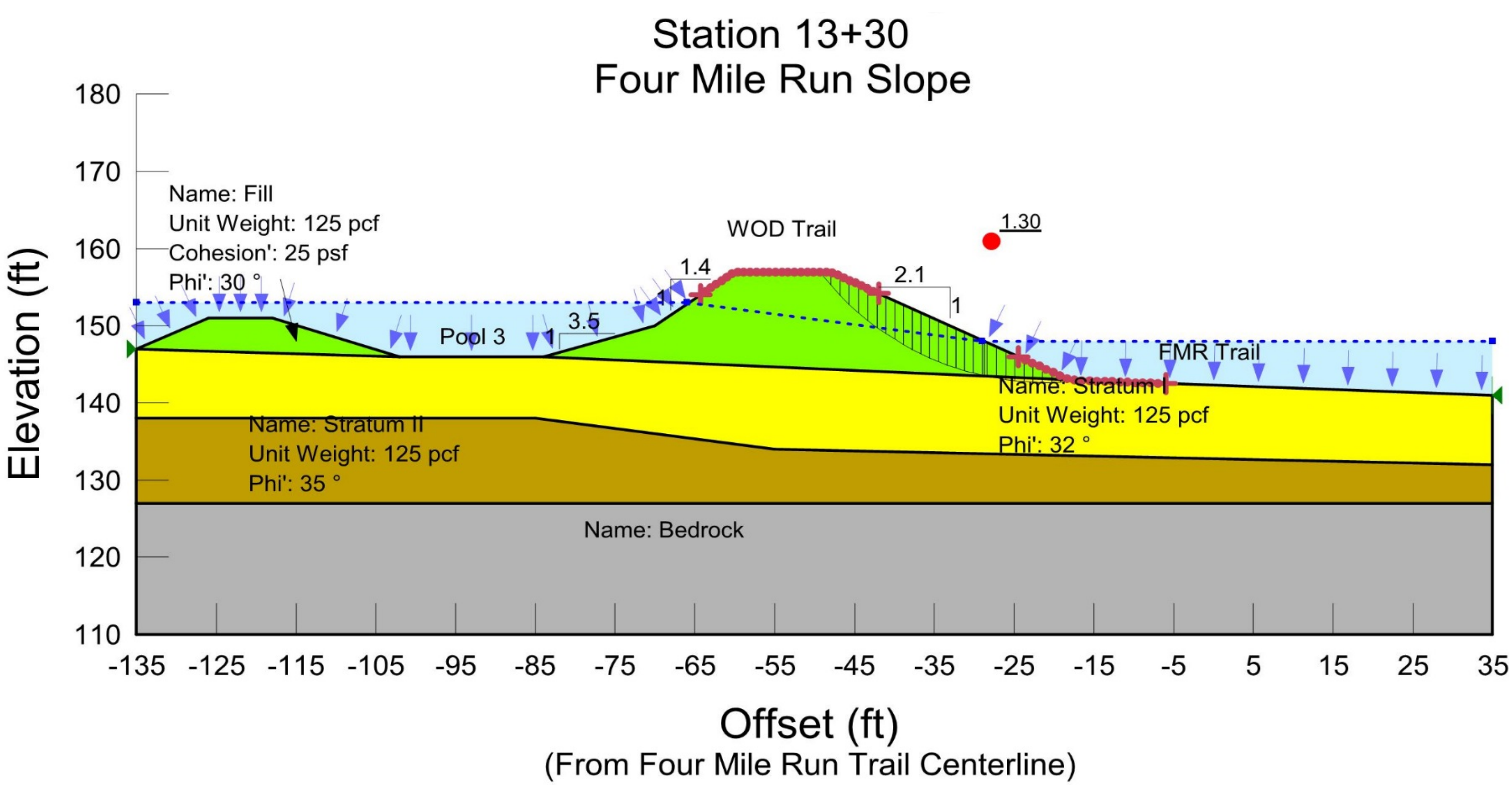

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Figure: **D-3d**

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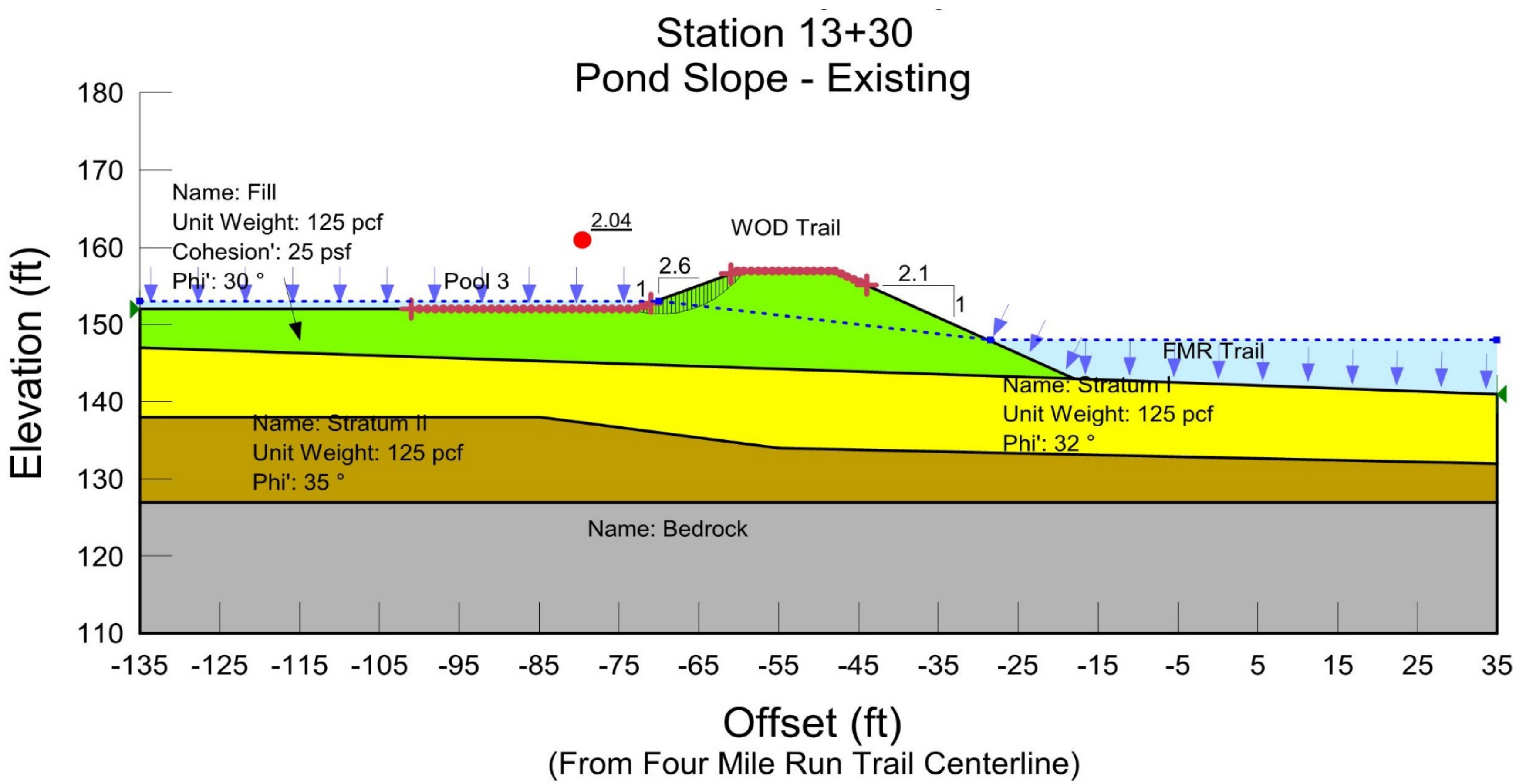

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Figure: **D-3e**

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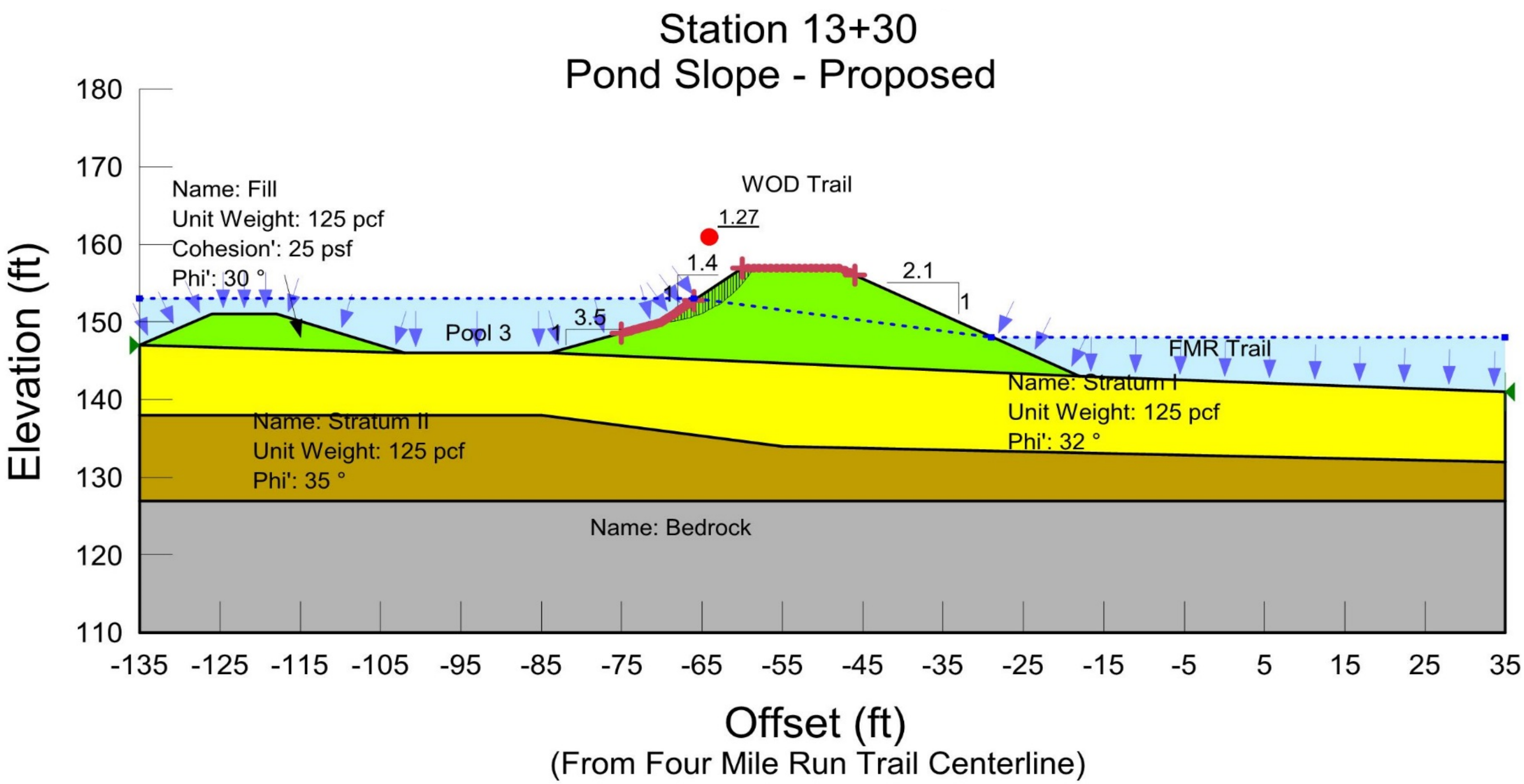

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Figure: **D-3f**

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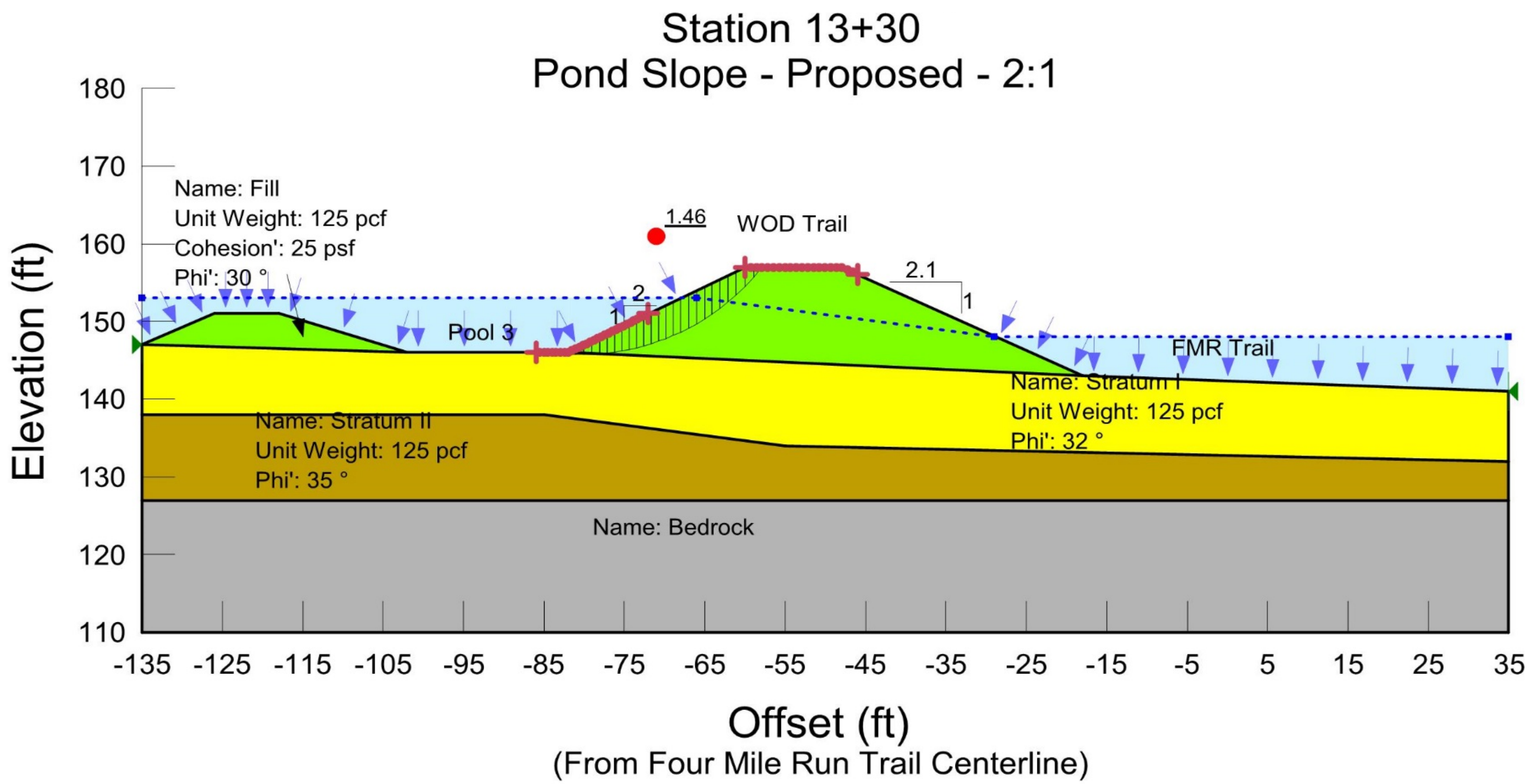

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Figure: **D-3g**

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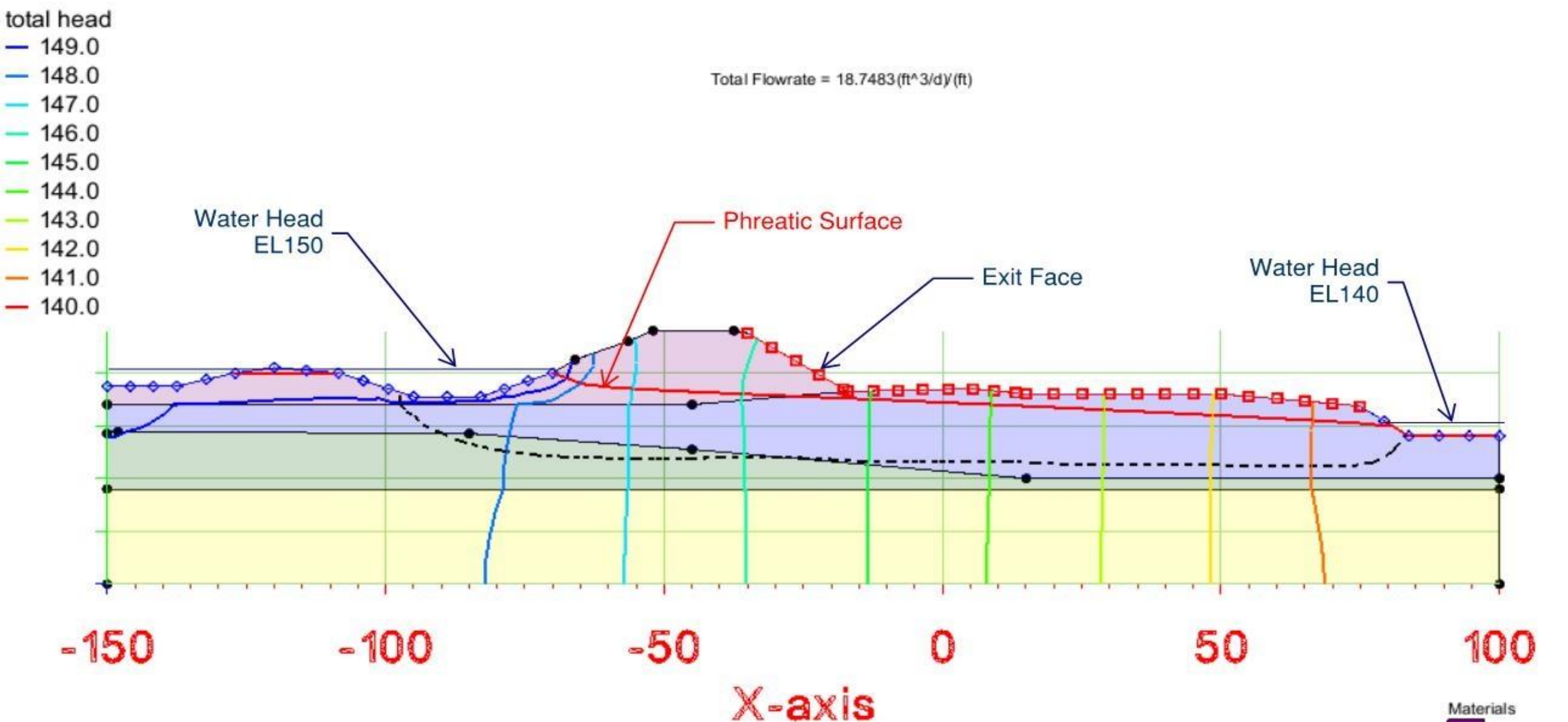

STEADY STATE SEEPAGE
FLOW HEAD
STA 11+33

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Sparrow Pond Stability Study

Seepage Analysis

Figure: **D-4a**

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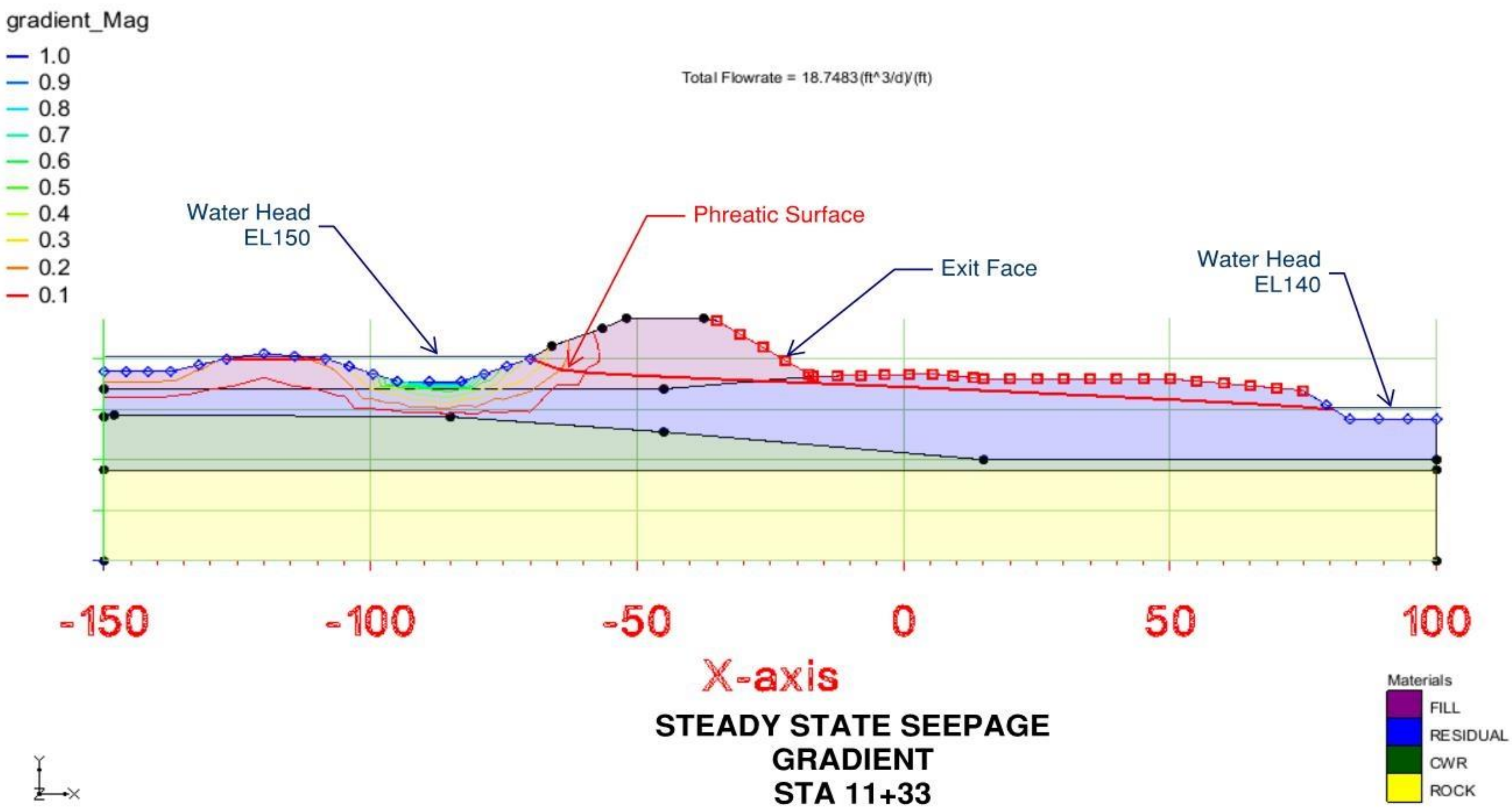

STEADY STATE SEEPAGE
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Sparrow Pond Stability Study

Seepage Analysis

Figure: **D-4b**

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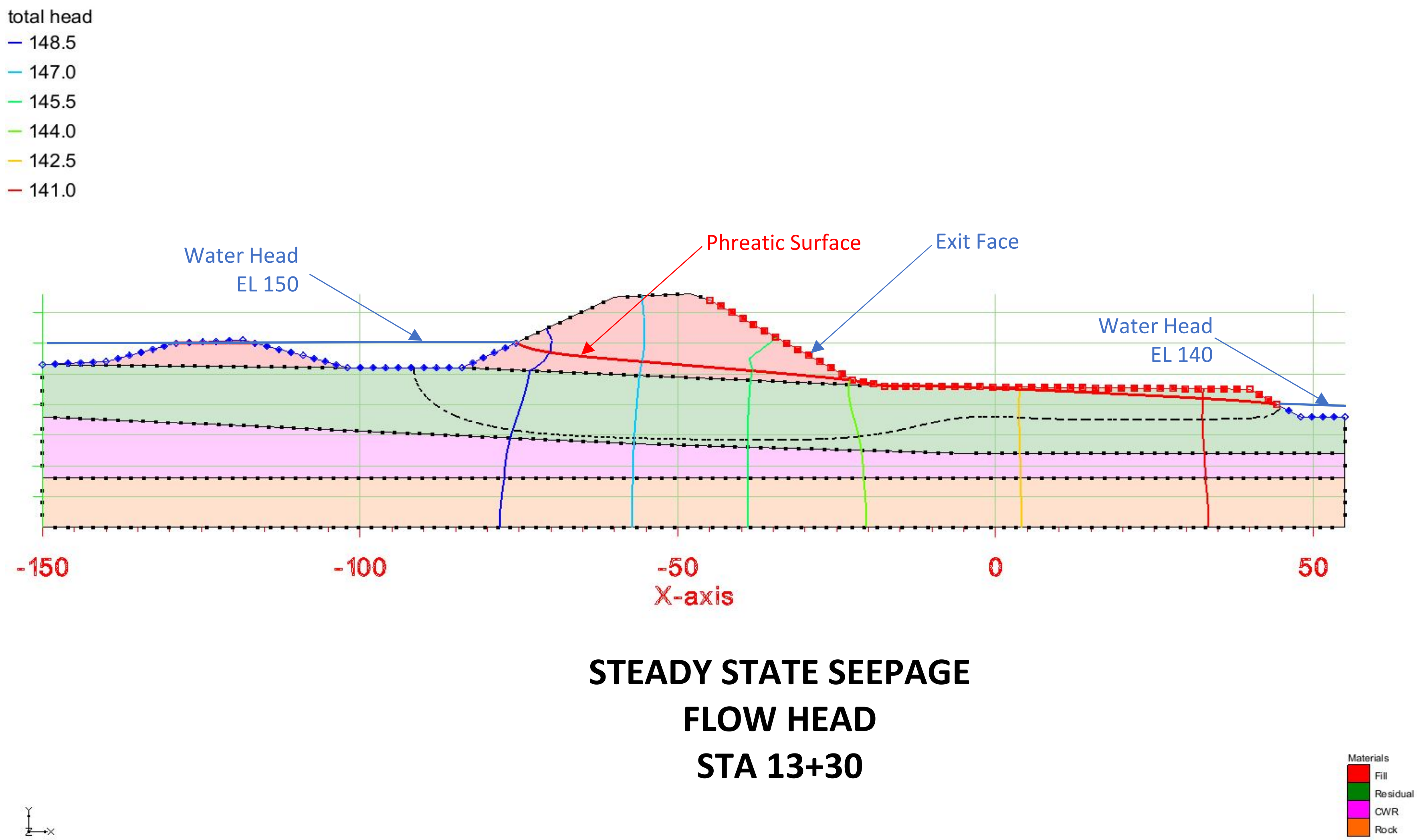

STEADY STATE SEEPAGE
FLOW HEAD
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Sparrow Pond Stability Study

Seepage Analysis

Figure: **D-4c**

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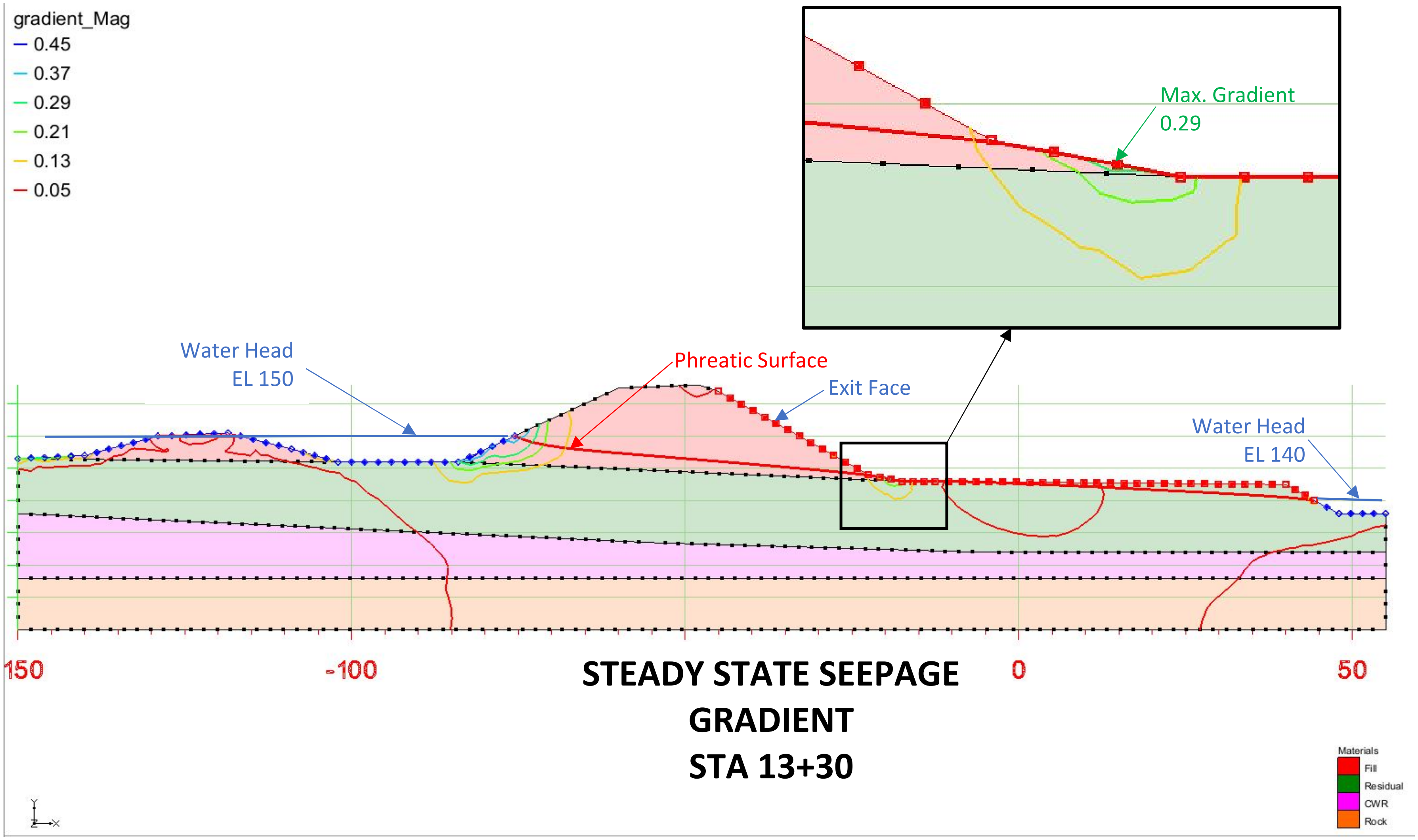

STEADY STATE SEEPAGE GRADIENT STA 13+30

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Sparrow Pond Stability Study

Seepage Analysis

Figure: **D-4d**

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