Beneficial Use of Mosaic Phosphogypsum

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Prepared for:
Mosaic Fertilizer, LLC

Prepared by:
Dr. Timothy G. Townsend, Principal Investigator
Kate Weiksnar, Graduate Research Assistant
Jordan Magnuson, Graduate Research Assistant
Malik DeWindt, Graduate Research Assistant

University of Florida
Sustainable Materials Management Research Laboratory
Department of Environmental Engineering Sciences
Engineering School of Sustainable Infrastructure and Environment

List of Acronyms

BUD	Beneficial Use Demonstration
DWS	Drinking Water Standard
EPA	U.S. Environmental Protection Agency
F.A.C	Florida Administrative Code
FDOT	Florida Department of Transportation
GCTL	Groundwater Cleanup Target Level
HELP	Hydrologic Evaluation of Landfill Performance
IWEM	Industrial Waste Management Evaluation Model
LR	Limerock
LS	Liquid-to-solid
PG	Phosphogypsum
PPE	Personal Protective Equipment
RAP	Recycled Asphalt Pavement
RCA	Recycled Concrete Aggregate
SCS CN	Soil Conservation Service Curve Number
SCTL	Soil Cleanup Target Level
SMMRL	Sustainable Materials Management Research Lab
TFI	The Fertilizer Institute
UF	University of Florida

Executive Summary

The Mosaic Company (Mosaic) has been investigating the feasibility of using their phosphogypsum (PG) as a partial supplement in road base material through chemical and physical characterization. Past work included identifying several potential sources of PG and performing preliminary chemical characterization, including total and mobile constituent concentrations. Based on this past work, and in concurrence with Environmental Protection Agency (EPA) and Florida regulations surrounding PG reuse, Mosaic identified a blending approach to incorporate PG into road base with traditional road base aggregates, specifically limerock (LR), recycled asphalt pavement (RAP), or recycled concrete aggregate (RCA), or as a cement stabilized base, at a replacement percentage of no more than 50% PG.

Through a combination of physical strength testing and chemical behavior analysis, Mosaic identified several mix designs incorporating no more than 50% PG to serve as the aggregates for a road base pilot project test on Mosaic's Mulberry, Florida facility. The chemical analysis included assessment for direct exposure and leaching to groundwater risk of the PG-amended road bases, and fate and transport modeling using the EPA Industrial Waste Management Evaluation Model (IWEM). These results are detailed in the following report, along with a monitoring plan designed to provide additional insight into the behavior of the road base in-situ and protection of human health and the environment.

Based on the preliminary total and mobile concentrations from the PG-amended base aggregates, four constituents of concern were identified: Strontium (Sr), Molybdenum (Mo), fluoride (F), and sulfate (SO_4^{-2}). However, the preliminary analysis does not account for actual conditions experienced by the road base in-situ, such as encapsulated by a pavement layer or a low liquid-to-solid ratio (<1). The fate and transport modeling employed using IWEM and site-specific parameters (infiltration, hydraulic conductivity, etc.) demonstrates that none of the constituents of concern exceed water quality thresholds at 10, 50, or 100 ft from the roadway. With road and aquifer conditions typical of Polk County, all constituents demonstrate reduction to well below risk thresholds from subsurface dilution and attenuation.

A monitoring plan incorporating background soil, groundwater sampling, and lysimeter implementation before and after pilot project implementation is included. The pilot project will include a test section incorporating each of the mix designs (PG-LR, PG-RCA, PG-RAP, and PG-sand-cement) as well as controls (segments with no PG) as road base aggregates. The purpose of the pilot project and monitoring plan is to evaluate the realistic mobility of these constituents and evaluate behavior at the site, both directly from the base as assessed by lysimeter sampling and into the groundwater as assessed by groundwater monitoring well collection.

1.0 Introduction

1.1 Objectives

The Mosaic Company (Mosaic) is currently pursuing the beneficial reuse of phosphogypsum (PG) from its New Wales phosphoric acid production facility blended with common aggregates and as a sand/cement mix as a road construction material. Based on laboratory testing and literature results, Mosaic has designed a pilot road project to demonstrate the efficacy of the mix designs. This involves constructing a series of roadway strips onsite at the New Wales facility using road base consisting of several PG-aggregate mixes as well as control strips made using standard road base materials without PG, all overlain by asphalt pavement.

This document provides a technical evaluation of the potential environmental and public health impacts of the reuse application as well as the physical performance of Mosaic PG and PG-aggregate blends as a road base material and presents details of a beneficial use demonstration (BUD) project at the New Wales location. To perform a full risk assessment with fate and transport modeling, historical data about the permeability of the asphalt, the infiltration rate, and characteristics of the subsurface environment was assumed. The pilot project demonstration will be assessed by comparing fate and transport modeling results to limitations outlined by the EPA for element concentrations. The evaluation supporting this document incorporates the results of total concentration analysis, leaching tests, hydrologic modeling, pollutant fate and transport modeling, and control measures which apply specifically to the Mosaic New Wales site and PG.

1.2 Overview and Organization

This report begins in Section 1 (this section) by introducing the objectives of the beneficial reuse options of PG as a road base material. Section 2 includes details on the specific demonstration project, including background, road design, and monitoring techniques. Section 3 describes the risk assessment approach, and Sections 4 and 5 discuss the direct exposure and leaching test results from the risk assessment. Section 6 explains the interactions of the PG-aggregate leachate with site specific soils as well as the soil characteristics from the demonstration site, and Section 7 details the infiltration analysis, including an explanation of the approach, permeability testing, and modeling. Finally, Section 8 uses data from previous sections to report fate and transport modeling and comparison of the screening levels, and Section 9 details the monitoring plan and parameters. Section 10 provides a summary of the demonstration project and recommendations. Appendices A-E provide supplementary data on total element concentrations, leached concentrations, physical performance testing, comprehensive modeling results, and complete AutoCAD engineering drawings.

2.0 Demonstration Project

2.1 Project Background

Studies investigating PG as a road base material have been performed in the past (Gregory et al., 1984, Chang et al., 1988, Mingkai, 2002, Shen et al., 2009, Folek et al. 2011). These studies investigated the use of PG in road base either stabilized with cement, fly ash, or simply mixed with existing soil as soil cements. Past laboratory and field scale experiments indicate that PG blended with other, common road base materials has the potential to be used as a road base. These results helped guide the recommendations for the Mosaic PG-road base pilot project discussed in Section 2.

Stacked PG from the New Wales facility gypstacks, designated as “PG B Old”, was identified as an appropriate source for the pilot project due to initial physical and environmental testing and proximity to the pilot project site. For the project discussed in this document, the physical and environmental performance of PG blended with other, road base aggregates such as limerock (LR), recycled concrete aggregate (RCA), and recycled asphalt pavement (RAP) was investigated and optimized to meet physical performance standards and environmental regulations. The aggregate materials selected for the laboratory analysis were sourced from FDOT-certified aggregate mines close in proximity to the New Wales facility, and therefore are likely to be used for construction of the pilot road.

The demonstration pilot road, illustrated in Figure 2-1, will be constructed on the grounds of Mosaic’s New Wales facility in Mulberry, Florida and will replace a 3,200-ft length of unpaved road west of the stormwater retention pond on site. The existing road is a 24-ft wide, two-lane road on reclaimed mine land near a Mosaic PG stack, and prior to placing the pilot road, the existing road and base will be removed completely. Incorporating feedback from local regulatory and research agencies, four approaches to incorporate PG into road base based on road base materials used in Florida have been identified: blending with LR, RCA, and RAP, and mixing with sand-cement to create a soil cement. Each 500-ft PG-amended road base section will be installed contiguous to its corresponding 300-ft control section as shown in Figure 2-2. For example, there will be one section with PG – LR base followed by a section with a LR base. Table 2-1 provides details for the eight test sections and the amount of PG required for each PG section. Based on the dimensions of the road and recommended blending proportions, the total amount of PG required for this demonstration project will be 1,190 tons.

Figure 2-1. Location of the demonstration road at the Mosaic New Wales Facility

Figure 2-2: Pilot road configuration. The road will be 3,200 ft long with alternating segments of 500-ft PG-mix designs and 300-ft controls (no PG added).

Table 2-1: Road segment characteristics of the pilot road including Segment ID, length (ft), blend description, and approximate PG required (tons).

Segment	Length (ft)	Blend Description	Approximate Amount of PG Required (tons)
PG Mix 1	500	50% PG – 50% LR	316
Control 1	300	100% LR	0
PG Mix 2	500	50% PG – 50% RCA	306
Control 2	300	100% RCA	0
PG Mix 3	500	50% PG- 50% RAP	275
Control 3	300	50% Sand- 50% RAP	0
PG Mix 4	500	50% PG – 43% Sand – 7% Cement	293
Control 4	200	93% Sand – 7% Cement	0
Total	3,200	---	1,190

2.2 Road Design

The pilot road has been designed according to FDOT Standard Specifications for Road and Bridge Construction Section 200 (FDOT, 2022); a traditional asphalt roadway includes an asphalt layer, a 6-12” base layer, a subbase layer, and the existing subgrade, as displayed in Figure 2-3. The asphalt layer serves as the pavement layer, providing friction and smoothness necessary for traffic. The aggregate base course acts to distribute the load beneath the asphalt layer while providing strength and drainage to the road. The sub-base is an optional layer that also contributes to strength and acts as structural support beneath the base course but above the soil.

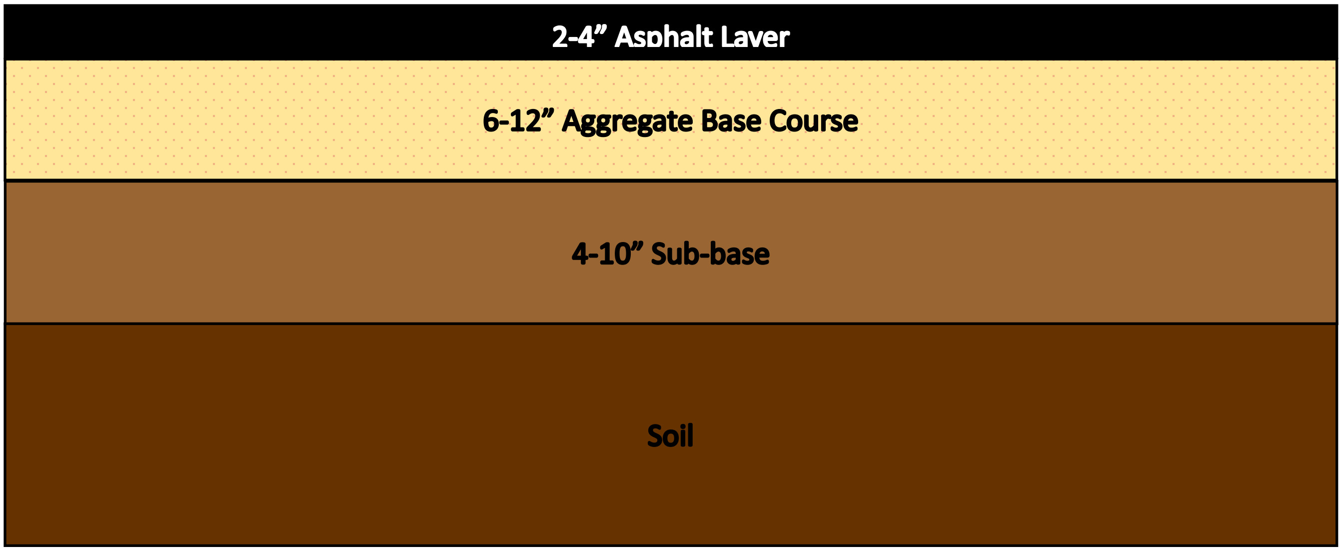

Figure 2-3. Cross section of a common roadway.

Prior to implementation of the demonstration road, the existing road material and underlying subgrade will be excavated a width of 44 feet and a depth of approximately 26 inches. An embankment will be created in the excavated area using fill material yielding an LBR value of no less than 40. The center of the constructed embankment will be excavated with a total width of 24 feet and depth of 10 inches. In the excavated area, the base will be constructed on top of the subgrade and then paved with asphalt pavement. As part of the monitoring and research endeavors, lysimeters will be installed under the base layer for each test section. The lysimeters will serve as a leachate collection system to capture water from the bottom of the base layer and are discussed in further detail in Section 9. Each of the test and control sections will have a 10-inch-thick base layer, constructed in three courses and not extending past the width of the asphalt pavement, and be overlain by 4-inches of asphalt pavement. The road will be constructed following an FDOT typical road cross section, displayed in Figure 2-4. The site-specific engineering drawings are included in Appendix E.

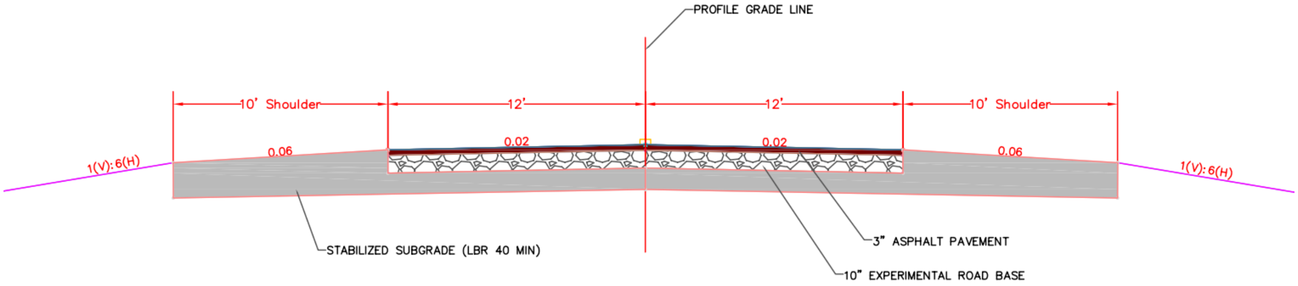

Figure 2-4: Detailed cross section of the demonstration road

3.0 Risk Assessment Approach

In order to beneficially reuse a waste material or industrial byproduct, the potential risk to human health and the environment should be assessed and appropriate risk mitigation measures should be implemented. The approach used to assess risk associated with the Mosaic New Wales PG demonstration project follows the established approach for beneficial use in the state of Florida (FDEP, 2001; FDEP, 2019). This study shows the level of analysis required to obtain approval to beneficially use PG in road construction in Florida. Most states would have a similar process as discussed in The Fertilizer Institute's October 2019 Request for Approval of Additional Uses of Phosphogypsum[1].Similar pilot road demonstration projects have been developed for Hillsborough and Pasco counties, in which waste-to-energy ash was beneficially used as a constituent in road base. Beneficial use projects of this sort require extensive physical and environmental testing of the material to provide a full risk assessment, and a similar risk assessment approach is presented here.

The two risk pathways considered in the assessment for this demonstration project include direct exposure and leaching to groundwater risk. As discussed in Section 3.1, direct exposure risk is assessed by examining potential pathways of human contact with the material, such as inhalation, dermal contact, and ingestion. The leaching-to-groundwater pathway is first assessed by examining the leaching behavior of the four road base blends by conducting standardized leaching tests on the materials. With this information, the fate and transport of leached constituents from the road base, down to the aquifer, and horizontally to a point of compliance is estimated with a fate and transport model. In both cases, the location of the demonstration project (within the Mosaic facility with controlled access) and nature of the reuse application (encapsulated below the asphalt pavement) significantly impact the risk mitigation plan. A flow chart displaying the risk assessment process is displayed in Figure 3-1.

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[1] Pursuant to 40 CFR 61.206, Appendix 3, Human Health Risk Screening for Metals and Metalloids: Phosphogypsum in Road Construction, October 11, 2019, pg. 12-15

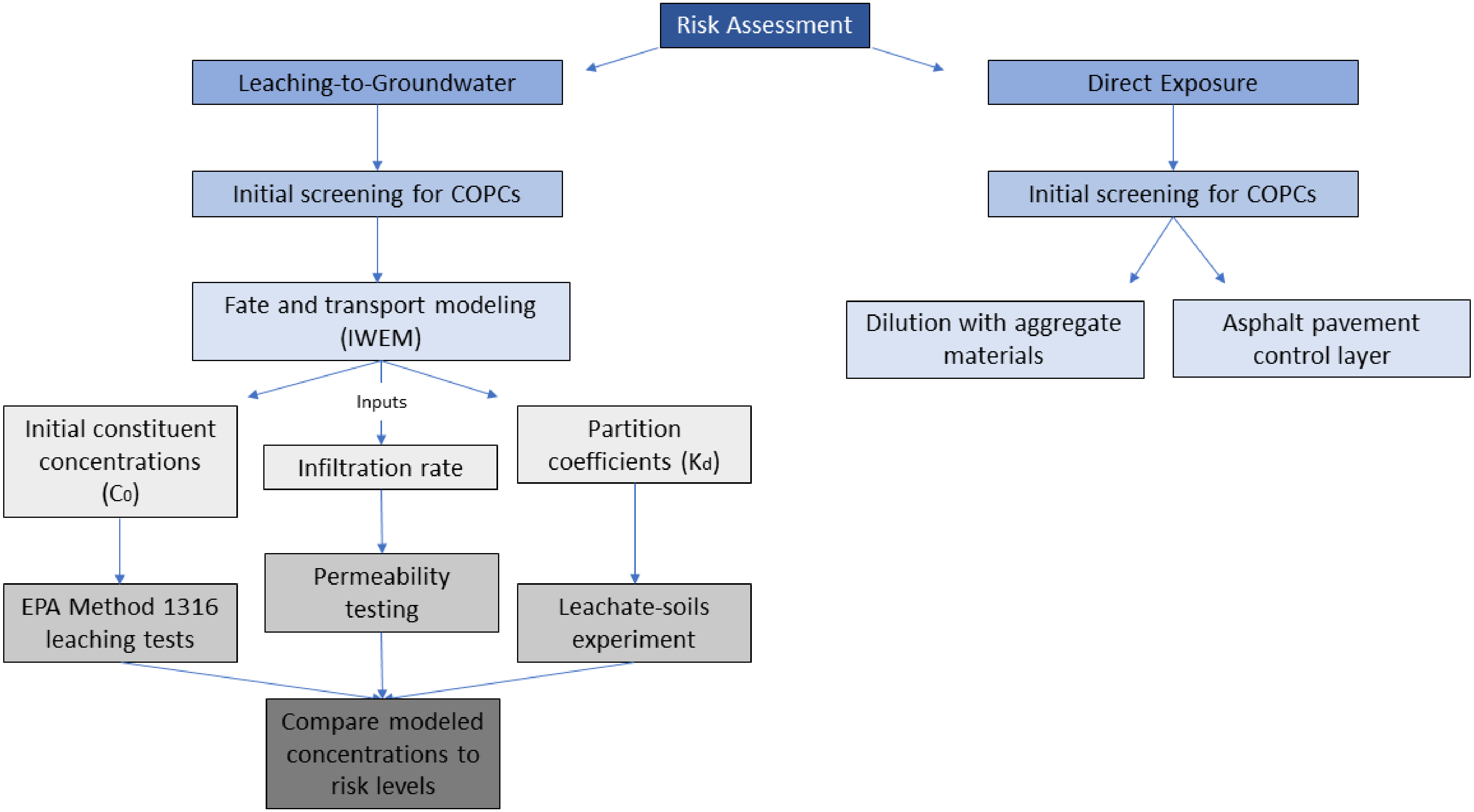

Figure 3-1: Schematic illustrating a typical risk assessment approach.

3.1 Direct Exposure

Assessing direct exposure risk involves comparing the total concentration of constituents in a material to regulatory guidelines, in this case, Florida's Soil Cleanup Target Levels (SCTLs). To calculate the total constituent concentrations in the PG-aggregate blends, the materials were first acid digested according to EPA Method 3050B: Acid Digestion of Sediments, Sludges, and Soils (EPA, 1996) to mobilize constituents from complex matrices, allowing any potential environmentally available concentrations to be accurately measured. Following the acid digestion, inductively coupled plasma atomic emission spectrometry (ICP-AES) was employed following EPA Method 200.7: Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emission Spectrometry (US EPA, 1994) to determine trace metal concentrations. The concentrations for each individual material were compared to Florida's SCTLs, which are set by FDEP and can be found in 62-777, F.A.C. (FDEP, 2005).

Due to the methodology of EPA Method 3050B and the small mass of sample required, PG-aggregate blends were not digested but rather estimated by calculating theoretical contributions of each material at the blends using equation (1) below:

$$Estimated\ Blend\ Total\ Element\ Concentration = \\ (\%_{PG} * C_{PG}) + (\%_{aggregate} * C_{aggregate}). \tag{1}$$

Where $\%_{PG}$ represents the percent of PG in the blend (%), C_{PG} represents the total concentration of the element in the PG (mg/kg-dry), $\%_{aggregate}$ represents the percent of aggregate in the blend (%), and $C_{aggregate}$ represents the total concentration of the element in the aggregate. The $\%_{PG}$ and $\%_{aggregate}$ total 100% of the blend.

Full direct exposure results, including theoretical calculations for constituent concentrations in the PG-aggregate blends, are outlined in Chapter 4. In addition to the asphalt pavement layer which will encapsulate the base material in the road base, any contaminants present in the PG are expected to be reduced in the final road base product through blending with the aggregate materials and will likely pose a lower risk of direct exposure than unblended PG. After wetting, compaction, and confinement by the asphalt pavement layer, the direct exposure risk will be significantly reduced during the service life of the road. Worker exposure will be controlled through proper construction techniques, such as wetting the PG to control dust (OSHA, 1970).

3.2 Leaching-to-Groundwater

Assessment of leaching-to-groundwater risk involves examining the leaching behavior of various constituents from the reuse material and road base blends and modeling the mobility from the placement site to a target compliance point. For the beneficial use of material in road base, a theoretical description of the contaminant pathway is as follows: upon contact with infiltrating water through the surficial pavement layer, constituents leach out of the road base, travel vertically through the subbase and vadose zone, and enter the aquifer. Once inside the saturated zone, they are horizontally transported via groundwater movement. Dilution and attenuation of the constituent is expected at each stage, suggesting concentrations will decrease. An illustration of this process is included in Figure 3-2.

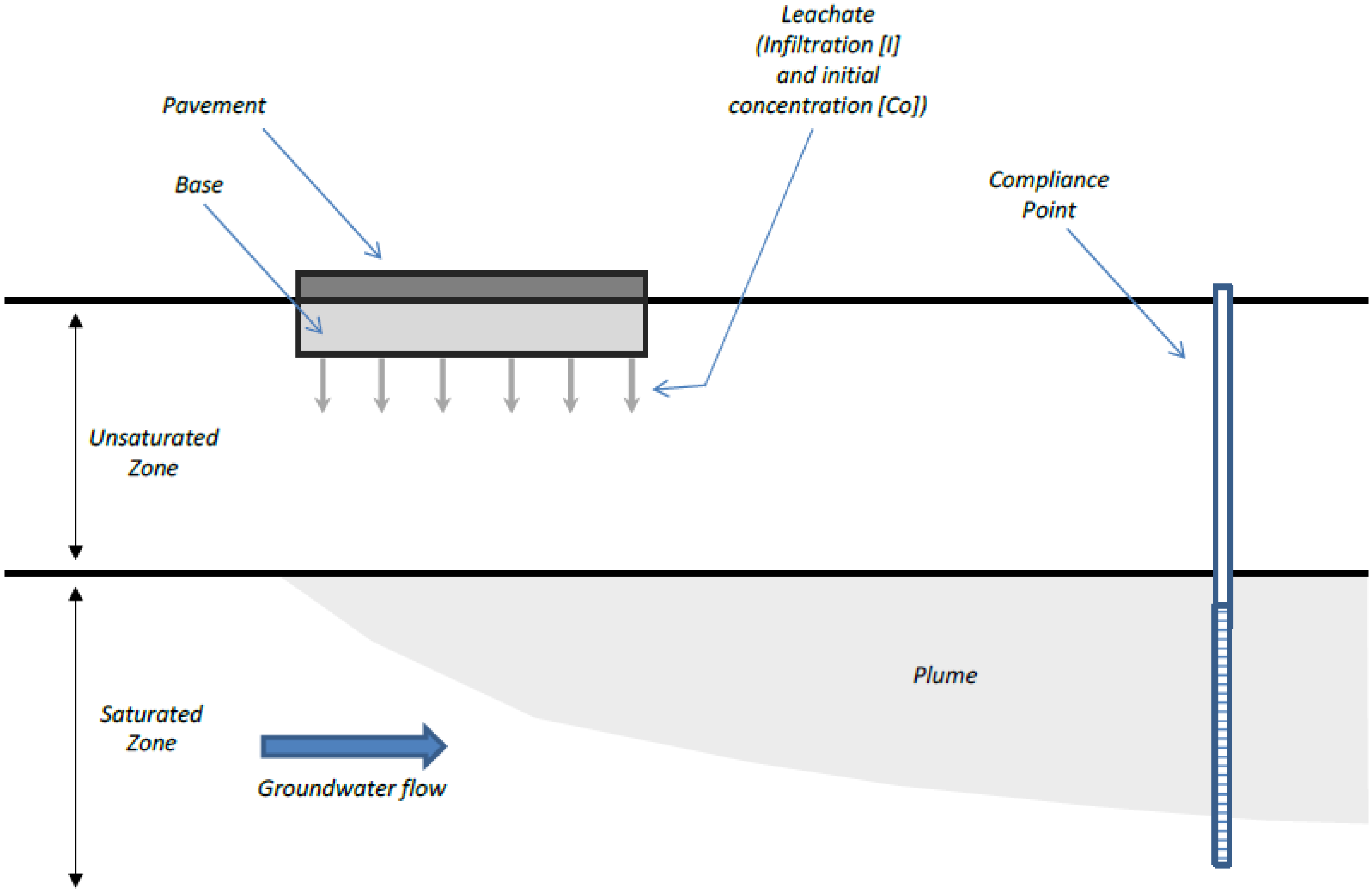

Figure 3-2: Illustration of constituent transport from the placement site to a point of compliance.

To identify the constituents that require further site-specific modeling, the blends were leached according to EPA Method 1316 (EPA, 2012) and concentrations were compared to Florida's Groundwater Cleanup Target Levels (GCTLs). The materials leached for this test were 50-50 blends of PG with LR, RCA, RAP, and a sand-cement mixture. While the final road base design may contain less than 50% PG, these blends will provide a conservative estimate of the leaching-to-groundwater risk. Additional information about EPA Method 1316 test may be found in Section 6.1. The leaching test values are compared to health-based groundwater cleanup target levels (GCTL), and initial values (C_0) that exceed the GCTL are used to calculate target dilution and attenuation factors (DAF), as displayed in equation 2:

$$DAF = \frac{C_0}{GCTL} \qquad (2)$$

Elements with a DAF greater than 1 are further investigated to understand the element fate and transport at the specific site. The fate and transport model chosen for this risk assessment is the EPA's Industrial Waste Management Evaluation Model (IWEM). This model is commonly used to evaluate potential groundwater impacts resulting from beneficial use material applications and requires site-specific parameters such as infiltration through the pavement, depth to groundwater, and soil-attenuation values. To provide the most accurate site-specific assessment, these characteristics were determined by calculating site-specific partitioning coefficients, road base permeability, estimating soil and aquifer depth based on existing site data, and using the Hydrologic Evaluation of Landfill Performance (HELP) model to develop realistic, conservative pavement infiltration rates. Using these inputs, the IWEM model predicts a conservative estimate (90th percentile) of groundwater concentrations which are then used to assess potential groundwater impacts from the reuse scenario. These experiments and models are described thoroughly in the following sections.

4.0 Direct Exposure Assessment

When evaluating a material for a beneficial use demonstration project, potential risk from direct human exposure is typically assessed. As discussed previously, these pathways include ingestion, inhalation, and dermal contact. While much of the direct exposure risk for PG will be mitigated by engineering controls in the road base application, understanding the chemical composition of unblended PG and aggregate materials is important for determining if any constituents require attention when designing the road base blends. The PG, LR, and RCA were analyzed for total inorganic elements and results were compared to Florida's risk-based commercial and industrial direct exposure SCTLs, which may be found at 62-777, F.A.C (FDEP, 2005).

Five replicates of each sample were digested according to EPA Method 3050B to dissolve complex matrices and extract environmentally available elements. The samples were then analyzed with ICP-AES in accordance with EPA Method 200.7 to determine total element concentrations. The results in Table 4-1 compare the total element concentrations found in the PG and aggregate materials to Florida's SCTLs. Mean concentrations of all tested elements are below the commercial/industrial direct exposure limits. Arsenic is the only element to exceed the residential SCTL of 2.1 mg/kg-dry in any of the materials, with an average concentration of 2.51 mg/kg-dry in RCA but does not exceed the residential SCTL in PG, LR, or RAP.

Thus, when blending the PG with RCA at a 50-50 mix, the total As concentration in the resulting road base mix may slightly exceed the SCTL. However, the chosen LR and RAP samples contained an average of 0.50 and 0.663 mg As/kg-dry, suggesting the As concentration in the PG-LR and PG-RAP mix designs will be reduced below the SCTL. Theoretical calculations of total constituent concentrations in the blends may be found in Table 4-1 and 4-2. These were calculated based on total element data from PG and each aggregate material, under the conservative assumption of 50-50 PG-aggregate material blends, using equation (1) from Section 3.1. This table also includes total constituent concentrations from the PG-sand-cement mixes following a seven-day curing period to accurately represent the material as it will be applied on site. Full results for total element concentrations in all materials, including theoretical calculations of blends, are presented in Appendix A.

The potential for worker exposure during ash processing, transport, and recycling will be limited and controlled through proper construction techniques, such as dust control and proper Personal Protective Equipment (PPE). It is important to recall that the PG mix designs will be encapsulated under an asphalt pavement layer, so its direct exposure risk will be mitigated during normal road usage.

Table 4-1: Total element concentrations (mg/kg-dry) in Mosaic PG, LR, RCA, and RAP compared to commercial and industrial soil cleanup target levels (SCTL)

Constituent	Commercial/ Industrial SCTL (mg/kg-dry)	Residential SCTL (mg/kg-dry)	PG-B Old mean (mg/kg-dry)	LR mean (mg/kg-dry)	RCA mean (mg/kg-dry)	RAP mean (mg/kg-dry)
Al	-	80,000	950	515	5,570	3,030
As	12	2.1	1.92	0.537	**2.51**	0.663
B	430,000	17,000	8.82	2.76	31.4	6.08
Ba	130,000	120	26.7	2.85	57.3	18.8
Be	1,400	120	0.100	0.100	0.253	0.163
Ca	-	-	72,000	441,000	123,000	20,000
Cd	1,700	82	0.100	0.100	0.200	0.328
Cr	470	210	5.21	7.44	14.8	7.14
Cu	89,000	150	0.797	14.0	14.6	9.71
Fe	-	53,000	2,850	321	7,040	2,800
K	-	-	245	69.8	696	1,040
Mg	-	-	6.63	3,400	16,400	2,690
Mn	43,000	3,500	5.67	7.45	118	16.8
Mo	11,000	440	1.55	0.267	1.76	0.643
Na	-	-	132	208	415	149
Ni	35,000	340	0.130	1.25	6.25	9.9
Pb	1,400	400	3.39	0.400	26.5	0.230
Sb	370	27	0.547	0.300	0.300	0.156
Se	11,000	440	0.623	0.713	0.740	0.250
Sn	880,000	-	0.523	1.24	1.28	1.64
Sr	-	-	257	1,250	246	26.0
V	10,000	67	1.42	3.11	16.4	28.0
Zn	630,000	26,000	2.61	3.87	174	33.6

Table 4-2: Theoretical total element concentrations (mg/kg-dry) in 50-50 mix designs

Constituent	Commercial/Industrial SCTL (mg/kg-dry)	Residential SCTL (mg/kg-dry)	PG-LR 50-50 Mix Design (mg/kg-dry)	PG-RCA 50-50 Mix Design (mg/kg-dry)	PG-Sand/Cement 50-50 Mix Design (mg/kg-dry)	PG-RAP 50-50 Mix Design (mg/kg-dry)
Al	-	80,000	733	3,260	3,200	1990
As	12	2.1	1.23	**2.22**	**2.60**	1.29
B	430,000	17,000	5.79	20.1	4.71	7.45
Ba	130,000	120	14.8	42.0	28.7	22.8
Be	1,400	120	0.100	0.177	0.160	0.132
Ca	-	-	257,000	97,500	66,000	46,000
Cd	1,700	82	0.100	0.150	0.166	0.214
Cr	470	210	6.325	10.0	7.09	6.18
Cu	89,000	150	7.40	7.70	21.3	5.26
Fe	-	53,000	1,590	4,950	2,570	2,830
K	-	-	157	471	142	643
Mg	-	-	1,700	8,200	291	1,350
Mn	43,000	3,500	6.56	61.8	8.81	11.2
Mo	11,000	440	0.909	1.66	4.50	1.10
Na	-	-	170	274	79.7	140
Ni	35,000	340	0.690	3.19	2.08	5.03
Pb	1,400	400	1.90	14.9	5.97	1.81
Sb	370	27	0.424	0.424	0.552	0.351
Se	11,000	440	0.668	0.682	0.448	0.437
Sn	880,000	-	0.882	0.902	1.19	1.08
Sr	-	-	754	252	162	141
V	10,000	67	2.27	8.91	4.79	14.7
Zn	630,000	26,000	3.24	88.3	26.3	18.1

5.0 Leaching-to-Groundwater Assessment

5.1 Test Methods

Multiple leaching tests were conducted to assess the mobility of elements from the PG-aggregate blends. To determine leaching behavior at multiple liquid-to-solid (LS) ratios, EPA Method 1316: Liquid-Solid Partitioning as a Function of Liquid-to-Solid Ratio in Solid Materials Using a Parallel Batch Procedure was conducted on the Mosaic PG, aggregate sources, blends, and soil cement (EPA, 2017). This method is a leaching procedure run under saturated conditions to examine constituent leaching as a function of liquid to solid (LS) ratio. While it is onerous to perform an accurate leaching test at the LS that would likely flow through an asphalt layer to a road base, the results of this test may be extrapolated to predict leaching behavior for site-specific conditions, characterized by variables such as rainfall and water infiltration to the road base, and used as input values for the IWEM modeling portion of the assessment.

The tested materials included four PG-aggregate mixes: PG-LR, PG-RCA, PG-RAP, and PG-sand/cement, all blended at a 50-50 ratio. The blends were contacted with DI water at LS ratios of 1, 2, 5, 10, and 20 by mass and rotated for the method-prescribed time in order to reach equilibrium. The resulting leachate was vacuum-filtered through a 0.45-µm polypropylene filter, preserved according to each analytical method, and then analyzed to determine the constituent concentrations. To determine leached inorganic element concentrations, leachate subsamples were acid digested following EPA Method 3010A (US EPA, 1992) prior to analysis with ICP-AES following EPA Method 200.7 (US EPA, 1994) to determine total metal concentrations. They were also analyzed for anion concentrations following EPA Method 9056A (EPA, 2007), which does not require preliminary acid digestion, as well as for radionuclide concentrations, specifically 226-Ra. This determines the concentration of trace elements, anions, and radionuclides in filtered aqueous solutions. Appendix B contains extended results of all leaching tests conducted for this project.

As discussed in Section 3.2, the leaching results presented in the following sections are compared to Florida GCTLs and Drinking Water Standards (DWS) to screen the PG for potential constituents of concern. GCTLs were developed for use in contaminated site remediation and are often used as a point of comparison for beneficial use assessments. Molybdenum and strontium are compared to the respective GCTL, however fluoride and sulfate do not have a determined GCTL, thus they are compared to the National DWS. Fluoride is compared to the primary and secondary DWS, while sulfate was compared to the secondary DWS due to a lack of primary DWS. The secondary DWS provide guidance on non-health base effects, including aesthetic, cosmetic, and technical effects, that could be caused by elevated concentrations of the elements. The GCTL for Aluminum (Al) is equivalent to the secondary DWS and is not a health-based threshold, thus Al is compared to the EPA's Regional Screening Levels (RSL), which presents health-based target levels. Table 5-1 presents the results of the leaching test at an LS ratio of 10 for each of the pilot project road base blends compared to the respective threshold. Elements in bold indicate a sample average that exceeds the respective GCTL.

Table 5-1. Average Leachate Concentrations (mg/L) for 50-50 PG-Aggregate Mix Designs at an LS of 10

Constituent	Residential GCTL (mg/L)	PG-LR (mg/L)	PG-RCA (mg/L)	PG-Sand-Cement (mg/L)	PG-RAP (mg/L)
pH	-	7.80	10.4	12.2	7.73
Al	7	0.209	0.406	0.044	0.232
As	0.01	< 0.004	< 0.004	< 0.004	< 0.004
B	1.4	< 0.01	< 0.01	0.012	< 0.01
Ba	2	0.015	0.134	0.06	0.029
Be	0.004	< 0.001	< 0.001	< 0.001	< 0.001
Ca	-	689	725	1,640	691
Cd	0.005	< 0.001	< 0.001	< 0.001	< 0.001
Cr	0.1	0.004	0.019	0.078	0.003
Cu	1	0.008	0.013	0.004	0.006
Fe	0.3	0.046	0.034	0.026	0.004
Mg	-	1.32	0.860	0.288	1.68
Mn	0.050	0.003	< 0.001	< 0.001	0.006
Mo	0.035	0.009	0.021	**0.062**	0.013
Na	160	1.03	6.61	3.16	1.24
Ni	0.1	< 0.001	< 0.001	< 0.001	0.003
Pb	0.015	< 0.004	< 0.004	0.008	< 0.004
Sb	0.006	< 0.003	< 0.003	0.006	< 0.003
Se	0.05	0.005	0.006	0.004	0.002
Sn	4.2	< 0.002	< 0.002	< 0.002	< 0.002
Sr	4.2	1.96	**6.45**	1.47	1.71
V	0.049	0.007	0.003	0.002	0.297
Zn	5	0.009	0.005	0.06	0.007
Ra-226	5*	1.9	1.3	-	-
Cl-	250	27.7	28.3	37.8	0.023
F-	2	**17.0**	**20.7**	**4.08**	**23.3**
SO42-	250	**1,290**	**1,420**	**1,260**	**2,000**

*Units of pCi/L

5.2 Leaching Behavior Results

The PG-LR, PG-RCA, PG-RAP, and PG-Sand-Cement mixes described in the previous sections were tested using EPA Method 1316. Complete leaching results of each blend are displayed in Tables B-1 and B-2 in Appendix B. As outlined in Table 5-1, most of the elements tested with Method 1316 fell below the respective GCTLs at an LS of 10, which provides a preliminary screening assessment. However, multiple elements exceeded target levels at one or more LS ratios in multiple blends; these elements are further investigated throughout this report to determine their potential impact to groundwater. It is important to note that these constituents will not necessarily exceed target levels after traveling through the subsurface environment and reaching a point of compliance, which will be determined via fate and transport modeling with IWEM (discussed in Section 8.0) for LR, RCA, and Sand-Cement blends; tests are ongoing regarding RAP. Constituents that exceeded drinking water benchmarks in one or more blend at any LS ratio are listed as follows, with the standard used for comparison in parentheses:

- Fluoride (primary DWS, secondary DWS)
- Sulfate (secondary DWS)
- Molybdenum (GCTL)
- Strontium (GCTL)
- Chromium (GCTL)
- Iron (GCTL)

The leaching behavior of the previously identified elements at various LS ratios are presented in Figures 5-1 through 5-6. Each element is compared to the respective health-based regulatory thresholds as outlined in Section 5.1. It is important to note that in the case of fluoride and sulfate, the secondary DWS are not health-based thresholds but rather recommended national guidelines for concentrations that may cause cosmetic or aesthetic effects (EPA, 2022). Sulfate does not currently have a primary DWS (health-based threshold), thus the secondary DWS was used to screen. As seen in Figures 5-1 through 5-6, Mo, Sr, Cr, and Fe leaching decrease as LS ratios increase, while sulfate and fluoride continue to leach around the same concentration as LS ratio increases for each road base blend. Data points represent the average of duplicate samples.

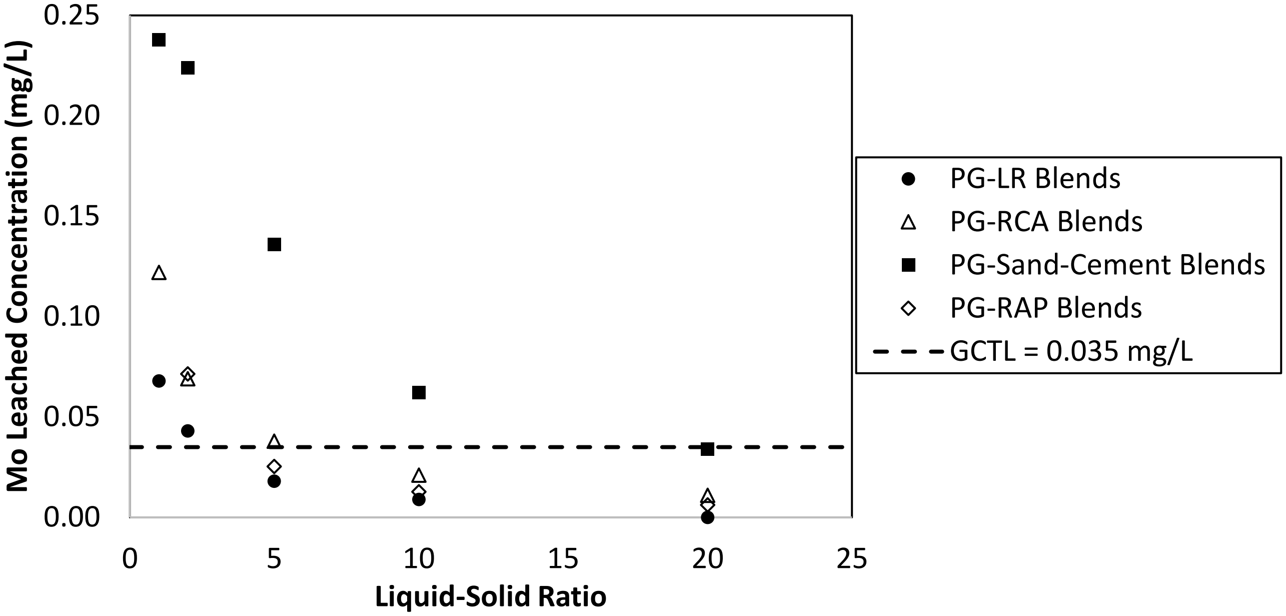

Figure 5-1: Method 1316 leaching test results (in mg/L) for molybdenum (Mo) from all blends at varying liquid-solid ratios

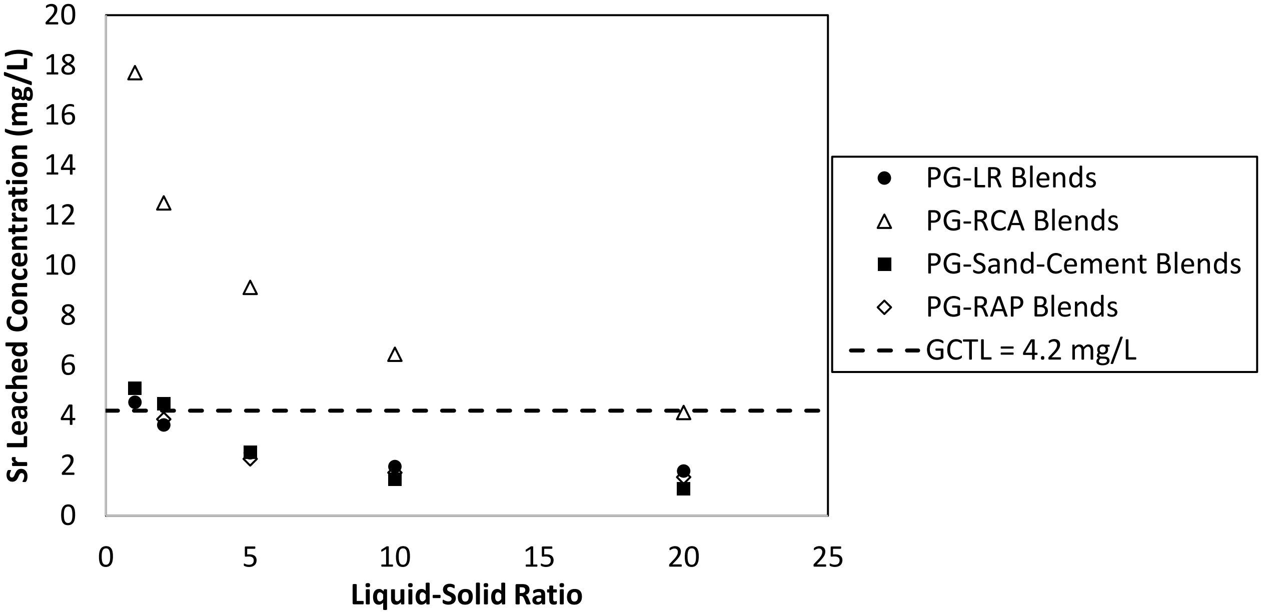

Figure 5-2: Method 1316 leaching test results (in mg/L) for strontium (Sr) from all blends at varying liquid-solid ratios

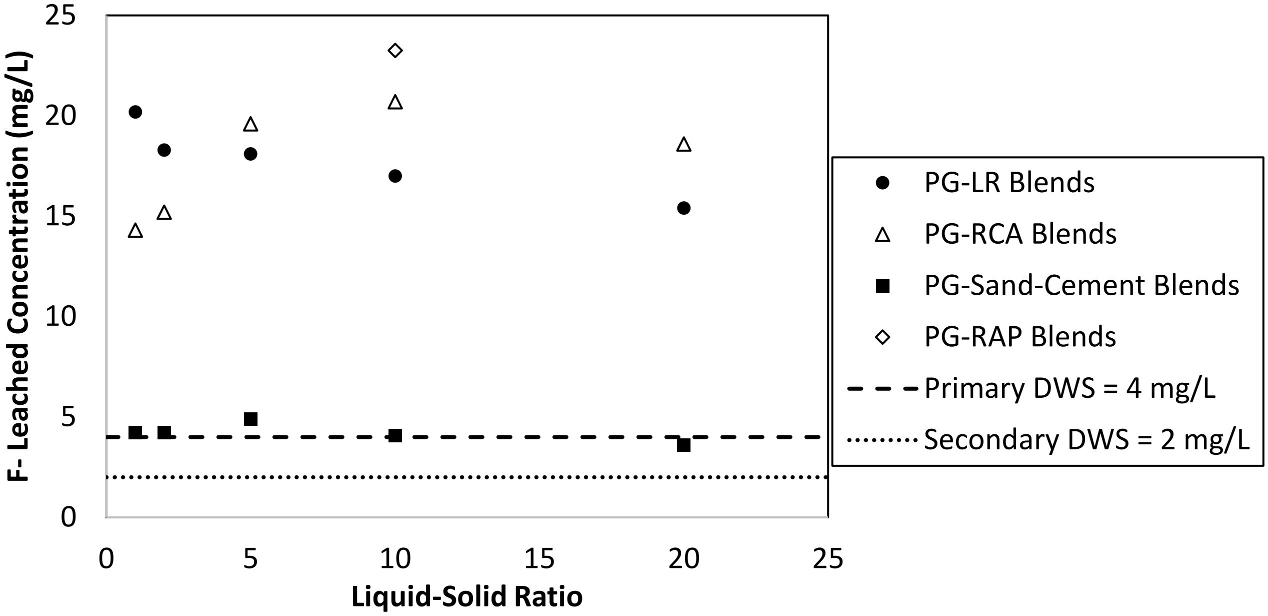

Figure 5-3: Method 1316 leaching test results (in mg/L) for fluoride (F-) from all blends at varying liquid-solid ratios

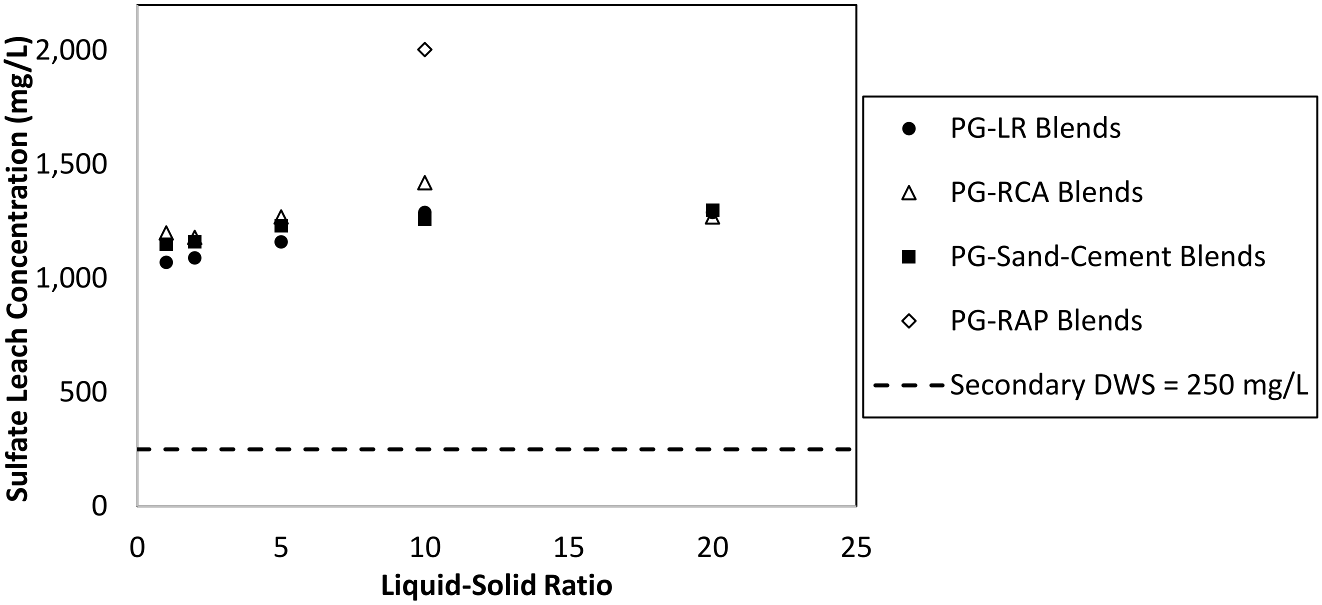

Figure 5-4: Method 1316 leaching test results (in mg/L) for sulfate from all blends at varying liquid-solid ratios

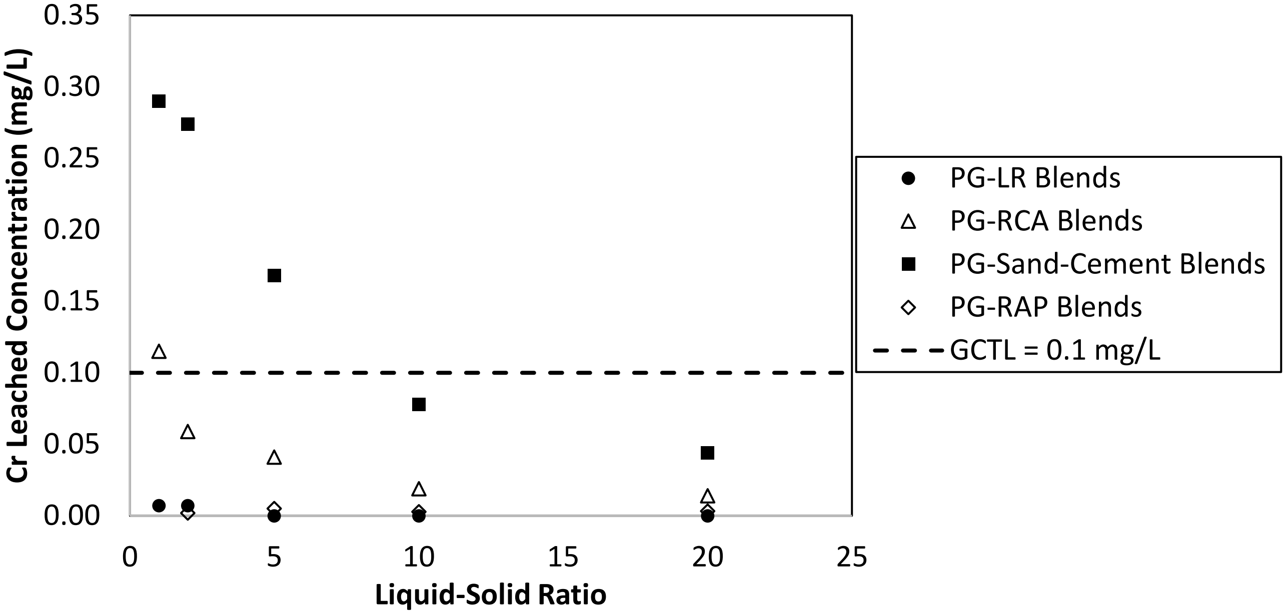

Figure 5-5: Method 1316 leaching test results (in mg/L) for chromium (Cr) from all blends at varying liquid-solid ratios

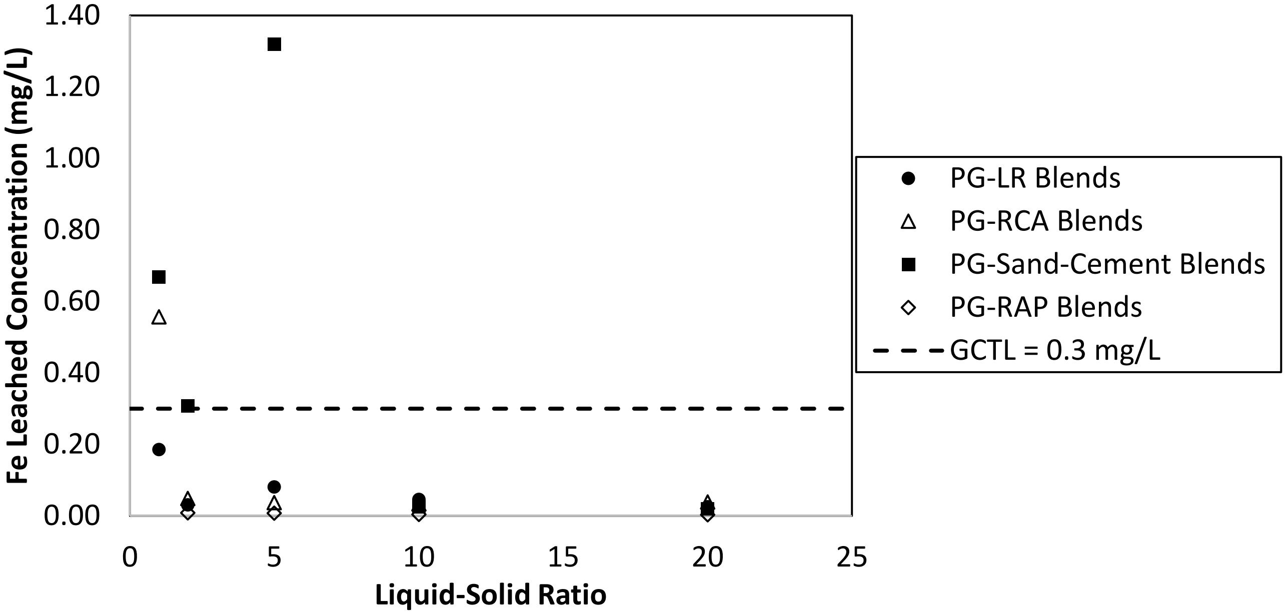

Figure 5-6: Method 1316 leaching test results (in mg/L) for iron (Fe) from all blends at varying liquid-solid ratios

6.0 PG-Aggregate Leachate Interaction with Soils

6.1 Methods and Materials

6.1.1 Research Approach

The batch leaching tests of the PG mix designs presented previously serve to screen for potential constituents of concern, however in the road application, the soil beneath the base would likely attenuate some of the leachable elements. To provide a better understanding of how leachate from the PG-LR and PG-RCA road base sections will interact with the site-specific underlying soils, a PG-aggregate leachate-to-soil partitioning experiment was conducted using soil samples collected from sites adjacent to the pilot road as well as soils collected from around the state. The results of the experiment were used to determine partition coefficients (K_d), which reflect the ratio of the concentration of a substance in one phase to a concentration in a second phase. The K_d values aid in accurately modeling the fate and transport of COPCs from the pilot road and are used in the IWEM modeling portion of the assessment. As noted in Section 3.2, this experiment was conducted using materials chosen for the pilot road project (PG, aggregates, sand-cement, and nearby soils) to determine site- and material-specific K_d values for each COPC.

6.1.2 Soil Collection and Characterization

For the PG-aggregate leachate-to-soil partitioning experiment, ten soils were chosen for this experiment and collected from various locations in Florida. Of the ten soils tested, six were collected and delivered by Mosaic from sites proximal to the New Wales and Bartow facilities. Of the soils delivered by Mosaic, two (Soils 5 and 6) were collected from the pilot road demonstration site. These are the soils for which partition coefficients were used in IWEM modeling, as they are most applicable to the demonstration site. Additional soils were tested to understand PG leachate interaction with soils of different characteristics, including pH, organic matter content, and metal and anion contents. Four 5-gallon buckets of Soils 1-6 were extracted from approximately 30 cm below the surface and delivered to UF (see Figure 6-1). Soils 7-10 were collected by UF from locations across central Florida. All samples were homogenized, air dried at room temperature, and passed through a 2 mm sieve prior to experimentation (see Figure 6-2 for subsamples of each soil). Figures 6-3, 6-4, and 6-5 provide aerial photos labeled with the soil sampling locations for the Mosaic-collected soils (Soils 1-6). Table 6-1 provides information on where each soil was collected.

Figure 6-1: Soil sampling location from adjacent to the New Wales demonstration site.

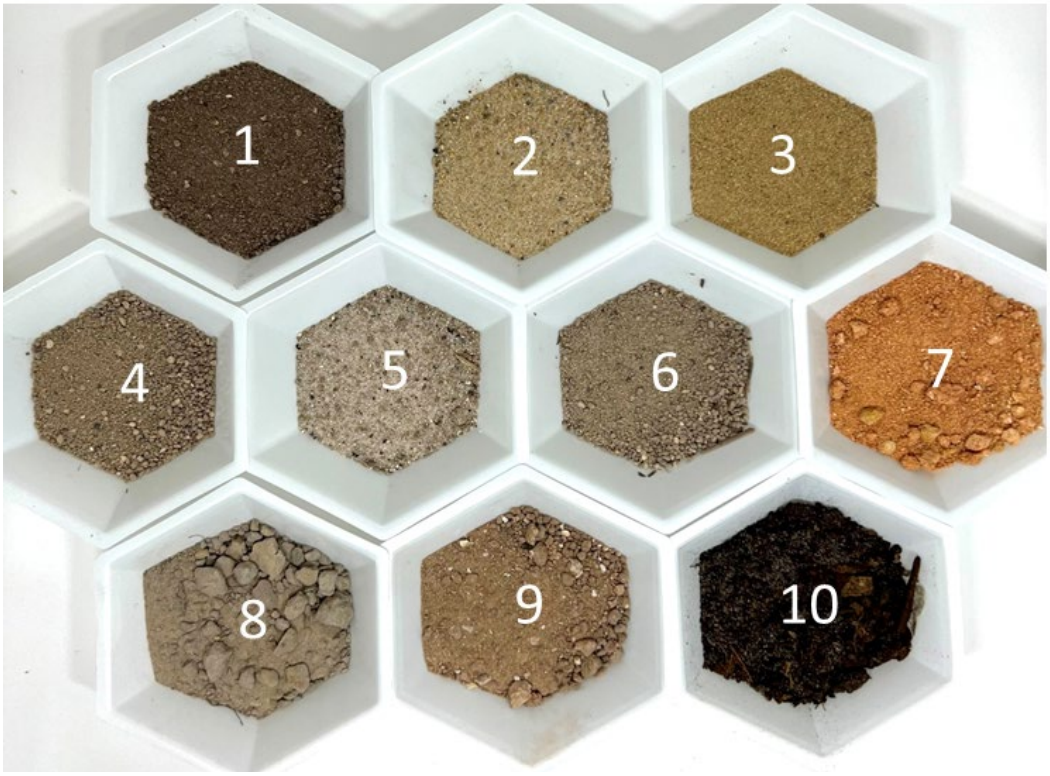

Figure 6-2: Selected soils for partition coefficient determinations

Figure 6-3: Location of additional soils delivered by Mosaic from the Bartow facility.

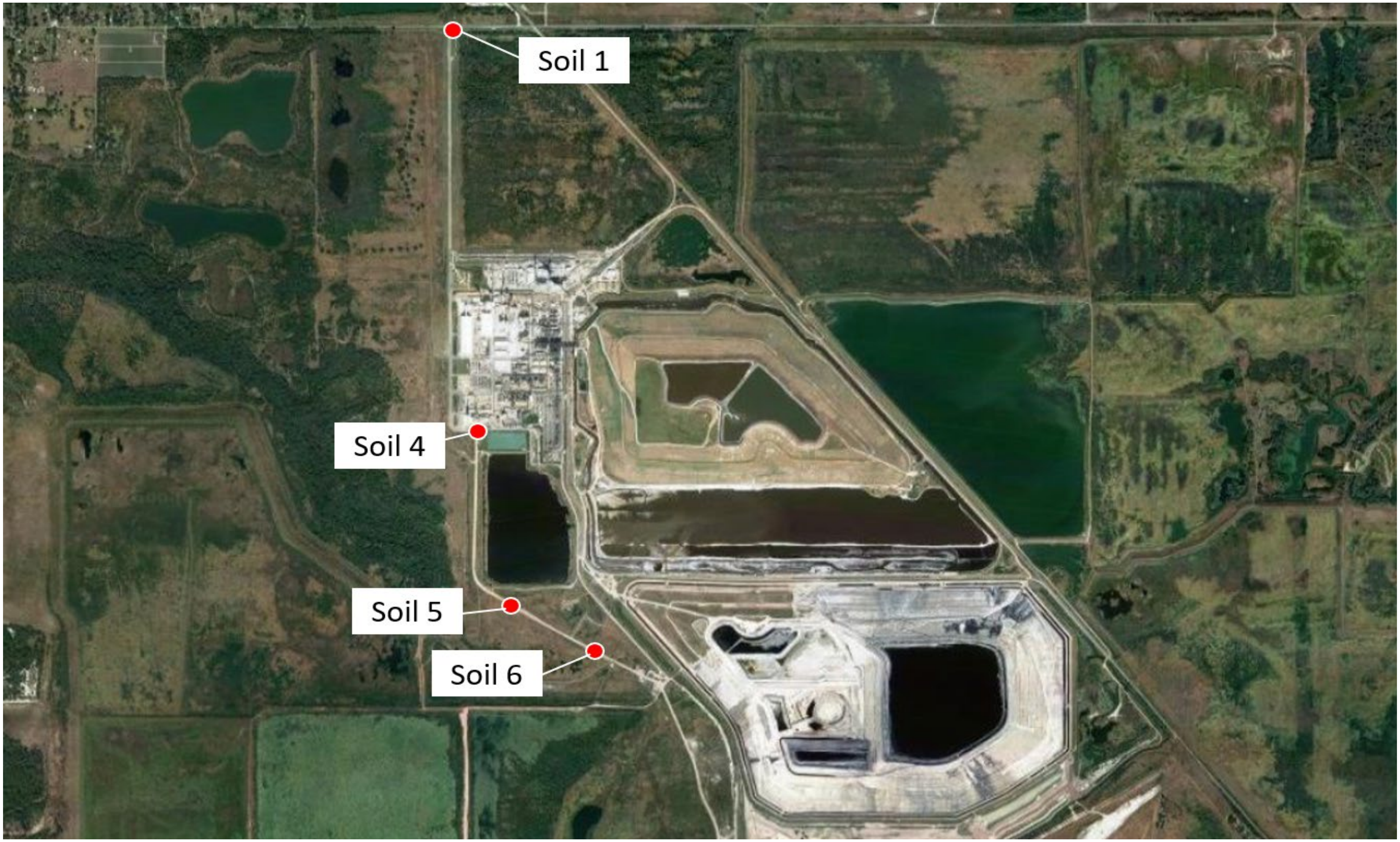

Figure 6-4: Location of soils delivered by Mosaic from the New Wales facility.

Figure 6-5: Location of soils delivered by Mosaic taken from the pilot road demonstration site and are thus representative of the soils proximal to or underlying the roadway

Table 6-1. Soil ID and collection locations for Soils 1-10

Soil ID	Location Sampled
Soil 1	New Wales Entrance Road, Florida
Soil 2	Bartow, Florida
Soil 3	Bartow, Florida
Soil 4	Mosaic New Wales, Florida
Soil 5	New Wales, North Pilot Site, Florida
Soil 6	New Wales, North Pilot Site, Florida
Soil 7	Hawthorne, Florida
Soil 8	New River, Florida
Soil 9	New River, Florida
Soil 10	Gainesville, Florida

6.1.3 Batch Leaching

For the experiment, two leachates were created by combining 50-50 blends of both PG-LR and PG-RCA with deionized (DI) water at an LS ratio of 10, hereby referred to as bulk leachate. The mixtures were rotated for 24-hours after which they are assumed to have reached equilibrium. The leachates were then vacuum filtered until a sufficient quantity of leachate was generated (approximately 20L). These bulk leachates are conservative representations of discharge from the road base under saturated conditions.

The filtered leachate was then contacted with one of ten soils at an LS ratio of 20, 50 g of soil and 1 L of PG-aggregate leachate. Each soil-leachate contacting experiment was repeated in triplicate to capture naturally occurring variability in the soil-leachate interactions. These samples were rotated for the prescribed time in ASTM Method D4646, which is a standard method for measuring contaminant sorption by soils and sediments (ASTM, 2016b), filtered, and acid digested according to EPA Method 3010A before constituent concentration analysis with ICP-AES following EPA Method 200.7. The leachate was analyzed for leached constituent concentrations before and after soil contact to determine the quantity of constituents that sorbed to the soil.

6.1.4 Developing Partition Coefficient (K_d value)

Partition coefficients for each COPC for LR and RCA blends contacted with each of the 10 soils were determined using equation (3):

$$K_d = \frac{(C_{initial} - C_{final})(V_{solution})}{(C_{final})(M_{soil})} \qquad (3)$$

where $C_{initial}$ is the concentration of a constituent in the PG-aggregate leachate before soil contact (mg/L), C_{final} is the concentration after soil contact (mg/L), $V_{solution}$ is the quantity of PG leachate contacted with the soil (L), and M_{soil} is the mass of the soil sample used (kg). The final units for partition coefficients in this experiment are L/kg. The K_d values for the six COPCs discussed in Section 6 (Mo, Sr, F^-, SO_4^{2-}) are displayed in the next section and were used as site-specific inputs for IWEM fate and transport modeling.

6.2 Soil Characterization Results

The Mosaic soils were characterized for total Aluminum (Al), Iron (Fe), and Manganese (Mn), as well as their sand, silt, and clay percentages and this data is displayed in Table 6-2. The soil classification provides valuable insight on the infiltration rates for the soil, as sandy soils tend to have higher infiltration rates whereas clayey soils may retain more water (Owens & Rutledge, 2005). Each soil was leached alone with DI water to determine initial leachable constituent concentrations from the soil itself. The full results from DI leaching may be found in Appendix B, but results for the pilot project site specific soils (Soils 5 and 6) are shown in Table 6-3 (mg/L). These represent the concentrations of COPCs initially present in the soils extracted adjacent to the pilot site, before interaction with PG.

Table 6-2. Soil characterization for soils 1-10 including natural pH, moisture content, total element concentration (mg/kg-dry), and sand, silt, clay characterization (%).

	Soil 1	**Soil 2**	**Soil 3**	**Soil 4**	**Soil 5**	**Soil 6**	**Soil 7**	**Soil 8**	**Soil 9**	**Soil 10**
pH	6.19	6.24	6.49	6.7	6.7	6.72	4.98	4.59	7.81	5.69
Moisture Content	10.3	4.7	19	8.99	0.33	14.64	0.64	1.88	2.09	18.22
	Total Element Content (mg-element/kg-dry soil)									
Aluminum	7,960	1,490	2,000	2,090	11,600	2,760	5,400	12,000	9,310	2,500
Iron	636	3,120	1,280	1,310	2,510	1,530	5,630	1,940	5,530	1,060
Manganese	5.70	18.3	4.95	5.09	39.4	35.0	0.66	2.60	7,957	86.0
	Physical Characterization (%)									
Sand	95	99	99.5	96	95	93	91.5	96	73	96.5
Silt	1	0.5	0	1.5	0.5	1	0	2.5	3	2
Clay	4	0.5	0.5	2.5	4.5	6	8.5	1.5	24	1.5
USDA classification	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sandy Clay Loam	Sand

Table 6-3: Constituents of potential concern leached concentrations from soils proximal to the pilot road site compared to the respective GCTL (mg/L).

Constituent (mg/L)	**GCTL**	**Soil 5**	**Soil 6**
Fluoride	4	0.130	0.055
Sulfate	250	8.16	9.45
Molybdenum	0.035	< 0.006	< 0.006
Strontium	4.2	0.068	0.096
Chromium	0.1	0.008	0.012
Iron	0.3	0.396	0.425

6.3 Bulk Leachate Interaction with Soils

To illustrate the sorption of COPCs by the various soils tested in this experiment, Figures 6-7 through 6-14 compare concentrations of fluoride, molybdenum, strontium, and sulfate 1) in the original bulk leachates for PG-LR and PG-RCA, 2) after contact with a specified soil, and 3) leached from only the soil. Leaching tests on the soils with deionized water serve as reference values for concentrations present in the soils before any PG leachate contact. These values are compared to the regulatory screening levels for each constituent.

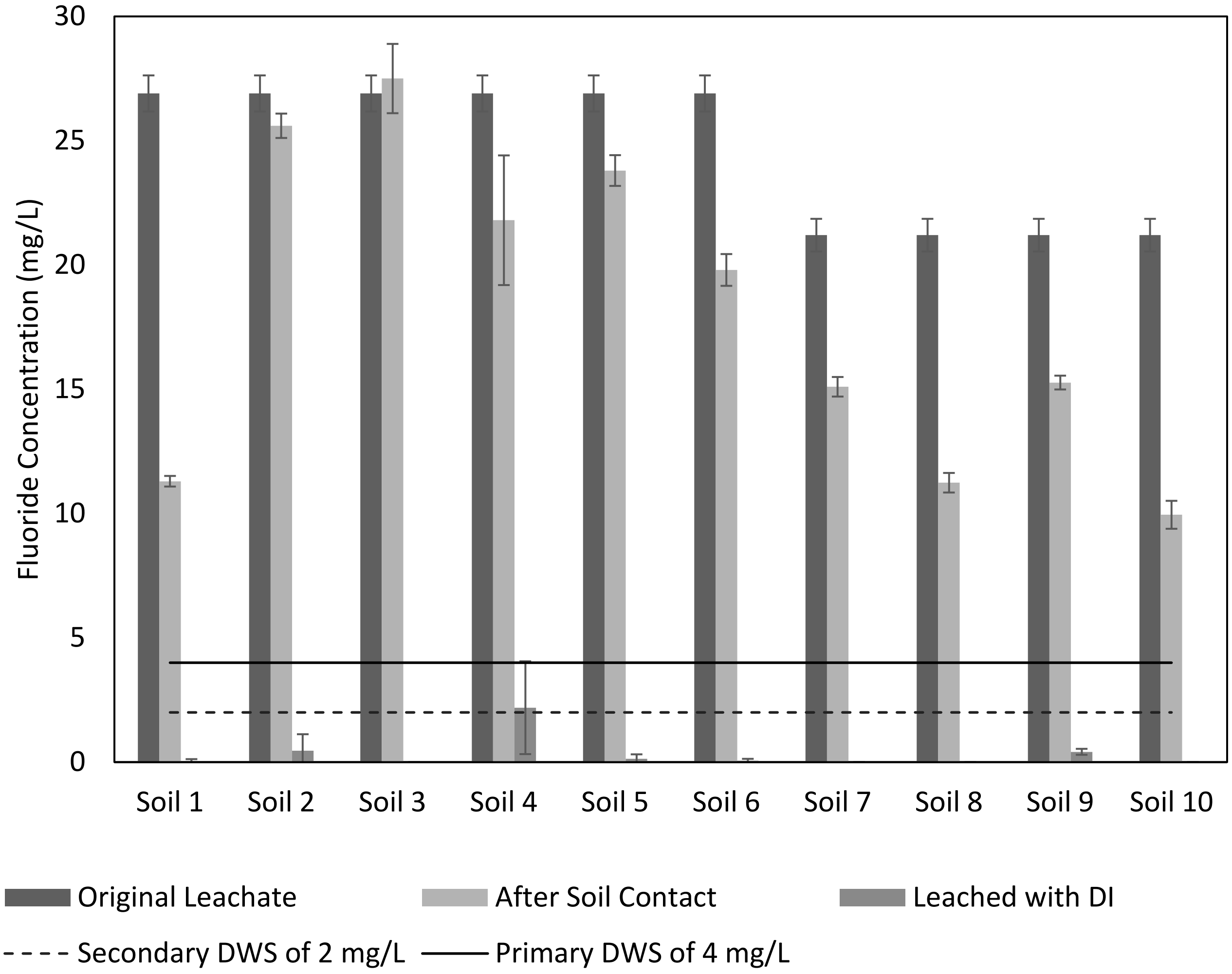

Figure 6-7: Fluoride leached concentrations in mg/L from ten tested soils with PG-LR bulk leachate. Original leachate refers to the concentrations in the 50-50 PG-LR leachate and is compared to concentrations in the leachate after 24-hours of contact with each soil. The third bar depicts concentrations present in soil before any PG contact. All values are compared to the primary and secondary DWS for Fluoride (4 and 2 mg/L)

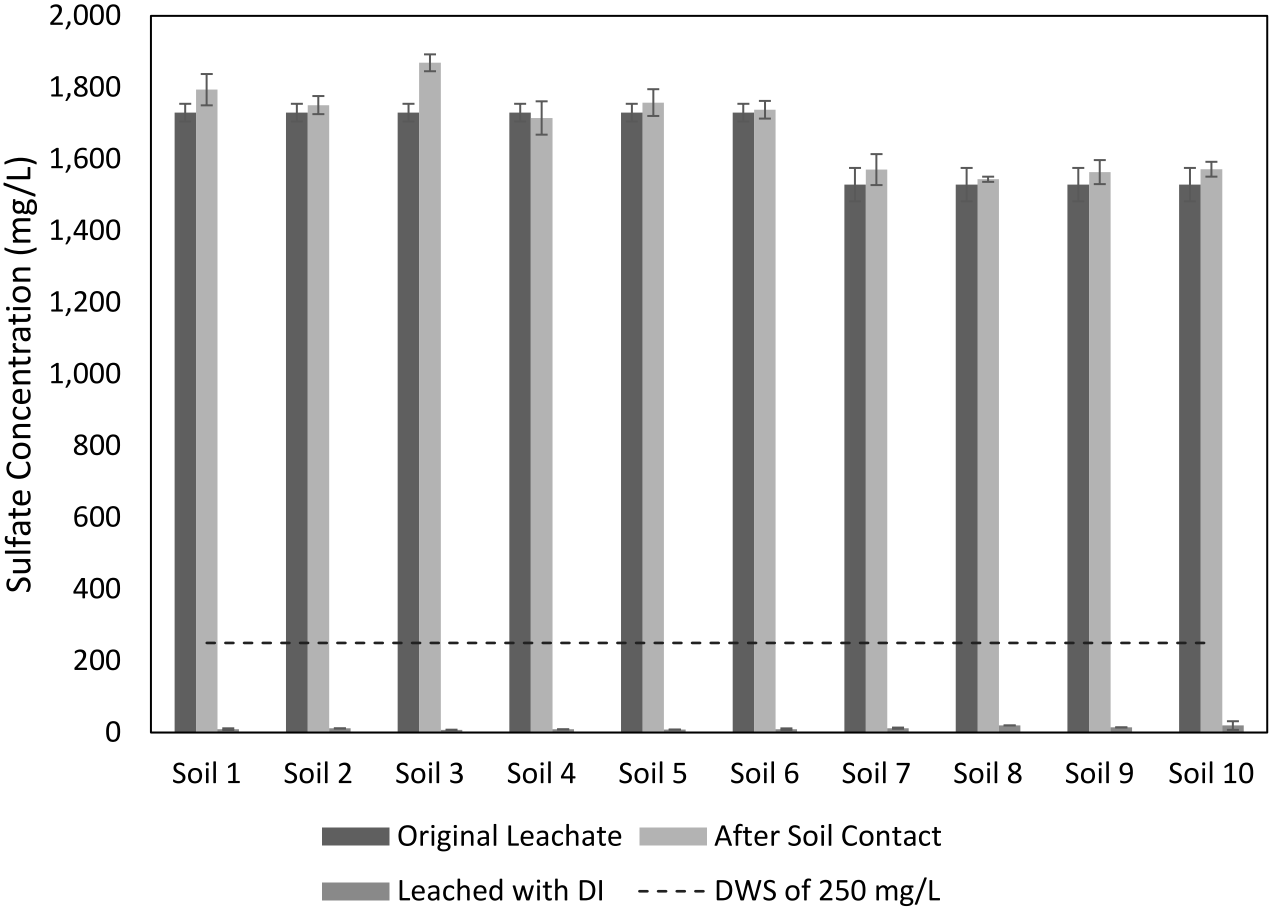

Figure 6-8: Sulfate leached concentrations in mg/L from ten tested soils with PG-LR bulk leachate. Original leachate refers to the concentrations in the 50-50 PG-LR leachate. This is compared to concentrations in the leachate after 24-hours of contact with each soil. The third bar depicts concentrations present in soil before any PG contact. All values are compared to the Secondary DWS of 250 mg/L

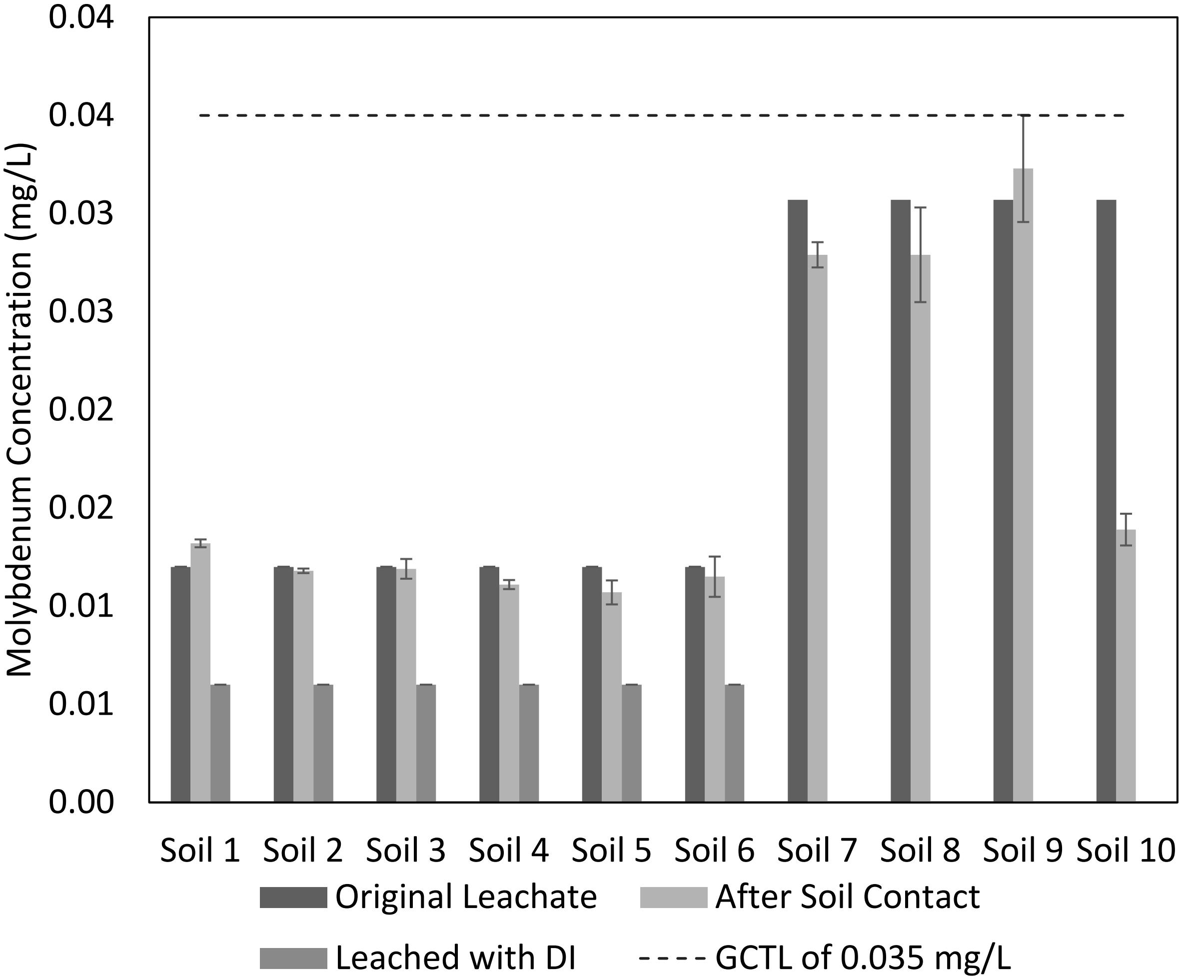

Figure 6-9: Molybdenum leached concentrations in mg/L from ten tested soils with PG-LR bulk leachate. Original refers to the concentrations in the 50-50 PG-LR leachate. This is compared to concentrations in the leachate after 24-hours of contact with each soil. The third bar depicts concentrations present in soil before any PG contact. All values are compared to the GCTL of 0.035 mg/L

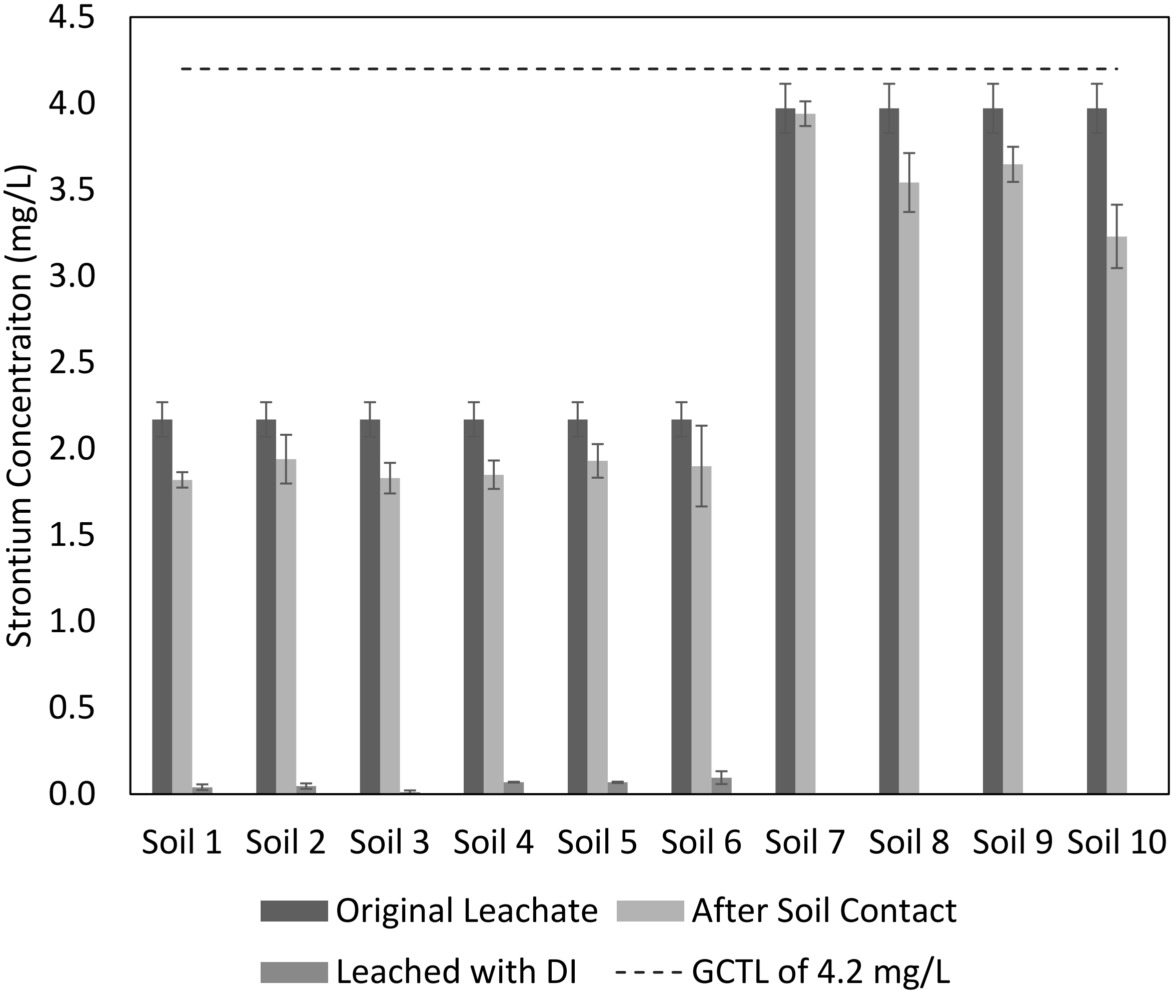

Figure 6-10: Strontium leached concentrations in mg/L from ten tested soils with PG-LR bulk leachate. Original leachate refers to the concentrations in the 50-50 PG-LR leachate. This is compared to concentrations in the leachate after 24-hours of contact with each soil. The third bar depicts concentrations present in soil before any PG contact. All values are compared with the GCTL of 4.2 mg/L

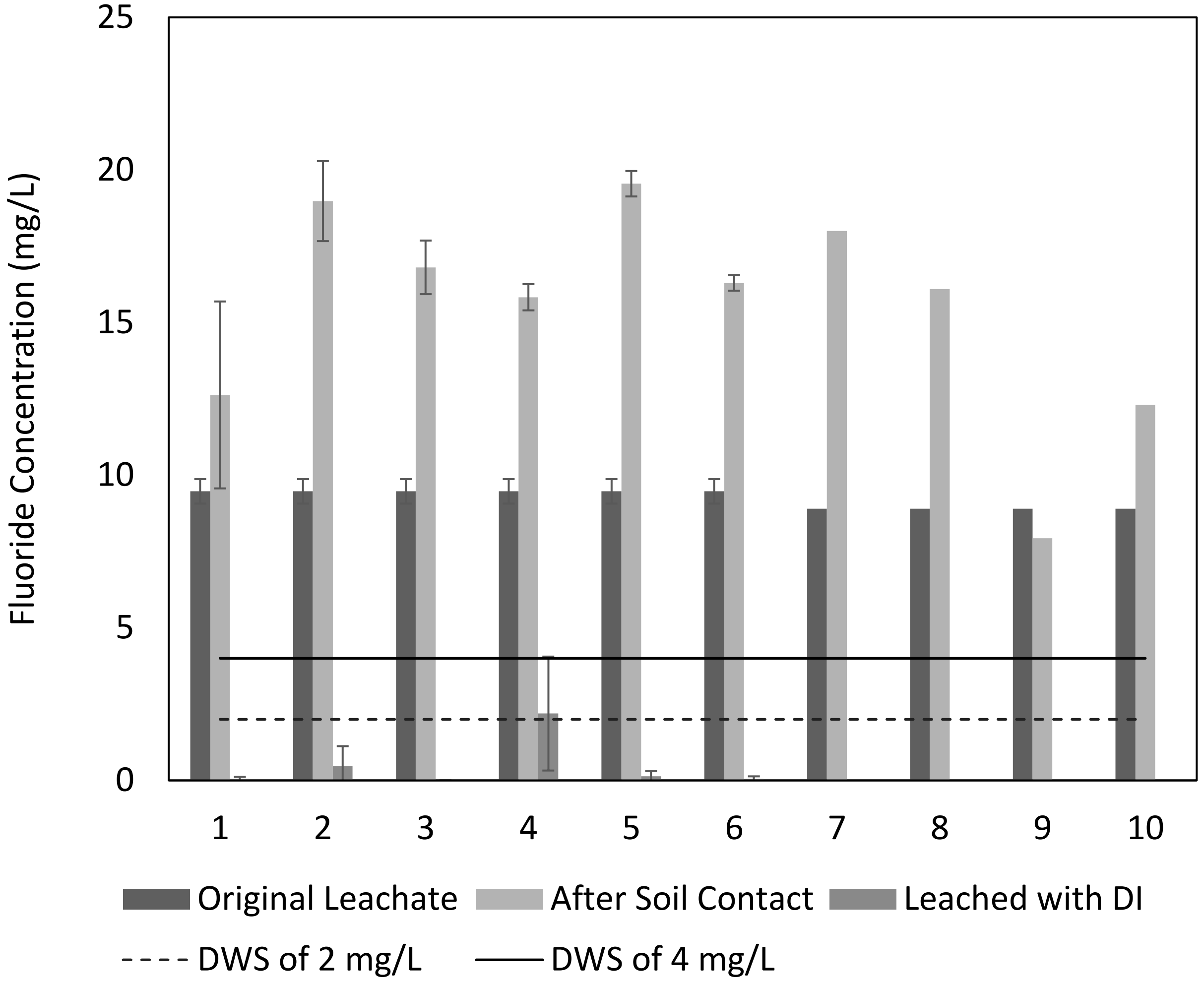

Figure 6-11: Fluoride leached concentrations in mg/L from ten tested soils with PG-RCA bulk leachate. Original leachate refers to the concentrations in the 50-50 PG-RCA leachate. This is compared to concentrations in the leachate after 24-hours of contact with each soil. The third bar depicts concentrations present in soil before any PG contact. All values are compared with the Primary and Secondary DWS of 2 mg/L and 4 mg/L

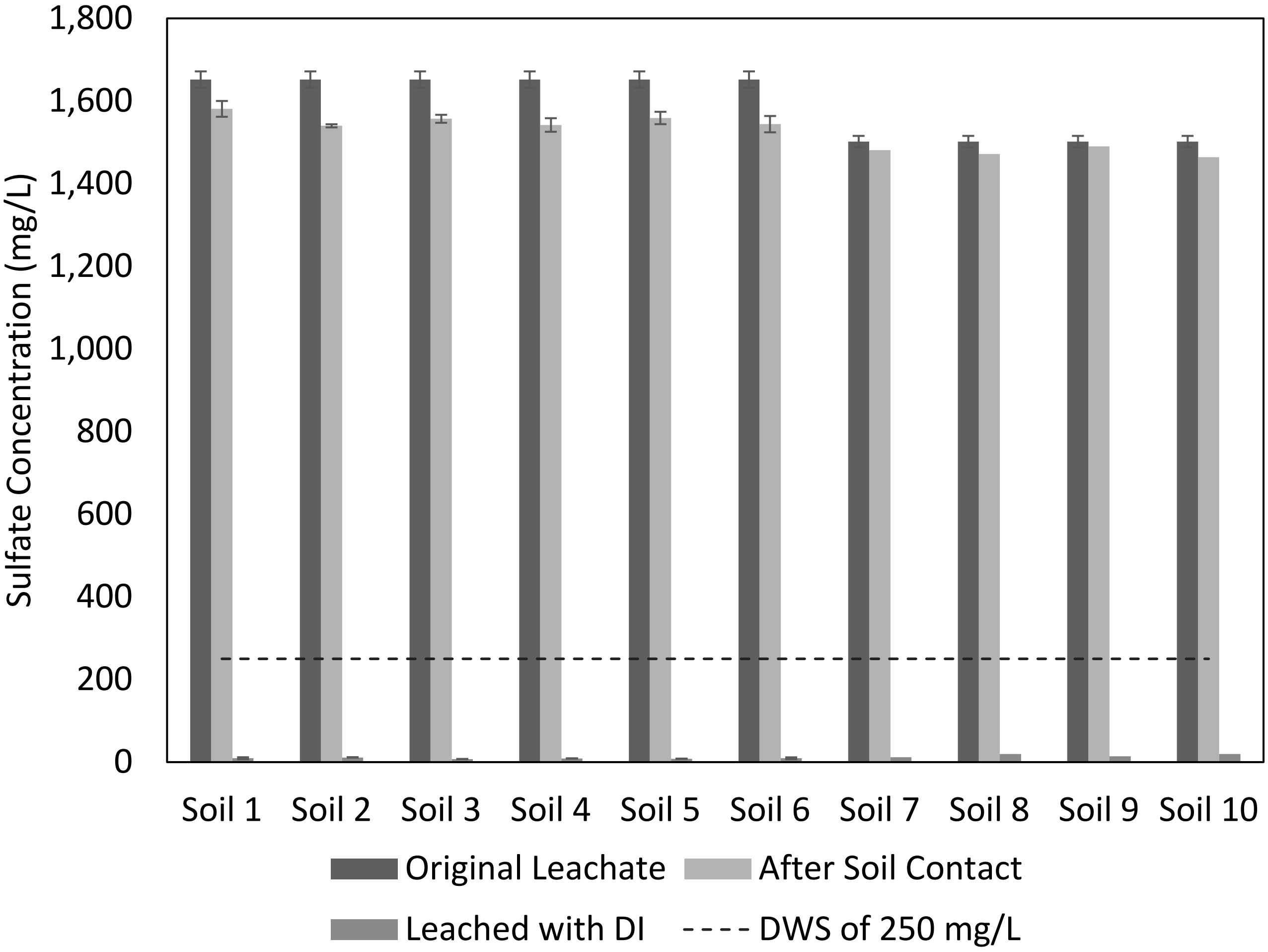

Figure 6-12: Sulfate leached concentrations in mg/L from ten tested soils with PG-RCA bulk leachate. Original leachate refers to the concentrations in the 50-50 PG-RCA leachate. This is compared to concentrations in the leachate after 24-hours of contact with each soil. The third bar depicts concentrations present in soil before any PG contact. All values are compared to the secondary DWS of 250 mg/L

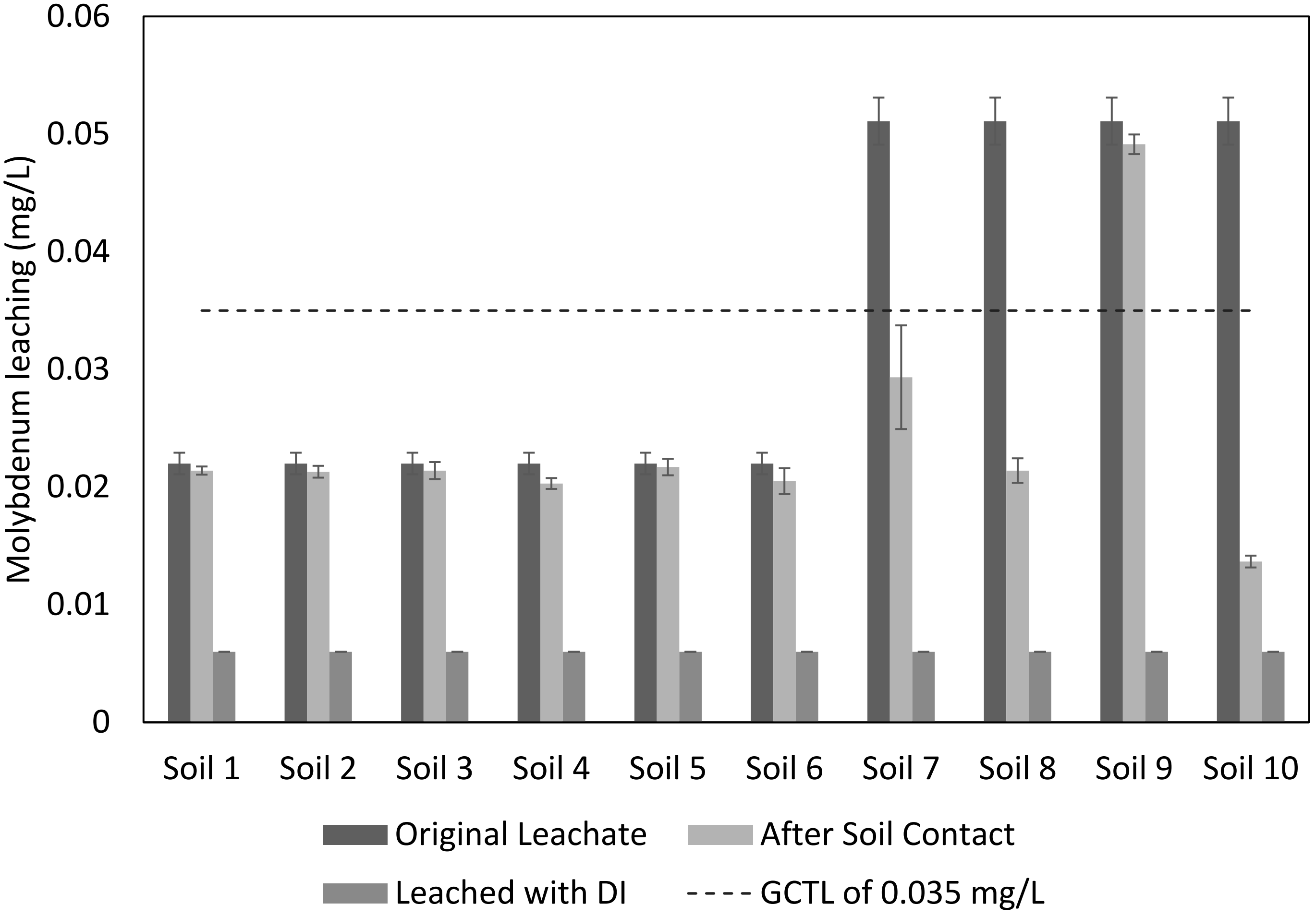

Figure 6-13: Molybdenum leached concentrations in mg/L from six tested soils with PG-RCA bulk leachate. Original leachate refers to the concentrations in the 50-50 PG-RCA leachate. This is compared to concentrations in the leachate after 24-hours of contact with each soil. The third bar depicts concentrations present in soil before any PG contact. All values are compared to the GCTL of 0.035 mg/L

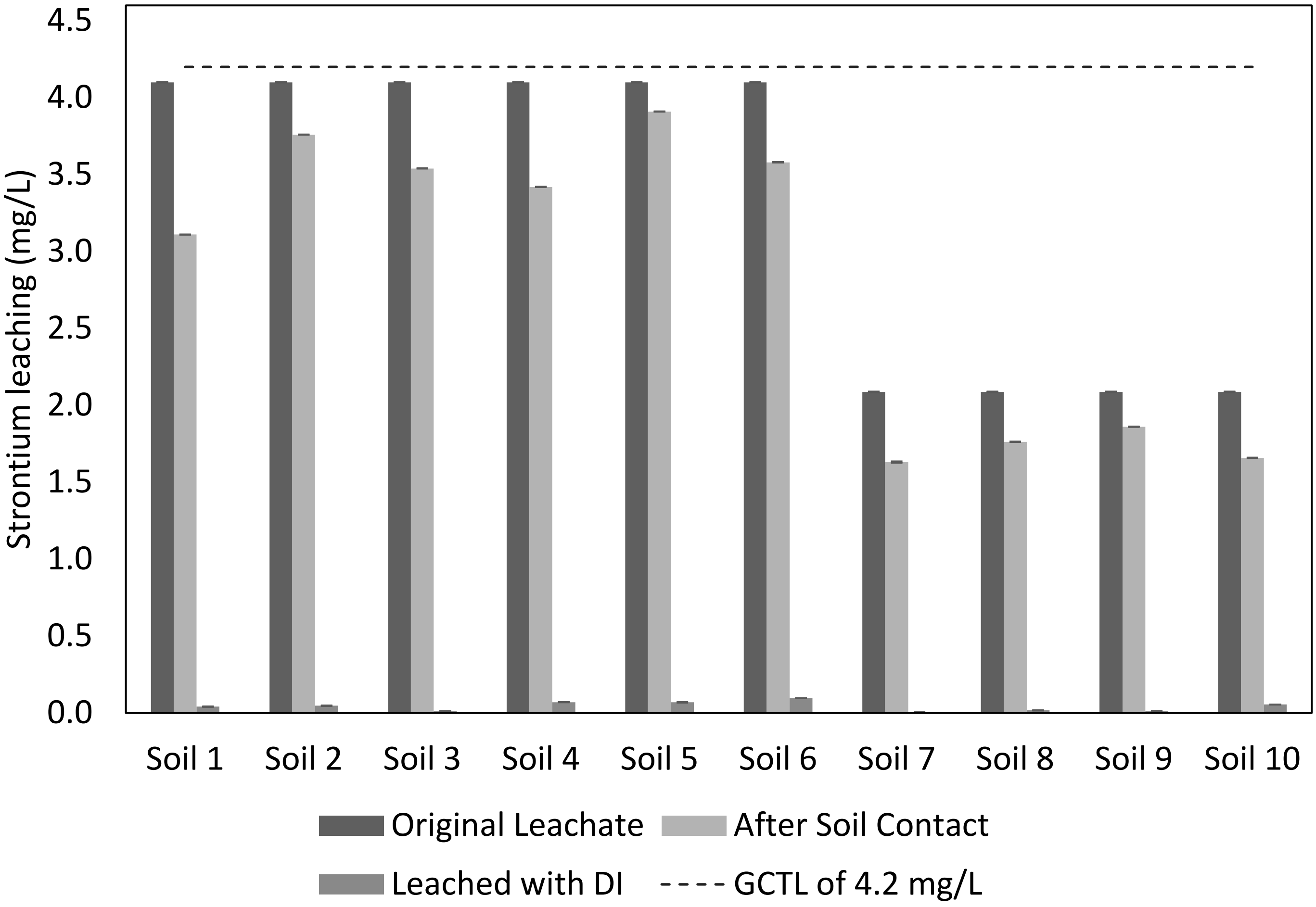

Figure 6-14: Strontium leached concentrations in mg/L from six tested soils with PG-RCA bulk leachate. Original leachate refers to the concentrations in the 50-50 PG-RCAR leachate. This is compared to concentrations in the leachate after 24-hours of contact with each soil. The third bar depicts concentrations present in soil before any PG contact. All values are compared to the GCTL of 4.2 mg/L

6.4 Determination of K_d values

Based on the reduction in concentrations from the original bulk leachate to the leachate after soil contact, partition coefficients were determined for the constituents of potential concern using equation (3) and are outlined in Tables 6-4 and6-5 for the PG-LR and PG-RCA blends. A value of “NA” denotes that the soil did not sorb any quantity of the material, so a partition coefficient could not be determined. These values are averaged replicates of soils 5 and 6 to ensure an accurate representation of the site environment.

Several constituent leaching increased following contact with the soil, such as sulfate and iron for LR blends and fluoride and iron for RCA blends. While this partition coefficient test serves to identify potential sorption, the concentrations in the final leachate could be contributed by the soils as they come in contact with the alkaline blend leachate. To determine the influence of pH on soil leaching of these constituents, the soils were leached concentrations of sodium hydroxide to raise the eluent pH and compared to the soil samples leached with DI water. These results are included in Figure 6-15. In each soil sample, leaching the soil at a more basic pH resulted in a release of fluoride from the soil.

Table 6-4: Partition coefficients for PG-LR leachate contacted with soils from pilot road site

Constituent	PG-LR Leachate (mg/L)	PG-LR After Soil Contact (mg/L)	Partition Coefficient (K_d) in L/kg
F^-	26.9	21.8	6.72
SO_4^{2-}	1,730	1,750	NA
Cr	0.004	0.004	NA
Fe	0.087	0.146	NA
Mo	0.012	0.011	1.56
Sr	2.17	1.91	2.67

Table 7-5: Partition coefficients for PG-RCA leachate contacted with soils from pilot road site

Constituent	PG-RCA Leachate (mg/L)	PG-RCA After Soil Contact (mg/L)	Partition Coefficient (K_d) in L/kg
F^-	9.47	17.9	NA
SO_4^{2-}	1,650	1,550	1.84
Cr	0.029	0.029	NA
Fe	0.036	0.091	NA
Mo	0.022	0.021	0.70
Sr	4.10	3.75	1.89

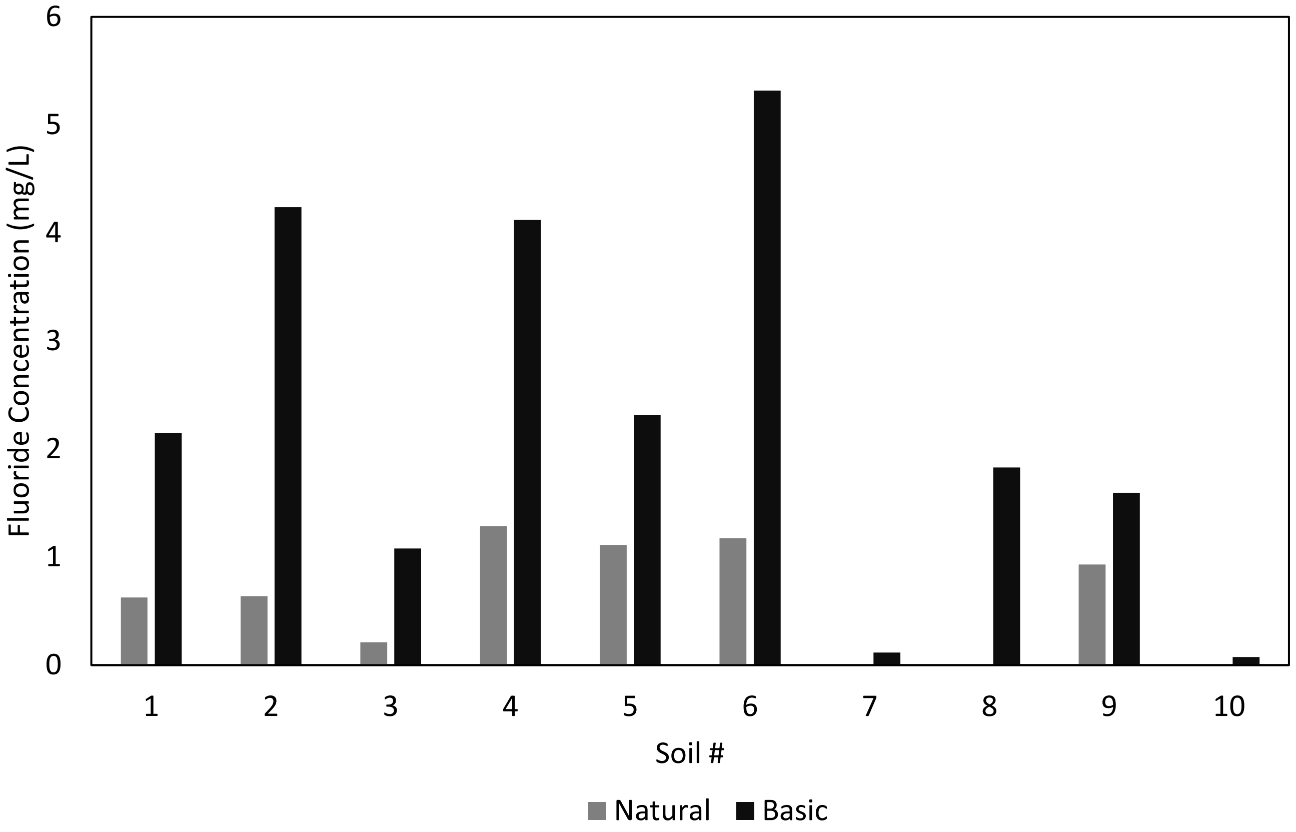

Figure 6-15: Fluoride leached concentrations in mg/L from ten tested soils. Natural soil refers to the concentrations in the soil leached with DI water only. Basic soil refers to the concentration in the soil leachate when leached with DI water and NaOH.

7.0 Infiltration Analysis

7.1 Approach

Infiltration is a crucial parameter in modeling the fate and transport of COPCs from the roadway. As discussed previously in this document, IWEM was the model chosen to model the fate and transport of elements from the demonstration project; IWEM allows the user to enter a value for infiltration of leachate from the road base into the subsurface environment. Selecting an appropriate infiltration value is essential in predicting accurate performance of the demonstration project. The infiltration parameter refers to the amount of water from a rainfall event that percolates through the asphalt pavement and through the road base layer to the underlying soil.

To calculate the amount of infiltration through the road base, a series of permeameter experiments were conducted to measure the hydraulic conductivity of the PG-LR and PG-RCA blends as described in Section 7.2 and subsequently the infiltration rate was calculated using the hydraulic conductivity of the base materials as inputs into the Hydrological Evaluation of Landfill Performance (HELP) model as described in Section 7.3. The hydraulic conductivity of the base layer is used in the analysis to provide a conservative estimate of the infiltration scenario.

7.2 Falling Head Permeability Testing

The hydraulic conductivity of the PG-LR and PG-RCA blends was determined with falling head permeability tests in a compaction mold permeameter following ASTM D 5856: Standard Test Method for Measurement of Hydraulic Conductivity of Porous Material Using a Rigid-Wall, Compaction-Mold Permeameter (ASTM, 2016). Figure 7-1 displays a diagram of the apparatus used. The samples were compacted prior to permeability analysis through the Modified Proctor Compaction test ASTM D1557 (ASTM, 2021) in 6-inch diameter molds, which were then installed into the permeameter device. DI water was passed through the sample at a falling head and allowed to saturate prior to recording permeability values. The hydraulic conductivity *k* is estimated using equation 4:

$$k = \frac{2.3(aL_f)}{A\,\Delta \mathrm{t}} \log\left(\frac{h_1}{h_2}\right) \quad (4)$$

Where *a* represents the cross-sectional area of the standpipe, L_f represents the final length of the specimen (cm), *A* represents the cross-sectional area of the specimen (cm), Δt represents the elapsed time between determination of h_1 and h_2 (s), and h_1 and h_2 represent the head loss across the specimen at time t_1 and t_2, respectively (cm).

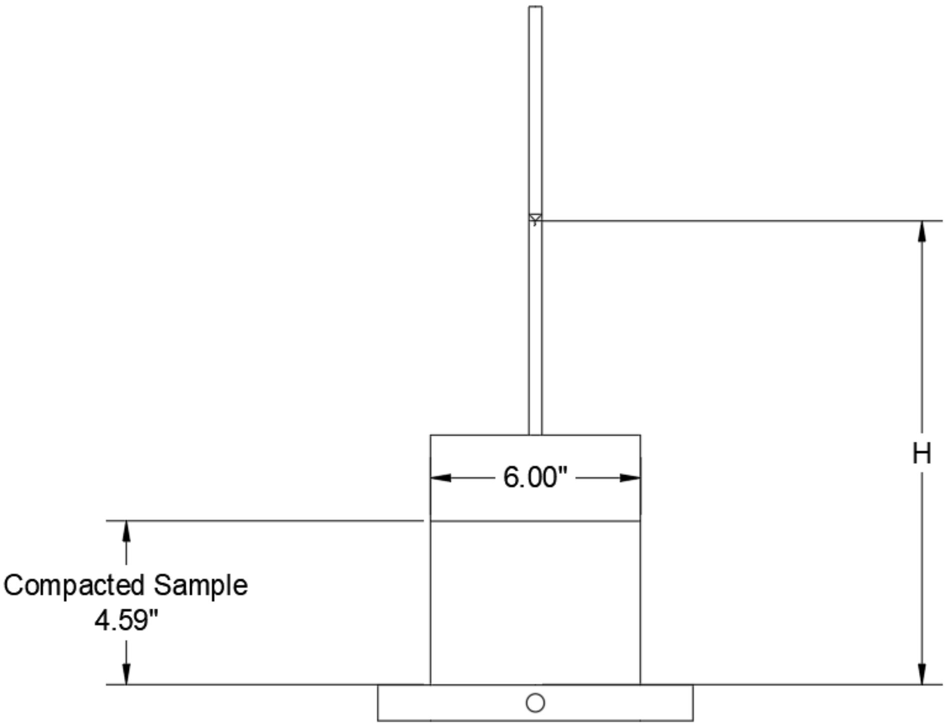

Figure 7-1: Falling head permeability apparatus used to perform hydraulic conductivity testing

Values received from the permeameter reflect the hydraulic conductivity of the *base* layer, and thus are conservative values as the asphalt layer encapsulating the road base will provide a barrier to infiltration. These values are reported in Table 7-1. After receiving permeameter values, the infiltration rate of the road was assessed using the Hydrological Evaluation Landfill Performance (HELP) model using the hydraulic conductivities from the falling head permeability tests. The hydraulic permeability for PG-RAP road base warrants future investigation, however literature results suggest permeabilities of RAP or RAP-soil mixtures yield concentrations within the ranges of PG-LR and PG-RCA blends (Blanco et al., 2003).

Table 7-1: Hydraulic permeability measurements for PG-LR and PG-RCA road base

Blend	Average* (10^{-6} cm/s)	Range (10^{-6} cm/s)
PG-LR 40-60	2.19	1.17-3.13
PG-RCA 50-50	6.84	3.08-11.3

7.3 HELP Modeling

The HELP model was created to simulate two-dimensional water movement across, into, though, and out of landfills. It models rainfall, runoff, and infiltration to determine the estimate of water that will accumulate at a specific site using the Soil Conservation Services curve number (SCS CN) method to determine runoff and infiltration. Parameters include vegetation, soil types, moisture conditions, layer thicknesses, slopes, and drains. The model uses precipitation data generated over the past 10 years at the specified location. The HELP model is meant to evaluate the hydrological environment of a landfill, though it may be adapted to represent other situations.

Two scenarios of HELP models were run for each blend to estimate infiltration rate under scenarios with and without the effect of evaporation. The pilot road site is situated on a plot of land exposed to full sun, so significant evaporation will occur when the roadway is exposed to moisture. First the infiltration rate was determined without the effect of evaporation. The configuration of the HELP model used is presented in Figure 7-2. The road base was represented by a sloped barrier layer with hydraulic conductivity from the permeability tests. The CN in these simulations were calculated by HELP using the slope and slope length. Above the road layer a vertical percolation layer and a lateral drainage layer are used to allow water to both enter the space downwards and runoff laterally. These two layers are set to have very high hydraulic conductivities to allow for unrestricted flow of water. Below the barrier layer a lateral drainage layer and geomembrane are placed to capture the infiltration through the barrier layer for quantification.

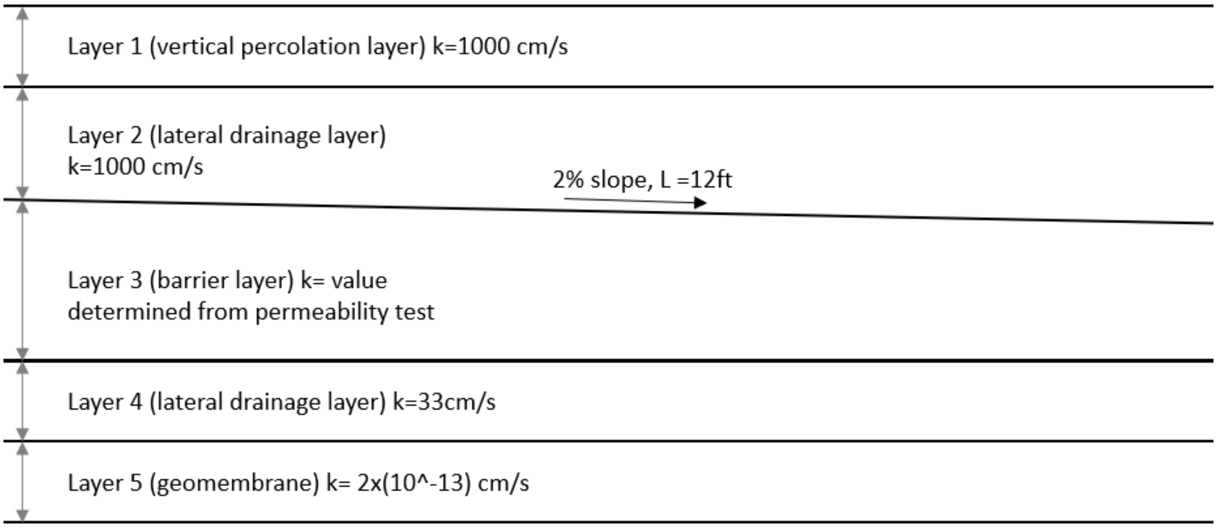

Figure 7-2: Layer configuration for HELP model without evaporation

The impact of evaporation was accounted for by using a different model configuration. The layer set up used for the analysis including evaporation is presented in Figure 7-3. In this model, the base layer is represented by a vertical percolation layer with the hydraulic conductivity from permeability testing. A lateral drainage layer is placed below the base layer with a slope of 2% and high hydraulic conductivity. Under the drainage layer is a geomembrane layer of low permeability to capture the water infiltrating through the base. In this second set of runs, the CN is user defined rather than calculated by HELP. The CN was varied in this configuration until an infiltration rate matching the initial set of runs is obtained. Then evaporative zone is set to half the base thickness.

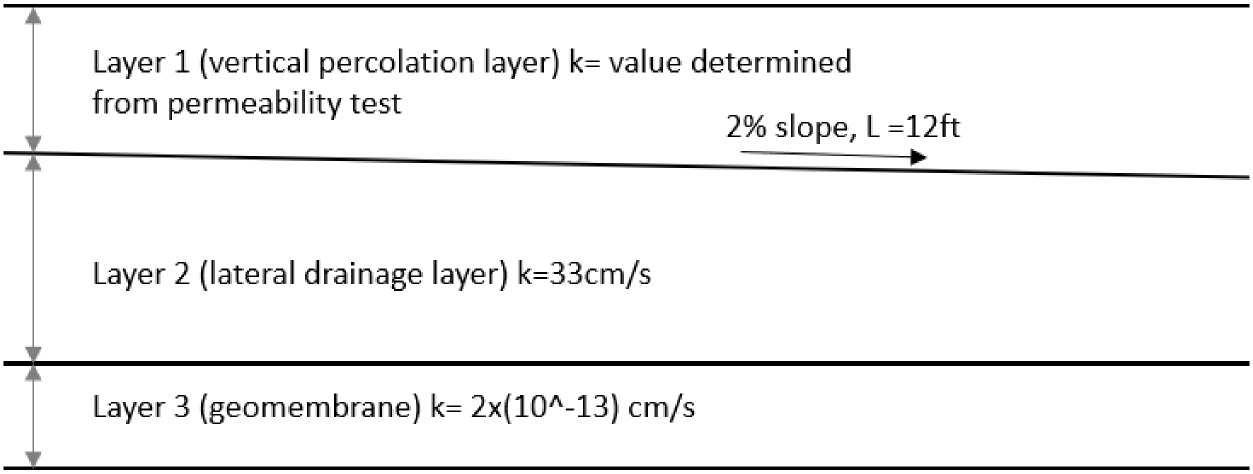

Figure 7-3: Layer configuration for HELP model with evaporation

The hydraulic conductivity values from Section 7.1 were input into the HELP model to determine the infiltration rate through the base layer as discussed in Section 7.2. The resulting infiltration rates from both the models with and without evaporation for each base material are tabulated in Table 7-2. For PG-Sand-Cement, the higher of the two PG-aggregate values was chosen. These values were input into IWEM for fate and transport modeling of selected constituents. Detailed HELP parameters and results are included in Appendix D.

Table 7-2: Infiltration rates determined from HELP model

Blend	Infiltration (mm/yr)	Infiltration (% Precipitation)
PG-LR	33.4	2.7
PG-LR With Evaporation	1.85	0.15
PG-RCA	86.1	6.96
PG-RCA With Evaporation	6.63	0.54
PG-Sand-Cement	86.1	6.96
PG-Sand-Cement With Evaporation	6.63	1.00

8.0 Fate and Transport Modeling

8.1 Modeling Approach

As discussed in Section 4, any elements that leach from the road base will continue to migrate through the soil and into the groundwater; in each stage, the chemicals in the leachate could be attenuated by the soil or diluted by the ground water. The factor of dilution and attenuation required by a constituent from the road base to the point of compliance is known at the DAF (dilution attenuation factor), calculated using equation (1) in Section 3. The DAF for each element that leached above the respective threshold is displayed in Table 8-1. The concentrations used to calculate the DAF are based on the highest leaching values received over all LS ratios, so the DAFs outlined in Table 8-1 are the most conservative estimates.

Table 8-1: Dilution and Attenuation factor targets for Mo, Sr, F^- and SO_4^{2-}

Element	GCTL or DWS (mg/L)	Highest leached concentration (mg/L)	Highest leaching blend	Calculated DAF
Mo	0.035	0.238	PG-Sand-Cement	6.8
Sr	4.2	17.7	PG-RCA	4.2
F^-	4	20.7	PG-RCA	5.2
SO_4^{2-}	250	1, 420	PG-RCA	5.7

To ensure the elements leached from the road base demonstration project meet target DAFs and are below groundwater thresholds at an assumed compliance point, the US EPA's IWEM was used to model the fate and transport of contaminants in this assessment. IWEM is often used in state and federal beneficial use decision-making efforts to determine the impact of constituents leaching to groundwater. As mentioned previously, inputs include site-specific parameters such as pollutant concentration, roadway geometry, distance to point of compliance, and rate of water infiltration to pavement. IWEM hosts a national database of hydrogeologic conditions, including depth to groundwater, aquifer pH and thickness, and soil-chemical partitioning coefficients, that the user may select for the model based on site characteristics. Additionally, the database contains climactic information, including annual precipitation and aquifer recharge, for the site under consideration.

To model the emission of constituents from a roadway, the user enters site-specific parameters such as the rate of water infiltration through the pavement, initial constituent concentrations leaching from the base material, and distance to the point of compliance. To accurately model contaminant transport through the subsurface, IWEM hosts a national database of hydrogeologic conditions, including depth to groundwater, aquifer pH and thickness, and soil-chemical partitioning coefficients (see Figure 3-2). Additionally, the database contains climatic information, including annual precipitation and aquifer recharge, for the site under consideration. For a detailed list of inputs used in the IWEM runs for this risk assessment, refer to Section 8.4.

A series of 9 IWEM runs were conducted for varying road base subsections and receptor distances (10 ft, 50 ft, 100 ft). All inputs can be found in Tables 8-2 through 8-3 and model results are listed in Section 8.4. The site-specific values are typical of Polk County, according to a 2006 US Geological Survey (USGS) report titled Hydrology of Polk County, Florida. A hydraulic gradient of 0.00124 m/day and an approximate depth to groundwater of 160 feet were calculated for this location based on two groundwater well locations outlined in the 2006 USGS report. Receptor well distances of 10 ft, 50 ft, and 100 ft from the road were simulated to predict constituent behavior from the PG amended road bases, however the pilot project and monitoring plan are designed to provide the most realistic results. These model runs will reflect constituent concentrations up to 100 feet from the road and how they attenuate while moving through the subsurface environment.

8.2 IWEM Inputs

Along with initial constituent concentrations and partition coefficients, IWEM requires an infiltration rate of leachate leaving the road base and entering the subsurface environment. To estimate leachate infiltration, permeability tests were performed on the compacted road base blends. These permeability measurements were used in the Hydrologic Evaluation of Landfill Performance (HELP) model as discussed in Section 7.0 to estimate plausible conservative infiltration rates to use in the IWEM model.

Once initial concentrations (C_0) and infiltration rates of constituents leaving the road base are established, IWEM allows the user to run the model with default partition coefficient (K_d) values. A complete overview of partition coefficients as related to this demonstration project are outlined in Chapter 6.0. Partition coefficients describe the behavior of a material between liquid and solid phases at equilibrium. Specifically, they assist in estimating the quantity of each constituent that will be sorbed to a solid media; in this case, the constituents in leachate from the road base that will be attenuated by the underlying soil. IWEM contains a catalog of default K_d values based on leachate pH and subsurface environment conditions. However, it is widely understood that relying on default partition coefficients from the literature, which contains a broad range of values for each constituent, is less accurate than using site- and material-specific values (EPA, 1999). Section 6.0 describes assessment of soils local to the pilot project site and derivation of site-specific K_d values. The difference between concentrations before and after soil contact was used to determine K_d values for each constituent.

Table 8-2: IWEM model input parameters and justification for PG-LR test strips

Input	Selection	Justification
Model Source Type	Roadway	-
Test Strip Width	7.31 m (24 ft)	Standard
Number of Layers in Road	2 (pavement, base)	
Layer Thickness	0.102 m (4 in) [pavement] 0.254 m (10 in) [base]	Typical layer thickness
Layer Hydraulic Conductivity	100 m/yr [pavement] 0.691 m/yr [base]	
Layer Bulk Density	2.4 g/cm3 (150 pcf) [pavement] 2.01 g/cm3 (126 pcf) [base]	Laboratory test results
Roadway Segment Length	152.4 m (500 ft)	Parameter
Distance to Point of Compliance	3.05 m (10 ft), 15.24 m (50 ft), 30.5 m (100 ft)	Assumption
Groundwater Flow Angle with Respect to Road	90°	Assumption
Subsurface Environment	Unconsolidated and Semi-consolidated Shallow Aquifer	IWEM default - most representative of shallow surficial aquifer present in Polk County
Depth to Groundwater, Groundwater pH	(9.14 m) 22 ft	Ardaman
Hydraulic Conductivity	(725 m/yr) 6.52 ft/day	Ardaman
Aquifer Thickness	(12.5 m) 41ft	Ardaman
Hydraulic Gradient	2 ft/mile 0.00038 ft/ft	Ardaman
Soil Type	Sandy loam	IWEM default -most representative of soil type in Hillsborough County
Aquifer Recharge Rate	0.103 m/yr (4.05 in/yr)	IWEM default
Infiltration Rate	0.00185 m/yr with evaporation 0.0334 m/yr without evaporation	(University of Florida, 2015)
COPC Input C_o Values	EPA Method 1316 (leaching) (mg/L) Strontium 4.53 Molybdenum 0.068 Fluoride 20.2 Sulfate 1000 EPA Method 3050B (totals) Strontium 754 Molybdenum 0.909 Fluoride 40.4 Sulfate 28	Laboratory test results
Partitioning Coefficients (Kd in L/kg)	Fluoride (4.7) Sulfate (NA) Mo (1.56) Sr (2.67)	Site-specific soil contact experiment
Reference Groundwater Concentrations	EPA Regional Screening Levels National Primary Drinking Water Standards	Most applicable and current risk-based drinking water thresholds

Table 8-3: IWEM model input parameters and justification for PG-RCA test strips

Input	Selection	Justification
Model Source Type	Roadway	-
Test Strip Width	7.31 m (24 ft)	
Number of Layers in Road	2 (asphalt, base)	
Layer Thickness	0.102 m (4 in) [pavement] 0.254 m (10 in) [base]	Typical layer thickness
Layer Hydraulic Conductivity	100 m/yr [asphalt pavement] 2.16 m/yr [base]	
Layer Bulk Density	2.4 g/cm3 (150 pcf) [pavement] 1.95 g/cm3 (121.8 pcf) [base]	Laboratory test results
Roadway Segment Length	60.96 m (200 ft)	parameter
Distance to Point of Compliance	3.05 m (10 ft), 15.24 m (50 ft), 30.5 m (100 ft)	Assumption
Groundwater Flow Angle with Respect to Road	90°	Assumption
Subsurface Environment	Unconsolidated and Semi-consolidated Shallow Aquifer	IWEM default - most representative of shallow surficial aquifer present in Polk County
Depth to Groundwater, Groundwater pH	(9.14 m) 22 ft	Ardaman
Hydraulic Conductivity	6.52 ft/day	Ardaman
Aquifer Thickness	41ft	Ardaman
Hydraulic Gradient	2 ft/mile 0.00038 ft/ft	Ardaman
Soil Type	Sandy loam	IWEM default -most representative of soil type in Hillsborough County
Aquifer Recharge Rate	0.103 m/yr (4.05 in/yr)	IWEM default
Infiltration Rate	0.0063 m/yr with evaporation 0.086 m/yr without evaporation	(University of Florida, 2015)
COPC Input C_o Values	EPA Method 1316 (leaching) (mg/L) Strontium 17.7 Molybdenum 0.123 Fluoride 20.7 Sulfate 1000 EPA Method 3050B (Total) (mg/kg) Strontium 252 Molybdenum 1.66 Fluoride 40.4 Sulfate 2580	Laboratory test results
Partitioning Coefficients (Kd in L/kg)	Fluoride (NA) Sulfate (1.84) Mo (0.696) Sr (1.89)	Site-specific soil contact experiment
Reference Groundwater Concentrations	EPA Regional Screening Levels or National Primary Drinking Water Standards	Most applicable and current risk-based drinking water thresholds

Table 8-4: IWEM model input parameters and justification for PG-sand/cement test strips

Input	**Selection**	**Justification**
Model Source Type	Roadway	-
Test Strip Width	7.31 m (24 ft)	
Number of Layers in Road	2 (asphalt, base)	
Layer Thickness	0.102 m (4 in) [pavement] 0.254 m (10 in) [base]	Typical layer thickness
Layer Hydraulic Conductivity	100 m/yr [asphalt pavement] 2.16 m/yr [base]	
Layer Bulk Density	2.4 g/cm3 (150 pcf) [pavement] 1.82 g/cm3 (114.0 pcf) [base]	Standard value for asphalt pavement Proctor compaction dry density for base and subbase
Roadway Segment Length	60.96 m (200 ft)	Assumption
Distance to Point of Compliance	3.05 m (10 ft), 15.24 m (50 ft), 30.5 m (100 ft)	Assumption
Groundwater Flow Angle with Respect to Road	90°	Assumption
Subsurface Environment	Unconsolidated and Semi-consolidated Shallow Aquifer	IWEM default - most representative of shallow surficial aquifer present in Polk County
Depth to Groundwater, Groundwater pH	(9.14 m) 22 ft	Ardaman
Hydraulic Conductivity	6.52 ft/day	Ardaman
Aquifer Thickness	41ft	Ardaman
Hydraulic Gradient	2 ft/mile or 0.00038 ft/ft	Ardaman
Soil Type	Sandy loam	IWEM default -most representative of soil type in Hillsborough County
Aquifer Recharge Rate	0.103 m/yr (4.05 in/yr)	IWEM default
Infiltration Rate	0.0063 m/yr with evaporation 0.086 m/yr without evaporation	(University of Florida, 2015)
COPC Input C_o Values	EPA Method 1316 (leaching) (mg/L) Strontium 5.08 Molybdenum 0.238 Fluoride 4.9 Sulfate 1000 EPA Method 3050B (Total) (mg/kg) Strontium 162 Molybdenum 4.5 Fluoride 9.8 Sulfate 2580	Laboratory test results
Partitioning Coefficients (Kd in L/kg)	Fluoride (NA) Sulfate (NA) Mo (NA) Sr (NA)	Site-specific soil contact experiment
Reference Groundwater Concentrations	EPA Regional Screening Levels or National Primary Drinking Water Standards	Most applicable and current risk-based drinking water thresholds

8.3 IWEM Results

Results of the IWEM analysis for each potential element of concern investigated are displayed in table 8-5 to 8-7. Three receptor location scenarios were modeled: 100 ft, 50 ft, and 10 ft from the roadway. It is highly unlikely that no evaporation will occur, so results assume evaporation and are reported here. The IWEM generated reported for the PG:LR models are included in appendix D.

Table 8-5: IWEM 90th percentile concentrations for PG-LR blends in road base at receptor distances of 10, 50, and 100 ft

Modeled Infiltration Scenarios	
COPC	**90th Percentile Concentration at Receptor Location 10ft from Road (mg/L)**
Molybdenum	0.000062
Strontium	8.81E-06
Fluoride	07.58E-08
Sulfate	0.0041
COPC	**90th Percentile Concentration at Receptor Location 50ft from Road (mg/L)**
Molybdenum	0.0000146
Strontium	1.06E-06
Fluoride	8.56E-08
Sulfate	0.0157
COPC	**90th Percentile Concentration at Receptor Location 100ft from Road (mg/L)**
Molybdenum	1.1E-04
Strontium	7.91E-06
Fluoride	4.06E-08
Sulfate	0.0139

Table 8-6: IWEM 90th percentile concentrations for PG-RCA blends in road base at receptor distances of 10, 50, and 100 ft

Modeled Infiltration Scenarios	
COPC	**90th Percentile Concentration at Receptor Location 10ft from Road (mg/L)**
Molybdenum	0.0018
Strontium	0.19
Fluoride	0.22
Sulfate	0.705
COPC	**90th Percentile Concentration at Receptor Location 50ft from Road (mg/L)**
Molybdenum	0.00624
Strontium	0.433
Fluoride	1.17
Sulfate	1.33
COPC	**90th Percentile Concentration at Receptor Location 100ft from Road (mg/L)**
Molybdenum	0.00448
Strontium	0.327
Fluoride	0.779
Sulfate	0.939

Table 8-7: IWEM 90th percentile concentrations for PG-sand-cement blends in road base at receptor distances of 10, 50, and 100 ft

Modeled Infiltration Scenarios	
COPC	**90th Percentile Concentration at Receptor Location 10ft from Road (mg/L)**
Molybdenum	0.00272
Strontium	0.0861
Fluoride	0.100
Sulfate	29.2
COPC	**90th Percentile Concentration at Receptor Location 50ft from Road (mg/L)**
Molybdenum	0.0143
Strontium	0.262
Fluoride	0.217
Sulfate	49.3
COPC	**90th Percentile Concentration at Receptor Location 100ft from Road (mg/L)**
Molybdenum	0.00947
Strontium	0.220
Fluoride	0.185
Sulfate	41.4

8.4 Comparison to GCTLs

None of the constituents of potential concern (fluoride, sulfate, molybdenum, strontium) exceeded water quality thresholds at 10ft, 50ft, or 100ft from the road from any of the evaluated mix designs. The IWEM parameters selected assume conservative site-specific conditions and predicted partitioning coefficients provide a conservative estimate of constituent concentrations at these point of compliance locations. The purpose of the pilot project and monitoring plan is to evaluate the realistic mobility of these constituents and evaluate behavior at the site, both directly from the base as assessed by lysimeter sampling and into the groundwater as assessed by groundwater monitoring well collection.

9.0 Monitoring

To monitor the road construction and performance, physical testing will occur during and after construction, including density checks, field LBR tests, and installation and monitoring of metal deflection strips. Density checks will be performed after laying each base course to ensure sufficient compaction, and field LBR tests will be employed to assess the consistency of bearing strength within each test section. The road will also be monitored throughout the lifespan for visual performance indicators such as cracking, rutting, and shoving.

To support site-specific constituent fate and transport modeling, the depth to groundwater and the hydraulic gradient was determined prior to constructing the road, and this data was incorporated in modeling as described in Section 8.0. Soil samples adjacent to the road at the northern- and southern- most ends were taken to determine site-specific constituent partitioning and risk characterizations. Details regarding soil characteristics can be found in Section 6.2. A total of 24 monitoring wells for periodic groundwater sampling for environmental analysis have been installed according to FDEP specifications upgradient and downgradient of the road at each of the eight test sections and will be sampled from before and after road construction. These wells were designed based on permanence, installation methodology, and well construction requirements as outlined by the FDEP Monitoring Well Design and Construction Guidance Manual (FDEP, 2008).

These monitoring wells will provide data on the constituent concentrations in the groundwater at a selected point of compliance prior to road installation that can be compared to data collected after construction to assess any impact on the groundwater from the demonstration road. Characteristics such as pH, turbidity, and oxidation reduction potential (ORP) will be analyzed on site at the time of collection from each of the 24 wells. There will be three monitoring wells for each test section, one upgradient and two downgradient. Four initial wells were installed to determine the regional hydraulic gradient, these will then also serve as monitoring wells for test sections. The well locations for these initial wells and the monitoring wells for each subsection are displayed in Figure 9-1.

In addition to the monitoring wells, one lysimeter will be installed in each test section of the road under the road base to collect leachate from the base for environmental analysis. The eight lysimeters will collect leachate from the base layer and lead it outwards from the road to be accumulated in a reservoir on the road shoulder. The collection system will consist of a 6-inch deep 1-foot wide trench filled with gravel, holding a 2-inch schedule 40 PVC pipe. The trench will originate in the center of the road and lead outwards towards the shoulder, following the slope of the pavement. The trench will be 12 feet long, the width of one lane of the road base. The lysimeters will be comprised of a drainage 200 mil geo-composite and 30 mil PVC liner underlying the base under which will be a trench containing a PVC pipe surrounded by gravel. The lysimeter will occupy a 40ft length of one lane of each test section. The trench will be oriented such that the pipe will slope outwards from the center of the lane to a collection vessel following the slope of the pavement. The current lysimeter design is shown on Pages 10-

12 of the most recent drawing set in Appendix E. Monitoring will occur quarterly for 18 months where upon monitoring frequency will be reassessed based on project needs.

Constituents evaluated from the monitoring wells and lysimeters include pH, ORP, turbidity, heavy metal and anion concentration, and radionuclide concentrations. Samples will be tested at a certified NELAP lab. An overview of sampling types, locations, and analytes measured are displayed in Table 9-1. **Table 9-1.** Monitoring samples (groundwater, lysimeter, and soil), analytes measured, and frequency of measurement for the pilot project road at Mosaic's Mulberry site.

Sample Type	**Analytes Measured**	**Frequency**
Background Groundwater Sample from all 24 wells	pH, ORP, tubidity, Al, As, Ba, B, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mn, Mg, Na, Sb, Sr, Sn, V, Zn, F^0, SO_4^{2-}(mg/L), Ra^{226} (pCi/L)	Twice prior to road implementation.
Groundwater Sample from all 24 wells	pH, ORP, tubidity, Al, As, Ba, B, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mn, Mg, Na, Sb, Sr, Sn, V, Zn, F^0, SO_4^{2-}(mg/L), Ra^{226} (pCi/L)	Immediately following road implementation; quarterly for 18 months.
Lysimeter sampling from all 8 lysimeters	pH, ORP, tubidity, Al, As, Ba, B, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mn, Mg, Na, Sb, Sr, Sn, V, Zn, F^0, SO_4^{2-}(mg/L), Ra^{226} (pCi/L)	Quarterly following road implementation for 18 months.
Background soil samples adjacent to North and South points of the road	Al, As, Ba, B, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mn, Mg, Na, Sb, Sr, Sn, V, Zn (mg/kg), Ra^{226} (pCi/kg)	Prior to road implementation.
Soil samples adjacent to North and South points of the road.	Al, As, Ba, B, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mn, Mg, Na, Sb, Sr, Sn, V, Zn (mg/kg), Ra^{226} (pCi/kg)	Following 18-month monitoring period.

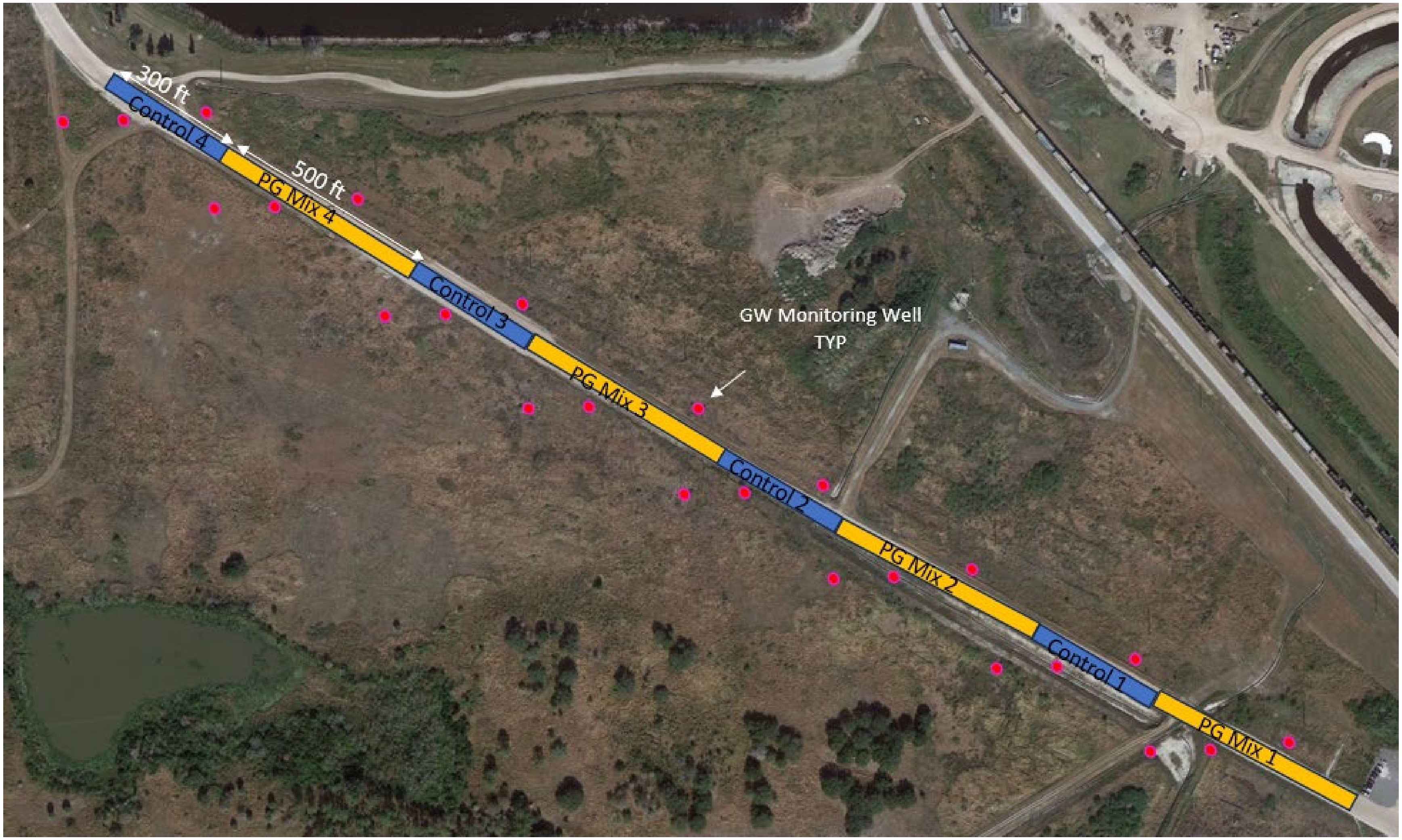

Figure 9-1: Groundwater monitoring well locations for each road base subsection

10.0 Summary of Demonstration Project and Risk Mitigation

Mosaic is investigating the reuse potential of PG from its New Wales facility as a constituent in road base in four scenarios: PG-LR, PG- RCA, PG-RAP, and PG-sand-cement. Based on results from past testing, the demonstration project will incorporate aged PG from a New Wales facility gypstack designated as "PG B Old", which presented the lowest leaching-to-groundwater risk and performed well when blended with the four chosen materials (limerock, recycled concrete aggregate, recycled asphalt pavement, and a sand-cement mix) in preliminary limerock bearing ratio (LBR) testing. The aggregate materials used were sourced from FDOT-approved facilities proximal to the demonstration site for ease of transport during construction of the pilot road.

Mosaic has identified a location for demonstrating the feasibility of recycling its PG as a road base material. A 3,200-ft paved roadway at Mosaic's New Wales facility has been selected for the demonstration project, with PG incorporated into the base layer beneath the asphalt surface. The road will be composed of four test strips, each 500 ft long, and four controls, each 300 ft long, incorporating mix designs including PG-LR, PG-RCA, PG-RAP, and PG-sand-cement blends, and corresponding control strips with LR, RCA, sand-RAP, or sand-cement base without PG.

Because PG is a manufacturing byproduct proposed for beneficial use, the potential risk to human health and the environment was evaluated. Two risk pathways were assessed: direct exposure and leaching-to-groundwater. The site location (private property owned by Mosaic) and the method of PG reuse (encapsulation under pavement and blending with aggregates or sand-cement) mitigate the direct exposure pathway. The average concentrations of all constituents tested were below the FDEP direct exposure SCTL for commercial and industrial settings with the exception of As, which narrowly exceeded screening thresholds in PG and RCA. Leaching-to-groundwater risk was assessed using a combination of established laboratory leaching procedures and fate and transport modeling. Leaching tests indicated that most constituents leached from the PG-LR, PG-RCA, PG-RAP, and PG-sand-cement mixes at concentrations below FDEP's risk-based groundwater cleanup target levels (GCTLs). The four elements that leached above the GCTL for one or more mixes are fluoride, sulfate, molybdenum, and strontium. The EPA historically restricted the use of PG based out of concern with naturally occurring radioactive material (NORM) in PG. Radium was not found to leach above the GCTL from any of the PG-aggregate blends, however, only LS 5 and 10 were tested for radium. It should be noted that the potential for leaching to groundwater or surface water has been previously considered by the USEPA and others and found to present negligible risk. (see for example Appendix 2 Section E of the Petition).

Once these constituents of concern were identified using regulatory screening tools, additional soil partitioning and fate and transport modeling were evaluated to assess predicted dilution and attenuation of leaching risk from the surrounding environment. Based on modeling with laboratory-derived site-specific partition coefficients, the constituents F-, SO42-, Mo, and

Sr will be attenuated to some degree in both the underlying soil and during their transport through the aquifer. Fate and transport modeling with IWEM using aquifer conditions typical of Polk County indicate that all constituents will be reduced to well below risk thresholds at 100 ft from the road via dilution and attenuation.

The results of this evaluation demonstrate that “PG B Old” sourced from Mosaic’s New Wales gypstack, when combined at a 50/50 ratio with LR, RCA, RAP, and a 43-7 blend of sand-cement, and when recycled in a manner consistent with the procedures and constraints identified in this report, will not pose a threat to human health and the environment. Direct human exposure should not be a concern because the PG is encapsulated under a paved surface, diluted with aggregate material, and is on county-controlled property. While some elements leach above health-based thresholds, based on site-specific partitioning coefficients and surficial aquifer conditions, these elements should be diluted and attenuated to safe concentrations at distances 100 ft or less from the roadway.

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Appendix A: Total Element Concentrations in Aggregate Materials

Table A-1: Mean total element concentrations in aggregate materials chosen for pilot road.

Constituent	Commercial/Industrial SCTL (mg/kg-dry)	Limerock (mg/kg-dry)	RCA (mg/kg-dry)	RAP (mg/kg-dry)
Al	-	515	5,570	3,030
As	12	0.537	2.51	0.663
B	430,000	2.76	31.4	6.08
Ba	130,000	2.85	57.3	18.8
Be	1,400	0.100	0.253	0.163
Ca	-	441,000	123,000	20,000
Cd	1,700	0.100	0.200	0.328
Co	42,000	0.430	2.36	7.14
Cr	470	7.44	14.8	9.71
Cu	89,000	14.0	14.6	2,800
Fe	-	321	7,040	1,040
K	-	69.8	696	2,690
Mg	-	3,400	16,400	16.8
Mn	43,000	7.45	118	0.643
Mo	11,000	0.267	1.76	149
Na	-	208	415	9.9
Ni	35,000	1.25	6.25	0.230
Pb	1,400	0.400	26.5	0.156
Sb	370	0.300	0.300	0.250
Se	11,000	0.713	0.740	1.64
Sn	880,000	1.24	1.28	26.0
Sr	-	1,250	246	28.0
V	10,000	3.11	16.4	33.6
Zn	630,000	3.87	174	3,030

Table A-2: Theoretical total element concentrations in 50-50 PG blends.

Constituent	Commercial /Industrial SCTL (mg/kg-dry)	PG-LR 50-50 Mix Design (mg/kg-dry)	PG-RCA 50-50 Mix Design (mg/kg-dry)	PG-Sand/Cement 50-50 Mix Design (mg/kg-dry)	PG-RAP 50-50 Mix Design (mg/kg-dry)
Al	-	733	3,260	3,200	1,990
As	12	1.23	2.22	2.60	1.29
B	430,000	5.79	20.1	4.71	7.45
Ba	130,000	14.8	42.0	28.7	22.8
Be	1,400	0.100	0.177	0.160	0.132
Ca	-	257,000	97,500	66,000	46,000
Cd	1,700	0.100	0.150	0.166	0.214
Cr	470	6.325	10.0	7.09	6.18
Cu	89,000	7.40	7.70	21.3	5.26
Fe	-	1,590	4,950	2570	2,830
K	-	157	471	142	643
Mg	-	1,700	8,200	291	1,350
Mn	43,000	6.56	61.8	8.81	11.2
Mo	11,000	0.909	1.66	4.50	1.10
Na	-	170	274	79.7	140
Ni	35,000	0.690	3.19	2.08	5.03
Pb	1,400	1.90	14.9	5.97	1.81
Sb	370	0.424	0.424	0.552	0.351
Se	11,000	0.668	0.682	0.448	0.437
Sn	880,000	0.882	0.902	1.19	1.08
Sr	-	754	252	162	141
V	10,000	2.27	8.91	4.79	14.7
Zn	630,000	3.24	88.3	26.3	18.1

Table A-3: Total element concentrations in Soils 1-5

Constituent	Commercial/Industrial SCTL (mg/kg-dry)	Soil 1	Soil 2	Soil 3	Soil 4	Soil 5
Al	-	9431	6615	1135	1918	1670
As	12	2.01	0.600	6.26	0.407	1.35
B	430,000	7.33	2.26	11.1	4.15	4.95
Ba	130,000	79.4	53.3	15.8	9.03	16.0
Be	1,400	0.423	0.190	0.187	0.100	0.220
Ca	-	31200	3230	32000	1610	24700
Cd	1,700	0.393	0.100	0.543	0.100	0.230
Co	42,000	0.770	0.303	0.543	0.190	0.587
Cr	470	18.3	9.66	7.62	2.15	7.02
Cu	89,000	1640	1.15	1.32	1.28	0.440
Fe	-	212	538	3150	1260	995
K	-	1730	63.9	158	35.3	192
Mg	-	23.7	145	187	101.2	412
Mn	43,000	0.983	4.34	19.5	4.72	22.3
Mo	11,000	440	0.323	2.57	0.300	0.720
Na	-	4.23	50.3	406	38.0	347
Ni	35,000	3.44	2.57	1.69	1.06	2.09
Pb	1,400	0.277	5.90	1.67	1.83	1.86
Sb	370	0.307	0.300	0.353	0.410	0.437
Se	11,000	0.883	0.200	0.743	0.200	0.200
Sn	880,000	239	0.663	0.617	0.653	0.553
Sr	-	14.7	96.6	118	18.1	95.1
V	10,000	14.7	4.98	9.11	2.27	8.69
Zn	630,000	6.24	1.94	6.83	2.57	5.88

Table A-4: Total element concentrations in Soils 6-10

Constituent	Commercial/Industrial SCTL (mg/kg-dry)	Soil 6	Soil 7	Soil 8	Soil 9	Soil 10
Al	-	6380	4490	9460	6910	2970
As	12	1.46	0.769	0.018	0.668	0.340
B	430,000	6.34	6.01	2.19	5.78	4.65
Ba	130,000	42.0	2.20	17.0	8.97	34.3
Be	1,400	0.307	<	15.6	3.27	31.9
Ca	-	24300	0.02	0.098	0.080	0.404
Cd	1,700	0.300	27.7	141	28500	5900
Co	42,000	0.590	0.064	0.016	0.084	0.204
Cr	470	13.8	10.1	11.0	11.0	7.58
Cu	89,000	2.17	05.3	11.0	16.6	15.0
Fe	-	1340	4830	1600	4500	909
K	-	248	19.4	60.5	120	152
Mg	-	812	41.3	184	393	435
Mn	43,000	18.6	0.614	1.92	6.37	77.9
Mo	11,000	0.830	0.526	0.220	0.878	0.330
Na	-	352	13.9	32.2	33.3	37.6
Ni	35,000	2.65	0.350	1.99	0.962	1.86
Pb	1,400	2.12	1.89	4.55	3.59	15.2
Sb	370	0.613	0.174	0.068	0.030	0.276
Se	11,000	0.200	0.566	0.188	0.320	0.448
Sn	880,000	0.647	0.632	0.940	0.860	1.10
Sr	-	145	2.02	4.56	35.1	37.1
V	10,000	11.6	17.2	25.7	22.6	2.18
Zn	630,000	5.24	1.50	2.84	3.23	72.0

Appendix B: Supplementary Leaching Data

Table B-1: Average leachate concentrations for 50-50 PG-LR mix designs as a function of LS ratio.

Constituent	Residential GCTL (mg/L)	LS Ratio				
		1	2	5	10	20
pH	-	7.46	7.58	7.87	7.80	7.39
Al	7	0.133	0.054	0.152	0.209	0.112
As	0.01	0.009	< 0.004	< 0.004	< 0.004	< 0.004
B	1.4	0.038	0.029	0.021	< 0.01	< 0.01
Ba	2	0.030	0.028	0.026	0.015	0.009
Be	0.004	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Ca	-	738	743	744	689	693
Cd	0.005	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	0.1	0.007	0.007	< 0.002	< 0.002	< 0.002
Cu	1	0.009	0.006	0.009	0.008	0.007
Fe	0.3	0.186	0.031	0.081	0.046	0.026
Mg	-	10.3	6.33	2.86	1.32	0.859
Mn	0.050	0.012	0.007	0.004	0.003	0.003
Mo	0.035	**0.068**	**0.043**	0.018	0.009	< 0.003
Na	160	4.70	3.30	1.90	1.03	0.800
Ni	0.1	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Pb	0.015	< 0.004	0.008	< 0.004	< 0.004	< 0.004
Sb	0.006	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Se	0.05	0.007	0.007	0.008	0.005	0.006
Sn	4.2	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Sr	4.2	**4.53**	3.62	2.51	1.96	1.78
V	0.049	< 0.001	0.007	0.007	0.007	0.007
Zn	5	0.006	0.019	0.013	0.009	0.006
Ra-226	5	-	-	2.2	1.9	-
Cl-	250	30.2	28.6	28.1	27.7	27.5
F-	2	**20.2**	**18.3**	**18.1**	**17.0**	**15.4**
SO42-	250	**1,070**	**1,090**	**1,160**	**1,290**	**1,290**

Table B-2: Average leachate concentrations for 50-50 PG-RCA mix designs as a function of LS ratio.

Constituent	Residential GCTL (mg/L)	LS Ratio				
		1	2	5	10	20
pH	-	9.75	10.14	10.24	10.42	10.22
Al	7	1.18	0.244	0.435	0.406	0.574
As	0.01	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
B	1.4	0.024	< 0.01	< 0.01	< 0.01	< 0.01
Ba	2	0.178	0.143	0.138	0.134	0.081
Be	0.004	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Ca	-	707	601	670	725	708
Cd	0.005	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	0.1	**0.115**	0.059	0.041	0.019	0.014
Cu	1	0.072	0.048	0.027	0.013	0.013
Fe	0.3	**0.557**	0.049	0.037	0.034	0.039
Mg	-	1.38	s1.22	1.16	0.860	0.712
Mn	0.050	0.004	< 0.001	< 0.001	< 0.001	< 0.001
Mo	0.035	**0.122**	**0.069**	**0.038**	0.021	0.011
Na	160	45.2	23.3	12.3	6.61	3.63
Ni	0.1	0.015	0.008	0.003	< 0.001	< 0.001
Pb	0.015	0.010	< 0.004	< 0.004	< 0.004	< 0.004
Sb	0.006	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Se	0.05	0.010	0.009	0.005	0.006	0.004
Sn	4.2	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Sr	4.2	**17.7**	**12.5**	**9.12**	**6.45**	4.12
V	0.049	0.003	0.003	0.005	0.003	0.005
Zn	5	0.012	0.010	0.008	0.0050	0.00
Ra-226	5	-	-	1.3	1.3	-
Cl-	250	32.1	30.3	28.8	28.3	29.1
F-	2	**14.3**	**15.2**	**19.6**	**20.7**	**18.6**
SO42-	250	**1,200**	**1,180**	**1,270**	**1,420**	**1,270**

Table B-3: Average leachate concentrations for 50-50 PG-sand/cement mix designs as a function of LS ratio.

Constituent	Residential GCTL (mg/L)	LS Ratio				
		1	2	5	10	20
pH	-	12.46	12.40	12.38	12.15	11.92
Al	7	0.754	0.43	1.36	0.044	0.032
As	0.01	0.008	0.008	0.008	0.008	0.004
B	1.4	0.004	0.002	0.006	0.012	0.004
Ba	2	0.08	0.084	0.07	0.06	0.052
Be	0.004	0.002	0.002	0.002	0.002	0.002
Ca	-	2,260	2,440	1,990	1,640	1,490
Cd	0.005	0.002	0.002	0.002	0.002	0.002
Cr	0.1	**0.290**	**0.274**	**0.168**	0.078	0.044
Cu	1	0.008	0.006	0.006	0.004	0.004
Fe	0.3	**0.668**	**0.308**	1.32	0.026	0.02
K	-	32.8	25.2	9.76	5.26	3.06
Mg	-	0.162	0.14	0.27	0.288	0.182
Mn	0.050	0.002	0.002	0.002	0.002	0.002
Mo	0.035	**0.238**	**0.224**	**0.136**	**0.062**	0.034
Na	160	17.52	13.46	5.64	3.16	1.868
Ni	0.1	0.008	0.006	0.004	0.002	0.002
Pb	0.015	0.008	0.008	0.008	0.008	0.008
Sb	0.006	0.006	0.006	0.006	0.006	0.006
Se	0.05	0.006	0.004	0.004	0.004	0.004
Sn	4.2	0.004	0.004	0.004	0.004	0.004
Sr	4.2	**5.08**	**4.48**	2.52	1.47	1.064
V	0.049	0.002	0.002	0.002	0.002	0.002
Zn	5	0.062	0.066	0.058	0.06	0.056
Cl-	250	41.6	39.7	41.3	37.8	37.6
F-	2	**4.23**	**4.22**	**4.90**	**4.08**	**3.60**
SO42-	250	**1,150**	**1,160**	**1,230**	**1,260**	**1,300**

Table B-4: Average leachate concentrations for 50-50 PG-RAP mix designs as a function of LS ratio

Constituent	Residential GCTL (mg/L)	LS Ratio				
		1	2	5	10	20
pH	-		7.66	7.86	7.73	7.74
Al	7		0.1955	0.1697	0.23225	0.18935
As	0.01		0.004	0.004	0.004	0.004
B	1.4		0.0387	0.01215	0.01	0.01
Ba	2		0.0269	0.0299	0.02885	0.0244
Be	0.004		0.001	0.001	0.001	0.001
Ca	-		657.6	684.8	690.6	713.8
Cd	0.005		0.001	0.001	0.001	0.001
Cr	0.1		0.002	0.005	0.00275	0.00335
Cu	1		0.0164	0.00375	0.00605	0.00445
Fe	0.3		0.0084	0.00785	0.00415	0.0031
Mg	-		6.743	3.0905	1.675	1.00965
Mn	-		0.0193	0.00885	0.00555	0.0595
Mo	0.05		**0.0715**	0.0253	0.0128	0.00615
Na	0.035		3.4755	1.771	1.238	0.9418
Ni	160		0.0086	0.0033	0.0028	0.0033
Pb	0.1		0.004	0.004	0.004	0.004
Sb	0.015		0.00735	0.0037	0.00315	0.0033
Se	0.006		0.00545	0.00465	0.002	0.00265
Sn	0.05		0.002	0.002	0.002	0.002
Sr	4.2		**3.8515**	**2.272**	**1.713**	1.5415
V	4.2		0.91355	0.3278	0.29675	0.1795
Zn	0.049		0.00675	0.00635	0.0065	0.00875
Ra-226	5					
Cl-	250				0.02277	
F-	2				**23.252**	
SO42-	250				**2,004**	

Table B-5: Average leached element concentrations for LR and RCA leached with DI water at an LS ratio of 10.

Constituent	Residential GCTL (mg/L)	Limerock Mean Concentrations (mg/L)	RCA Mean Concentrations (mg/L)
pH	-	9.44	11.72
Al	7	0.120	1.61
As	0.01	0.002	0.001
B	1.4	0.009	0.002
Ba	2	0.001	0.112
Be	0.004	0.001	0.001
Ca	-	4.71	196
Cd	0.005	0.001	0.001
Cr	0.1	0.004	0.029
Cu	1	0.002	0.022
Fe	0.3	0.002	0.002
K	-	0.100	16.4
Mg	-	0.898	0.068
Mn	0.050	0.001	0.001
Mo	0.035	0.003	0.010
Na	160	0.732	9.98
Ni	0.1	0.001	0.001
Pb	0.015	0.004	0.004
Sb	0.006	0.003	0.003
Se	0.05	0.002	0.002
Sn	4.2	0.001	0.001
Sr	4.2	0.208	1.59
V	0.049	0.002	0.001
Zn	5	0.002	0.001
Cl-	250	11.4	13.3
F-	2	BDL	BDL
SO42-	250	8.59	46.3

Table B-6a: Leached constituents from PG-LR bulk leachate before and after contact with soils.

Constituent	Residential GCTL (mg/L)	Original PG-LR Leachate	PG-LR Bulk Leachate Contacted With:				
			Soil 1	Soil 2	Soil 3	Soil 4	Soil 5
pH	-	7.71	6.88	7.41	6.86	7.28	7.75
Al	7	0.128	0.949	0.729	0.330	1.29	0.999
As	0.01	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
B	1.4	0.177	0.185	0.165	0.159	0.150	0.162
Ba	2	0.014	0.006	0.011	0.007	0.029	0.027
Be	0.004	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Ca	-	790	759	698	690	704	711
Cd	0.005	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	0.1	< 0.002	0.005	< 0.002	0.005	< 0.002	< 0.002
Cu	1	0.006	0.008	0.007	0.008	0.011	0.012
Fe	0.3	0.087	0.097	**0.310**	0.191	0.157	0.214
K		0.503	0.471	0.405	0.430	0.559	0.509
Mg	-	1.63	3.78	1.87	1.84	6.48	3.24
Mn	0.050	0.008	0.008	0.003	0.015	0.008	0.011
Mo	0.035	0.012	0.013	0.012	0.012	0.011	0.011
Na	160	0.767	1.13	1.78	0.767	0.829	0.800
Ni	0.1	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Pb	0.015	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Sb	0.006	< 0.003	< 0.003	< 0.003	**0.007**	**0.007**	**0.008**
Se	0.05	0.012	0.005	0.007	0.006	0.010	0.010
Sn	4.2	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Sr	4.2	2.17	1.82	1.94	1.83	1.85	1.93
V	0.049	0.012	0.032	0.007	0.007	0.021	0.021
Zn	5	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Ra-226	5	1.5	0.5	1.7	0.4	2.8	2.0
Cl-	250	22.1	20.3	21.2	22.9	23.8	21.3
F-	2	**26.9**	**11.3**	**25.6**	**27.5**	**21.8**	**23.8**
SO42-	250	**1,730**	**1,790**	**1,750**	**1,870**	**1,720**	**1,760**

Table B-6b: Cont'd: Leached constituents from PG-LR bulk leachate before and after contact with soils.

Constituent	Residential GCTL (mg/L)	Original PG-LR Leachate	PG-LR Bulk Leachate Contacted With:				
			Soil 6	Soil 7	Soil 8	Soil 9	Soil 10
pH	-	7.71	7.39	6.75			
Al	7	0.128	0.317	0.355	1.54	0.814	0.178
As	0.01	< 0.004	< 0.004	0.011	0.006	0.014	0.045
B	1.4	0.177	0.167	0.022	0.026	0.028	0.028
Ba	2	0.014	0.022	0.055	0.186	0.121	0.093
Be	0.004	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Ca	-	790	723	686	630	686	624
Cd	0.005	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	0.1	< 0.002	< 0.002	0.009	0.010	0.008	0.005
Cu	1	0.006	0.009	0.002	0.007	0.002	0.002
Fe	0.3	0.087	0.078	0.002	0.214	0.044	0.002
K		0.503	0.581	3.72	3.89	4.81	5.82
Mg	-	1.63	7.11	7.35	11.9	10.3	18.1
Mn	0.050	0.008	0.005	0.049	0.090	0.025	0.001
Mo	0.035	0.012	0.012	0.028	0.028	0.033	0.014
Na	160	0.767	0.841	52.3	49.8	50.9	48.1
Ni	0.1	< 0.001	< 0.001	0.062	0.054	0.011	< 0.001
Pb	0.015	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Sb	0.006	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Se	0.05	0.012	0.010	0.003	0.003	0.004	0.002
Sn	4.2	< 0.002	< 0.002	< 0.002	0.005	0.003	< 0.002
Sr	4.2	2.17	1.90	3.94	3.54	3.65	3.23
V	0.049	0.012	0.018	0.001	0.005	0.001	0.001
Zn	5	< 0.001	< 0.001	0.004	0.006	< 0.001	0.057
Ra-226	5	1.5	2.1				
Cl-	250	22.1	21.9	15.7	15.6	17.1	15.3
F-	2	**26.9**	**19.8**	**15.1**	**11.2**	**15.2**	**9.95**
SO42-	250	**1,730**	**1,740**	**1,570**	**1,540**	**1,560**	**1,570**

Table B-7a: Leached constituents from PG-RCA bulk leachate before and after contact with soils.

Constituent	Residential GCTL (mg/L)	Original PG-RCA Leachate	PG-RCA Bulk Leachate Contacted With:				
			Soil 1	Soil 2	Soil 3	Soil 4	Soil 5
pH	-	9.75	6.69	8.19	7.38	8.17	8.93
Al	7	0.320	0.359	1.12	0.132	0.548	0.727
As	0.01	0.008	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
B	1.4	0.020	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ba	2	0.067	0.010	0.038	0.021	0.045	0.057
Be	0.004	0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Ca	-	634	587	602	578	563	619
Cd	0.005	0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	0.1	0.029	0.027	0.028	0.024	0.025	0.030
Cu	1	0.010	0.004	0.004	0.008	0.008	0.010
Fe	0.3	0.036	0.081	**0.508**	0.186	0.069	0.101
K		10.3	9.08	9.63	8.97	8.84	10.0
Mg	-	1.24	3.07	1.56	1.59	5.88	2.64
Mn	0.050	< 0.001	0.007	< 0.001	0.007	< 0.001	< 0.001
Mo	0.035	0.022	0.021	0.021	0.021	0.021	0.022
Na	160	5.78	5.83	6.52	5.45	5.44	5.85
Ni	0.1	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Pb	0.015	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Sb	0.006	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Se	0.05	0.004	0.005	< 0.002	0.005	< 0.002	0.005
Sn	4.2	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Sr	4.2	4.10	3.11	3.76	3.54	3.41	3.91
V	0.049	< 0.001	0.021	0.005	< 0.001	< 0.001	0.006
Zn	5	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Ra-226	5	1.2	1.5	1.0	1.3	6.2	4.0
Cl-	250	16.5	29.1	17.0	13.5	13.7	14.8
F-	2	**9.47**	**12.6**	**18.9**	**16.8**	**15.8**	**19.6**
SO42-	250	**1,650**	**1,580**	**1,540**	**1,560**	**1,540**	**1,560**

Table B-7b: Cont'd: Leached constituents from PG-RCA bulk leachate before and after contact with soils.

Constituent	Residential GCTL (mg/L)	Original PG-RCA Leachate	PG-RCA Bulk Leachate Contacted With:				
			Soil 6	Soil 7	Soil 8	Soil 9	Soil 10
pH	-	9.75	8.19	6.32	5.45	8.06	9.45
Al	7	0.320	0.46	2.18	13.0	0.170	2.04
As	0.01	0.008	< 0.004	< 0.004	0.006	0.006	< 0.004
B	1.4	0.020	< 0.01	0.035	0.038	0.027	0.033
Ba	2	0.067	0.044	0.037	0.115	0.077	0.060
Be	0.004	0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Ca	-	634	582	1,140	1,170	1,250	1,210
Cd	0.005	0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	0.1	0.029	0.028	0.008	0.004	0.011	0.003
Cu	1	0.010	0.007	0.014	0.004	0.007	0.004
Fe	0.3	0.036	0.081	0.121	8.14	0.038	0.252
K		10.3	9.23	31.1	33.9	38.14	42.1
Mg	-	1.24	5.76	9.29	17.6	13.6	34.3
Mn	0.050	< 0.001	< 0.001	0.006	0.019	0.002	0.005
Mo	0.035	0.022	0.020	0.029	0.021	0.049	0.014
Na	160	5.78	5.49	92.5	106	112	108
Ni	0.1	< 0.001	< 0.001	0.002	0.004	0.002	0.002
Pb	0.015	< 0.004	< 0.004	0.008	0.008	0.008	0.006
Sb	0.006	< 0.003	< 0.003	0.006	0.006	0.006	0.006
Se	0.05	0.004	0.005	0.004	0.004	0.004	0.004
Sn	4.2	< 0.002	< 0.002	0.004	0.004	0.004	0.004
Sr	4.2	4.10	3.59	1.63	1.76	1.86	1.66
V	0.049	< 0.001	< 0.001	0.002	0.002	0.002	0.002
Zn	5	< 0.001	< 0.001	3.31	0.289	0.081	0.101
Ra-226	5	1.2	4.0				
Cl-	250	16.5	14.2	14.5	14.7	15.8	14.6
F-	2	**9.47**	**16.3**	**18.0**	**16.1**	**7.94**	**12.3**
SO42-	250	**1,650**	**1,540**	**1,480**	**1,470**	**1,490**	**1,460**

Table B-8a: Leached constituent concentrations from soils collected proximal to the chosen pilot road site. Leaching tests were conducted with DI water at an LS ratio of 10.

Constituent	Residential GCTL (mg/L)	Soil 1	Soil 2	Soil 3	Soil 4	Soil 5
pH	-	6.96	7.40	7.71	7.97	8.15
Al	7	2.16	1.23	1.65	3.39	2.58
As	0.01	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
B	1.4	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ba	2	0.014	0.009	0.033	0.025	0.016
Be	0.004	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Ca	-	2.43	2.54	0.200	7.34	5.66
Cd	0.005	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	0.1	0.009	0.009	0.011	0.011	0.008
Cu	1	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Fe	0.3	**0.458**	**1.51**	**0.845**	0.183	**0.396**
K		0.353	0.463	0.251	0.791	0.971
Mg	-	1.03	1.17	0.505	3.16	2.19
Mn	0.050	0.003	0.044	0.003	0.003	0.009
Mo	0.035	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Na	160	0.767	0.741	0.368	1.37	0.891
Ni	0.1	0.003	0.003	0.003	0.004	0.003
Pb	0.015	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Sb	0.006	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Se	0.05	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Sn	4.2	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Sr	4.2	0.040	0.047	0.012	0.070	0.068
V	0.049	0.020	0.006	0.010	0.013	0.011
Zn	5	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cl-	250	15.1	17.3	14.7	16.2	14.0
F-	2	0.050	0.465	0	2.19	0.130
SO42-	250	9.45	11.5	7.52	8.91	8.16

Table B-8b: Cont'd: Leached constituent concentrations from soils collected proximal to the chosen pilot road site. Leaching tests were conducted with DI water at an LS ratio of 10.

Constituent	Residential GCTL (mg/L)	Soil 6	Soil 7	Soil 8	Soil 9	Soil 10
pH	-	7.75				
Al	7	3.27	0.095	59.8	0.246	1.21
As	0.01	< 0.004	< 0.004	< 0.004	< 0.004	0.006
B	1.4	< 0.01	0.003	0.009	0.006	0.024
Ba	2	0.023	0.002	0.018	0.006	0.008
Be	0.004	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Ca	-	5.50	1.99	10.8	40.4	56.8
Cd	0.005	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cr	0.1	0.012	0.004	0.013	0.004	0.004
Cu	1	< 0.002	< 0.002	< 0.002	0.010	< 0.002
Fe	0.3	0.425	0.044	7.79	0.022	0.423
K		0.424	0.219	1.48	2.98	8.08
Mg	-	3.70	0.485	1.99	2.81	10.2
Mn	0.050	0.004	0.002	0.004	0.002	0.006
Mo	0.035	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Na	160	1.33	0.752	4.12	2.23	4.14
Ni	0.1	0.003	0.002	0.006	0.002	0.003
Pb	0.015	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Sb	0.006	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Se	0.05	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Sn	4.2	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Sr	4.2	0.096	0.004	0.016	0.013	0.054
V	0.049	0.012	0.002	0.002	0.002	0.002
Zn	5	< 0.001	0.071	0.101	0.077	0.073
Cl-	250	15.3	42.3	42.8	41.4	42.1
F-	2	0.055	0	0	0.415	0
SO42-	250	9.44	12.1	19.9	14.4	19.5

Appendix C: Physical Data

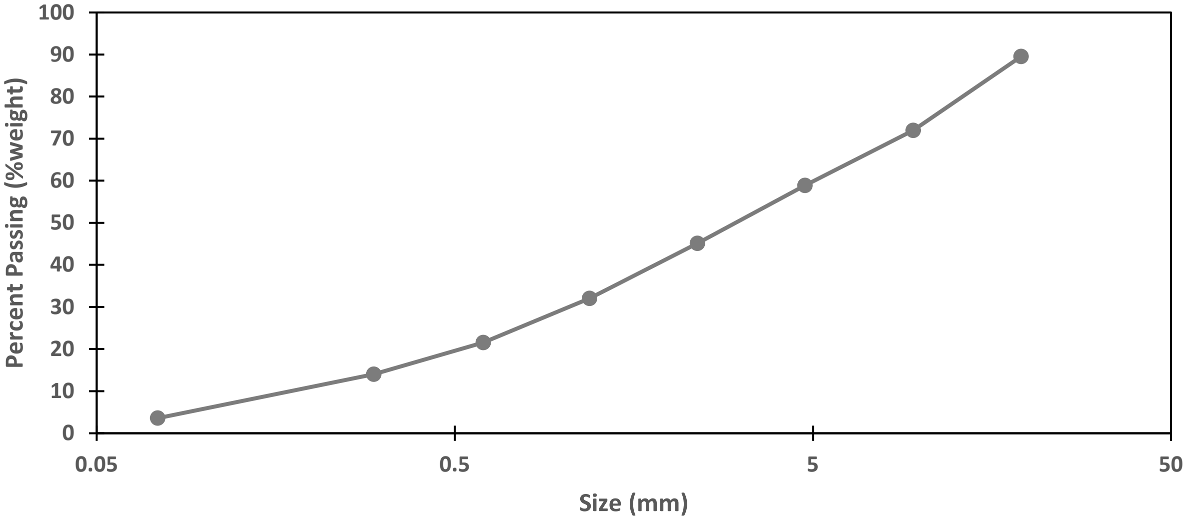

Figure C-1 Particle Size Distribution of LR

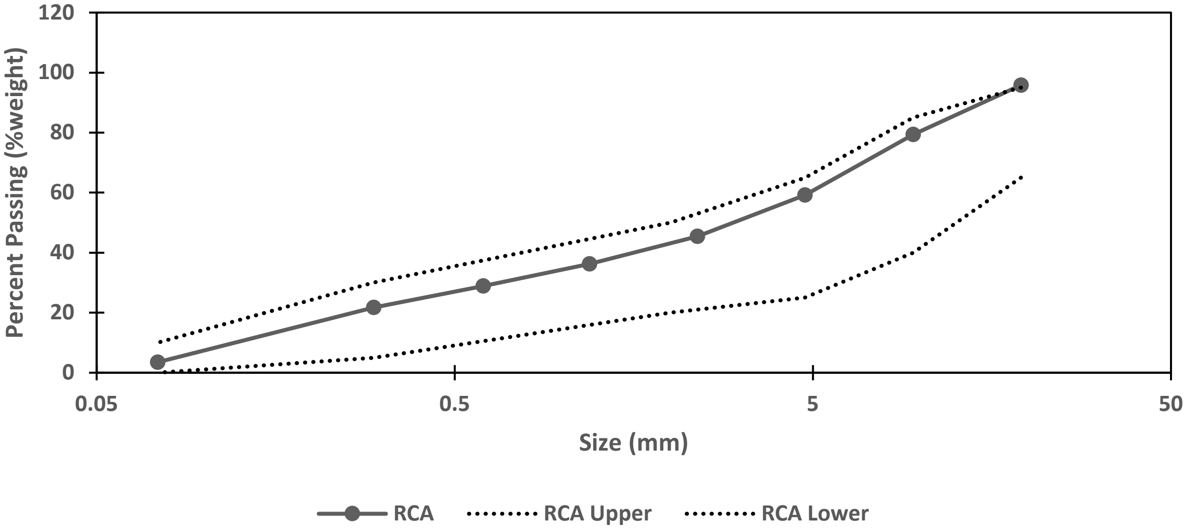

Figure C-2 Particle Size Distribution of RCA

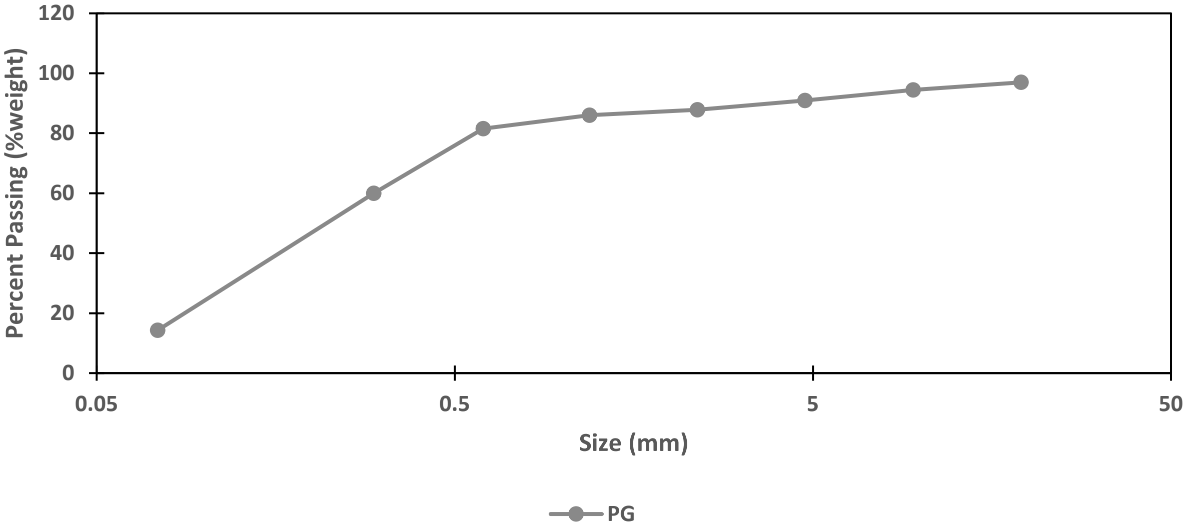

Figure C-3 Particle Size Distribution of PG

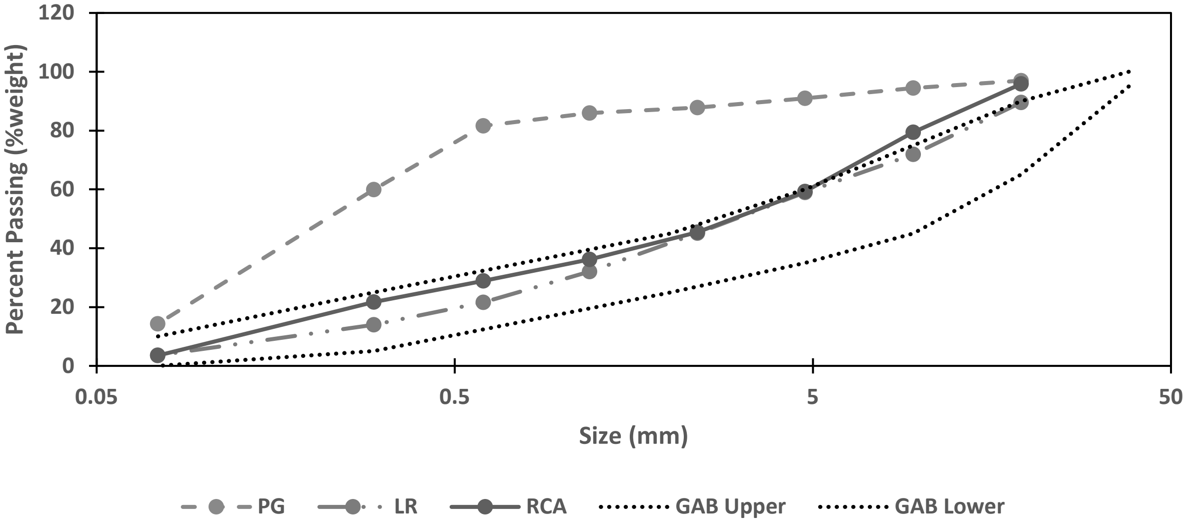

Figure C-4 Particle Size Distribution of PG and Aggregates

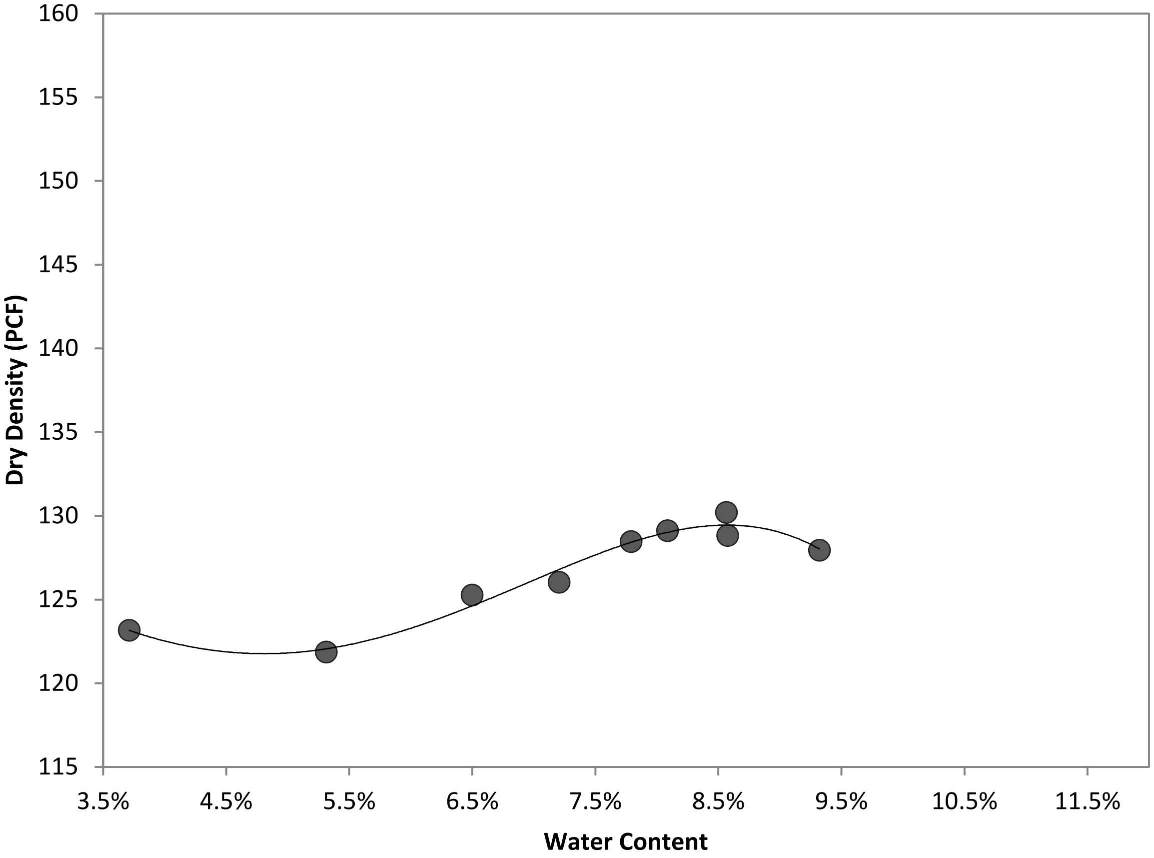

Figure C-5. Moisture-Density Relationship of LR

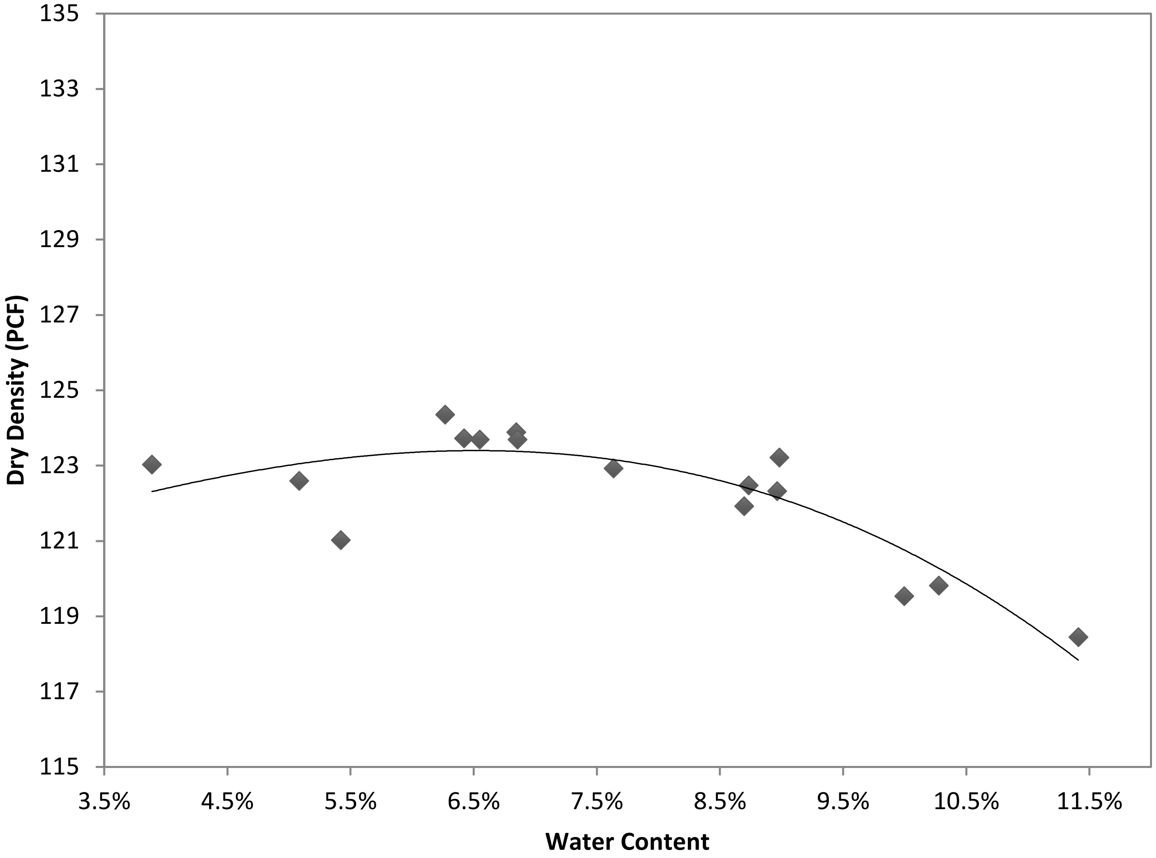

Figure C-6. Moisture Density Relationship of 50% PG – 50% LR

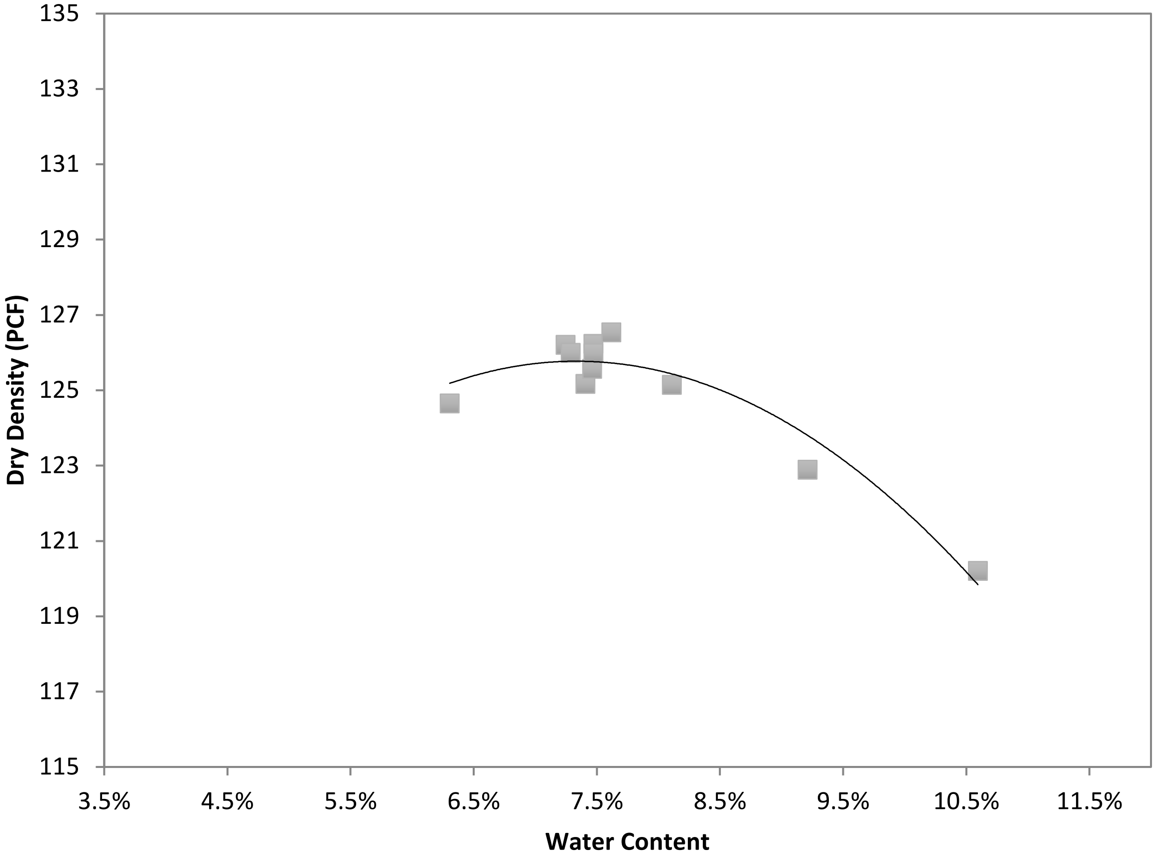

Figure C-7. Moisture Density Relationship of 40% PG – 60% LR

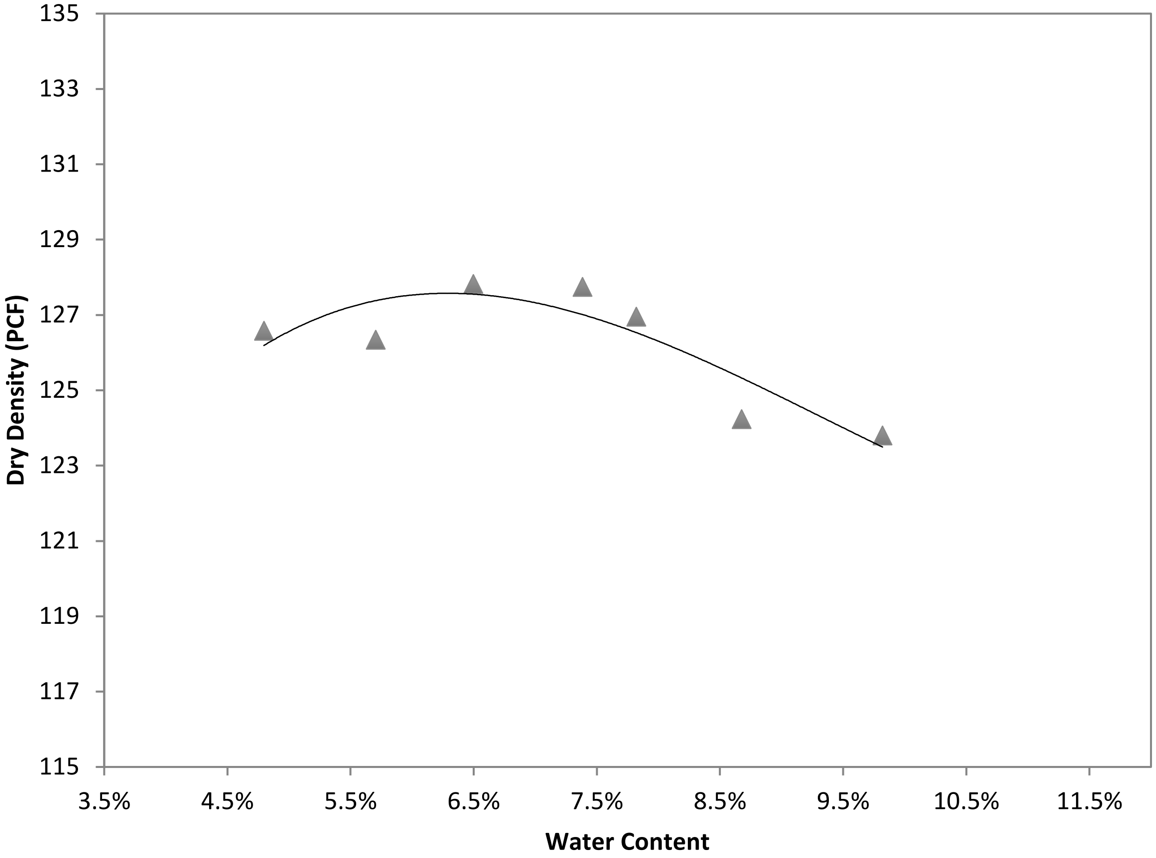

Figure C-8. Moisture Density Relationship of 30% PG – 70% LR

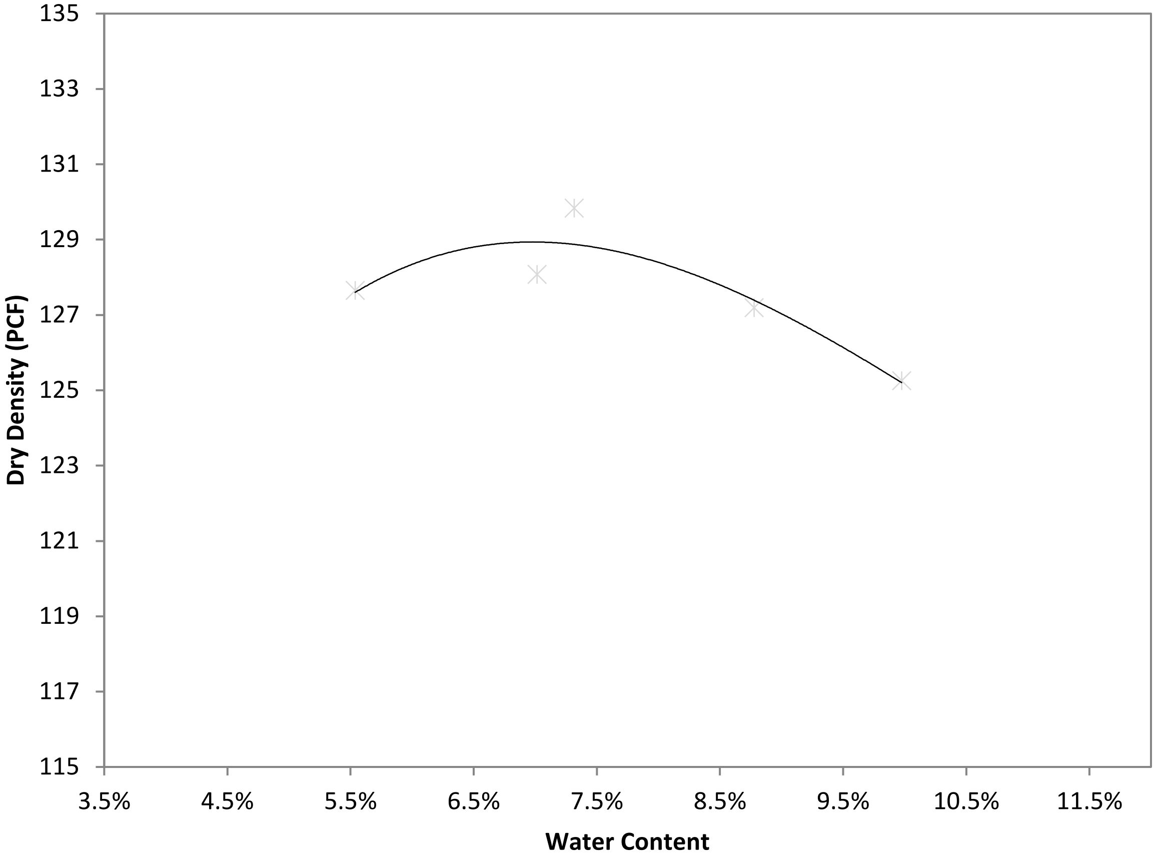

Figure C-9. Moisture Density Relationship of 20% PG – 80% LR

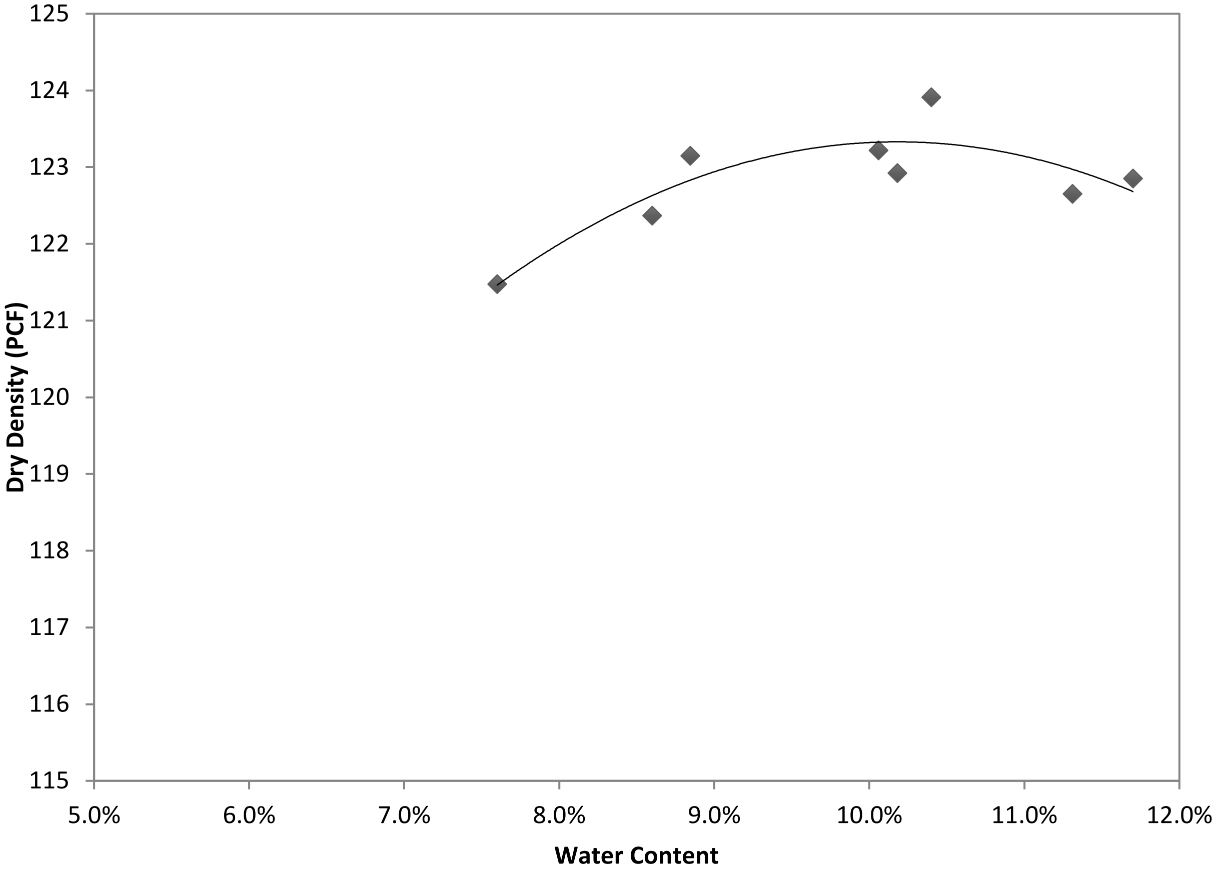

Figure C-10. Moisture-Density Relationship of RCA

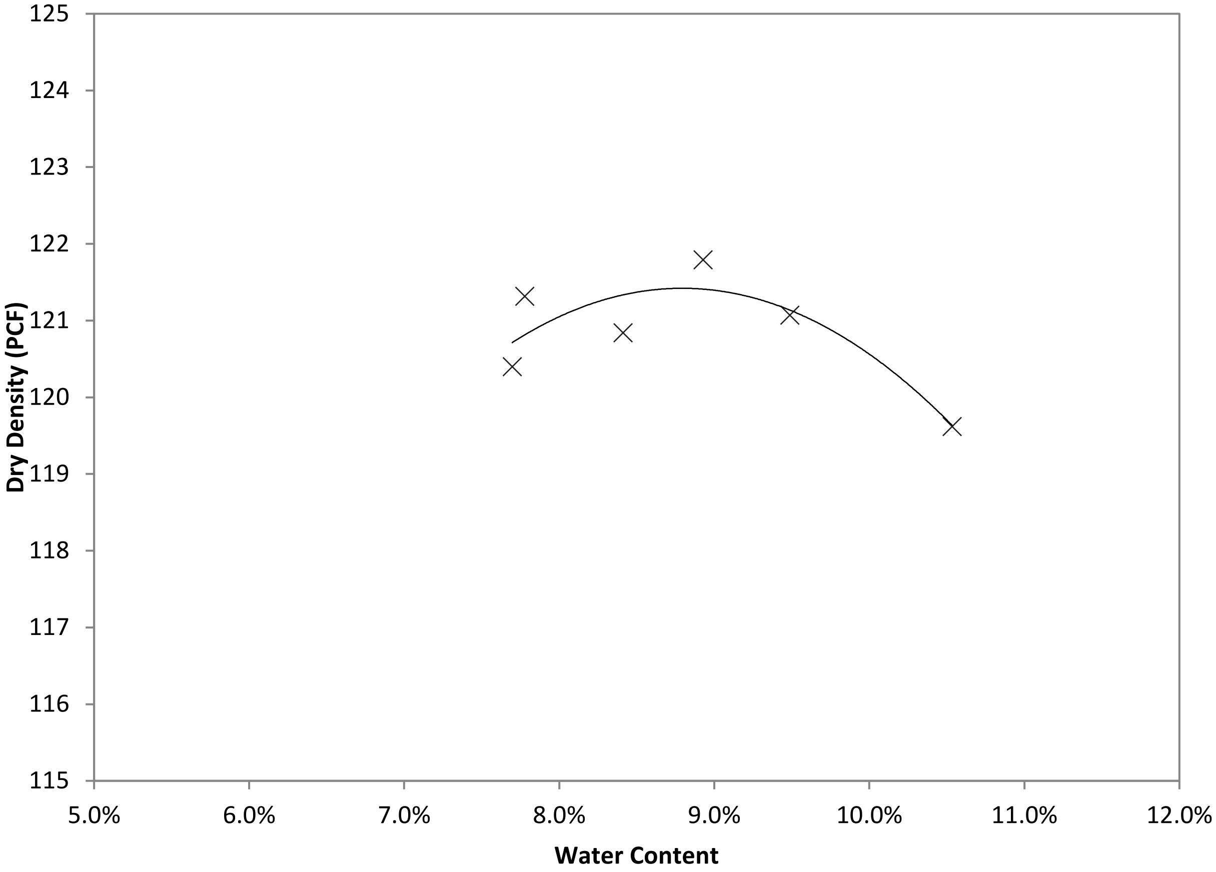

Figure C-12. Moisture-Density Relationship of 50% PG – 50% RCA

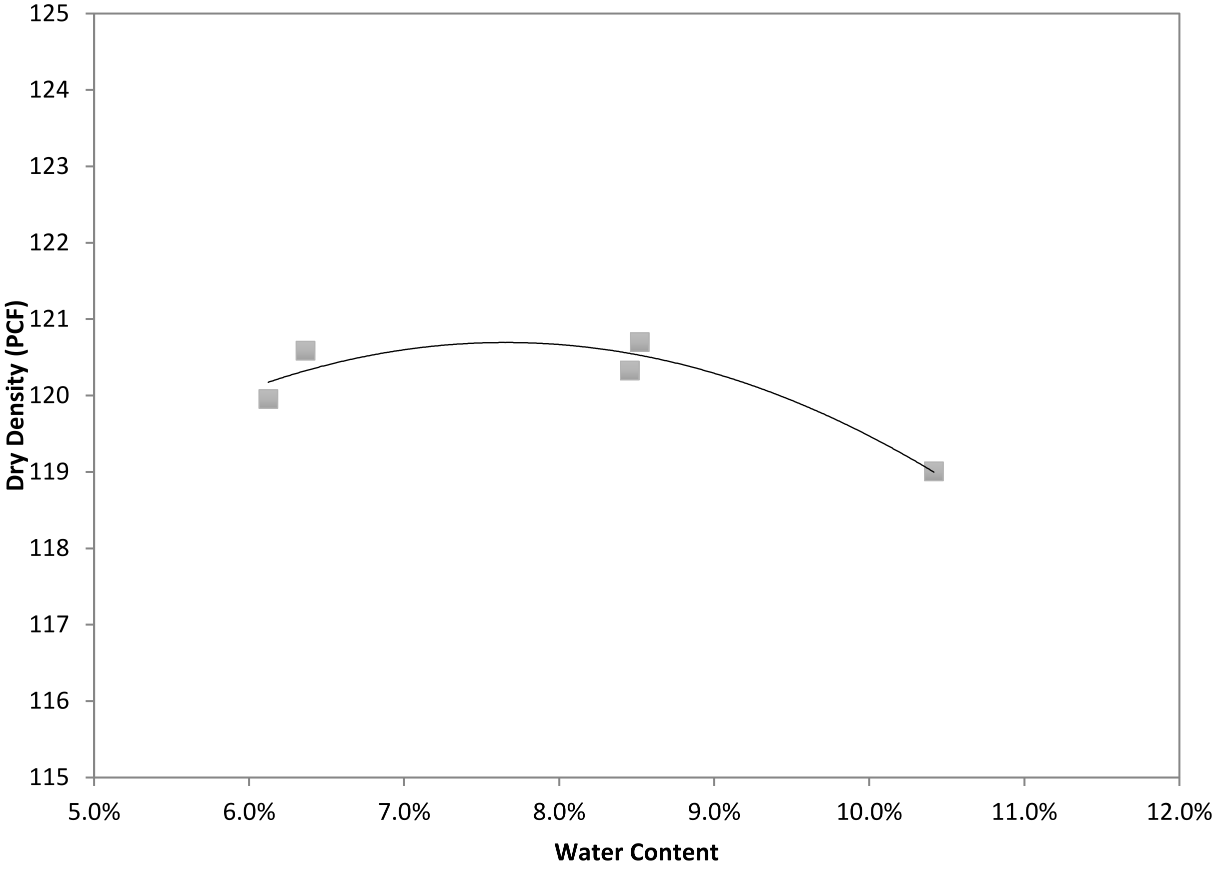

Figure C-13. Moisture-Density Relationship of 40% PG – 60% RCA

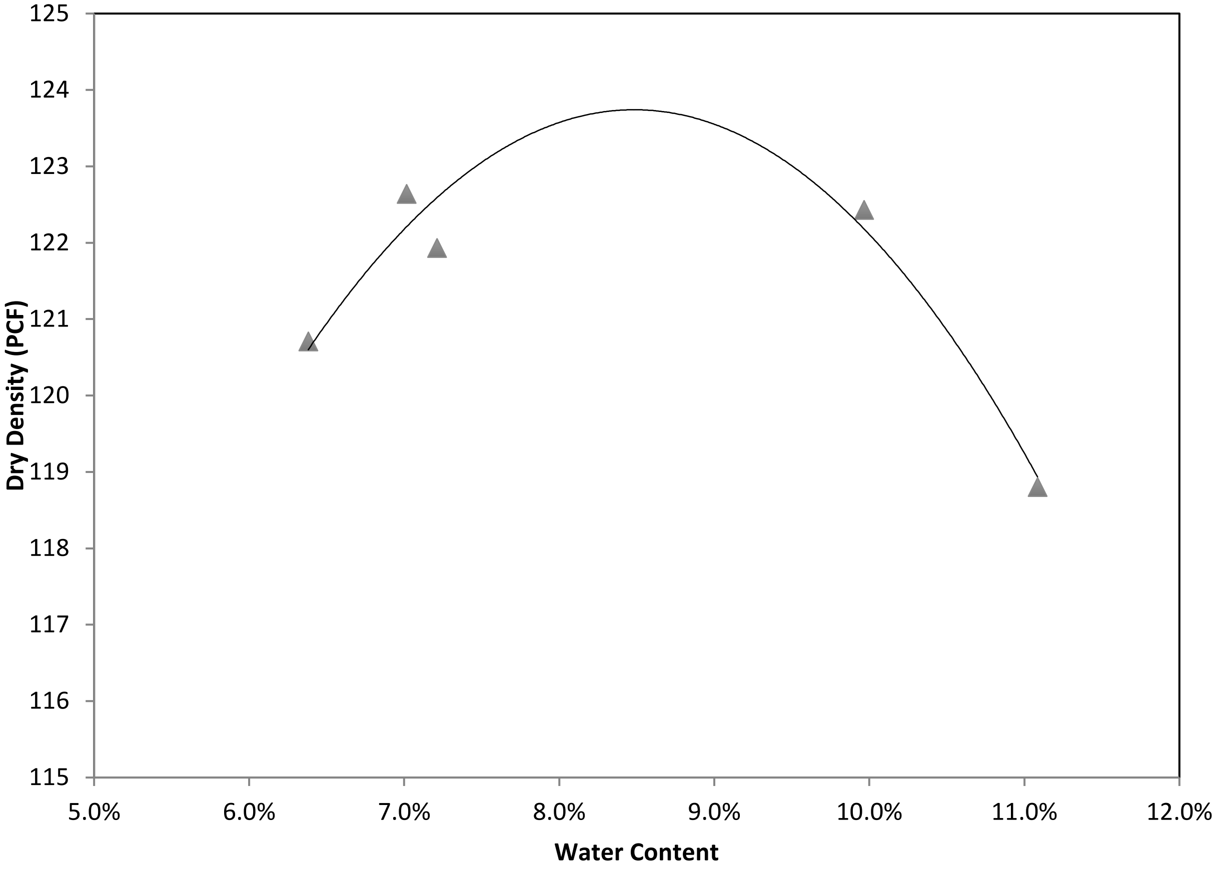

Figure C-14. Moisture-Density Relationship of 30% PG – 70% RCA

Table C-1 Modified Proctor Compaction and LBR Results

Material	OWC (% dry)	MDD (PCF)	LBR
LR	8.6	129.5	191.3
RCA	10.3	123.4	206.8
50% PG – 50% LR	6.5	123.7	150.6
40% PG – 40% LR	7.3	126.1	208.9
30% PG – 70% LR	6.5	127.8	225.2
20% PG – 80% LR	7.3	129.8	243.5
50% PG – 50% RCA	8.9	121.8	194.5
40% PG – 60% RCA	8.5	120.7	185.6
30% PG – 70% RCA	6.3	123.5	210.7

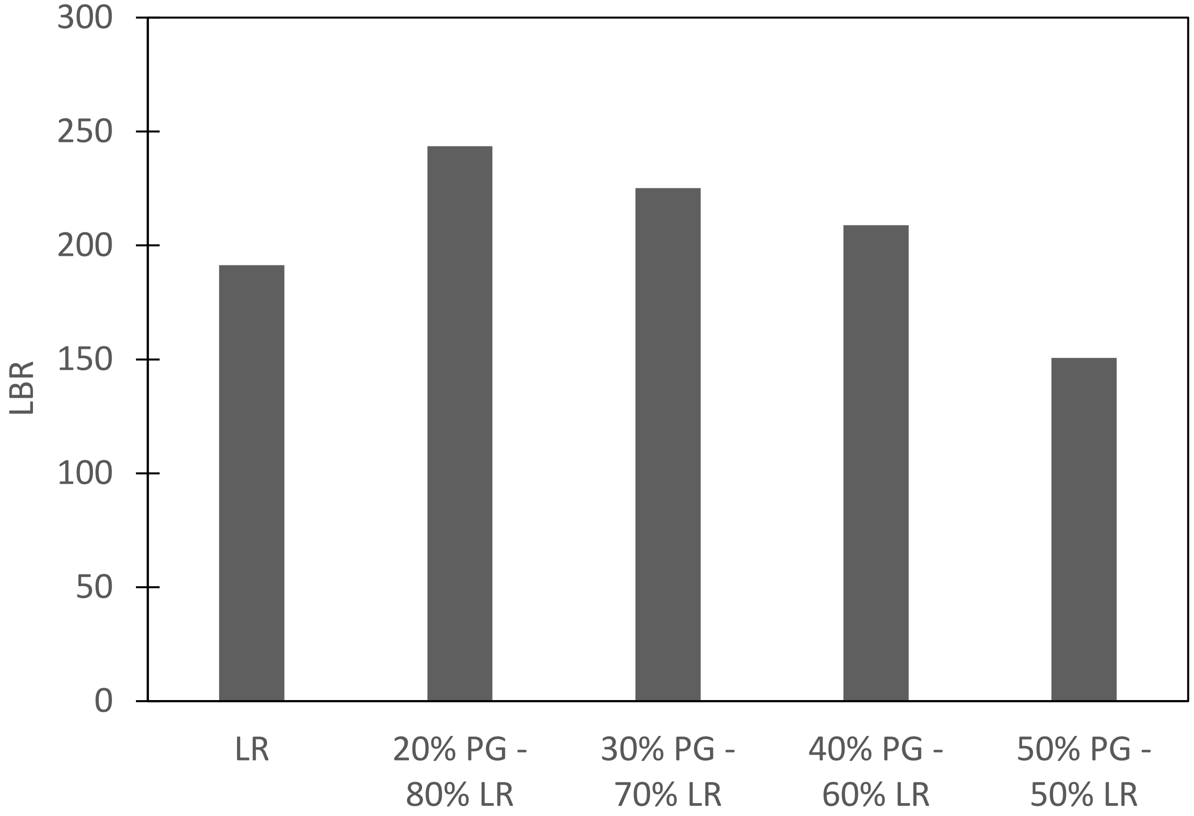

Figure C-15. LBR of LR and PG-LR Blends

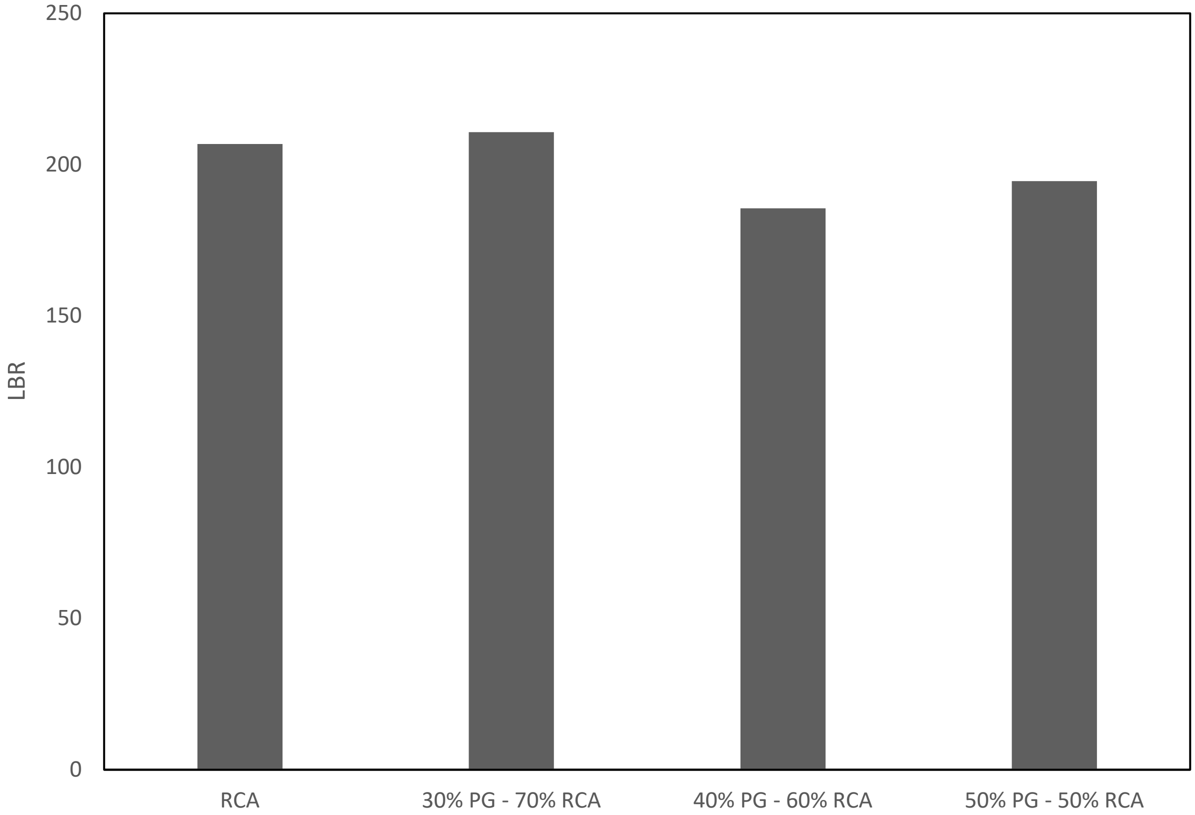

Figure C-16. LBR of RCA and PG-RCA Blends

Appendix D: IWEM and HELP modeling

Help Model Data:

PG-LR Scenario 1: No Evaporation

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE

HELP MODEL VERSION 4.0 BETA (2018)

DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Help Model using RCA for BUD Simulated On: 5/2/2022 11:59

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)

Psuedo Layer
Material Texture Number 44

Thickness = 1 centimeters 1
Porosity = 0.5 vol/vol 0.5
Field Capacity = 0.002 vol/vol 0.002
Wilting Point = 0.001 vol/vol 0.001
Initial Soil Water Content = 0.0179 vol/vol 0.0179
Effective Sat. Hyd. Conductivity = 1.00E+03 cm/sec 1000

Layer 2
Type 2 - Lateral Drainage Layer
Psuedo Layer_Drainage
Material Texture Number 45

Thickness = 10 centimeters 10
Porosity = 0.416 vol/vol 0.416
Field Capacity = 0.002 vol/vol 0.002
Wilting Point = 0.001 vol/vol 0.001
Initial Soil Water Content = 0.002 vol/vol 0.002
Effective Sat. Hyd. Conductivity = 1.00E+03 cm/sec 1000
Slope = 2 % 2

```
Drainage Length                         =       3.66    meters          3.66

                    Layer 3
                    Type 3 - Barrier Soil Liner
                    40% PG- 60% LR
                    Material Texture Number 43
Thickness                       =       25.4    centimeters             25.4
Porosity                        =       0.183   vol/vol         0.183
Field Capacity                  =       0.1     vol/vol         0.1
Wilting Point                   =       0.09    vol/vol         0.09
Initial Soil Water Content                      =       0.183   vol/vol         0.183
Effective Sat. Hyd. Conductivity                        =       2.19E-06        cm/sec
0.00000131

                    Layer 4
                    Type 2 - Lateral Drainage Layer
                    Drainage
                    Material Texture Number 46
Thickness                       =       6       centimeters             6
Porosity                        =       0.1     vol/vol         0.1
Field Capacity                  =       0.09    vol/vol         0.09
Wilting Point                   =       0.08    vol/vol         0.08
Initial Soil Water Content                      =       0.09    vol/vol         0.09
Effective Sat. Hyd. Conductivity                        =       3.30E+01        cm/sec
33
Slope                   =       2       %               2
Drainage Length                         =       3.66    meters          3.66

                    Layer 5
                    Type 4 - Flexible Membrane Liner
                    HDPE Membrane
                    Material Texture Number 35
Thickness                       =       30      centimeters             30
Effective Sat. Hyd. Conductivity                        =       2.00E-13        cm/sec
2E-13
FML Pinhole Density                     =       0       Holes/Hectare           0
FML Installation Defects                        =       0       Holes/Heactare
0
FML Placement Quality                           =       1       Perfect         1
-----------------------------------------------------------------------------------------------------------------
--
Note:   Initial moisture content of the layers and snow water were
```

computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number = 97.2 97.2
Fraction of Area Allowing Runoff = 0 %
0
Area projected on a horizontal plane = 1 Hectares
1
Evaporative Zone Depth = 0.001 cm 0.001
Initial Water in Evaporative Zone = 0 cm
0
Upper Limit of Evaporative Storage = 0 cm
0
Lower Limit of Evaporative Storage = 0 cm
0
Initial Snow Water = 0 cm 0
Initial Water in Layer Materials = 5.23 cm
5.23
Total Initial Water = 5.23 cm 5.23
Total Subsurface Inflow = 0 mm/year
0

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude = 27.82 Degrees 27.82
Maximum Leaf Area Index = 0 0
Start of Growing Season (Julian Date) = 0 days
0
End of Growing Season (Julian Date) = 0 days
0
Average Wind Speed = 12 kph 12
Average 1st Quarter Relative Humidity = 77 %
77
Average 2nd Quarter Relative Humidity = 76 %
76

Average 3rd Quarter Relative Humidity = 82 %
82
Average 4th Quarter Relative Humidity = 79 %
79

Note: Evapotranspiration data was obtained for ,

Normal Mean Monthly Precipitation (mm)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
64.58783096	36.26784947	82.67678526	80.1338851	78.39159083	173.2628763
175.0941724	196.9682273	166.4142016	63.44174916	58.3088706	61.84558984

Note: Precipitation was simulated based on HELP V4 weather simulation for:

Lat/Long: 27.82/-82.05

Normal Mean Monthly Temperature (Degrees Celsius)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
22	21.3	22.7	25.4	28.4	29.1
29.6	29.9	26.7	25.2	24.1	24.5

Note: Temperature was simulated based on HELP V4 weather simulation for:

Lat/Long: 27.82/-82.05
Solar radiation was simulated based on HELP V4 weather simulation for:

Lat/Long: 27.82/-82.05
Average Annual Totals Summary

Title: Help Model using RCA for BUD
Simulated on: 5/2/2022 12:00

```
                  Average Annual Totals for Years 1 - 10*
                  (millimeters)**          [std dev]         (cubic meters) (percent)
Precipitation              1,237.39        [144.68]          12,373.9       100.00
Runoff            0.000    [0]      0.0000 0.00
Evapotranspiration                  1.207  [0.337] 12.1      0.10
Subprofile1
Lateral drainage collected from Layer 2                      1,202.7574     [141.2597]     12,027.6
         97.20
Percolation/leakage through Layer 3         33.428811     [4.281406]     334.3   2.70
Average Head on Top of Layer 3              0.0173 [0.0021]         ---      ---
Subprofile2
Lateral drainage collected from Layer 4                      33.4288        [4.2814]       334.3   2.70
Percolation/leakage through Layer 5         0.000000      [0]       0.0000 0.00
Average Head on Top of Layer 5              0.0327 [0.0042]         ---      ---
Water storage
Change in water storage            0.0000 [0.2178]        -0.0003        0.00

* Note: Average inches are converted to volume based on the user-specified area.

**Note: head on liners expressed in cm
Peak Values Summary

Title:    Help Model using RCA for BUD
Simulated on:  5/2/2022 12:00

                  Peak Values for Years 1 - 10*
                  (millimeters)*           (cubic meters)
Precipitation              112.75          1,127.5
Runoff            0.000             0.0000
Subprofile1
Drainage collected from Layer 2             112.7177                1,127.2
Percolation/leakage through Layer 3         0.950786                9.5079
Average head on Layer 3            0.2751  (cm)    ---
Maximum head on Layer 3            0.0024  (cm)    ---
Location of maximum head in Layer 2                  0.01      (meters from drain)
Subprofile2
Drainage collected from Layer 4             0.9508         9.5079
Percolation/leakage through Layer 5         0.000000                0.0000
Average head on Layer 5            0.3396  (cm)    ---
Maximum head on Layer 5            0.0006  (cm)    ---
Location of maximum head in Layer 4                  0.00      (meters from drain)
Other Parameters
Snow water                 0.0538          0.5384
Maximum vegetation soil water               0.3312  (vol/vol)
```

Minimum vegetation soil water 0.0010 (vol/vol)

*Note: head on liners expressed in cm
Final Water Storage in Landfill Profile at End of Simulation Period

Title: Help Model using RCA for BUD
Simulated on: 5/2/2022 12:00
Simulation period: 10 years

Layer	Final Water Storage (centimeters)	(vol/vol)
1	0.0180	0.0180
2	0.0200	0.0020
3	4.6482	0.1830
4	0.5400	0.0900
5	0.0000	0.0000
Snow water	0.0000	---

PG-LR Scenario 2: With Evaporation

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE

HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: Simulated On: 5/2/2022 12:47

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
RCA
Material Texture Number 43
Thickness = 25.4 centimeters
Porosity = 0.151 vol/vol
Field Capacity = 0.1 vol/vol

Wilting Point = 0.01 vol/vol
Initial Soil Water Content = 0.1 vol/vol
Effective Sat. Hyd. Conductivity = 2.19E-06 cm/sec

Layer 2
Type 2 - Lateral Drainage Layer
Drainage
Material Texture Number 46
Thickness = 6 centimeters
Porosity = 0.1 vol/vol
Field Capacity = 0.09 vol/vol
Wilting Point = 0.01 vol/vol
Initial Soil Water Content = 0.1 vol/vol
Effective Sat. Hyd. Conductivity = 3.30E+01 cm/sec
Slope = 2 %
Drainage Length = 3.66 meters

Layer 3
Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35
Thickness = 30 centimeters
Effective Sat. Hyd. Conductivity = 2.00E-13 cm/sec
FML Pinhole Density = 0 Holes/Hectare
FML Installation Defects = 0 Holes/Heactare
FML Placement Quality = 1 Perfect

--

Note: Initial moisture content of the layers and snow water

were specified by the user.

General Design and Evaporative Zone Data

SCS Runoff Curve Number = 99.9
Fraction of Area Allowing Runoff = 100 %
Area projected on a horizontal plane = 1 Hectares
Evaporative Zone Depth = 12.5 cm
Initial Water in Evaporative Zone = 1.25 cm
Upper Limit of Evaporative Storage = 1.89 cm
Lower Limit of Evaporative Storage = 0.12 cm
Initial Snow Water = 0 cm
Initial Water in Layer Materials = 3.14 cm
Total Initial Water = 3.14 cm

Total Subsurface Inflow = 0 mm/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude = 27.82 Degrees
Maximum Leaf Area Index = 0
Start of Growing Season (Julian Date) = 0 days
End of Growing Season (Julian Date) = 0 days
Average Wind Speed = 12 kph
Average 1st Quarter Relative Humidity = 77 %
Average 2nd Quarter Relative Humidity = 76 %
Average 3rd Quarter Relative Humidity = 82 %
Average 4th Quarter Relative Humidity = 79 %

Note: Evapotranspiration data was obtained for ,

Normal Mean Monthly Precipitation (mm)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
64.58783096	36.26784947	82.67678526	80.1338851	78.39159083	173.2628763
175.0941724	196.9682273	166.4142016	63.44174916	58.3088706	61.84558984

Note: Precipitation was simulated based on HELP V4 weather simulation for:

Lat/Long: 27.82/-82.05

Normal Mean Monthly Temperature (Degrees Celsius)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
22	21.3	22.7	25.4	28.4	29.1
29.6	29.9	26.7	25.2	24.1	24.5

Note: Temperature was simulated based on HELP V4 weather simulation for:

Lat/Long: 27.82/-82.05
Solar radiation was simulated based on HELP V4 weather simulation for:

Lat/Long: 27.82/-82.05

Average Annual Totals Summary

Title:

```
Simulated on:  5/2/2022 12:48

               Average Annual Totals for Years 1 - 10*
               (millimeters)**         [std dev]       (cubic meters) (percent)
Precipitation          1,237.39        [144.68]        12,373.9       100.00
Runoff         1,181.557       [142.653]       11,815.6       95.49
Evapotranspiration             55.172 [5.014] 551.7  4.46
Subprofile1
Lateral drainage collected from Layer 2                1.8494 [2.1204]        18.5     0.15
Percolation/leakage through Layer 3            0.000000        [0]     0.0000 0.00
Average Head on Top of Layer 3                 0.0022 [0.0024]        ---      ---
Water storage
Change in water storage                -1.1850         [2.5156]        -11.9    -0.10

* Note: Average inches are converted to volume based on the user-specified area.

**Note: head on liners expressed in cm
Peak Values Summary

Title:
Simulated on:  5/2/2022 12:48

               Peak Values for Years 1 - 10*
               (millimeters)*          (cubic meters)
Precipitation          112.75          1,127.5
Runoff         112.354                 1,123.5
Subprofile1
Drainage collected from Layer 2                0.7697          7.6973
Percolation/leakage through Layer 3            0.000000                0.0000
Average head on Layer 3                0.4863  (cm)    ---
Maximum head on Layer 3                0.0005  (cm)    ---
Location of maximum head in Layer 2                    0.00     (meters from drain)
Other Parameters
Snow water             0.0538          0.5384
Maximum vegetation soil water                  0.0984  (vol/vol)
Minimum vegetation soil water                  0.0100  (vol/vol)

*Note: head on liners expressed in cm
Final Water Storage in Landfill Profile at End of Simulation Period

Title:    Help Model using RCA for BUD
Simulated on:  5/2/2022 12:48
Simulation period:      10 years
```

```
        Final Water Storage
Layer   (centimeters)  (vol/vol)
1       1.4149 0.0557
2       0.5400 0.0900
3       0.0000 0.0000
Snow water     0.0000 ---
```

PG-RCA Scenario 1: Without Evaporation

```
                              ------------------------------------------------------------------------------------
-------------------------------
                              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE

                              HELP MODEL VERSION 4.0 BETA (2018)
                              DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH
LABORATORY
                              ------------------------------------------------------------------------------------
-------------------------------
        Title:                                              Simulated On:
        4/28/2022 16:09
                              ------------------------------------------------------------------------------------
-------------------------------

                              Layer 1
                              Type 1 - Vertical Percolation Layer (Cover Soil)
                              Psuedo Layer
                              Material Texture Number 44
        Thickness                        =       1       centimeters
        Porosity                         =       0.5     vol/vol
        Field Capacity                   =       0.002   vol/vol
        Wilting Point                    =       0.001   vol/vol
        Initial Soil Water Content                =       0.0179 vol/vol
        Effective Sat. Hyd. Conductivity                  =       1.00E+03        cm/sec

                              Layer 2
                              Type 2 - Lateral Drainage Layer
                              Psuedo Layer_Drainage
                              Material Texture Number 45
        Thickness                        =       10      centimeters
        Porosity                         =       0.416   vol/vol
        Field Capacity                   =       0.002   vol/vol
        Wilting Point                    =       0.001   vol/vol
        Initial Soil Water Content                =       0.002   vol/vol
        Effective Sat. Hyd. Conductivity                  =       1.00E+03        cm/sec
```

Slope = 2 %
Drainage Length = 3.66 meters

Layer 3
Type 3 - Barrier Soil Liner
RCA
Material Texture Number 43

Thickness = 25.4 centimeters
Porosity = 0.151 vol/vol
Field Capacity = 0.1 vol/vol
Wilting Point = 0.08 vol/vol
Initial Soil Water Content = 0.151 vol/vol
Effective Sat. Hyd. Conductivity = 2.81E-06 cm/sec

Layer 4
Type 2 - Lateral Drainage Layer
Drainage
Material Texture Number 46

Thickness = 6 centimeters
Porosity = 0.1 vol/vol
Field Capacity = 0.09 vol/vol
Wilting Point = 0.08 vol/vol
Initial Soil Water Content = 0.09 vol/vol
Effective Sat. Hyd. Conductivity = 3.30E+01 cm/sec
Slope = 2 %
Drainage Length = 3.66 meters

Layer 5
Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness = 30 centimeters
Effective Sat. Hyd. Conductivity = 2.00E-13 cm/sec
FML Pinhole Density = 0 Holes/Hectare
FML Installation Defects = 0 Holes/Heactare
FML Placement Quality = 1 Perfect

--

Note: Initial moisture content of the layers and snow water were

computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number = 97.2
Fraction of Area Allowing Runoff = 0 %
Area projected on a horizontal plane = 1 Hectares
Evaporative Zone Depth = 0.001 cm
Initial Water in Evaporative Zone = 0 cm
Upper Limit of Evaporative Storage = 0 cm
Lower Limit of Evaporative Storage = 0 cm
Initial Snow Water = 0 cm
Initial Water in Layer Materials = 4.41 cm
Total Initial Water = 4.41 cm
Total Subsurface Inflow = 0 mm/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude = 27.82 Degrees
Maximum Leaf Area Index = 0
Start of Growing Season (Julian Date) = 0 days
End of Growing Season (Julian Date) = 0 days
Average Wind Speed = 12 kph
Average 1st Quarter Relative Humidity = 77 %
Average 2nd Quarter Relative Humidity = 76 %
Average 3rd Quarter Relative Humidity = 82 %
Average 4th Quarter Relative Humidity = 79 %

Note: Evapotranspiration data was obtained for ,

Normal Mean Monthly Precipitation (mm)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
64.58783096	36.26784947	82.67678526	80.1338851	78.39159083	173.2628763
175.0941724	196.9682273	166.4142016	63.44174916	58.3088706	61.84558984

Note: Precipitation was simulated based on HELP V4 weather simulation for:

Lat/Long: 27.82/-82.05

Normal Mean Monthly Temperature (Degrees Celsius)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
22	21.3	22.7	25.4	28.4	29.1
29.6	29.9	26.7	25.2	24.1	24.5

```
          ----------------------------------------------------------
          Note:   Temperature was simulated based on HELP V4 weather simulation for:

                  Lat/Long: 27.82/-82.05
                  Solar radiation was simulated based on HELP V4 weather simulation for:

                  Lat/Long: 27.82/-82.05
                            Average Annual Totals Summary

Title:    Help Model using RCA for BUD
Simulated on:  4/28/2022 16:10

                  Average Annual Totals for Years 1 - 10*
                  (millimeters)**          [std dev]          (cubic meters) (percent)
Precipitation             1,237.39         [144.68]           12,373.9       100.00
Runoff            0.000   [0]       0.0000 0.00
Evapotranspiration                  1.207  [0.337] 12.1       0.10
Subprofile1
Lateral drainage collected from Layer 2                       1,194.5609     [142.1864]     11,945.6
          96.54
Percolation/leakage through Layer 3           41.625276      [3.250411]     416.3   3.36
Average Head on Top of Layer 3                0.0172 [0.0022]           ---        ---
Subprofile2
Lateral drainage collected from Layer 4                       41.6253        [3.2504]       416.3   3.36
Percolation/leakage through Layer 5           0.000001       [0]        0.0000 0.00
Average Head on Top of Layer 5                0.0317 [0.0025]           ---        ---
Water storage
Change in water storage                0.0000 [0.2179]       -0.0003           0.00

* Note: Average inches are converted to volume based on the user-specified area.

**Note: head on liners expressed in cm
                  Peak Values Summary

Title:    Help Model using RCA for BUD
Simulated on:  4/28/2022 16:10

                  Peak Values for Years 1 - 10*
                  (millimeters)*           (cubic meters)
Precipitation             112.75           1,127.5
Runoff            0.000             0.0000
Subprofile1
Drainage collected from Layer 2               112.7115                 1,127.1
Percolation/leakage through Layer 3           1.218328                 12.2
```

```
Average head on Layer 3                0.5289  (cm)    ---
Maximum head on Layer 3                0.0024  (cm)    ---
Location of maximum head in Layer 2                 0.01      (meters from drain)
Subprofile2
Drainage collected from Layer 4                1.2183           12.2
Percolation/leakage through Layer 5           0.000000                    0.0000
Average head on Layer 5                0.3384  (cm)    ---
Maximum head on Layer 5                0.0008  (cm)    ---
Location of maximum head in Layer 4                 0.00      (meters from drain)
Other Parameters
Snow water              0.0538            0.5384
Maximum vegetation soil water                0.3312  (vol/vol)
Minimum vegetation soil water                0.0010  (vol/vol)

*Note: head on liners expressed in cm
                             Final Water Storage in Landfill Profile at End of Simulation Period

Title:    Help Model using RCA for BUD
Simulated on:  4/28/2022 16:10
Simulation period:      10 years

          Final Water Storage
Layer   (centimeters)  (vol/vol)
1         0.0180 0.0180
2         0.0200 0.0020
3         3.8354 0.1510
4         0.5400 0.0900
5         0.0000 0.0000
Snow water     0.0000 ---
```

PG-RCA Scenario 2: With Evaporation

```
Rca evap
                                   HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE

                                   HELP MODEL VERSION 4.0 BETA (2018)
                                   DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH
LABORATORY
                                   -----------------------------------------------------------------------------------------
-------------------------------
          Title:    Help Model using RCA for BUD                                      Simulated On:
          4/28/2022 18:31
                                   -----------------------------------------------------------------------------------------
-------------------------------
```

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
RCA
Material Texture Number 43
Thickness = 25.4 centimeters
Porosity = 0.151 vol/vol
Field Capacity = 0.1 vol/vol
Wilting Point = 0.01 vol/vol
Initial Soil Water Content = 0.1 vol/vol
Effective Sat. Hyd. Conductivity = 2.81E-06 cm/sec

Layer 2
Type 2 - Lateral Drainage Layer
Drainage
Material Texture Number 46
Thickness = 6 centimeters
Porosity = 0.1 vol/vol
Field Capacity = 0.09 vol/vol
Wilting Point = 0.01 vol/vol
Initial Soil Water Content = 0.1 vol/vol
Effective Sat. Hyd. Conductivity = 3.30E+01 cm/sec
Slope = 2 %
Drainage Length = 3.66 meters

Layer 3
Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35
Thickness = 30 centimeters
Effective Sat. Hyd. Conductivity = 2.00E-13 cm/sec
FML Pinhole Density = 0 Holes/Hectare
FML Installation Defects = 0 Holes/Heactare
FML Placement Quality = 1 Perfect

--

Note: Initial moisture content of the layers and snow water

were specified by the user.

General Design and Evaporative Zone Data

SCS Runoff Curve Number = 99.9
Fraction of Area Allowing Runoff = 100 %

Area projected on a horizontal plane = 1 Hectares
Evaporative Zone Depth = 12.5 cm
Initial Water in Evaporative Zone = 1.25 cm
Upper Limit of Evaporative Storage = 1.89 cm
Lower Limit of Evaporative Storage = 0.12 cm
Initial Snow Water = 0 cm
Initial Water in Layer Materials = 3.14 cm
Total Initial Water = 3.14 cm
Total Subsurface Inflow = 0 mm/year

Note: SCS Runoff Curve Number was User-Specified.

Evapotranspiration and Weather Data

Station Latitude = 27.82 Degrees
Maximum Leaf Area Index = 0
Start of Growing Season (Julian Date) = 0 days
End of Growing Season (Julian Date) = 0 days
Average Wind Speed = 12 kph
Average 1st Quarter Relative Humidity = 77 %
Average 2nd Quarter Relative Humidity = 76 %
Average 3rd Quarter Relative Humidity = 82 %
Average 4th Quarter Relative Humidity = 79 %

Note: Evapotranspiration data was obtained for:

Normal Mean Monthly Precipitation (mm)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
64.58783096	36.26784947	82.67678526	80.1338851	78.39159083	173.2628763
175.0941724	196.9682273	166.4142016	63.44174916	58.3088706	61.84558984

Note: Precipitation was simulated based on HELP V4 weather simulation for:

Lat/Long: 27.82/-82.05

Normal Mean Monthly Temperature (Degrees Celsius)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
22	21.3	22.7	25.4	28.4	29.1
29.6	29.9	26.7	25.2	24.1	24.5

```
          Note:     Temperature was simulated based on HELP V4 weather simulation for:

                    Lat/Long: 27.82/-82.05
                    Solar radiation was simulated based on HELP V4 weather simulation for:

                    Lat/Long: 27.82/-82.05
Average Annual Totals Summary

Title:    Help Model using RCA for BUD
Simulated on:       4/28/2022 18:31

                    Average Annual Totals for Years 1 - 10*
                    (millimeters)**               [std dev]           (cubic meters) (percent)
Precipitation                 1,237.39            [144.68]            12,373.9            100.00
Runoff              1,181.400           [142.528]           11,814.0            95.47
Evapotranspiration                      54.907 [5.53]       549.1     4.44
Subprofile1
Lateral drainage collected from Layer 2                     2.2725 [2.7041]               22.7      0.18
Percolation/leakage through Layer 3               0.000000            [0]       0.0000 0.00
Average Head on Top of Layer 3                    0.0020 [0.0023]             ---       ---
Water storage
Change in water storage                 -1.1850             [2.5363]            -11.9     -0.10

* Note: Average inches are converted to volume based on the user-specified area.

**Note: head on liners expressed in cm
Peak Values Summary

Title:    Help Model using RCA for BUD
Simulated on:       4/28/2022 18:31

                    Peak Values for Years 1 - 10*
                    (millimeters)*                (cubic meters)
Precipitation                 112.75              1,127.5
Runoff              112.354                       1,123.5
Subprofile1
Drainage collected from Layer 2                   0.8315              8.3147
Percolation/leakage through Layer 3               0.000000                      0.0000
Average head on Layer 3                 0.3953  (cm)        ---
Maximum head on Layer 3                 0.0005  (cm)        ---
Location of maximum head in Layer 2                         0.00      (meters from drain)
Other Parameters
Snow water                    0.0538              0.5384
Maximum vegetation soil water                     0.0980  (vol/vol)
```

Minimum vegetation soil water 0.0100 (vol/vol)

*Note: head on liners expressed in cm

Final Water Storage in Landfill Profile at End of Simulation Period

Title: Help Model using RCA for BUD
Simulated on: 4/28/2022 18:32
Simulation period: 10 years

Layer	Final Water Storage (centimeters)	(vol/vol)
1	1.4149	0.0557
2	0.5400	0.0900
3	0.0000	0.0000
Snow water	0.0000	---

IWEM Modeling PG:LR 10, 50, 100 ft