APPENDIX I: PRELIMINARY LOW IMPACT DEVELOPMENT PLAN

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PRELIMINARY LOW IMPACT DEVELOPMENT PLAN

VESTING TENTATIVE TRACT MAP NO. 82874

Project Address:
Southwest of West San Bernardino Road &
North Rimsdale Avenue
City of Covina, CA

Prepared for:

TRUMARK HOMES

450 Newport Center Drive, Suite 300
Newport Beach, CA 92660
(949) 999-9800

Prepared by:

Hunsaker & Associates Irvine, Inc.
3 Hughes
Irvine, CA 92618
(949) 583-1010

Preparation Date:
May 5, 2020

W.O. 3593-42

PRELIMINARY LOW IMPACT DEVELOPMENT PLAN

"VESTING TENTATIVE TRACT MAP NO. 82874"

City of Covina, CA

W.O. 3593-42

PRELIMINARY
LOW IMPACT DEVELOPMENT (LID) PLAN

VESTING TENTATIVE TRACT MAP NO. 82874

SOUTHWEST OF WEST SAN BERNARDINO ROAD &
NORTH RIMSDALE AVENUE
CITY OF COVINA, COUNTY OF LOS ANGELES

PREPARED FOR:

TRUMARK HOMES

450 NEWPORT CENTER DRIVE, SUITE 300
NEWPORT BEACH, CA 92660
(949) 999-9800

SUBMITTED TO:

CITY OF COVINA
PLANNING DEPARTMENT
125 E. COLLEGE STREET
COVINA, CA 91723
(626) 384-5450

PREPARED BY:

H&A

HUNSAKER & ASSOCIATES IRVINE, INC.
3 HUGHES
IRVINE, CA 92618
(949) 583-1010

PREPARED:

MAY 5, 2020

W.O. 3593-42

Engineer's Certification
Low Impact Development (LID) Plan

<table>
<tr><th colspan="4">Preparer (Engineer) Certification</th></tr>
<tr><td colspan="4">Preparer (Engineer): David Francke</td></tr>
<tr><td>Title</td><td>Project Manager/Engineer</td><td>PE Registration #</td><td>49068</td></tr>
<tr><td>Company</td><td colspan="3">Hunsaker & Associates Irvine, Inc.</td></tr>
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<tr><td>Email</td><td colspan="3">dfrancke@hunsaker.com</td></tr>
<tr><td>Telephone #</td><td colspan="3">949-583-1010</td></tr>
<tr><td colspan="4">I HEREBY CERTIFY THAT THIS LOW IMPACT DEVELOPMENT (LID) PLAN IS IN COMPLIANCE WITH THE REQUIREMENTS SET FORTH IN ORDER NO. R4-2012-0175/NPDES NO. CAS004001 OF THE LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD.
I certify under penalty of law that this document and all attachments were prepared under my jurisdiction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, to the best of my knowledge and belief, the information submitted is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations</td></tr>
<tr><td>Preparer Signature</td><td></td><td>Date</td><td></td></tr>
<tr><td>Place Stamp Here</td><td colspan="3"></td></tr>
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LID NOTES:

1. Determine and provide the pre and post development pervious and impervious areas created by the proposed development (Includes only project's development area. Does not include Lot 1)

POST DEVELOPMENT

Impervious Area	3.904	Acres	Percent Impervious	86	%
Pervious Area	0.636	Acres	Percent Pervious	14	%

PRE DEVELOPMENT

Impervious Area	4.268	Acres	Percent Impervious	94	%
Pervious Area	0.272	Acres	Percent Pervious	6	%

2. Any modifications to the approved Low Impact Development (LID) report must be resubmitted to the City for approval.
3. A copy of the approved Low Impact Development (LID) report must be in the possession of a responsible person and available at the site at all times.
4. All structural BMP's shall be accessible for inspection and maintenance.
5. Prior to commencement of any work for connection to City or County maintained storm drain, an encroachment permit from the appropriate party shall be obtained.

I. LID Requirements and Project Description

A. LID Background

In 1987, The Federal Water Pollution Control Act (also referred to as the Clean Water Act [CWA] was amended to provide that the discharge of pollutants to waters of the United States from stormwater is effectively prohibited, unless the discharge is in compliance with a National Pollutant Discharge Elimination System (NPDES) Permit. The 1987 amendments to the CWA added Section 402 (p), which established a framework for regulating municipal, industrial and construction stormwater discharges under the NPDES program. In California, these permits are issued through the State Water Resources Control Board – (SWRCB) and the nine Regional Water Quality Control Boards.

On November 8, 2012, the Regional Water Quality Control Board, Los Angeles Region (RWQCB), adopted Order No. R4-2012-0175. This Order is the NPDES Permit (NPDES No. CAS004001) for municipal stormwater and urban runoff discharges within the County of Los Angeles.

As adopted in November 2012, the requirements of Order No. R4-2012-0175 (the "Permit') cover 84 cities and the unincorporated areas of Los Angeles County. The County of Los Angeles and the 84 incorporated cities are designated as Permittees.

In compliance with the Permit, the Permittees have implemented a stormwater quality management program (SQMP) with the ultimate goal of accomplishing the requirements of the Permit and reducing the amount of pollutants in stormwater and urban runoff wherein new development/redevelopment projects are required to prepare a Low Impact Development (LID) report.

As a Permittee of the County of Los Angeles, Best Management Practices (BMPs) are enforceable by the City of Covina.

B. Designated Project Categories

Table 1, Designated Project Categories, identifies the Project as **Category 1 and 6**, thereby requiring development of this Low Impact Development (LID) report.

Table 1 – Designated Project Categories	
Category	Description
1	All development projects equal to 1 acre or greater of disturbed area and adding more than 10,000 square feet of impervious surface area.
2	Industrial parks with 10,000 square feet or more of surface area.
3	Commercial malls with 10,000 square feet or more of surface area.
4	Retail gasoline outlets with 5,000 square feet or more of surface area.
5	Restaurants (Standard Industrial Classification [SIC] of 5812) with 5,000 square feet or more of surface area.
6	Parking lots with 5,000 square feet or more of impervious surface area, or with 25 or more parking spaces.
7	Automotive service facilities (SIC Codes: 5013, 5014, 5511, 5541, 7532-7534 and 7536-7539) with 5,000 square feet or more of surface area.

Table 1 – Designated Project Categories	
Category	Description
8	Projects located in or directly adjacent to, or discharging directly to a Significant Ecological Area (SEA), where the development will: • Discharge stormwater runoff that is likely to impact a sensitive biological species or habitat; and • Create 2,500 square feet or more of impervious surface area.
9	Redevelopment projects, which are developments that result in creation or addition or replacement of either: 5,000 square feet or more of impervious surface on a site that was previously developed as described in the above bullets; or (2) 10,000 square feet or more of impervious surface area on a site that was previously developed as a single family home. • Where 50 percent or more of the impervious surface of a previously developed site is proposed to be altered and the previous development project was not subject to post-construction stormwater quality control measures, the entire development site (e.g., both the existing development and the proposed alternation) must meet the requirements of the LID Standards Manual. • Where less than 50% of the impervious surface of a previously developed site is proposed to be altered and the previous development project was not subject to post-construction stormwater quality control measures, only the proposed alteration must meet the requirements of the LID Standards Manual. • Redevelopment does not include routine maintenance activities that are conducted to maintain original line and grade, hydraulic capacity, original purpose of facility or emergency redevelopment activity required to protect public health and safety. Impervious surface replacement, such as the reconstruction of parking lots and roadways which does not disturb additional area and maintains the original grade and alignment, is considered a routine maintenance activity. Redevelopment does not include the repaving of existing roads to maintain original line and grade.

C. Site Description

The project is located just southwest of the intersection of West San Bernardino Road and North Rimsdale Avenue, in the City of Covina. The assessor's parcel numbers (APN) for the site are 8434-017-008, 8343-0017-009 and 8434-018-020.

Surrounding land use include commercial to the north and east; single-family residential to the south; and residential (apartments) to the west.

Existing land use for the project site is commercial, with the northern portion of the site consisting of a portion of an existing bowling alley, the southeastern and south-central portion consisting of a parking lot and the southwestern portion consisting of a building facility previously used for a church.

D. Project Description

Trumark Homes proposes Vesting Tentative Tract Map No. 82874 for a mixed-use development consisting of residential and commercial uses. The commercial building located in the northeastern portion of the project site will remain as existing. The remaining site will consist of 16 multi-level buildings to accommodate 132 multi-family residential units, common landscaping areas, private streets, curb, gutter, sidewalk and storm drain improvements, wet and dry utilities and related infrastructure improvements. The project will also include street and parkway improvements to Rimsdale Avenue to the east.

A summary of the project's land use is as follows:

Lot	Land Use	Acres
1	Mixed Use (Residential and Commercial)	5.49
Total	--	5.49

Parking for the project will include garage one or two-car garages for each residential unit (14 spaces and 236 spaces, respectively), 27 uncovered spaces within the project's private residential drives, 33 open spaces in the commercial area and 37 spaces along the west side of Rimsdale Avenue. Total parking proposed is 347 spaces.

Proposed landscaping will consist of common open space areas located along project walkways and parkways. Total landscaping is anticipated to consist of approximately 14% of the project site, or 0.636 acres.

Paved and other impervious areas of the site include the project's project private drives, parking areas, curb, walkways and gutter improvements, the building footprint of each residential unit as well as the existing commercial building. Total impervious surface is anticipated to consist of 86% of the total project site, or 3.904 acres.

Activities typical of residential developments can be anticipated for the residential portion of the project. These are anticipated to include day to day activities such as recreation, commuting, gardening and other typical residential activities.

Activities typical of commercial shopping centers can be anticipated for the commercial portion of the project and include shopping and related activities.

E. Geotechnical Conditions

Topography – The topography of the project site relatively flat, with elevations ranging from 479.5 feet above mean sea level to 472.5 feet above mean sea level to the southwest. Small areas of landscaping areas reside in the southern portions of the site, while the remaining site is mostly paved with scattered tree planters throughout.

Soil Type and Geology – Geographically, the subject property is located within the Transverse Ranges Geomorphic province of California. The Transverse Ranges consist of generally east-west trending mountains and valleys, which are in contrast to the north-northwest regional trend elsewhere in the state.

The Transverse Ranges are characterized by a very thick, nearly continuous sequence of Upper Cretaceous through Quaternary sedimentary rocks that has been deformed into a series of east-west trending folds associated with thrust and reverse faults. This deformation has created intrabasin highlands and intervening lowlands.

Based on onsite geotechnical investigations, the subsurface soils include Alluvium consisting of interbedded silty very fine to fine sand, fine to medium sand and fine to very course sand with gravel/rock.

Based on the County of Los Angeles soils information, onsite soils primarily consist of Hanford Fine Sandy Loam (County Soil Type 006).

Groundwater – Groundwater was encountered in any of the subsurface evaluations conducted by the geotechnical investigation (up to 30' below existing surface). Groundwater maps published by the Department of Conservation Division of Mines and Geology indicate that the historic high groundwater resides at more than 150' below existing ground surface

Other Geotechnical Issues – Based on the project's geotechnical investigations (GSC, 2017 and LGC, 2020), field evaluations have indicated the presence of soils highly susceptible to hydro-collapse.

F. Watershed Area and Drainage Conditions

Watershed – The project site lies within the eastern-central portion of the San Gabriel River Watershed. The central and lower portions of the watershed is heavily urbanized, with the lower part of the river flowing through a concrete-lined channel prior to becoming a soft bottom channel near the City of Long Beach.

Existing Drainage – Stormwater and surface water onsite generally flow from north to south and is discharged to the existing storm drain system (Facility BI 1123) in West Badillo Street via a gutter flow that feeds into existing catch basin inlets along North Rimsdale Avenue and West Badillo Street. Runoff is then conveyed westerly approximately 2.25 miles prior to discharging to Big Dalton Wash, an open, concrete lined, rectangular-channel. Runoff is then conveyed southeasterly approximately 2 miles to the confluence with the Walnut Creek Channel, prior to discharging to Reach 3, 2 and 1 of the San Gabriel River, and ultimately outflowing to the Pacific Ocean.

Proposed Drainage – In the developed condition, stormwater and surface water onsite will be conveyed as surface flow to the project's backbone storm drain system and conveyed southerly prior to discharging to the existing storm drain system in West Badillo Street.

Based on preliminary soils infiltration testing onsite for the project, project soils is conducive for infiltration. However, further study of soil composition onsite determined that due to the presence of soils highly susceptible to hydro-collapse, the intentional addition of water into these soils could result in significant soil settlement potentially impacting existing offsite improvements and/or proposed onsite improvements. Therefore, the project's geotechnical professional has determined that the intentional infiltration of stormwater is not feasible.

G. Other Site Considerations

Existing Utilities – Based on preliminary site assessment, the locations of existing utilities onsite and offsite would not pose any issues to the project's proposed BMPs.

H. Receiving Water Impairments

When designated beneficial uses of a particular water body are compromised by water quality, Section 303(d) of the Clean Water Act requires identifying and listing that water body as "impaired". Once a water body has been deemed impaired, a Total Maximum Daily Load ("TMDL") must be developed for each water quality constituent that compromises a beneficial use. A TMDL is an estimate of the total load of pollutants, from point, non-point, and natural sources, that a water body may receive without exceeding applicable water quality standards (with a "factor of safety" included). For point sources, including stormwater, the load allocation is referred to as a "Waste Load Allocation" (WLA) whereas for nonpoint sources, the allocation is referred to simply as a "Load Allocation".

Impairments to the project's receiving waters are as follows:

Receiving Water	303(d)	TMDL Status
Walnut Creek	Benthic Community Effects Indicator Bacteria pH	TMDL Required
San Gabriel River Reach 3	Indicator Bacteria	Being addressed with USEPA approved TMDL
San Gabriel River Reach 2	Cyanide Temperature	TMDL Required
	Lead	Being addressed with USEPA approved TMDL
San Gabriel River Reach 1	pH Temperature	TMDL Required
San Gabriel River Estuary	Dioxin Nickel Oxygen, Dissolved	TMDL Required
	Copper Indicator Bacteria	Being addressed with USEPA approved TMDL

I. Pollutants of Concern

Urban storm water run-off in both the dry and rainy season contains pollutants that can be carried through the storm drain networks to lakes, streams and beaches. The anticipated pollutants of concern for this Project are as follows:

Bacteria and Viruses. Potential sources of bacteria for the Project include landscaping areas, pet wastes, food wastes and naturally occurring sources.

Nutrients. Potential sources of nutrients in storm water consist of the macro-nutrients nitrogen and phosphorous, which are typically found in fertilizers from landscaping areas, decaying vegetation from preservation/natural areas and trash and debris.

Pesticides. Potential sources of pesticides include common landscaping areas and homeowner-owned landscaping areas.

Sediment/Suspended Solids. Potential sources of sediment and suspended solids include landscaping areas.

Trash & Debris. Potential sources include misplacement or overfill of food wastes, wrappers, and other trash materials.

Metals. Potential sources include vehicles and vehicular fluids.

Oil and Grease. Potential sources of oil and grease include automotive vehicles and fluids and maintenance equipment.

Toxic Organic Compounds. Potential sources include pesticides, solvents and hydrocarbons.

II. BEST MANAGEMENT PRACTICES (BMP's)

BMPs are natural or constructed devices, procedures, rules or methods, which when implemented and followed, should reduce and/or eliminate the specific source of pollution of which the BMP is targeted.

A. Site Design Principles

The intention of site design principles is to reduce runoff peak flows and volumes resulting from land development. As required by the MS4 Permit and the County of Los Angeles Low Impact Development Manual, the following site design principles must be considered for use on all projects:

Site Planning – Project proponents must implement a holistic approach to site design in order to develop a more hydraulically-functional site, help maximize the effectiveness of on-site retention and integrate storm water management throughout the project site.

Based on the project's geotechnical report, focused infiltration of runoff is feasible. The project's landscaping areas will provide some retention of runoff via absorption from vegetation and underlying soils.

Protect and Restore Natural Areas – Conservation of natural areas, soils and vegetation helps to retain numerous functions of pre-development hydrology, including rainfall interception, infiltration, and evapotranspiration. Each project site possesses unique topographic, hydrologic, and vegetative features, some of which are more suitable for development than others. Sensitive areas, such as streams and their buffers, floodplains, wetlands, steep slopes, and highly-permeable soils, should be protected and/or restored. Slopes can be a major source of sediment and should be properly protected and stabilized. Locating development in less sensitive areas of a project site and conserving naturally vegetated areas can minimize environmental impacts from storm water runoff.

The pre-project site consists of very little vegetation and no natural areas to preserve. Project proposes the use of drought tolerant landscaping within common landscape areas.

Minimize Land Disturbance – The purpose of this site design principle is to protect water quality by preserving the natural hydrologic function of the project site to the maximum extent practicable. By designing a project site layout to preserve natural hydrology and drainage ways at the project site, it reduces the need for grading and disturbance of native vegetation and soils. Siting buildings and impervious surfaces away from steep slopes, drainage ways, and floodplains limits the amount of grading and clearing necessary and reduces the hydrologic impact. This site design principle is most applicable in Greenfield settings, but opportunities to implement this principle may exist in redevelopment projects.

The project site consists of commercial facilities with no natural hydrologic function. Therefore, this site design principle has not been incorporated into project design.

Minimize Impervious Area – The potential for discharge of pollutants in storm water runoff from a project site increases as the percentage of impervious area within the project site increases because impervious areas increase the volume and rate of storm water runoff. Pollutants deposited on impervious areas are easily mobilized and transported by storm water runoff. Minimizing impervious area through site design is an important method to reducing the pollutant load in storm water runoff.

The Project proposes to minimize impervious area via the use of multi-level units, as well as minimum-width roadway and sidewalk sections wherever feasible.

B. Source Control Measures

Source control measures are designed to prevent pollutants from contacting storm water runoff or preventing discharge of contaminated storm water runoff to the storm drain system and/or receiving water.

This section describes structural-type, source control measures that must be considered for implementation, in conjunction with appropriate non-structural source control measures, such as good housekeeping and employee training, to optimize pollution prevention.

Structural Controls

Storm Drain Message and Signage (S-1) – Storm drain stencils are highly visible source controls that are typically placed directly adjacent to storm drain inlets. The stencil contains a brief statement that prohibits the dumping of improper materials into the storm water conveyance system. Graphical icons, either illustrating anti-dumping symbols or images of receiving water fauna, are effective supplements to the anti-dumping message.

- All storm drain inlets and catch basins within the project area must be stenciled with prohibitive language (such as: "NO DUMPING – DRAINS TO OCEAN") and/or graphical icons to discourage illegal dumping.
- Signs and prohibitive language and/or graphical icons, which prohibit illegal dumping, must be posted at public access points along channels and creeks within the project area.
- Legibility of stencils and signs must be maintained.

All onsite catch basin will be stenciled with the language, "NO DUMPING – DRAINS TO OCEAN" or equivalent phrase. The stencils shall be maintained by the HOA.

Outdoor Material Storage Areas (S-2) – None proposed.

Outdoor Trash Storage/Waste Handling Areas (S-3) – None proposed for residential. No new facility proposed for commercial site.

Outdoor Loading/Unloading Dock Area (S-4) – None proposed.

Outdoor Vehicle/Equipment Repair/Maintenance Area (S-5) – None proposed.

Outdoor Vehicle/Equipment/Accessory Wash Area (S-6) – None proposed.

Fuel and Maintenance Area (S-7) – None proposed.

Landscape Irrigation Practices (S-8) – Irrigation runoff provides a pathway for pollutants (i.e., nutrients, bacteria, organics, sediment) to enter the storm drain system. By controlling irrigation, runoff and the potential for pollutant transport is minimized.

Landscape and irrigation areas shall meet the following requirements:

- Minimize use of fertilizer, pesticides, and herbicides.
- Plan sites with sufficient landscaped area and dispersal capacity.
- Consult a landscape professional regarding appropriate plants, fertilizer, mulching applications and irrigation requirements to ensure healthy flora.
- Choose plants that minimize need for fertilizer and pesticides.
- Use native and/or drought tolerant plant species. Group plantings with similar water requirements.
- Employ use of mulch.
- Install rain sensors and pressure sensors to shut off irrigation system during, after rain storms and pressure drops/leaks.
- Implement integrated Pest Management Practices.

Building Materials Selection (S-9) – Building materials can potentially contribute pollutants of concern to storm water runoff through leaching. The use of alternative building materials can reduce pollutants in storm water by eliminating compounds that can leach into storm water runoff. This BMP shall be considered during any work conducted onsite by the property owner.

Alternative materials include the following:

- Replace use of pressure treated wood with cement-fiber or vinyl.
- Minimize the use of copper and galvanized metals on buildings and fencing.

Animal Care and Handling Facilities (S-10) – None proposed.

Outdoor Horticulture Areas (S-11) – None proposed.

Non-Structural Controls

Education of Property Owners, Tenants and Occupants –Educational materials will be provided to homeowners at close of escrow by the owner and periodically thereafter by the HOA to inform them of their potential impacts to downstream water quality. Materials include those described in Attachment F of this report.

Activity Restrictions – Activity restrictions to minimize potential impacts to water quality and with the purpose of protecting water quality will be prescribed by the project's Covenant, Conditions and Restrictions (CC&Rs).

Common Area Landscape Management – Maintenance activities for landscape areas shall be consistent with County and manufacturer guidelines for fertilizer and pesticide. Maintenance includes trimming, weeding and debris removal and vegetation planting and replacement. Stockpiled materials during maintenance activities shall be placed away from drain inlets and runoff conveyance devices. Wastes shall be properly disposed of or recycled. Application of materials shall be limited to the minimum required amounts and restricted within 48 hours prior to rain events.

Common Area Litter Control – Litter control onsite will include the use of HOA, violation reporting and clean up during landscaping maintenance activities and as needed to ensure good housekeeping of the project's common areas.

Street Sweeping Private Streets– The project's private streets shall be swept on a quarterly (at minimum) basis, including prior to the start of the traditional rainy season and as needed.

C. Storm Water Quality Design Volume (SWQDv)

The design storm, from which the SWQDv is calculated, is defined as the greater of:

- The 0.75-inch, 24-hour rain event; or
- The 85th percentile, 24-hour rain event as determined from the Los Angeles County 85th percentile precipitation isoheytal map.

The SWQDv values for the project were determined using the HydroCalc Program.

Drainage Management Area (DMA)	Acres	% Imp.	D_{85} (in)	Q_{BMP} (cfs)	SWQDv (cu-ft)
DMA 1	4.44	0.86	1.0	0.7949	12,595.6
DMA 2	0.71	0.96	1.0	0.1473	2,218.6

D. Storm Water Quality Control Measures

Storm water quality control measures function to augment site design principles and source control measures to reduce storm water runoff volume and potential pollutant loads in runoff to the maximum extent practicable.

Selection of the project's treatment BMPs was based on MS4 Permit requirements, which requires that all designated projects retain the SWQDv on-site using retention based measures, unless retention based measures are determined to be infeasible. Consideration was also given to site constraints, effectiveness in addressing the project's anticipated pollutants of concern; as well as compliance with receiving water impairments and discharge limitations.

Per the project's Geotechnical Engineering Investigations (GeoSoils Consultants, 2017 and LGC, 2020) and the preliminary infiltration testing results conducted onsite, infiltration was initially assumed to be feasible. However, based on additional information provided from borings conducted onsite, which indicated the presences of soils that are susceptible to hydro-collapse, infiltration has been determined to be infeasible by the project's geotechnical professional.

Harvest and Reuse (aka. Rainwater Harvesting) BMPs are LID BMPs that capture and store storm water runoff for later use. These BMPs are engineered to store a specified volume of water and have no design surface discharge until this volume is exceeded. Harvest and use BMPs include both above-ground and below-ground cisterns. Examples of uses for harvested water include irrigation, toilet and urinal flushing, vehicle washing, evaporative cooling, industrial processes and other non-potable uses. Harvest and use is not feasible due to limited landscaping, approximately 0.64 acres and the use of xeriscape landscaping that require low water use.

With geotechnical constraints as well as the lack of available landscaping areas for retention (infiltration and harvest/use) and also non-proprietary biofiltration BMP's, the project proposes the use of Proprietary Biotreatment BMP's to address potential pollutants in the project's storm water runoff.

Per the RWQCB letter dated October 4, 2019, MWS Linear are an approved alternative on-site biofiltration design in situations where a project applicant has demonstrated technical infeasibility for retention BMPs. The have been sized based on the Adjusted Design Intensity to provide additional capture in lieu of volume reduction per Design Table 6 of "Equivalency Analysis and Design Criteria for Modular Wetland Systems" pursuant to Los Angeles County MS4 Permit, Order R4-2012-0175.

The corresponding treatment rates and sizing of the proposed MWS units are provided in the following table. Supporting calculations are provided in Attachment C of this report.

DMA	Area (AC)	T_C (min)	C_D	Ix (in/hr)	Q_{PM} (cfs)	MWS #	MWS Size	MWS Capacity (cfs)	Provided Capacity (cfs)
DMA1	4.44	39	0.788	0.352	1.2726	#1	MWS-8-24	0.693	1.386
						#2	MWS-8-24	0.693	
DMA2	0.71	35	0.868	0.369	0.229	#3	MWS-4-19	0.237	0.237

To meet the zero trash discharge requirement, all project catch basins will be equipped with FULL CAPTURE catch basin inserts/inlet screens to remove trash/litter, debris and sediment from runoff entering the project's storm drain system.

E. Hydromodification Requirements

The project is exempt from the hydromodification requirements of the MS4 Permit, as the project discharges through a fully improved storm drain system that discharges to Big Dalton Wash, Walnut Creek and the San Gabriel River that is not susceptible to hydromodification impacts.

III. Storm Water Quality Control Measure Maintenance

1. Maintenance and inspection activities for the identified BMPs will be performed as indicated on the enclosed BMP Inspection and Maintenance Responsibility/Frequency Matrix in Attachment D.

2. The project owner and proponent, TRUMARK HOMES shall employ self-inspections and record keeping for BMPs, as applicable. The owner shall retain all maintenance records for a period of five (5) years after the recorded inspection date for the lifetime of the Project. The records shall be made readily available for review by all government agencies. Depending on the type of BMP, minimum frequency of inspections may range from weekly, to once a month, quarterly, or yearly.

3. The contact information for the owner is as follows:

Property Owner:	TRUMARK HOMES
Contact:	Joe Martin
Address:	450 Newport Center Drive, Suite 300 Newport Beach, CA 92660
Phone:	(949) 999-9800

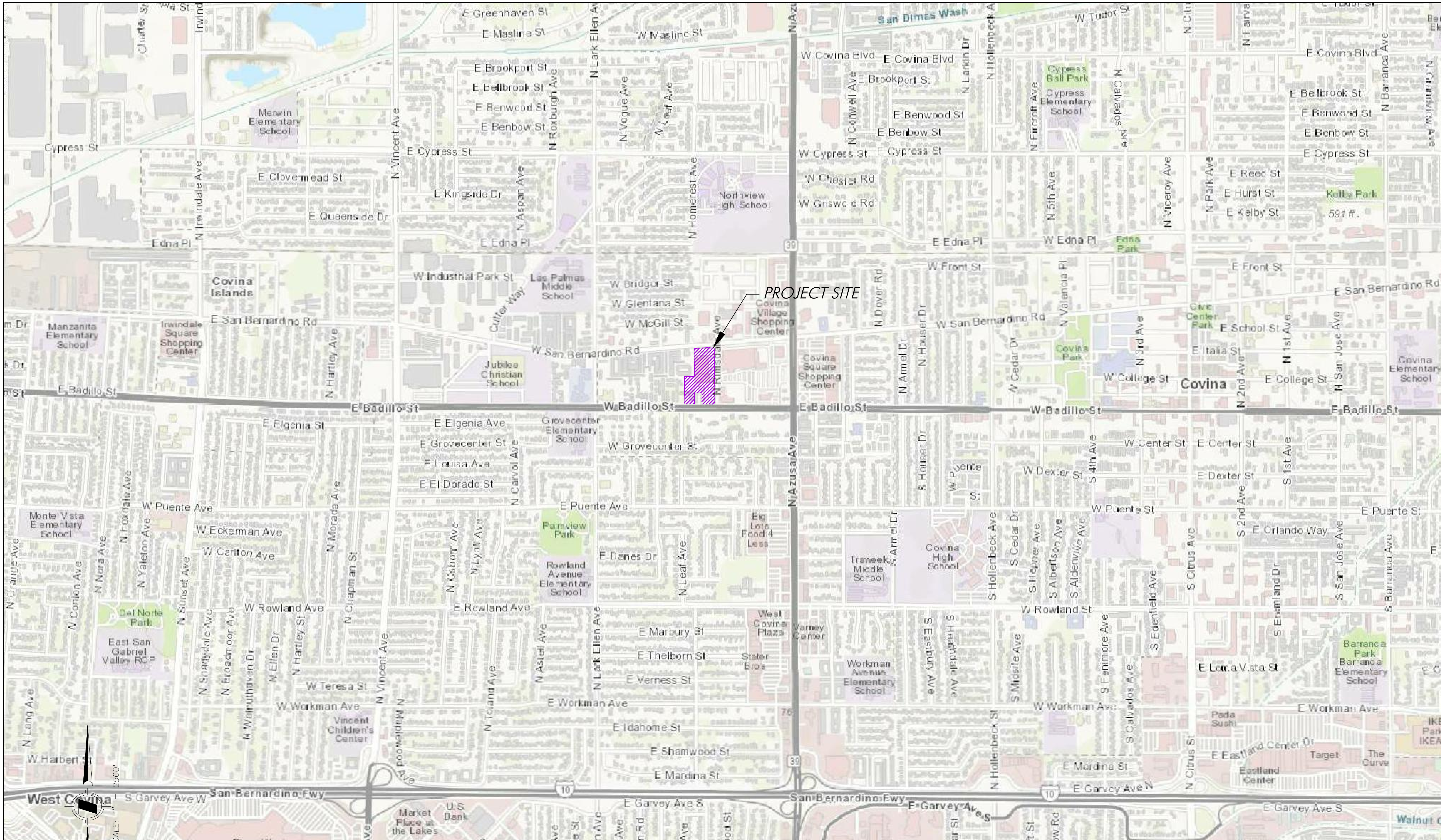
   TRUMARK HOMES shall be responsible for the management of the residential portion of the project site and implementation and maintenance of the requirements of this LID Report until such time, the property has not been turned over to the HOA for ownership and maintenance.

4. A copy of the project's on-site BMP maintenance covenant to be recorded at the County of Los Angeles shall be inserted in Attachment F. This maintenance covenant has been devised by the County of Los Angeles to legally assign responsibilities for maintenance of proposed BMP facilities such that they run with the land. In order to comply with item A of the LID Report (provide proof of ongoing BMP maintenance), responsibilities have been listed as an encumbrance on the property (per the maintenance covenant), and shall be signed by the owners, and shall be recorded in the Los Angeles County Recorder's Office.

5. Should a transfer of ownership occur, appropriate notification shall be filed with the County of Los Angeles confirming the change in responsibility and continued implementation of stormwater management requirements.

ATTACHMENTS

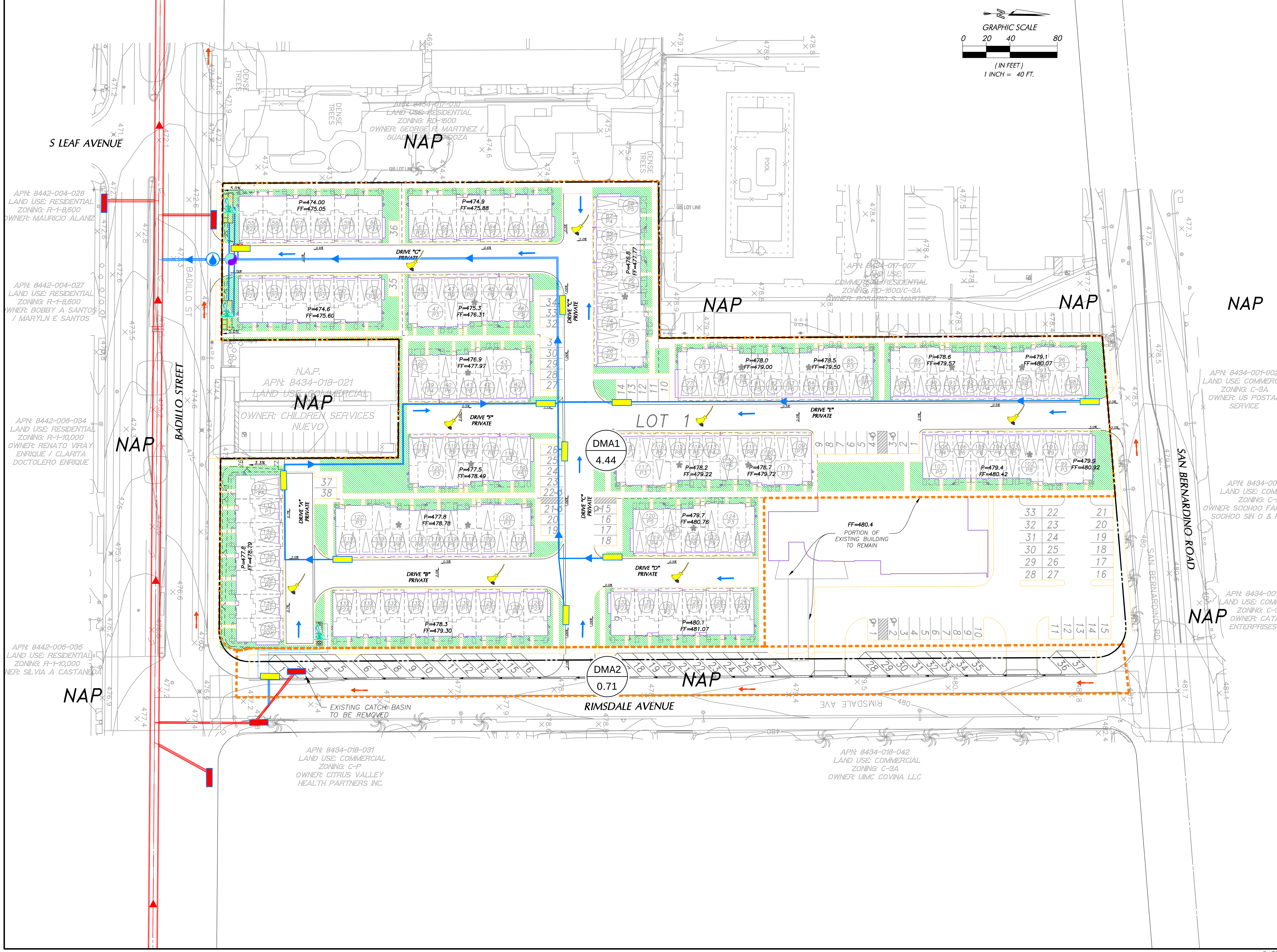
ATTACHMENT A VICINITY MAP



DRAWN BY: TIH	PREPARED BY:	PREPARED FOR:	TENTATIVE TRACT MAP NO. 82874	LID PLAN
DATE: 05/05/2020	HUNSAKER & ASSOCIATES IRVINE, INC.	TRUMARKHOMES	SOUTHWEST OF WEST SAN BERNARDINO ROAD AND NORTH RIMSDALE AVENUE	VICINITY
W.O.: 3593-42	PLANNING ■ ENGINEERING ■ SURVEYING Three Hughes, Irvine, CA 92618 ■ PH: (949) 583-1010 ■ FX: (949) 583-0759	450 NEWPORT CENTER DRIVE, SUITE 300 NEWPORT BEACH, CA 92660 (949) 999-9800	COVINA, CA	MAP

DATE: May. 05, 2020 12:45:29 PM FILE: F:\1080\Planning\SY_WQ\LID\Exhibits\LID_VIC Covina Bowl.dwg

ATTACHMENT B SITE PLAN



LEGEND

- PROJECT LIMITS
- DRAINAGE MANAGEMENT AREA (DMA) BOUNDARY
- DMA / ACRE — DMA DESIGNATION AND ACREAGE
- NAP — NOT A PART
- SURFACE FLOW (ONSITE)
- SURFACE FLOW (OFFSITE)
- EXISTING DRAINAGE SYSTEM
- PROPOSED DRAINAGE SYSTEM
- EXISTING CATCH BASIN
- PROPOSED CATCH BASIN/INLET WITH BMP
  S1 – STORM DRAIN SYSTEM STENCILING/SIGNAGE
  T-6 – CATCH BASIN INSERTS/SCREENS
- PROPOSED BUILDING FOOTPRINT
- PROPOSED OPEN SPACE/LANDSCAPING AREA WITH BMPS
  S8 – LANDSCAPE IRRIGATION PRACTICES
  COMMON AREA LANDSCAPE MANAGEMENT
- PROJECT DRIVEWAYS AND WALKWAYS
- PROJECT PRIVATE DRIVES WITH BMP
  STREET SWEEPING
- WATER QUALITY DIVERSION STRUCTURE
- DISCHARGE POINT
- BMP T-6 PROPRIETARY BIOTREATMENT
  MODULAR WETLAND SYSTEM

BMP SUMMARY

DMA	Area (AC)	T_C (min)	C_D	Ix (in/hr)	Q_{PM} (cfs)	MWS #	MWS Size	MWS Capacity (cfs)	Provided Capacity (cfs)
DMA1	4.44	39	0.788	0.352	1.2726	#1	MWS-8-24	0.693	1.386
						#2	MWS-8-24	0.693	
DMA2	0.71	35	0.868	0.369	0.229	#3	MWS-4-19	0.237	0.237

LOW IMPACT DEVELOPMENT (LID) PLAN - SITE PLAN

APPLICANT:
TRUMARKHOMES
450 NEWPORT CENTER DRIVE, SUITE 300
NEWPORT BEACH, CA 92660
(949) 999-9800

PREPARED BY:
HUNSAKER & ASSOCIATES
IRVINE, INC.
PLANNING • ENGINEERING • SURVEYING
Three Hughes • Irvine, CA 92618 • PH: (949) 583-1010 • FX: (949) 583-0759

TENTATIVE TRACT MAP NO. 82874
SOUTHEAST OF WEST SAN BERNARDINO ROAD &
NORTH RIMSDALE AVENUE
COVINA, CA

DRAFTED BY: TIH | DATE: 05/05/2020 | W.O. NO: 3593-42 | SHEET NO: 1 OF 1

DATE: May. 05, 2020 12:56:53 PM FILE: F:\1080\Planning\SY_WQ\LID\Exhibits\LID_SP Covina Bowl.dwg

ATTACHMENT C BMP CALCULATIONS AND DETAILS

BMP Calculations

The project will be required to comply with the newly adopted MS4 Permit. This will require all filtration water quality devices to be sized per Adjusted Design Intensity to Provide Additional Capture In Lieu of Volume Reduction (see attached below).

July 2018

Table 6: Adjusted Design Intensity to Provide Additional Capture In Lieu of Volume Reduction (Option B)

Adjusted Time of Concentration (min)	Reliable Infiltration Rate at Site			
	0 in/hr (ET only) Capture Efficiency Target = 93.8%	**0.01 in/hr** Capture Efficiency Target = 94.1%	**0.05 in/hr** Capture Efficiency Target = 95.4%	**0.15 in/hr** Capture Efficiency Target = 98.1%
	Adjusted MWS Design Precipitation Intensities, in/hr			
5	0.55	0.57	0.66	N/A
7.5	0.51	0.53	0.60	0.96
10	0.48	0.49	0.57	0.90
15	0.44	0.45	0.52	0.79
20	0.41	0.42	0.48	0.74
30	0.37	0.38	0.43	0.64
60	0.31	0.31	0.35	0.50

NA = additional capture is not a viable option to offset volume reduction in these cases.

On-site Area (Area 1A)

Per SUSMP flow rate calculations,

$Q_{PM} = C_D * I_X * A_{Total} * (1.008333 \text{ ft}_3\text{-hour / acre-inches-seconds})$

Where:

QPM =Peak Mitigation Flow Rate (cfs)

$C_D = (0.9 * \text{Imp.}) + [(1.0 - \text{Imp.}) * C_U]$

Imp=0.86 for Apartments and Condominiums Residential, Cu=0.1 per below

=0.9*0.86+ (1-0.86)*0.1

=**0.788**

C_U = Undeveloped Runoff Coefficient, (**0.1** for Soil 06)
I_X = **0.352**, Rainfall Intensity (inches / hour) (per above Table 6 using Infiltration Rate at 0 in/hour,
TC=**39 minutes** per 85th Percentile HydroCalc Calculations)
A_{Total} = **4.44 acres** (Total Area in acres)

Rimsdale Avenue Widening (Area 2B)

Please note, only Half Street of Rimsdale Avenue tributary areas are applied in the BMP sizings.

Per SUSMP flow rate calculations,

$Q_{PM} = C_D * I_X * A_{Total} * (1.008333\ ft^3\text{-hour / acre-inches-seconds})$

Where:

QPM =Peak Mitigation Flow Rate (cfs)

$C_D = (0.9 * Imp.) + [(1.0 - Imp.) * C_U]$

Imp=0.96 for the roadway, Cu=0.1 per below

=0.9*0.96+ (1-0.96)*0.1

=**0.868**

C_U = Undeveloped Runoff Coefficient, (**0.1** for Soil 06)
I_X = **0.369**, Rainfall Intensity (inches / hour) (per above Table 6 using Infiltration Rate at 0 in/hour,
TC=**35 minutes** per 85th Percentile HydroCalc Calculations)
A_{Total} = **0.71 acres** (Total Area in acres – half street of Rimsdale Avenue)

The LID flow rate calculations can be found from the following table.

LID Flow Rate and Treatment BMP Summary Table
Covina Bowl - VTTM 82874
City of Covina, County Of Los Angeles

DMA	Area (acre)	TC (Min)	C_D	Ix (in/hr)	Q_{PM} (cfs)	MWS #	MWS Size	MWS Design Capacity (cfs)	Provided Capacity (cfs)
On-Site Area	4.44	39	0.788	0.352	1.2726	#1	MWS-8-24	0.693	1.386
						#2	MWS-8-24	0.693	
Rimsdale Widening	0.71	35	0.868	0.369	0.229	#3	MWS-4-19	0.237	0.237

Peak Flow Hydrologic Analysis

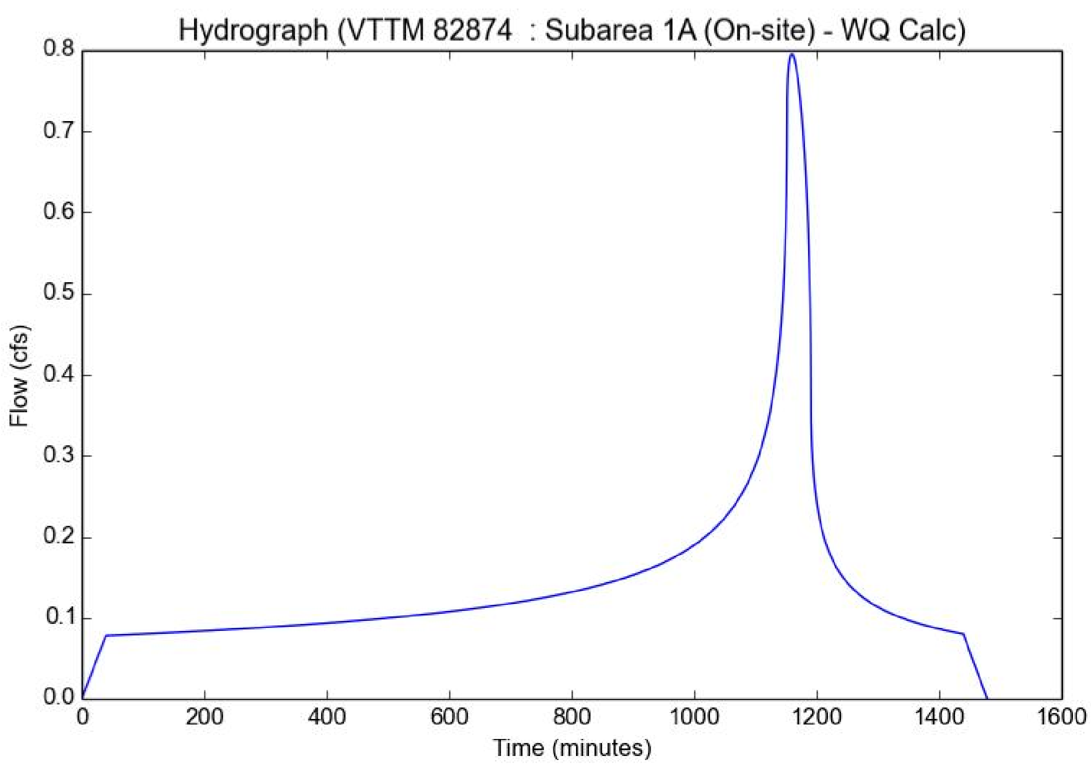
File location: C:/SD/Covina Bowl/VTTM 82874 - Subarea 1A (On-site) - WQ Calc.pdf
Version: HydroCalc 1.0.3

Input Parameters

Project Name	VTTM 82874
Subarea ID	Subarea 1A (On-site) - WQ Calc
Area (ac)	4.44
Flow Path Length (ft)	880.0
Flow Path Slope (vft/hft)	0.007
85th Percentile Rainfall Depth (in)	1.0
Percent Impervious	0.86
Soil Type	6
Design Storm Frequency	85th percentile storm
Fire Factor	0
LID	True

Output Results

Modeled (85th percentile storm) Rainfall Depth (in)	1.0
Peak Intensity (in/hr)	0.2272
Undeveloped Runoff Coefficient (Cu)	0.1
Developed Runoff Coefficient (Cd)	0.788
Time of Concentration (min)	39.0
Clear Peak Flow Rate (cfs)	0.7949
Burned Peak Flow Rate (cfs)	0.7949
24-Hr Clear Runoff Volume (ac-ft)	0.2892
24-Hr Clear Runoff Volume (cu-ft)	12595.6378



Peak Flow Hydrologic Analysis

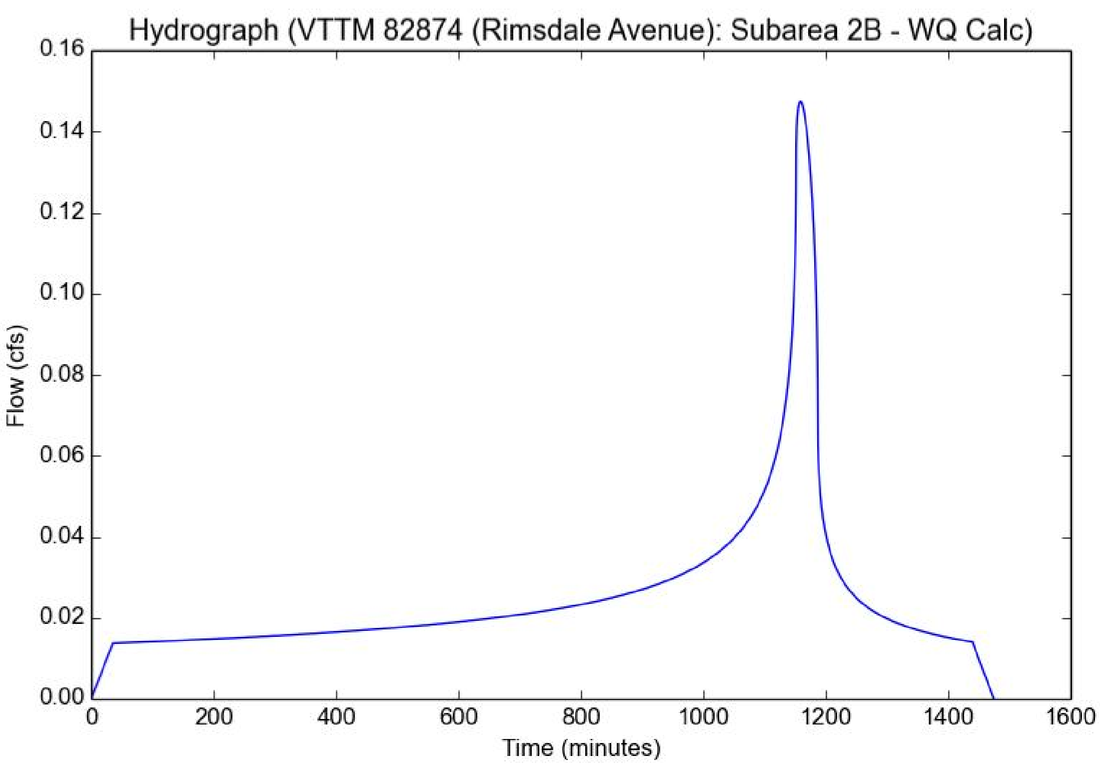
File location: C:/SD/Covina Bowl/VTTM 82874 (Rimsdale Avenue) - Subarea 2B - WQ Calc.pdf
Version: HydroCalc 1.0.3

Input Parameters

Project Name	VTTM 82874 (Rimsdale Avenue)
Subarea ID	Subarea 2B - WQ Calc
Area (ac)	0.71
Flow Path Length (ft)	760.0
Flow Path Slope (vft/hft)	0.0055
85th Percentile Rainfall Depth (in)	1.0
Percent Impervious	0.96
Soil Type	6
Design Storm Frequency	85th percentile storm
Fire Factor	0
LID	True

Output Results

Modeled (85th percentile storm) Rainfall Depth (in)	1.0
Peak Intensity (in/hr)	0.2391
Undeveloped Runoff Coefficient (Cu)	0.1
Developed Runoff Coefficient (Cd)	0.868
Time of Concentration (min)	35.0
Clear Peak Flow Rate (cfs)	0.1473
Burned Peak Flow Rate (cfs)	0.1473
24-Hr Clear Runoff Volume (ac-ft)	0.0509
24-Hr Clear Runoff Volume (cu-ft)	2218.6428



EQUIVALENCY ANALYSIS AND DESIGN CRITERIA for MODULAR WETLANDS SYSTEMS (MWS LINEAR)

Pursuant to:

Los Angeles County MS4 Permit (Order R4-2012-0175)

Prepared for

Bio Clean, a Forterra Company

Prepared by

Geosyntec consultants

engineers | scientists | innovators

621 SW Morrison Street, Suite 600
Portland, Oregon 97205

July 2018

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1 INTRODUCTION

The Los Angeles County MS4 Permit (Order No. R4-2012-0175) (MS4 Permit) requires that new development and redevelopment projects infiltrate 100 percent of the Stormwater Quality Design volume (SWQDv) on-site as the preferred approach unless technical infeasibility or alternative approaches apply (Provision 7.c). When it is not technically feasible to fully infiltrate the SWQDv, the MS4 Permit allows for on-site biofiltration to be used if it meets the specific criteria in Attachment H of the MS4 Permit. The MS4 Permit also allows for Los Angeles County Regional Water Quality Control Board (Regional Board) Executive Officer to approve alternate biofiltration design criteria.

The purpose of this report is to develop a design basis for Modular Wetland Systems Linear (MWS Linear) such that these systems will provide equivalent performance to biofiltration BMPs as defined in Attachment H of the MS4 Permit. This report is intended to serve as technical support for requests to the Executive Officer of the Regional Board for approval of alternative design criteria for MWS Linear systems. This report describes the basis for evaluating equivalency, details the design approach and equivalency criteria for MWS Linear systems to achieve equivalent performance to conventional biofiltration, and provides the supporting rationales for these equivalency criteria.

The remainder of this report is organized as follows:

Section 2 – BMP Descriptions (Conventional Biofiltration and MWS Linear)

Section 3 – Basis and Methodology for Evaluating Equivalency

Section 4 – MWS Linear Design Approach and Equivalency Criteria

Section 5 – Discussion and Conclusions

Section 6 – References

Appendix A – Design Assumptions for Conventional Biofiltration

Appendix B – SWMM Modeling Methodology and Assumptions

Appendix C – Datasets and Analysis Methods for Pollutant Treatment Evaluation

Appendix D – Results of BMP Treatment Performance Evaluation

2 BMP DESCRIPTIONS

2.1 Conventional Biofiltration

Biofiltration (also known as bioretention with underdrain) consists of shallow landscaped depressions that capture and filter stormwater runoff through engineered media. These facilities function as soil and plant-based filtration systems that remove pollutants through a variety of physical, biological, and chemical treatment processes. Biofiltration facilities normally consist of a ponding area, mulch layer, soils, and plantings (Figure 1). An optional gravel layer added below the planting soil coupled with an upturned elbow (or similar hydraulic control approach) can provide additional storage volume for infiltration. As stormwater passes through the planting soil pollutants are filtered, adsorbed, and biodegraded by the soil media, microorganisms living in the soil and optional gravel layer, and plants. Conventional biofiltration is typically designed as a "volume-based" BMP, meaning that is it sized based on capture of the runoff from a specific size of storm event (the SWQDv).

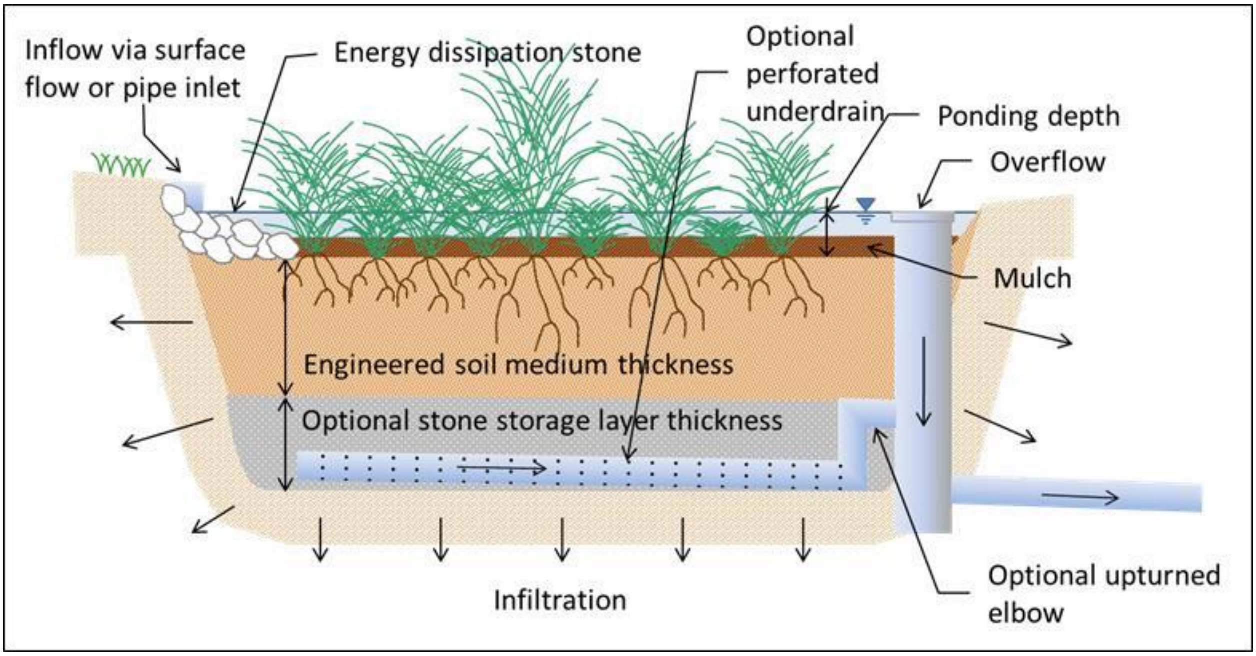

Figure 1: Cross sections of typical biofiltration system

2.2 MWS Linear

MWS Linear consist of a pre-treatment chamber, a horizontal flow biofiltration zone, and a discharge structure (Figure 2). The pre-treatment chamber separates trash and debris from smaller contaminants and includes pre-filter cartridges that utilize BioMediaGREEN filter material for reduction of TSS and hydrocarbons. This step helps to prevent clogging of the biofiltration media and acts as a small detention/equalization basin that can increase the effective time of concentration in small watersheds. The wetland biofiltration zone provides similar contaminant removal mechanisms to conventional biofiltration but uses a horizontal flow pattern to prevent clogging and improve filtration. The discharge structure provides flow control through the system. The flowrate of the system is limited by an orifice at the flow control structure. When the system fills, and the inflow rate exceeds the treated discharge rate through the orifice, flows in excess of the treatment capacity bypass treatment. MWS Linear units are available in a variety of configurations and sizes, but each has these common elements.

The MWS Linear technology has a General Use Level Designation (GULD) approved for Basic (TSS), Enhanced (dissolved metals), and Phosphorus treatment by the Washington State

Technology Assessment Protocol – Ecology (TAPE) program. It has approved treatment efficiencies and/or authorization for use as a BMP from Virginia Department of Environmental Quality, Maryland Department of the Environment, Rhode Island Department of Environmental Management, New York Department of Environmental Conservation, and City of Portland (Oregon) Environmental Services. These approvals are provided for reference only. The equivalency analysis presented in this report is based on an independent evaluation of MWS Linear performance. It is not contingent on approvals in other jurisdictions.

MWS units are typically designed as “flow-based” criteria, meaning that they are sized based on capture of the runoff from a specific rainfall rate (intensity) or runoff flowrate. However, the volume in the system upstream of the discharge structure provides some equalization of peak inflow rates.

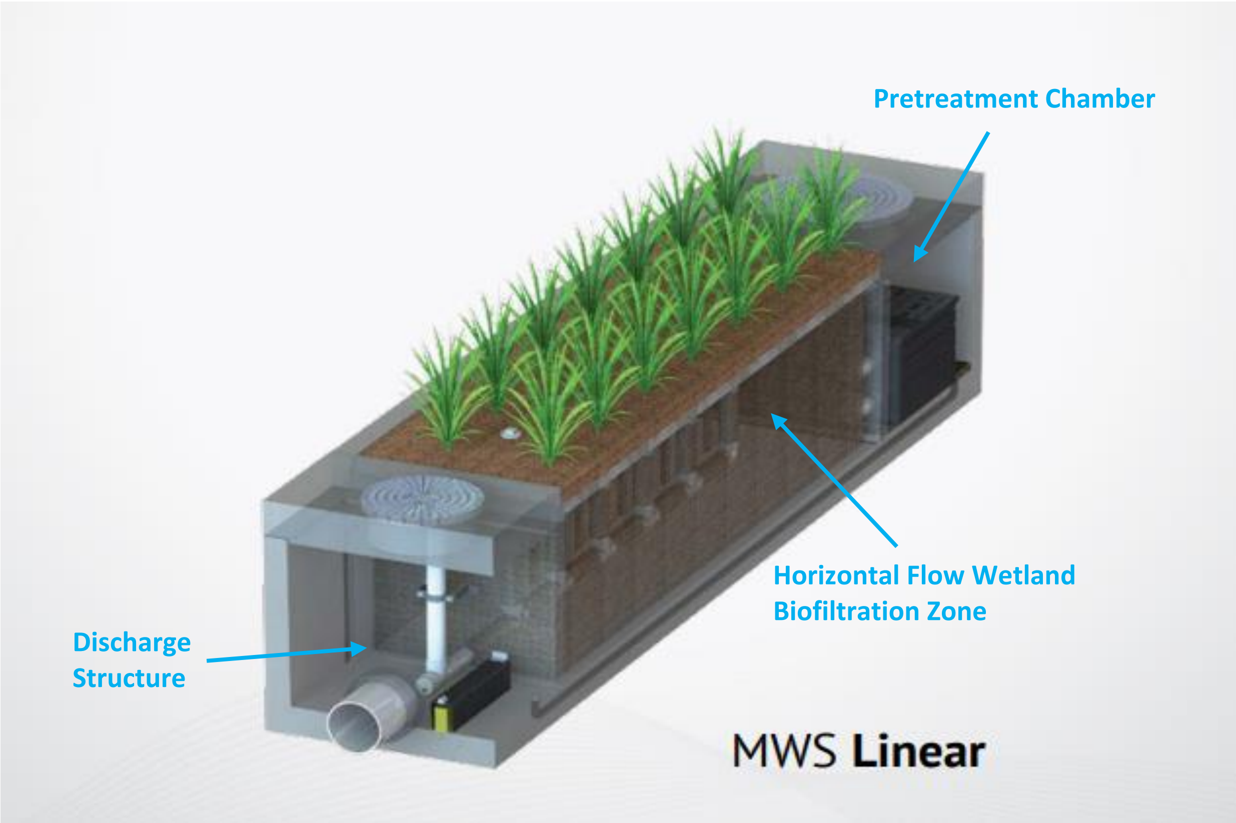

Figure 2: Typical MWS Linear Configuration

3 METHODOLOGY FOR EVALUATING EQUIVALENCY

3.1 Basis for Equivalency

The equivalency of MWS Linear to conventional biofiltration as described in Attachment H of the MS4 Permit was evaluated based on the following factors that influence pollutant load reduction performance of stormwater BMPs:

- **Capture efficiency:** The percent of long-term stormwater runoff volume that is treated by the BMP vs. bypassed.
- **Volume reduction:** The percent of long-term stormwater runoff volume that is removed from the system via infiltration or evapotranspiration and does not discharge directly to the storm sewer or surface waters.
- **Concentration reduction:** The difference in contaminant concentration between the raw stormwater runoff and the BMP-treated stormwater runoff.

The equivalency analysis consisted of three parts:

1) The baseline performance of conventional biofiltration was estimated, including representative estimates of capture efficiency, volume reduction, and concentration reduction provided by conventional designs.
2) Sizing criteria were developed for MWS Linear (with supplemental infiltration systems if needed) such that MWS Linear would provide equivalent load pollutant reduction performance to conventional biofiltration.
3) A design methodology for MWS Linear was developed to ensure consistent application of the equivalent sizing criteria in the design of MWS Linear systems.

3.2 Methods and Assumptions for Establishing Baseline for Conventional Biofiltration Performance

3.2.1 Hydrologic Performance (Capture Efficiency and Volume Reduction)

Attachment H of the MS4 Permit specifies several criteria that influence the hydrologic performance of the conventional biofiltration BMPs:

- 6 to 18-inch ponding area above media
- Optional layer of mulch
- 2 to 3 feet of engineered filter media (2 feet typical) with a design infiltration rate of 5 to 12 inches/hour; the Attachment H specification calls for a mix of 60 to 80% fine sand and 20 to 40% compost
- Gravel storage layer below the bioretention media to promote infiltration
- Underdrain placed near the top of the gravel layer (or an infiltration sump otherwise provided via an equivalent hydraulic control approach) in cases where underlying soil allows incidental infiltration
- Underdrain discharge to the storm drain system

- Capacity (including stored and filtered water) adequate to biofilter 150 percent of the portion of the SWQDv not reliably retained (i.e., infiltrated or evapotranspired).

Within the bounds established by these criteria, a range of actual conventional biofiltration designs could result as a function of site infiltration conditions as well as designer and local jurisdiction preferences. An example of potential design variability is illustrated in Appendix A. For this analysis, representative design assumptions were developed within the range of potential design assumptions. These assumptions are also presented in Appendix A with supporting rationales. Long-term continuous simulation SWMM 5.1 modeling was conducted using 18 years of 5-minute resolution precipitation data, as described in Appendix B, to estimate the long-term capture efficiency and volume reduction of the baseline biofiltration design scenario for a range of site infiltration rates. Biofiltration BMPs will tend to provide more volume reduction when installed in sites with higher incidental and allowable infiltration rates. Table 1 describes the baseline hydrologic performance of biofiltration BMPs.

Table 1. Conventional Biofiltration Hydrologic Performance

Site Soil Infiltration Rate, in/hr	Long-Term Capture Efficiency (percent of total runoff volume)	Long-Term Volume Reduction (percent of total runoff volume) (ET + Infiltration)
0	92 to 94%[1] (93% capture is representative)	4%
0.01		5%
0.05		10%
0.15		21%
0.30[2]		33%

1 - Capture efficiency varies slightly as a function of soil infiltration rate (and associated differences in design profile) and land use imperviousness. These differences are relatively minor and are less important than the variability in performance that may result from different design approaches and maintenance conditions that may be encountered. Therefore, a single baseline value of 93 percent long-term capture was used in this analysis.
2 - A maximum soil infiltration rate of 0.3 inches per hour was evaluated because for soil infiltration rates greater than 0.3 inches per hour the MS4 Permit requires that infiltration be evaluated.

3.2.2 Concentration Reduction

Pollutant concentration reduction performance for baseline biofiltration was evaluated based on analysis of bioretention with underdrain studies in the International Stormwater BMP Database. Analyses were conducted based on a screened subset of studies that were considered most representative of MS4 Permit Attachment H design criteria (16 studies). Additionally, four peer-reviewed research studies (Davis 2007; Li and Davis 2009; David et al., 2011; Gilbreath et al. 2012) not contained in the International BMP Database were added to the sample pool for analysis. Two of these studies were conducted in the San Francisco Bay area based on biofiltration design standards and media specifications very similar to Attachment H of the Los Angeles MS4 Permit. The two other additional studies were included due to their similarity to the MS4 Permit Attachment H design criteria. Note that this is the same set of conventional biofiltration studies that were considered in the Filterra Equivalency Analysis (Geosyntec Consultants, 2015). The resulting number of studies is adequate to estimate representative concentration reduction performance of conventional biofiltration.

Concentration reduction performance was characterized using a moving window bootstrapping method (Leisenring et al., 2009; see details in Appendix C) that accounts for the influence of influent concentration on effluent concentration and characterizes the relative uncertainty in performance estimates within each range of influent quality. Both the median and mean summary statistics were evaluated using these methods. Additionally, literature on the influence of biofiltration design variables on performance was summarized to support the criteria that were used to select the 20 BMP studies that were included in the screened dataset. The pollutant treatment evaluation was based on total suspended solids, total phosphorus, total nitrogen, total copper, and total zinc. Influent concentrations characteristic of single family, multi family, commercial, and light industrial land uses were applied to estimate effluent concentrations and concentration change.

Generally, biofiltration provides good removal of TSS, moderate removal of copper and zinc, and generally shows export of nutrients. Export of nutrients tends to be greater when influent concentrations are low. Details about pollutant treatment analyses are provided in Appendix C, and results of these analyses are provided in Appendix D.

3.3 <u>Modular Wetland System Analysis to Determine Equivalent Design Criteria</u>

This section provides information on how MWS Linear performance was analyzed to determine the conditions under which these systems provide equivalent performance to conventional biofiltration.

3.3.1 Capture Efficiency

Capture efficiency by MWS Linear is a function of the tributary area and runoff coefficient of the tributary area, the time of concentration of the associated watershed and internal equalization storage, and the design precipitation intensity used to size the MWS. A fully impervious catchment was used for all simulations. Continuous simulation with EPA SWMM 5.1 using the same 18 years of 5-minute resolution precipitation data (as was used for conventional biofiltration), as described in Appendix B, was used to determine the effect of time of concentration and MWS Linear sizing criteria on capture efficiency. The effect of time of concentration was determined by changing the modeled width of a one-acre catchment to match a range of time of concentrations. The treatment rate (and associated design precipitation intensity) of the unit was accounted for by using a flow rate-based flow splitter. The details of this analysis are provided in Appendix B. Figure 3 presents the results of the simulations.

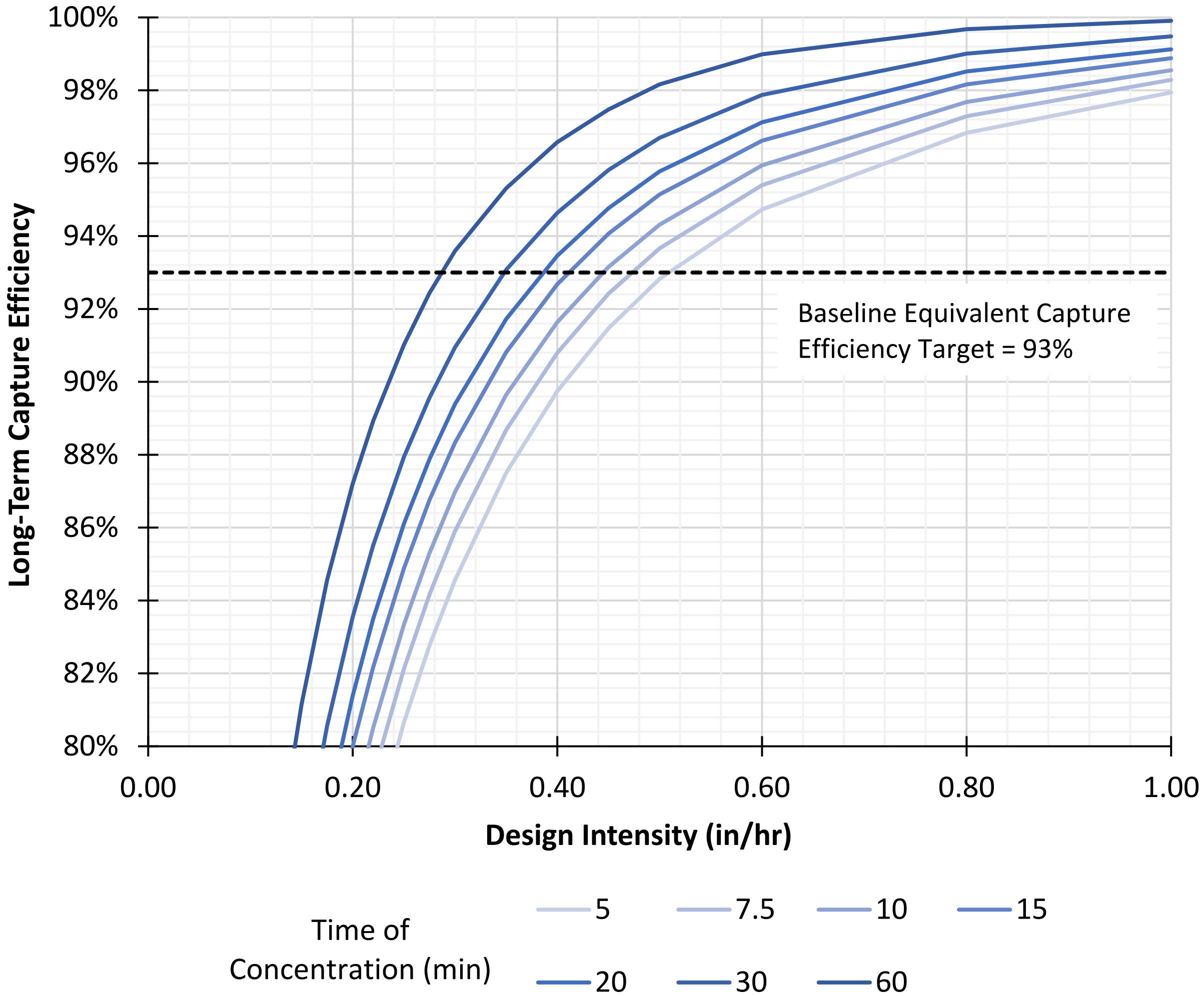

Figure 3: MWS Long-Term Capture Efficiency based on Design Intensity and Time of Concentration

3.3.2 Equalization Provided by Internal Storage

For MWS Linear, the storage within the system provides some equalization/detention prior to treatment. Because the systems are designed to limit flowrate via an orifice on the downstream end of the treatment train, the pretreatment forebay and storage within the wetland biofiltration cell must fill before bypass would occur. This was not explicitly modeled in SWMM because the ratios of storage volume to treatment flowrate vary by MWS Linear size model. The effect of this is akin to the hydrograph attenuation resulting from a longer time of concentration from the watershed. Therefore, as part of the design approach described in Section 4, this effect is accounted for by adding the detention time provided by the internal storage to the time of concentration of the watershed before looking up the required design intensity from the performance nomograph. This is a reasonable simplification.

3.3.3 Volume Reduction (MWS and Supplemental Infiltration Storage)

Volume reduction through MWS Linear is minor due to the small surface area and impermeable bottom of the treatment unit. Supplemental infiltration components may need to be added, either upstream, downstream, or underneath of the MWS Linear, to provide equivalent volume reduction to what conventional biofiltration would typically achieve under the same site conditions. Volume reduction is a function of the storage volume provided and the infiltration rate of the underlying soil. EPA SWMM 5.1 was used to conduct long-term continuous simulation to model supplemental infiltration compartments to determine the magnitude of volume reduction that would be provided if these were paired with an MWS Linear unit. A range of soil infiltration values were used to determine the long-term volume reduction of a supplemental infiltration compartment based upon the volume of the infiltration component. Infiltration component sizing was based on various fractions of the SWQDv. The details of this analysis are presented in Appendix B, and results are presented in Figure 4.

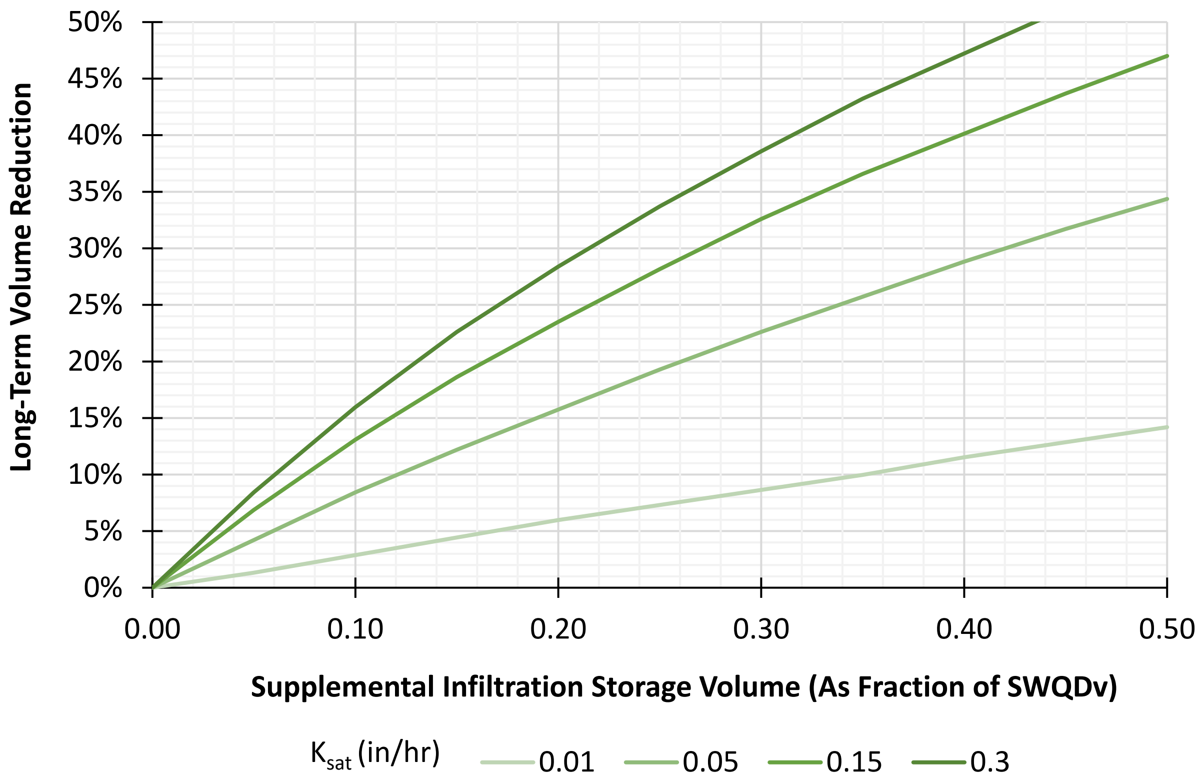

Figure 4: Volume Reduction Provided by a Supplemental Infiltration Compartment

3.3.4 Pollutant Treatment

MWS Linear performance data were analyzed using the same moving window bootstrapping methods used for conventional biofiltration. Data from two third party studies were utilized in this analysis. This analysis sought to determine whether MWS Linear performance is reasonably similar to the treatment performance of conventional biofiltration BMPs under representative ranges of influent quality.

The water quality equivalency analysis as described in Appendix C and D indicates that MWS Linear have similar or superior pollutant removal performance compared to conventional biofiltration. The bullets summarize findings:

- **Total Suspended Sediment:** Both MWS Linear and conventional biofiltration performed well for TSS. Based on achieved effluent quality, MWS Linear provided somewhat better performance than conventional biofiltration. TSS removal efficiencies were greater than 75% for all evaluated land use influent concentrations, typically better than 80%.
- **Metals (Copper and Zinc):** Performance was generally similar between MWS Linear and conventional biofiltration for copper and zinc. MWS Linear showed better performance for some representative influent concentrations and conventional biofiltration showed better concentration reductions for others. In general, both provided moderate concentration reductions of metals. MWS Linear exhibited removal efficiencies generally greater than 40% for copper and 50% for zinc for all evaluated land use influent concentrations.
- **Nutrients (Nitrogen and Phosphorus):** Variable nitrogen removal was evident for both conventional biofiltration and MWS Linear. There are relatively few total nitrogen samples for MWS Linear, especially for influent concentrations greater than 2 mg/L. The bootstrap regression plots (Appendix D) show comparable performance between conventional biofiltration and MWS Linear. For influent concentrations below 0.5 mg/L, conventional biofiltration exported phosphorus. Superior phosphorus performance was evident for MWS, with removal efficiencies exceeding 55% for all evaluated land use influent concentrations. This is likely a function of the low nutrient media included in the system.

Given these findings, MWS Linear are expected to provide similar or better pollutant concentration reduction across the representative site conditions considered. Notably, MWS Linear does not exhibit phosphorus export as is consistently observed in conventional biofiltration similar to Attachment H criteria.

3.3.5 Additional Capture In Lieu of Volume Reduction

For MWS Linear applications with minor deficiencies in volume reduction compared to conventional biofiltration, an alternative option to supplemental infiltration is to provide treatment of long-term runoff in excess of the 93% required for equivalency with conventional biofiltration.

As a simple approach for minor volume reduction deficiencies, the pollutant treatment performance of MWS Linear systems for TSS was used. Based on a representative removal efficiency of 80 percent, a BMP must treat and discharge 5 parts of water for every 4 parts of water that would be lost to infiltration or ET. This means that for every 1 percent of volume reduction deficit, 1.25 percent of long-term volume must be treated. This translates to 0.25 percent additional capture for every 1 percent of volume reduction deficit. This concept is illustrated in Figure 5. Calculations of required additional capture efficiency are provided in Table 2.

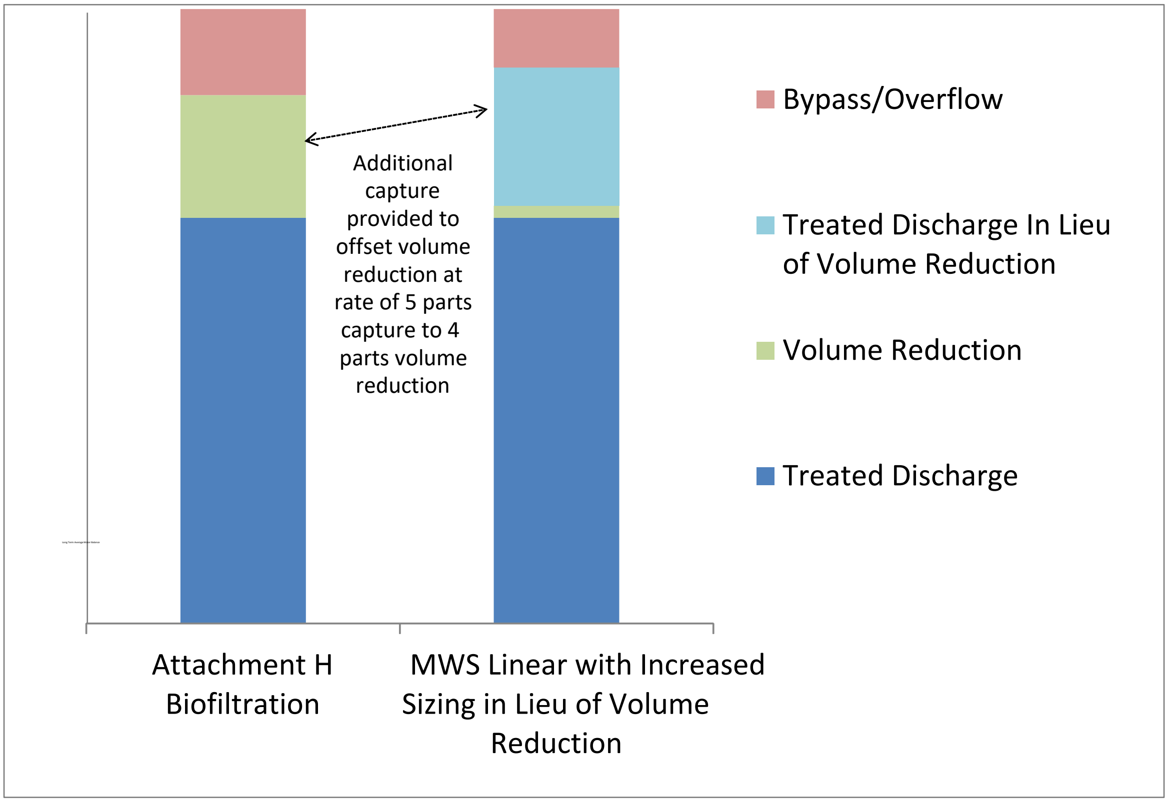

Figure 5. Illustration of Additional Capture In Lieu of Volume Reduction (Not to scale)

Table 2. Additional Capture Efficiency In lieu of Volume Reduction

Site Soil Infiltration Rate, in/hr	Attachment H Biofiltration Long-Term Volume Reduction[1, 2]	MWS Linear Long-Term Volume Reduction[1] (ET only)	Volume Reduction Deficit	Additional Required Capture Efficiency in Lieu of Volume Reduction[3]	Adjusted Target Capture Efficiency
0	3.7%	0.7%	3.0%	0.8%	93.8%
0.01	5.0%	0.7%	4.3%	1.1%	94.1%
0.05	10.3%	0.7%	9.6%	2.4%	95.4%
0.15	21.2%	0.7%	20.5%	5.1%	98.1%
0.30	33.4%	0.7%	32.7%	8.2%	N/A

1 – Based on modeling of ET from pores and standing water.
2 – Includes infiltration losses, where feasible
3 – Required additional capture calculated at a rate of 1 part additional for every 4-parts volume reduction deficit.

4 DESIGN METHODOLOGY AND EQUIVALENCY CRITERIA

This section explains how to apply the equivalency relationships developed in Section 3. Applying this design methodology is expected to result in equivalent treatment to a conventional biofiltration basin as described in Appendix H of the MS4 Permit.

Step 1: Characterize Site and Determine Key Attributes

The first steps in developing an equivalent design are to assess the location-specific characteristics of each proposed MWS Linear:

- Delineate the drainage area to the MWS Linear.
- Estimate the imperviousness of the tributary area; use this value to estimate a runoff coefficient for the drainage area using a method acceptable to the local jurisdiction.
- Calculate the drainage area time of concentration (T_c) using methods acceptable to the local jurisdiction.
- Determine local 85th percentile, 24-hour precipitation depth for the project location. This should be determined from the Los Angeles County 85th percentile precipitation isohyetal map (http://dpw.lacounty.gov/wrd/hydrologygis/). If the isohyetal map gives a value less than 0.75 in, use 0.75 in per the MS4 Permit.
- Calculate the site "scaling factor" (f*)* as the ratio of the project-specific 85th percentile, 24-hour storm event to the LAX 85th percentile, 24-hour storm event (1.0").
- Determine the long-term reliable infiltration rate of the soils underlying the future BMP location using appropriate methods, subject to the approval of the reviewing agency.

This information is applied in the following steps.

Step 2: Adjust the Drainage Area Time of Concentration to Account for Internal Detention Storage (Total Effective Time of Concentration for Drainage Area plus Storage)

The time of concentration of the tributary watershed can be augmented by the detention storage provided within the MWS, including the pre-treatment chamber and the void space within the wetland biofiltration cell. Both storage volumes are upstream of the outlet control orifice and are available to incoming water (the BioMediaGreen pre-treatment media has a higher flowrate than the outlet control orifice).

Table 3 shows the detention time adjustment for each MWS Linear model. This should be added to the Tc computed in Step 1. Note: Before knowing the required treatment flowrate, it will not be possible to select an MWS Linear model number. The first time through this process, select a minimum Tc adjustment of 9 minutes. After completing subsequent steps, if the selected model has a longer Tc, then revisit this step.

Table 3: MWS Model Selection Chart and Detention Time Calculation for MWS Linear® Models

Model #	Dimensions	Pre-treatment Chamber Volume (ft^3)	Wetland Biofiltration Chamber Effective Void Volume (ft^3)	Treatment Flow Rate (cfs)	Detention Time Adjustment to T_c (min)
MWS-L-4-4	4′ x 4′	19.6	11.3	0.052	10
MWS-L-4-6	4′ x 6′	19.6	18.6	0.073	9
MWS-L-4-8	4′ x 8′	33.6	27.0	0.115	9
MWS-L-4-13	4′ x 13′	54.4	38.2	0.144	11
MWS-L-4-15	4′ x 15′	56	50.4	0.175	10
MWS-L-4-17	4′ x 17′	54.4	62.7	0.206	9
MWS-L-4-19	4′ x 19′	54.4	74.9	0.237	9
MWS-L-4-21	4′ x 21′	54.4	87.2	0.268	9
MWS-L-8-8	8′ x 8′	70	53.9	0.23	9
MWS-L-8-12	8′ x 12′	112	80.9	0.346	9
MWS-L-8-16	8′ x 16′	168	107.9	0.462	10
MWS-L-8-20	8′ x 20′	168	134.9	0.577	9
MWS-L-8-24	8′ x 24′	192	161.8	0.693	9

Step 3: Select Design Approach for MWS Linear for Equivalent Long-Term Performance

MWS Linear must be designed to provide equivalent capture efficiency to conventional biofiltration. Additionally, because MWS Linear systems do not allow for infiltration, the design of MWS Linear must mitigate for deficiency in volume reduction compared to conventional biofiltration. Two options are available for meeting this requirement:

Option A: Provide a supplemental infiltration chamber either upstream, downstream, or underneath of the MWS unit. This is feasible in any condition where infiltration is allowable but requires supplemental BMPs.

Option B: Increase the size of the MWS unit to provide a higher capture efficiency in lieu of infiltration. This is most feasible when soils have very low permeability or infiltration is infeasible for other reasons, such that conventional BMPs would achieve relatively little incidental infiltration and therefore volume reduction.

Note that both options may not be feasible for a specific site. Step 4A provides guidance on Option A; Step 4B provides guidance on Option B.

Step 4A: MWS Linear Sizing with Supplemental Retention Storage (Option A)

This option involves selecting an MWS Linear model that achieves equivalent long-term capture efficiency to conventional biofiltration and sizing a supplemental retention system to achieve equivalent long-term volume reduction.

1. Based on the adjusted Tc from Step 2, select the required design precipitation intensity to achieve equivalent long-term capture efficiency.

Table 4: Design Precipitation Intensity to Achieve Equivalent Long-Term Capture Efficiency (supplemental infiltration provided separately)

Adjusted Time of Concentration (min)	Design Precipitation Intensity (in/hr)
5	0.51
7.5	0.47
10	0.44
15	0.41
20	0.39
30	0.35
60	0.29

2. Apply the Rational Method (Equation 1) to determine the design flowrate (Q) required for the MWS.

$$Q = CiA \times (\frac{1\,ft}{12\,in}) \times (\frac{1\,h}{3600\,s}) \times f \qquad (1)$$

Where,

Q = design flow rate (cfs)
C = runoff coefficient
i = design precipitation intensity (in/hr)
A = catchment area (ft^2)
f = site scaling factor

3. Consult Table 3 to select an MWS Linear model that equals or exceeds the required treatment flowrate.

4. Consult Table 5 to determine the fraction of the SWQDv that must be infiltrated to provide equivalent volume reduction to conventional biofiltration. For long-term reliable infiltration rates greater than 0.3 in/hr, full infiltration of the SWQDv must be considered.

Table 5: Supplemental Infiltration Volume for Equivalent Long-Term Volume Reduction

Estimated Long-Term Reliable Infiltration Rate below Site, inches per hour	Long-Term Volume Reduction Deficit, % of Long-Term Runoff	Required Supplemental Infiltration Storage Volume as Fraction of Local SWQDv, unitless[1,2]
0	3.0%	Not feasible; See Option B
0.01	4%	0.15
0.05	10%	0.12
0.15	21%	0.17
0.3	33%	0.24

1 – Values are not expected to follow a continually increasing trend.
2 - A 2.0-foot effective storage depth is assumed for supplemental storage.

5. Multiply the site-specific SWQDv for the MWS drainage area by the required supplemental infiltration storage volume fraction in Table 5 . This table assumes that the supplemental infiltration basin will be 2.0 ft in depth. Shallower or deeper storage would require different sizing factors. Supplemental calculations could be provided to demonstrate that an alternative storage configuration would provide equivalent long-term volume reduction.

Step 4B: MWS Linear Sizing for Excess Capture In Lieu of Volume Reduction

This option involves increasing the size of MWS Linear to achieve a higher level of capture efficiency in lieu of providing supplemental volume reduction.

1. Use Table 6 to determine the design rainfall intensity. The adjusted Tc from Step 2 should be used. For times of concentration less than 5 min, round up to 5 min. Interpolation between values in this table would be permissible.
2. Apply the Rational Method (Equation 1) to determine the design flowrate (Q) required for the MWS.
3. Select an MWS Linear Model from Table 3 to provide the required treatment flowrate.

Table 6: Adjusted Design Intensity to Provide Additional Capture In Lieu of Volume Reduction (Option B)

Adjusted Time of Concentration (min)	Reliable Infiltration Rate at Site			
	0 in/hr (ET only) Capture Efficiency Target = 93.8%	**0.01 in/hr** Capture Efficiency Target = 94.1%	**0.05 in/hr** Capture Efficiency Target = 95.4%	**0.15 in/hr** Capture Efficiency Target = 98.1%
	Adjusted MWS Design Precipitation Intensities, in/hr			
5	0.55	0.57	0.66	N/A
7.5	0.51	0.53	0.60	0.96
10	0.48	0.49	0.57	0.90
15	0.44	0.45	0.52	0.79
20	0.41	0.42	0.48	0.74
30	0.37	0.38	0.43	0.64
60	0.31	0.31	0.35	0.50

NA = additional capture is not a viable option to offset volume reduction in these cases.

5 DISCUSSION AND CONCLUSIONS

5.1 Key Observations and Findings

5.1.1 Capture Efficiency and Volume Reduction

Overall, if MWS Linear units are designed based on the methodology and criteria presented in Section 4 and effectively operated and maintained, these systems are expected to result in similar performance compared to conventional biofiltration. The following bullets summarize key findings from this analysis:

- The baseline level of capture efficiency and volume reduction provided by conventional biofiltration BMPs, if effectively designed per Attachment H of the MS4 Permit, is relatively high. This establishes a relatively high baseline standard for MWS Linear systems to meet in providing equivalent performance.
- There is substantial leeway within the MS4 Permit Attachment H criteria and local implementation guidance that is expected to result in significant design variations of conventional biofiltration throughout Los Angeles County. These variations result in variations in hydrologic performance. Additionally, variations in operations and maintenance conditions over time (i.e., decline in media rates, reduction in active storage volume from sedimentation) are also expected to influence performance.
- It is possible to design MWS units to match the capture efficiency of conventional biofiltration BMPs. This requires larger sizes of MWS units than was required for treatment control BMPs under the previous MS4 Permit. This also requires a commitment to regular maintenance consistent with MWS standard maintenance requirements.

- MWS units alone are not expected to match the volume reduction performance provided by effectively designed conventional biofiltration. However, it is possible for MWS systems to mitigate for deficiency in volume reduction via either a supplemental infiltration basin or by increasing the size of the MWS unit to increase capture efficiency, thereby providing equivalent TSS load reductions.

5.1.2 Water Quality Treatment

The water quality equivalency analysis as described in Appendix C and D indicates that MWS Linear have similar or better pollutant removal performance compared to conventional biofiltration. This is summarized in Section 3.3.4 above. Notably, MWS Linear has not exhibited phosphorus export as is consistently observed in conventional biofiltration systems that include compost similar to Attachment H criteria. MWS Linear does not include compost.

5.2 <u>Reliability and Limitations</u>

There are several uncertainties that could influence the reliability of the findings presented in this report. These are addressed in the paragraphs below.

Modeled hydrologic performance estimates. Performance estimates were based on models which were not calibrated. This introduces some uncertainty. However, this uncertainty was mitigated by applying identical input parameters and modeling approaches for conventional biofiltration and MWS units, as appropriate. This has the effect of offsetting most sources of bias.

Treatment performance estimates for conventional biofiltration. Treatment performance estimates were based on peer reviewed studies from the International Stormwater BMP Database and other peer reviewed third party studies that were selected to be representative of the BMPs being compared. Due to the limited documentation of these studies, it was not possible to quantitatively evaluate whether performance estimates are specifically representative of the MS4 Permit's Attachment H guidelines. Additionally, performance has been observed to vary greatly from site to site, indicative of the importance of design factors such as sizing, media composition, and sources of media components. The conventional biofiltration datasets analyzed are believed to provide reliable information about the range of potential performance that may be expected from conventional biofiltration in Los Angeles County; however, they are not intended to be used as a predictive tool for any one variation of biofiltration design. Reliability of these data was improved through the application of robust statistical methods that account for the influence of influent concentration and provide a quantification of uncertainty.

Treatment performance estimates for MWS units. MWS units have been evaluated in third-party field studies with representative stormwater conditions; however, none of these sites were in Los Angeles County. Additionally, the sample size of MWS datasets is still somewhat low in comparison to conventional biofiltration BMPs. These factors are mitigated to a large extent by the standardized design that accounts differences in rainfall intensity and ensures consistency in treatment processes. These factors improve the transferability of findings between regions. Additionally, the reliability of MWS performance data was improved by applying the same robust statistical methods as used for conventional biofiltration, which helps adjust for differences in influent quality between studies.

TSS removal as a surrogate for additional capture in lieu of volume reduction. For small deficiencies in volume reduction, a TSS treatment removal rate of 80 percent was used to calculate required additional capture efficiency in lieu of volume reduction. A multi-parameter approach would be more complex and would need to account for the export of nutrients in conventional biofiltration as well as variability in treatment performance with influent contraction. Given that this approach is only intended to offset minor volume reduction (up to about 20%), this is considered a reasonable approach.

Sensitivity to site conditions. The effectiveness of volume reduction processes is particularly sensitive to estimates of a BMPs underlying infiltration rate. It is often not possible to anticipate with certainty what the long-term infiltration rate will be after construction. This limitation is largely mitigated for this analysis because the uncertainty in infiltration rate influences the design and performance of conventional biofiltration and MWS with supplemental infiltration storage similarly. Additionally, estimating the BMP location infiltration rate is now a standard part of developing a BMP plan for a site, so the reliability of approaches for developing this estimate should improve with time.

Variability in design and construction process. The analyses and criteria presented in this report assume that the BMPs will be designed, constructed, and maintained according to typical standards and manufacturer guidelines. It is inherent that the design of conventional biofiltration BMPs provides a greater degree of freedom and associated professional judgment as part of preparing design calculations, design drawings, and specifications that proprietary BMPs such as MWS Linear units. This introduces a wider potential range of resulting designs for conventional biofiltration: some may perform better than average, some may perform worse. In comparison, there is likely to be substantially less variability in the design and construction of MWS units as compared to biofiltration BMPs.

Sensitivity to operations and maintenance. Both types of systems are susceptible to decline in performance over time. **<u>Neither BMP type will continue to function as designed if not regularly and effectively maintained.</u>**

Overall, the analyses are believed to result in reliable design assumptions. Where substantial uncertainties exist, these are mostly offset for the purpose of estimating equivalency, because they effect both conventional biofiltration and MWS Linear similarly.

6 REFERENCES

Automated Surface Observing System (ASOS; 2018). ftp://ftp.ncdc.noaa.gov/pub/data/asos-fivemin/

BioClean: A Forterra Company. *MWS Linear: Sizing Options*. 2018. Webpage. http://www.biocleanenvironmental.com/mws-linear-sizing-options/

BioClean: A Forterra Company. *Modular Wetlands MWS Linear Brochure*. 2018. http://www.biocleanenvironmental.com/wp-content/uploads/2015/11/MWS-Linear-Brochure_web.pdf

California Department of Water Resources (CDWR, 2015). *California Irrigation Management Information System (CIMIS) Reference Evapotranspiration Zones*. http://missionrcd.org/wp-content/uploads/2014/04/CIMIS-Reference-Evapotranspiration-Zones.pdf

California Regional Water Quality Control Board, Los Angeles Region (2012). *Waste Discharge Requirements for Municipal Separate Storm Sewer System (MS4) Discharges Within the Coastal Watersheds of Los Angeles County, Except Those Discharges Originating from the City of Long Beach MS4*. Order No. R4-2012-0175. NPDES Permit NO. CAS004001. https://www.waterboards.ca.gov/rwqcb4/water_issues/programs/stormwater/municipal/la_ms4/2012/Order%20R4-2012-0175%20-%20A%20Final%20Order%20revised.pdf

California Regional Water Quality Control Board, Los Angeles Region (2012). *MS4 Discharges within the Coastal Watersheds of Los Angeles County*. *Attachment H: Bioretention/Biofiltration Design Criteria*. Order No. R4-2012-0175. NPDES Permit NO. CAS004001. https://www.waterboards.ca.gov/rwqcb4/water_issues/programs/stormwater/municipal/la_ms4/Dec5/Order%20R4-2012-0175%20-%20Final%20Attachment%20H.pdf

David N., Lent, M., Leatherbarrow, J., Yee, D., and McKee, L. (2011). *Bioretention Monitoring at the Daly City Library*. Final Report. Contribution No. 631. San Francisco Estuary Institute, Oakland, California.

Davis, A. P. (2007). *Field Performance of Bioretention: Water Quality*. Environ. Eng. Sci. 2007, 24, 1048–1063.

Geosyntec Consultants and Wright Water Engineers (2009). *Urban Stormwater BMP Performance Monitoring*. Prepared by Geosyntec Consultants and Wright Water Engineers, Inc. Prepared under Support from U.S. Environmental Protection Agency, Water Environment Research Foundation, Federal Highway Administration, Environmental and Water Resources Institute of the American Society of Civil Engineers. October 2009. http://www.bmpdatabase.org/Docs/2009%20Stormwater%20BMP%20Monitoring%20Manual.pdf

Gilbreath, A. N., Pearce, S. P. and McKee, L. J. (2012). *Monitoring and Results for El Cerrito Rain Gardens*. Contribution No. 683. San Francisco Estuary Institute, Richmond, California.

Herrera. (2014a). *Technical Evaluation Report Modular Wetland System Stormwater Treatment System Performance Monitoring*. Prepared for Modular Wetland Systems, Inc. April 1, 2014.

Herrera (2014b). *185th Avenue NE Bioretention Stormwater Treatment System Performance Monitoring*. Prepared for City of Redmond. Seattle, Washington, Final Report. March 6, 2014.

Herrera (2015a). *Interim Project Report: City of Redmond Six Bioretention Swales Monitoring. Prepared for City of Redmond*. Seattle, Washington. February 20, 2015.

Herrera (2015b). Analysis of Bioretention Soil Media for Improved Nitrogen, Phosphorous and Copper Retention, Final Report. Prepared for Kitsap County Public Works. Seattle, WA, July 17, 2015.

International Stormwater BMP Database (2018). Web. http://www.bmpdatabase.org/index.htm

Leisenring, M., Poresky, A., Strecker, E., and M. Quigley (2009). *Evaluating Paired BMP Influent and Effluent Data Using Running Bootstrap Medians*. Proceedings of the American Water Resources Association Annual Conference, Seattle WA, November 9-12, 2009.

Li, H. and Davis, A. (2009). *Water Quality Improvement through Reductions of Pollutant Loads Using Bioretention.* J. Environ. Eng., 135(8), 567–576.

Los Angeles County (LA County; 2000). *Los Angeles County 1994-2000 Integrated Receiving Water Impacts Report*.

Los Angeles County (LA County; 2001). *Los Angeles County 2000-2001 Stormwater Monitoring Report*.

Los Angeles County Department of Public Works. *Hydrology Map: A GIS viewer application to view the data for the hydrology manual*. Powered by ESRI. Web. http://dpw.lacounty.gov/wrd/hydrologygis/

National Climatic Data Center (NCDC). (2015). ftp://ftp.ncdc.noaa.gov/pub/data/hourly_precip-3240/.

Roseen, R.M. and Stone, R.M. (2013). *Bioretention Water Quality Treatment Performance Assessment*. Technical Memorandum. Prepared for Seattle Public Utilities.

Singh, K. and Xie, M. (2008) *Bootstrap: a statistical method*. Rutgers University.

United States Army Engineer Research and Development Center (USARDC; 2013). *U.S. Army Construction Engineering Research Laboratory Field Testing – Fort Hood, Texas – Summary of Results – Modular Wetland System Linear.*

United States Environmental Protection Agency (US EPA; 2017). *Stormwater Management Model (SWMM) 5.1*. March 30, 2017. Web Download. https://www.epa.gov/water-research/storm-water-management-model-swmm

Washington State Department of Ecology (2014). 2012 Stormwater Management Manual for Western Washington (as Amended in 2014. Publication Number 14-10-055.

APPENDIX A – CONVENTIONAL BIOFILTRATION DESIGN ASSUMPTIONS FOR PERFORMANCE MODELING

The following criteria from the MS4 Permit Attachment H were important for evaluating pollutant load reduction performance of "conventional biofiltration" scenarios:

- 6 to 18-inch ponding area above media
- Optional layer of mulch
- 2 to 3 feet of engineered filter media (2 feet typical) with a design infiltration rate of 5 to 12 inches/hour; the Attachment H specification calls for a mix of 60 to 80% fine sand and 20 to 40% compost
- Gravel storage layer below the bioretention media to promote infiltration
- Underdrain placed near the top of the gravel layer (or an infiltration sump otherwise provided via an equivalent hydraulic control approach) in cases where underlying soil infiltration rates allow
- Underdrain discharge to the storm drain
- Total physical water storage volume sized to be equal to at least the stormwater quality design volume (SWQDv = runoff volume from the 85th percentile, 24-hour storm event)
- Capacity (including stored and filtered water) adequate to biofilter 150 percent of the portion of the SWQDv not reliably retained.

Within the bounds established by these criteria, a range of actual biofiltration designs could result as a function of site infiltration conditions as well as designer and local jurisdiction preferences. An example of potential design variability is illustrated in Table A.1 below. For this analysis, representative design assumptions were developed within the range of potential design assumptions. These assumptions are also presented in Table A.1 with supporting rationales.

Table A.1 Biofiltration Design Assumptions from Various Sources and Selected Representative Design Assumptions

Design Assumption	Design References					Selected Representative Design Assumption	Rationale for Selected Design Assumption
	MS4 Permit Attachment H	Los Angeles County LID Manual, static method	Los Angeles County LID Manual, routing method	City of Los Angeles LID Manual	Ventura County TGM		
Ponding Depth, ft	0.5 to 1.5	0.5 to **1.5**	0.5 to **1.5**	0.5 to **1.5**	0.5 to **1.5**	1.5	Many designers will utilize deepest depth allowable because of space efficiency.
Media Depth, ft	2 to 3	**2** to 3	**2** to 3	**2** to 3	**2** to 3	2	Typical design approach is to use minimum depth due to cost of media.
Gravel “sump” depth below underdrain, ft	Not specified; narrative	Not specified, narrative	Not specified, narrative	At least 1 feet; up to **2** feet if soils allow incidental infiltration	**0.5** minimum below underdrain	Depth that would drain in 24 hours. For example, 1.5 ft if site infiltration rate estimated at just less than 0.3 in/hr	Approach produces a reasonable design that considers infiltration rates; Attachment H states that volume infiltrated within 24 hours can be considered retained.
Media Filtration Rate, in/hr	5 to 12	**5** to 12	**5** to 12	**5** to 12	1 to 12 **(5)**	5	Representative of long-term operation after some clogging
Allowable Routing Period for Biofiltration Treatment, hrs	Not specified	Routing is not part of simple method	Allows routing of **24-hour** design hydrograph from LA County HydroCalc model	**3** hours, unless using a routing model	Depth up to ponding depth (**1.5 ft**) can be considered routed	6 hours[1]	Based on evaluation of storm durations for events similar to design event. See footnote 1.
Resulting Footprint Factor at 0.3 in/hr Infiltration Rate, in/hr (% of impervious area)	Not enough information to calculate	5 to 10%	1.4%	2.4% (1.4% with routing similar to LA County)	2.8%	2.0%	Calculated based on assumptions.

Note: where a range of guidance is allowed, the bolded number indicates the value that was used in calculations. The design values were selected based on developing the most economical and space-efficient design that meets the applicable criteria.

1 – The allowable routing period was estimated based on the typical storm duration associated with events similar to the 85th percentile, 24-hour storm depth (1.0 inches at LAX). This was estimated in two ways. For days with precipitation totals between 0.9 and 1.1 inches, the total number of hours with rainfall was tabulated (average = 11 hours; 10th percentile = 6 hours). This does not consider dry periods between hours with rainfall, therefore is somewhat conservative in estimating the time available for routing biofiltered water during a given day. For unique precipitation events, separated by 6-hour dry period (potentially spanning across breaks in calendar days), with precipitation totals between 0.9 and 1.1 inches, the total storm durations were tabulated (average = 16 hours; 10th percentile = 7 hours). Based on this analysis, a 6-hour routing period is defensible and conservative in estimating the amount of water that can be routed through a biofiltration system during typical storm events similar to the design storm event.

APPENDIX B – SWMM MODELING METHODOLOGY AND ASSUMPTIONS

The relative performance of MWS Linear and conventional biofiltration was determined using the following data inputs and modeled site conditions:

- Rainfall: Los Angeles International Airport, 2000-2018, ASOS
- ET: CIMIS Zone 4
- Catchment imperviousness: 100%
- Catchment slope: 3%
- Area: 1 acre

For conventional biofiltration the sizing and design criteria described in Appendix A were followed, including underlying soil infiltration rates of 0, 0.01, 0.05, 0.15, and 0.30 in/hr.

For MWS Linear, all combinations of the following sizing and design criteria were evaluated:

- Time of concentration: 5, 7.5, 10, 15, 20, 30, and 60 min
- Design rainfall intensity: 20 values spanning 0.02 - 1.00 in/hr

Supplemental infiltration compartments were evaluated using the following sizing and design criteria:

- Time of concentration: 5 min (not a sensitive parameter for a volume-based BMP)
- Unit depth: 2 ft
- Underlying soil infiltration rate: 0.01, 0.05, 0.15, and 0.30 in/hr
- Percent of runoff depth, using the 24-hr, 85th percentile rainfall depth: 10 increments spanning 5% -50%.

Overview of SWMM Analysis Framework

SWMM was used to estimate the long-term capture efficiency and volume reduction from conventional biofiltration and MWS Linear for each scenario. SWMM simulates surface runoff, evaporation, infiltration, and flow routing. A conceptual representation of the SWMM model framework used for this analysis is provided in Figure B.1. Within this framework, parameters were adjusted for each scenario to account for soil condition and BMP sizing and design attributes.

In SWMM, subcatchment elements are used to generate a runoff hydrograph. Input data defining the surface characteristics include subcatchment area, imperviousness, width, depression storage, surface roughness, surface slope, and infiltration parameters. SWMM performs a mass balance of inflows and outflows to determine runoff from a subcatchment. The inflows to this mass balance are precipitation and any runoff directed from another subcatchment. The outflows from the mass balance include evaporation, infiltration, and runoff. The runoff parameters assumed for this analysis are discussed in this Appendix.

A variety of hydraulic flow routing elements exist in SWMM, but fundamentally the program includes nodes (i.e., storage units, manholes, and outfalls) and links (i.e., conduits, pipes, pumps, weirs, orifices, and outlets). For traditional biofiltration a storage unit was to represent the storage and routing attributes of BMPs. The elements defining the storage volume and related discharge were adjusted based on the various sizing and design criteria evaluated in the equivalency scenarios, the details of which are discussed in this Appendix. For MWS Linear, storage was not modeled explicitly. MWS Linear, a simple flow divider was used to represent the treatment capacity of the system. For runs considering the supplemental infiltration storage compartment, this compartment was modeled as a storage unit.

SWMM was run in continuous simulation mode over an 18-year period (January 2000-March 2018). A continuous hydrograph of runoff was generated and routed through the model representations of BMPs. The results were tracked and reported in terms of long-term runoff volume, long-term volume lost in the BMP, long-term volume bypassing or overflowing the BMP, and long-term volume treated in the BMP. The 18-year period of record was selected based on the availability of high quality 5-minute resolution precipitation data, which are important for representing urban catchments with short time of concentration. To ensure comparability, the same forcing data (rainfall, ET) were applied to conventional biofiltration scenarios and MWS Linear scenarios.

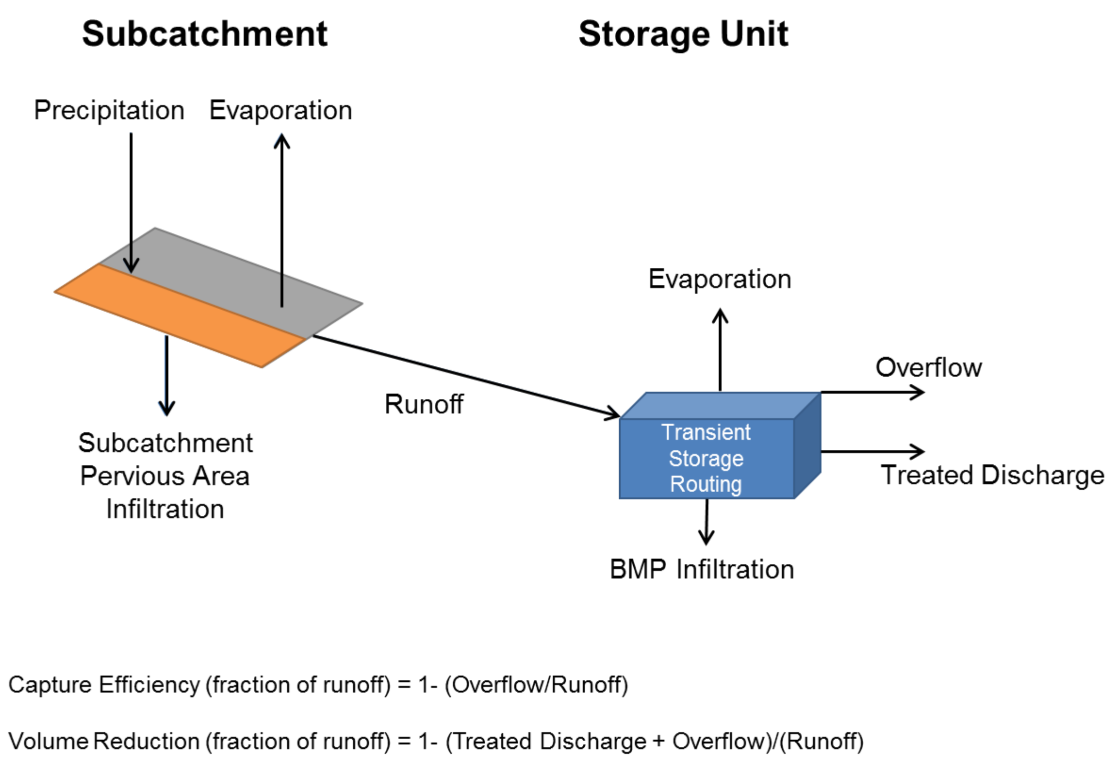

Figure B.1. Schematic SWMM modeling framework in support of equivalency analysis

Meteorological Inputs

Precipitation

Long-term modeling used 5-minute data obtained from the Automated Surface Observation System (ASOS). This data was compared to National Climatic Data Center (NCDC) hourly precipitation data to ensure quality, as NCDC data sets undergo a greater level of quality review than ASOS data sets. While the NCDC data spans 1948-2015 and the ASOS model spans only 2000-2018, the ASOS data was selected over the NCDC data because the improved temporal resolution is important for small catchments. Both ASOS and NCDC rainfall data were obtained from gauges located at Los Angeles International Airport.

Comparison of NCDC and ASOS data resulted in the elimination of 14 ASOS data points (for a total of 70 minutes of data out of the 17+ years of available) that were determined to be artificially high. Otherwise, ASOS and NCDC data agreed well. The 85th percentile, 24-hour depth was determined using NCDC data for days with rainfall greater than 0.1 inches. This value was slightly higher for the NCDC data (1.01”) than for the ASOS data (0.94”), which can be attributed to the difference in the length of available data sets (Table B.1).

Table B.1: LAX Storm Water Quality Design Volume

Data	Gage Location	85th Percentile 24-Hour Depth (in)
NCDC (1948-2015)	Los Angeles Airport (045114)	1.01
ASOS (2000-2018)	Los Angeles Airport (KLAX)	0.94

Evapotranspiration

Evapotranspiration (ET) values for Zone 4 as defined in the California Irrigation Management Information System (CIMIS) were used for all SWMM models (Table B.2). ET values used in the model were set to 60% of the reference ET values to account for mixed urban conditions and shading conditions based on guidance provided by CIMIS (CDWR, 2015). ET values have little influence on modeled outputs in SWMM.

Table B.2: CIMIS Zone 4 Evapotranspiration Values

Month	Evapotranspiration Rate (in/month)	Evapotranspiration Rate (in/day)	60% Evapotranspiration Rate (in/day)
January	1.86	0.05	0.06
February	2.24	0.08	0.08
March	3.41	0.12	0.11
April	4.5	0.17	0.15
May	5.27	0.22	0.17
June	5.7	0.26	0.19

Month	Evapotranspiration Rate (in/month)	Evapotranspiration Rate (in/day)	60% Evapotranspiration Rate (in/day)
July	5.89	0.28	0.19
August	5.58	0.25	0.18
September	4.5	0.19	0.15
October	3.41	0.13	0.11
November	2.4	0.07	0.08
December	1.86	0.05	0.06

Runoff Parameters

The key SWMM parameters used to estimate surface runoff from the impervious catchment are subcatchment area, width, depression storage, surface roughness, surface slope. The majority of surface characteristics were kept constant for both BMP systems and across all land use types. For MWS Linear simulations the width parameter (defines the overland flow length for runoff to travel), was adjusted to reflect differences in time of concentrations. Drainage widths were set to correspond with times of concentration of 5, 7.5, 10, 15, 20, 30, and 60 minutes in a 1-acre catchment via Equation B.1 (Table B.3):

$$T_c = \frac{0.93 \times L^{0.6} \times n^{0.6}}{I^{0.4} \times S^{0.3}} \qquad \text{(B.1)}$$

Where,

T_c= time of concentration (min)
L = length (ft)
n = Manning's n (0.12, corresponding to impervious surface Manning's n)
S = Slope (ft/ft) (0.03)
I = intensity (in/hr; set to the 85th percentile rainfall intensity at the corresponding time of concentration, as determined by ASOS data; Table B.3)

Table B.3: Rainfall Intensities Used to Determine Catchment Width

Time of Concentration (min)	85th Percentile Rainfall Intensity (in/hr)	Path Length Associated with Tc (ft)	SWMM Catchment Width to Represent Tc (ft)
5	0.24	92	474
7.5	0.24	181	241
10	0.24	292	149
15	0.20	508	86
20	0.18	765	57
30	0.16	1391	31
60	0.12	3644	12

Infiltration over the catchment was not modeled because the scenarios considered only 100 percent impervious catchments. This was done for both conventional biofiltration and MWS simulations. Runoff coefficients are applied as part of the design process.

Table B.4: EPA SWMM Parameters Used to Model BMPs

SWMM Runoff Parameters	**Units**	**Values**	**Source/Rationale**
Wet time step	seconds	60	Set to 20% of the time steps of precipitation input data (300 seconds)
Dry time step	seconds	14,400	Equivalent to 4 hours.
Period of Record		January 2000-March 2018	Availability of ASOS data
Percent of Impervious Area	percent	100	Representative of typical fully developed area draining to MWS; actual imperviousness would be used by designer to calculate runoff coefficient.
Impervious Manning's n	unitless	0.012	James and James, 2000
Drainage area	acres	1	Hypothetical for purpose of analysis
Width	feet	*Conventional biofiltration:* 174 ft *MWS Linear:* Variable to represent different time of concentrations (Table B.3)	*Conventional biofiltration:* Typical assumption for urban drainage patters (equates to 250-ft path length). Performance of volume-based BMPs is not sensitive to catchment width. *MWS Linear:* Calculated as described above.

SWMM Runoff Parameters	Units	Values	Source/Rationale
Slopes	ft/ft	0.03 (represents average of roofs, landscaping, and streets)	Professional judgment; actual slope would be used by designer to calculate Tc.
Evaporation	in / month	60% of reference ET values (Table B.4)	CIMIS (CWDR, 2015)
Depression storage, impervious	inches	0.02	James and James, 2000

Supplemental Infiltration Unit

Catchment parameters were kept the same for supplemental infiltration unit modeling as for MWS Linear runoff modeling (Table B.5). Catchment width was kept constant for all runs, using the conservative value associated with a time of concentration of 5 minutes. The unit was modeled with a constant depth and a total volume based upon a fraction of the SWQDv (Table B.1) (equal to the runoff from a 1.0” event).

Table B.5: EPA SWMM Parameters Used to Model Supplemental Infiltration

SWMM Runoff Parameters	Units	Values	Source/Rationale
Catchment Width	feet	473.6	Width of a 1 ac catchment with a 5 min time of concentration
Storage Unit Depth	ft	2.0	Typical value
Storage Unit Saturated Hydraulic Conductivity (in/hr)	in/hr	Varies by site condition: 0.01, 0.05, 0.1, 0.15, and 0.30	Allows for analysis of different underlying soil types

BMP Representation

Conventional Biofiltration

Conventional biofiltration was simulated using a storage unit with outlets to represent infiltration losses (if present) and treated discharge, and a weir to simulate overflow/bypass. The elevations of these elements within the storage unit were used to represent the design profiles of these systems. Storage compartments were divided in to: evaporation storage (i.e., water stored in soil that is not freely drained); infiltration storage (i.e., water stored below the lowest outlet that can either infiltration or ET only); and freely drained storage (i.e., water that can drain through the underdrains of the system at a rate controlled by the media hydraulic conductivity).

Sizing criteria for the conventional biofiltration system was based on the runoff from the 85th percentile, 24-hour storm depth (1.0 for LAX). For each scenario, this depth was applied to the catchment area to compute an estimated runoff volume. Storage profiles for the conventional biofiltration system were established to represent typical profiles for conventional biofiltration consistent with what is required by Attachment H of the MS4 Permit, which are presented in Appendix A of this report. The storage profiles included equivalent storage volumes provided in the ponding depth, media depth (divided between ET storage and freely drained storage), gravel layer, and placement of the underdrain system specific to the site conditions. Based on the equivalent storage depth in these profiles and the design storm runoff volume, the required footprints were calculated. For gravel, a porosity of 0.4 was assumed. For media, a porosity of 0.4 in/in was assumed, divided as 0.15 in/in soil suction storage (i.e. ET storage) and 0.25 in/in freely drained storage. The profiles used for this analysis and the typical footprints are presented in Table B.6.

For estimating long-term volume reduction and baseline capture efficiency, the entire pore volume was assumed to be immediately available. However, because water takes time to travel through the soil column, it is possible for a biofiltration BMP to overflow before the entire soil poor volume is utilized. Based on analysis of flow monitoring data, Davis et al. (2011) found that the volume immediately available within a storm is better represented by the bowl volume (surface ponding) and the freely drained pores within the root zone (approximately the top 1 foot of soil). To check whether this condition influenced long term capture efficiency, parallel model runs were conducted where the storage volume equaled the bowl volume plus freely drained pores in the soil root zone, and the drawdown time was adjusted for only this volume. The result was that this condition reduced capture efficiency by approximately 2 percent. This indicates that this condition controls performance relatively rarely but is not negligible.

Table B.6 Summary of Conventional Biofiltration Profiles

Infiltration Rate, in/hr	Retention Sump Depth (as gravel depth)[1], ft	Effective Water Storage in Retention Sump (ft)	Media Depth, ft	Effective Water Storage in Media[2], ft	Ponding Depth, ft	Total Effective Water Depth (ft)	Approximate Footprint Sizing Factor (Los Angeles)[3]
0.3	1.5	0.60	2	0.8	1.5	2.9	1.9%
0.15	0.75	0.30	2	0.8	1.5	2.6	2.1%
0.05	0.25	0.10	2	0.8	1.5	2.4	2.2%
0.01	0.05	0.02	2	0.8	1.5	2.32	2.3%
0	0	0.00	2	0.8	1.5	2.3	2.3%

1 Sump storage was determined based on the depth of water that would infiltrate in 24 hours based on guidance provided in Attachment H.
2 Media storage depth represented as 0.3 ft suction storage and 0.5 ft freely drained storage.
3 Expressed as BMP footprint as percent of tributary area.

MWS Linear

MWS Linear primarily operates as a flow-based BMP. Therefore, systems were modeled using only a flow rate-based flow divider, with the cutoff flow corresponding to a range of design rainfall intensities. Design rainfall intensities were converted to design maximum flow rates using the Rational Method Equation (Equation B.2):

$$Q = CiA \tag{B.2}$$

Where,

Q = flow rate (ft^3/hr)
C = runoff coefficient (0.90)
i = rainfall intensity (in/hr)
A = catchment area (43,560 ft^2, corresponding to 1 acre)

Twenty increments of design intensities ranging from 0.02 inches/hour up to 1.0 inches/hour were established to represent a range of potential MWS Linear sizing criteria to achieve equivalency. For each scenario, the design intensity was applied to the catchment area and imperviousness to calculate the runoff flowrate.

A representative ET loss from MWS Linear was calculated for an example scenario by adding a storage unit to the treated flow stream to represent the MWS Linear unit. The storage unit was sized by assuming a 1-acre catchment with a 10 min T_c, resulting in an 8 ft by 16 ft MWS Linear model. The storage unit was modeled with an evaporation factor of 1.0 and a media pore storage ratio of 0.15 in/in. The resulting ET loss was 1 percent.

Supplemental Infiltration Unit

Supplemental infiltration was modeled as a storage unit with a pervious underlying soil and an outlet. The infiltration unit was sized based on a percentage of the runoff volume from the 85th percentile, 24-hour depth. Every combination of ten sizes of basin (5%-50% of the SWQDv in 5% increments) and four infiltration rates (0.01, 0.05, 0.15, and 0.30 in/hr) were modeled. The depth of the unit was assumed to be 2 ft.

APPENDIX C – DATASETS AND ANALYSIS METHODS FOR POLLUTANT TREATMENT EVALUATION

Data Development and Analysis Framework

BMP performance is a function of BMP type, BMP design parameters, influent water quality characteristics, and other factors. As part of the MWS Linear equivalency analysis it was necessary to develop a statistical description of BMP performance, that accounted for the difference between conventional biofiltration and MWS Linear, and for the influence of land use runoff quality (i.e., BMP influent quality) on the expected BMP performance. The data development and analysis framework used for this project included four steps:

1) Compile and review data from monitoring studies of conventional biofiltration systems; then screen these studies to identify studies that are reasonably representative of conventional biofiltration designs that would meet the MS4 Permit requirements, particularly focusing on factors that would influence treated effluent quality.
2) Compile and review monitoring data from full-scale MWS Linear monitoring studies.
3) Apply a common statistical analysis framework to analyze the data from both datasets.
4) Determine representative land use runoff quality.
5) Based on results from step 3 and 4, estimate the effluent quality expected for conventional biofiltration compared to MWS Linear for each pollutant for a range of land use-based influent quality.

Compilation and Screening of Conventional Biofiltration Studies

Note, this analysis is equivalent to the analysis conducted as part of evaluating Filterra equivalency (Geosyntec, 2015). Based on review of the International BMP Database, limited new information about conventional biofiltration performance was available at the time of publication. It is possible that 2 to 3 additional studies are available that would have similar design parameters to Attachment H of the MS4 Permit. New data from two to three new studies would be unlikely to influence findings from the 20 studies that were used in the 2015 Filterra equivalency analysis, this previous assessment of baseline performance was not revised.

As of 2015, the International Stormwater BMP Database (www.bmpdatabase.org) included storm event monitoring data from 28 peer-reviewed studies of bioretention BMPs with underdrains. These data were used as the primary source for characterizing the treatment performance of conventional biofiltration BMPs in this study. In addition to the 28 studies from the International BMP Database, four peer-reviewed research studies (Davis 2007; Li and Davis 2009; David et al., 2011; Gilbreath et al. 2012) not contained in the International BMP Database were added to the sample pool for analysis. Two of these studies were conducted in the San Francisco Bay area, which has biofiltration design standards and media specifications nearly identical to Attachment H of the Los Angeles MS4 Permit. The two other additional studies were included due to their similarity to Attachment H design criteria and rigor of their analytical methods.

Screening Process for Developing Conventional Biofiltration Sample Pool

In general, the bioretention BMPs in the International BMP Database are representative of the range of designs that could meet the MS4 Permit Attachment H requirements. Most of the bioretention studies in the BMP Database were completed fairly recently (most between 2000 and 2015) and have typically been designed, constructed, and/or monitored under the supervision of experienced researchers. Many of these systems have been designed with BMP profiles (i.e., ponding depth, media depth), media filtration rates, and media composition that are similar to the criteria in Attachment H. However, where design attributes indicated that performance would be expected to be poorer than Attachment H designs and/or representativeness could not be evaluated, these studies were screened out of the analysis pool for this study. Systems that were expected to achieve similar or better performance than a typical BMP designed per Attachment H were kept in the pool; this is a conservative approach when evaluating MWS equivalency because it tends to establish a higher baseline for comparison than if these BMPs were excluded.

Screening criteria were developed based on professional judgment, as informed by review of literature and BMP performance studies. Our understanding of the influence of design parameters on bioretention performance was informed by studies in the BMP Database (see various summary reports at www.bmpdatabase.org), a recent evaluation by Roseen and Stone (2013), and review of recent bioretention media research in Washington State. A summary of the relevant findings is provided in the paragraphs below.

Roseen and Stone (2013) conducted an evaluation of biofiltration performance to determine how design criteria and media composition influence performance. As part of their research, they compiled site, design, and performance data for 80 field bioretention systems and 114 lab columns/mesocosms. Data from the International BMP Database were included in this pool as well as other research studies. Performance data were compiled as study summaries (e.g., study median influent, effluent, and removal efficiency). Roseen and Stone then utilized design information to categorizing systems into groups based on common combinations of factors. They then conducted a statistical evaluation of how performance was influenced by design factors such as presence/absence of mulch layers, use of compost in media, infiltration rate of media, ratio of tributary to biofiltration area, presence/absence of pretreatment, presence/absence of internal storage layers, etc. Roseen and Stone found that the presence of compost in mixes strongly influences the variability in performance and potential export of pollutants, including phosphorus, nitrogen, and copper. Systems without compost and/or with a high fraction of sand tended to provide the most consistent and best performance for these pollutants. Systems with an internal water storage zone tended to perform better for nutrients than systems without an internal water storage zone. Finally, they found that media flowrate and depth of media bed tended to have an influence on performance. Beyond these findings, the influence of other parameters was less conclusive.

Recent bioretention studies, many in Washington State (Herrera 2014b, 2015a, 2015b), have identified the potential severity of pollutant export of nitrogen, phosphorus, and copper from conventional biofiltration systems and have evaluated the potential sources of these issues. This research also found that some sand products can also contain elevated levels of phosphorus and copper. These studies are relevant because the standard biofiltration media specifications for Western Washington are very similar to Attachment H, calling for 60 to 65 percent sand and 35 to 40 percent compost. It should also be noted that the compost certification criteria in Washington State (Washington Department of Ecology, 2014) allow for half as much metals content as allowed in the Attachment H specification, therefore should theoretically have less potential for export of metals than compost meeting the Attachment H specification.

Based on these literature findings and best professional judgment, the following criteria were applied as part of screening bioretention studies:

- Systems with media filtration rates substantially higher than 12 inches per hour were excluded – while higher rate media has been found to provide good performance in some cases, the general trends observed by Roseen and Stone (2013) indicated a decline in performance for some parameters with increased infiltration rates.
- Systems with sizing factors (BMP area as fraction of tributary area) substantially smaller than the 3 to 5 percent (20:1 to 30:1 ratio of tributary area to BMP area) were excluded – this parameter is related to media filtration rate and is an indicator of the degree of hydraulic loading.
- Systems that were observed to have very infrequent underdrain discharge (i.e., mostly infiltration) were excluded – for these designs, the effluent that was sampled for water quality was likely not representative of the entire storm event.
- Systems with internal water storage zones were kept in the pool of data; these systems are believed to provide better control of nutrients than systems without internal water storage; Attachment H does not require internal water storage to be provided.
- Based on the findings of Roseen and Stone (2013) as well as recent research in Washington State, mixes with less compost and a higher fraction of sand than the Attachment H specification were kept in the sample pool because they are believed to provide more reliable performance and less potential for export of pollutants on average than a 70-30 sand/compost mix.
- Systems that contained media with experimental components were excluded.
- Finally, systems were excluded if there was not enough design information reported to be able to evaluate representativeness, and/or any other factors were noted by the original study researchers that were believed to contribute to poorer performance than average. For example, some studies were noted as underperforming studies due to construction issues, premature clogging, etc.

Overall, the screening that was applied is believed to improve the representativeness of the sample pool and generally increase the average performance of the sample pool compared to the entire pool of studies contained in the International BMP Database. As discussed above, establishing a higher baseline level of performance for conventional biofiltration is conservative in the context of this evaluation.

Screening Results

Table C.2 summarizes the number of data points for each constituent after applying screening to remove unrepresentative studies and without screening.

Table C.2. Summary of data points by parameter for conventional biofiltration BMPs

Constituent	Number of Screened Data Pairs	Number of Unscreened Data Pairs
Total Suspended Solids	234	354
Total Phosphorus	242	384
Total Nitrogen	71	184
Total Copper	190	216
Total Zinc	200	252

Inventory of Bioretention Studies and Screening Results/Rationales

Table C.4 (located at the end of this Appendix) provides an inventory of studies of bioretention with underdrains from the International BMP Database, screening results, and brief rationales for screening.

Compilation of MWS Linear Monitoring Studies

Data were compiled from two MWS Linear monitoring studies conducted in 2013 and 2014. The data from these two studies were found to cover the range of influent pollutant concentrations for the representative land uses. Both monitoring studies were based on full-scale field applications, were conducted by third-party entities, and employed flow weighted influent and effluent sampling of representatively sized MWS Linear systems under actual storm events. The following studies were used in this assessment with the number of data points included presented in Table C.3:

- **Herrera (2014a):** This assessment followed the Washington State Technology Acceptance Protocol-Ecology (TAPE) certification requirements. Storm event sampling of an MWS Linear system was conducted at the Albina Maintenance Facility in Portland, Oregon. Monitoring was conducted by Herrera Environmental Consultants. The sample results reported by the original researches were used in this evaluation.
- **United States Army Engineer Research and Development Center (USARDC, 2013):** Two MWS linear systems were evaluated by the US Army Research and Development Center at a site in Fort Hood, Texas. In addition to TSS and total zinc (reported below), total copper samples were obtained at this site. Total copper data were not included in this evaluation because four of six effluent samples were below the detection limit.

Table C.3. Inventory of evaluated MWS Linear studies and data points by parameter

Pollutant (total count of data pairs)	Data Pairs by Study	Reference
Total Suspended Solids (n = 47)	29	(Herrera, 2014)
	18	(USARDC, 2013)
Total Phosphorus (n=25)	25	(Herrera, 2014)
Total Nitrogen (n = 28)	28	(Herrera, 2014)
Total Copper (n = 29)	29	(Herrera, 2014)
Total Zinc (n = 47)	29	(Herrera, 2014)
	18	(USARDC, 2013)

Data Analysis Method

The most common ways to characterize BMP performance include (1) removal efficiency (percent removal) in various forms, and (2) effluent probability. In general, the effluent probability approach is recommended for evaluating BMP performance and applying BMP performance to pollutant load models (Geosyntec and Wright Water, 2009). This method involves conducting a statistical comparison of influent and effluent quality to determine if effluent is significantly different from influent. If effluent is significantly different from influent, then the effluent quality is characterized by a statistical distribution developed from all effluent data points. Probability plots are prepared indicating the probability that a certain effluent quality is achieved.

However, to isolate differences in performance between two BMP types, the effluent probability method requires the assumption that the influent quality was similar between the studies of the two BMP types being compared. This assumption is generally reliable for categorical analysis of BMPs in the International BMP Database because of the large number of studies in the most categories in the Database. However, when comparing BMP types with a relatively limited number of study sites (such as the MWS Linear dataset), this assumption may not be reliable.

To address these challenges and help ensure a valid comparison between conventional biofiltration and MWS Linear, a moving bootstrap method (Leisenring et al., 2009) was applied to both datasets. This method characterizes influent-effluent relationships such that the BMPs compared do not need to have been studied under conditions with similar influent quality. In this approach, all data pairs are used to form the total sample population. Then for each increment of influent quality, a subsample of the overall population is formed including only those data pairs that lie within a certain span of the selected influent quality. Applying bootstrap principles (Singh and Xie, 2008), the median or mean and the confidence interval around the median or mean is computed. Then a new increment of influent quality is selected, and the process is repeated with a new subsample population until a statistical description of effluent quality has been developed for each increment of influent quality over the range of the data. A minimum span of 5 was set for calculation of confidence intervals.

Resulting tables and plots from this analysis are presented in Appendix D.

Land Use Stormwater Quality Inputs and Assumptions

Representative stormwater runoff concentrations for the land use condition used in this analysis were developed based on the land use stormwater quality monitoring data reported in the Los Angeles County 1994-2000 Integrated Receiving Water Impacts Report, 2000 and Los Angeles County 2000-2001 Stormwater Monitoring Report, 2001(LA County 2000; LA County 2001). The median and mean runoff quality values from this dataset were used as representative influent water quality conditions for evaluating BMP performance. These concentrations represent only one land use monitoring station in one geographic area; actual conditions for a given drainage area in a given region are anticipated to vary. Beyond the range of water quality presented in this table, this analysis did not attempt to characterize the uncertainty/variability in runoff water quality. This simplification is considered appropriate for evaluating equivalency in BMP performance.

Land use runoff quality is reported in Appendix D.

Table C.4. Inventory of conventional biofiltration studies from the International BMP Database and screening rationale

Source	Site Name	Sponsoring Entity	State	City	Selected?	Selection/Rejection Reasons
Int. BMP Database	Rocky Mount Grassed Bioretention Cell 1	North Carolina State	NC	Rocky Mount	Yes	Aligns with Att. H; Has internal water storage zone and underdrain
Int. BMP Database	Rocky Mount Mulch/Shrub Bioretention Cell 1	North Carolina State	NC	Rocky Mount	Yes	Aligns with Att. H; Has internal water storage zone and underdrain
Int. BMP Database	CHS_BioFilter	The Thomas Jefferson Planning District Commission	VA	Charlottesville	Yes	Aligns with Att. H; Has internal water storage zone, underdrain, and mulch layer (0.25 feet)
Int. BMP Database	Parks & Forestry Bioretention	City of Overland Park	KS	Overland Park	Yes	Aligns with Att. H; Has internal water storage zone, underdrain, and mulch layer
Int. BMP Database	Bioretention 6	Johnson County	KS	Shawnee	Yes	Aligns with Att. H; Has internal water storage zone and underdrain
Int. BMP Database	G2	North Carolina State	NC	Greensboro	Yes	Aligns with Att. H; Has underdrain, and mulch layer (7-10 cm)
Int. BMP Database	G1	North Carolina State	NC	Greensboro	Yes	Aligns with Att. H; Has underdrain, and mulch layer (7-10 cm)
Int. BMP Database	L1	North Carolina State	NC	Louisburg	Yes	Aligns with Att. H; Appropriate loading ratio
Int. BMP Database	Bioretention 3B	Johnson County	KS	Shawnee	Yes	Aligns with Att. H; Has internal water storage zone and underdrain
Int. BMP Database	Parking Lot Bioretention Cell	City of Fort Collins	CO	Fort Collins	Yes	Aligns with Att. H; Has internal water storage zone and mulch layer
Int. BMP Database	Bioretention Cells	Johnson County SMP	KS	Overland Park	Yes	Aligns with Att. H; Has internal water storage zone, underdrain, and mulch layer
Int. BMP Database	Bioretention Cell	Johnson County SMP	KS	Overland Park	Yes	Aligns with Att. H; Has internal water storage zone and underdrain

Source	Site Name	Sponsoring Entity	State	City	Selected?	Selection/Rejection Reasons
Int. BMP Database	Bioretention System (D1)	UNH/Cooperative Institute for Coastal and Estuarine Environmental Technology	NH	Durham	Yes	Aligns with Att. H; Has pretreatment, internal water storage zone, underdrain, and mulch layer
Int. BMP Database	UDFCD Rain Garden	Urban Drainage and Flood Control District	CO	Lakewood	Yes	Aligns with Att. H; Has internal water storage zone, underdrain, and compost layer
Int. BMP Database	Hal Marshall Bioretention Cell	City of Charlotte, North Carolina	NC	Charlotte	Yes	Aligns with Att. H; Has underdrain, and mulch layer
Int. BMP Database	Rocky Mount Grassed Bioretention Cell 2	The Cooperative Institute for Coastal and Estuarine Environmental Technology	NC	Rocky Mountain	Yes	Aligns with Att. H; Has internal water storage zone and underdrain
Li and Davis (2009)	Bioretention Cell 1	Prince George's County Department of Environmental Resources/ U of MD	MD	College Park	Yes	Aligns with Att. H
Li and Davis (2009)	Bioretention Cell 2	Prince George's County Department of Environmental Resources/U of MD	MD	Silver Spring	Yes	Aligns with Att. H
Davis (2007)	Bioretention Cell 1	Prince George's County Department of Environmental Resources/U of MD	MD	College Park	Yes	Aligns with Att. H
David et al. (2011)	Daly City Library Rain Gardens	San Francisco Estuary Institute	CA	Daly City	Yes	Aligns with Att. H
Gilbreath et al. (2012)	San Pablo Ave Green Streets	San Francisco Estuary Institute	CA	El Cerrito	Yes	Aligns with Att. H
Int. BMP Database	Bioretention Area	Virginia Department of Conservation and Recreation	VA	Charlottesville	No	Not enough design info provided
Int. BMP Database	Small Cell	North Carolina Department of Transportation	NC	Knightdale	No	Infiltration rate low; noted to be underperforming BMP by study researchers
Int. BMP Database	BRC_B	North Carolina State	NC	Nashville	No	Infiltration too low and undersized
Int. BMP Database	North cell	North Carolina State	NC	Raleigh	No	Media very different from Att. H
Int. BMP Database	WA Ecology Embankment at SR 167 MP 16.4	Washington State Dept. of Transportation	WA	Olympia	No	Linear design; lateral flow; not representative of typical biofiltration design

Source	Site Name	Sponsoring Entity	State	City	Selected?	Selection/Rejection Reasons
Int. BMP Database	Bioretention Cell	Delaware Department of Transportation	DE	Dover	No	Design is very different from Att. H
Int. BMP Database	East 44th St. Pond	City of Tacoma	WA	Tacoma	No	No design data
Int. BMP Database	Tree Filter	UNH/Cooperative Institute for Coastal and Estuarine Environmental Technology	NH	Durham	No	Design is very different from Att. H
Int. BMP Database	BRC_A	North Carolina State University	NC	Raleigh	No	Infiltration rate very low; noted to be a partially clogged/failing system
Int. BMP Database	Cub_Run_Bioretention	Fairfax County	VA	Fairfax	No	No design data provided
Int. BMP Database	South cell	North Carolina State University (BAE)	NC	Raleigh	No	Design is very different from Att. H
Int. BMP Database	R Street	City of Tacoma	WA	Tacoma	No	No design data provided

APPENDIX D – RESULTS OF POLLUTANT TREATMENT DATA ANALYSIS

The data analysis methods described in Appendix C were applied to the datasets described in Appendix C. The following pages present tabular and graphical results of this analysis.

Table D.1 compares the mean and median summary statistics and confidence intervals from the moving window bootstrap analysis between the conventional biofiltration datasets and the MWS Linear datasets. The screened dataset refers to the 20 studies described in Appendix C that were considered representative of MS4 Permit Attachment criteria. The unscreened dataset includes all bioretention studies available in the International BMP Database as of 2015. These datasets are described in Appendix C.

Figure D.1 shows plots of the data analysis results based on the median statistic. Figure D.2 shows plots of the data analysis results based on the mean statistic.

Table D.1 Summary Statistics of Moving Window Bootstrap Analysis – Bioretention and MWS Studies

Median Statistics

Land Use	Pollutant	Units	Median Representative Runoff Quality	Traditional Biofiltration Effluent (Screened)		Traditional Biofiltration Effluent (Unscreened)		MWS Linear Effluent	
				Median	95th Percentile UCL on Median	Median	95th Percentile UCL on Median	Median	95th Percentile UCL on Median
Commercial	TSS	mg/L	53	12	13.7	11	12	12.8	17.2
	Total Phosphorus	mg/L	0.27	**0.46**	0.55	0.26	0.37	0.08	0.14
	Total Nitrogen	mg/L	2.3	1.6	2.9	1.19	1.52	1.77	2.75
	Copper	µg/L	22	12	15	12	14	10.3	12.9
	Zinc	µg/L	192	35	44	36	40	48.8	72.8
High Density Single Family Residential	TSS	mg/L	61	12	15	12	13	13	17.2
	Total Phosphorus	mg/L	0.32	**0.47**	0.55	0.28	0.43	0.1	0.19
	Total Nitrogen	mg/L	2	1.6	2.9	1.2	1.5	1.41	1.56
	Copper	µg/L	11	5.3	5.9	5.3	6.4	6.5	8
	Zinc	µg/L	66	20	27	18	26	39.5	53.5
Light Industrial	TSS	mg/L	129	16	18	16	18	17	19.4
	Total Phosphorus	mg/L	0.3	**0.47**	0.55	0.27	0.42	0.09	0.17
	Total Nitrogen	mg/L	2.4	1.6	2.9	1.2	1.5	1.8	2.75
	Copper	µg/L	21	12	15	12	13.85	10	12.6
	Zinc	µg/L	366	35	44	36	40	48.8	73.6
Multi-family Residential	TSS	mg/L	24	10.8	12.5	9.9	9.9	4.05	5.7
	Total Phosphorus	mg/L	0.14	**0.39**	0.45	**0.21**	0.25	0.04	0.05
	Total Nitrogen	mg/L	1.5	**1.6**	2.9	1.2	1.5	0.94	1.04
	Copper	µg/L	12	5.6	6.1	5.6	6.6	7	9
	Zinc	µg/L	89	20	27	18	26	39.5	53.5

Mean Statistics

Land Use	Pollutant	Units	Median Representative Runoff Quality	Traditional Biofiltration Effluent (Screened)		Traditional Biofiltration Effluent (Unscreened)		MWS Linear Effluent	
				Mean	95th Percentile UCL on Mean	Mean	95th Percentile UCL on Mean	Mean	95th Percentile UCL on Mean
Commercial	TSS	mg/L	66	28	49	25	39	14.1	6.24
	Total Phosphorus	mg/L	0.39	**0.8**	1.3	**0.65**	1	0.17	0.27
	Total Nitrogen	mg/L	3.6	2.9	4.3	2.1	2.8	2.28	2.8
	Copper	µg/L	39	19	29	16	24	20.6	33
	Zinc	µg/L	241	65	145	59	108	49.4	70.9
High Density Single Family Residential	TSS	mg/L	95	28	49	25	39	14.1	2.3
	Total Phosphorus	mg/L	0.39	**0.8**	1.3	**0.65**	1	0.17	0.27
	Total Nitrogen	mg/L	3	2.9	4.3	2.1	2.8	2.28	2.80
	Copper	µg/L	15	13	21	13	19	8.75	8.75
	Zinc	µg/L	79	33	50	32	46	39.5	55.1
Light Industrial	TSS	mg/L	240	46	105	40	87	28.5	10.6
	Total Phosphorus	mg/L	0.41	**0.8**	1.3	**0.65**	1	0.18	0.28
	Total Nitrogen	mg/L	3.1	2.9	4.3	2.1	2.8	2.28	2.8
	Copper	µg/L	32	19	29	16	24	15.5	33
	Zinc	µg/L	639	**NA**	NA	59	108	80	110
Multi-family Residential	TSS	mg/L	46	18	28	18	27	14.1	4.92
	Total Phosphorus	mg/L	0.2	**0.8**	1.3	**0.6**	1	0.07	0.09
	Total Nitrogen	mg/L	2.1	**2.9**	4.3	2.1	2.8	2.01	2.64
	Copper	µg/L	12	10	15	9	14	7	8.75
	Zinc	µg/L	146	45	90	32	46	46.3	66

NA: Average values could not be computed because the land use average influent was outside the range of influent observed in monitoring studies.
Red bold indicates median or mean effluent concentrations are greater than influent concentration. This is indicative of the potential for pollutant export.
Blue indicates upper confidence interval of effluent concentration is greater than the influent concentration. This is not a conclusive indicator but is provided for reference.

Figure D.1 Moving Window Bootstrap Plots of Medians

Screened Biofiltration Dataset | **Unscreened Biofiltration Dataset** | **MWS Dataset**

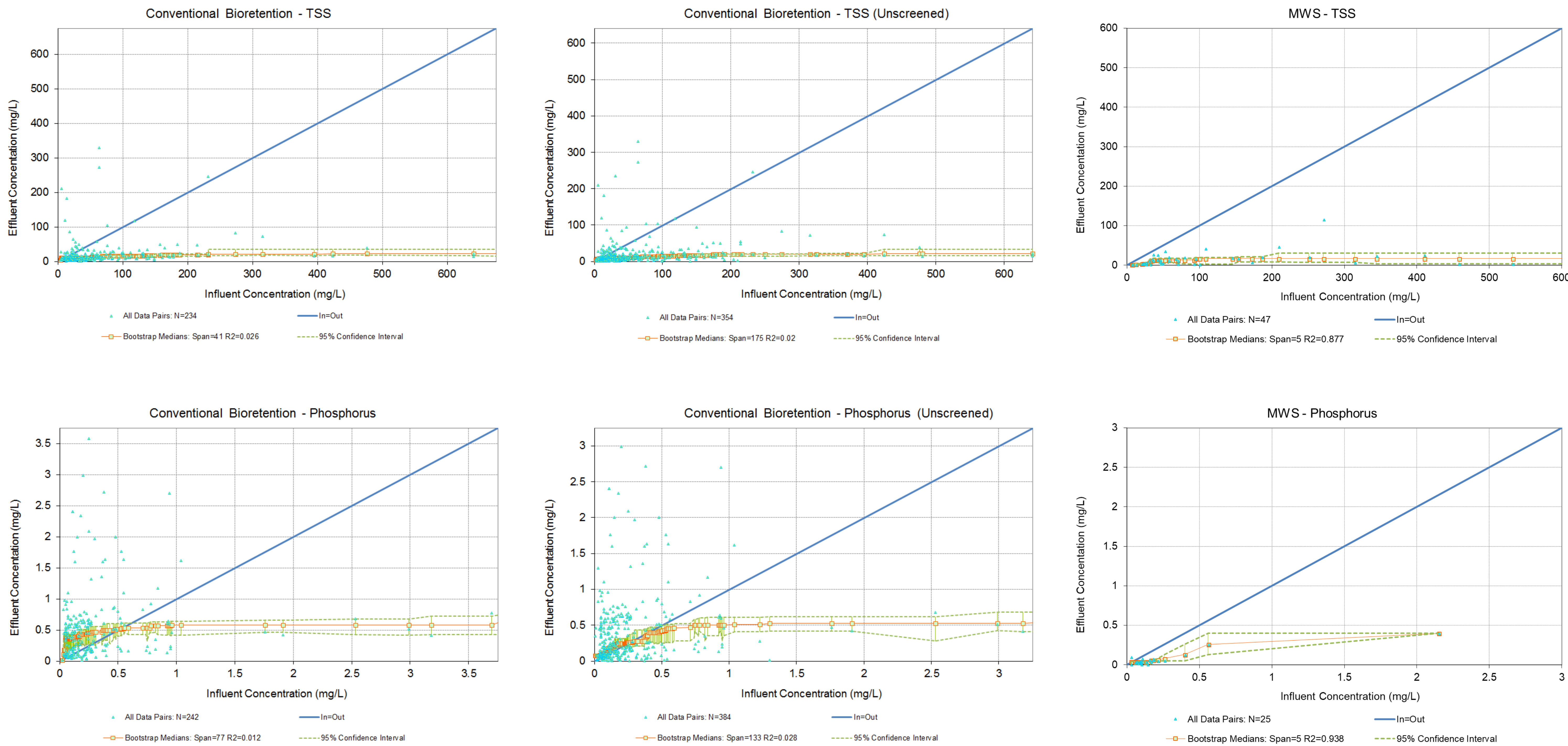

Figure D.1 Moving Window Plots of Medians (Cont.)

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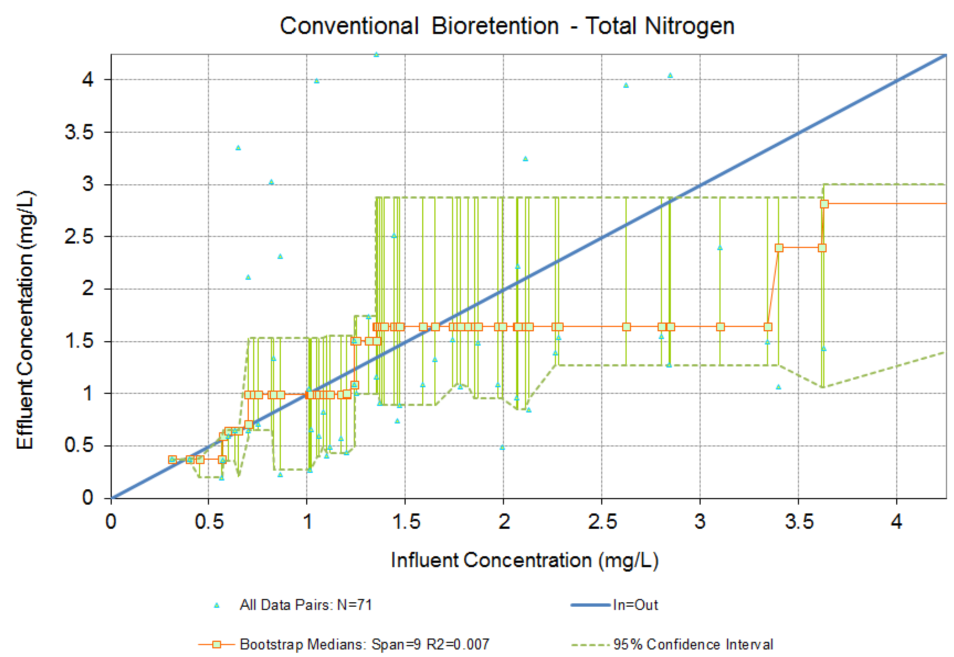

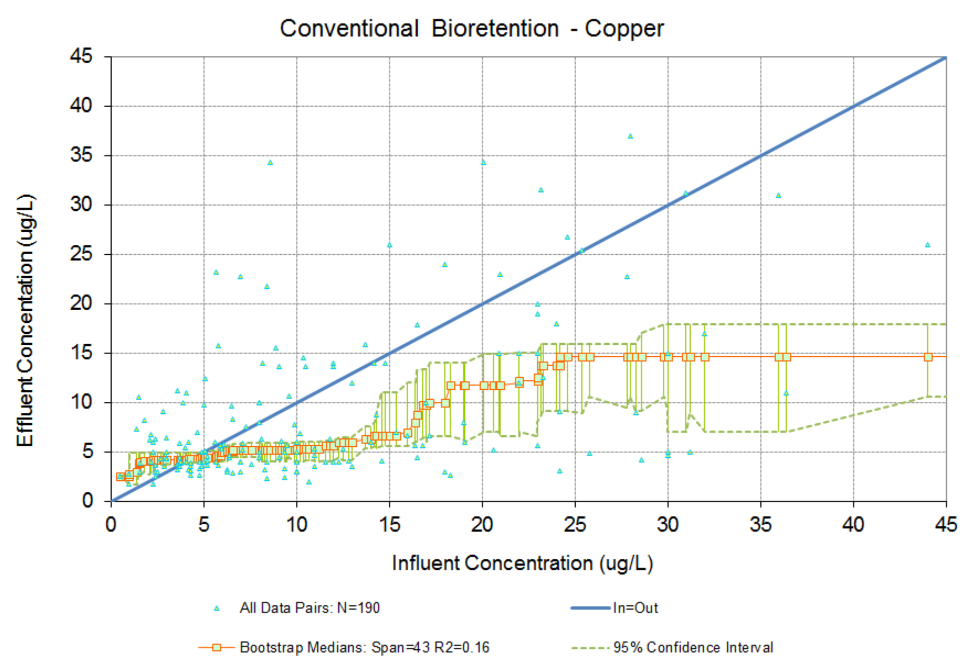

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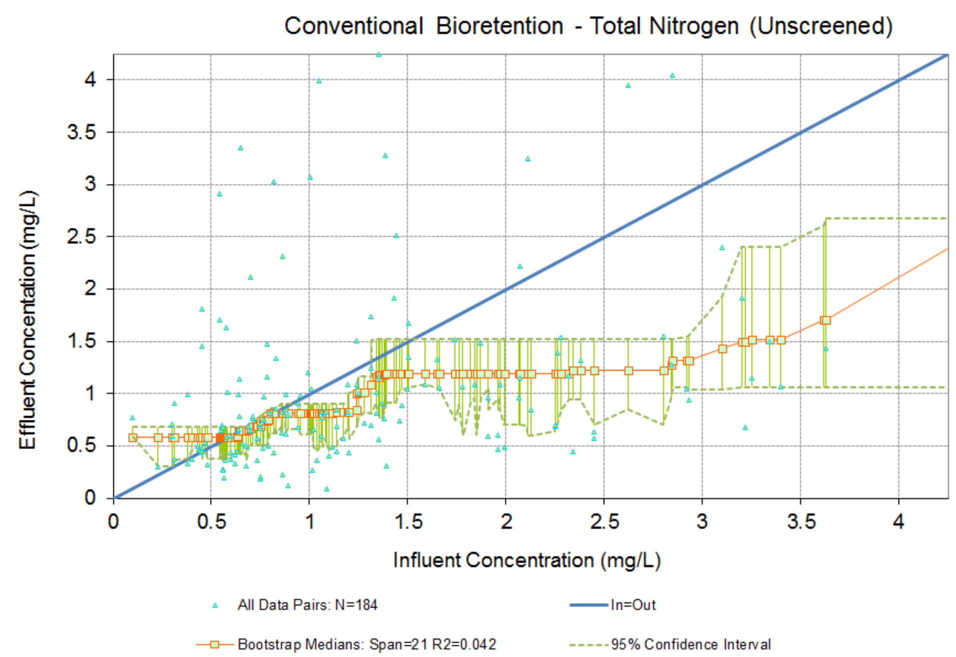
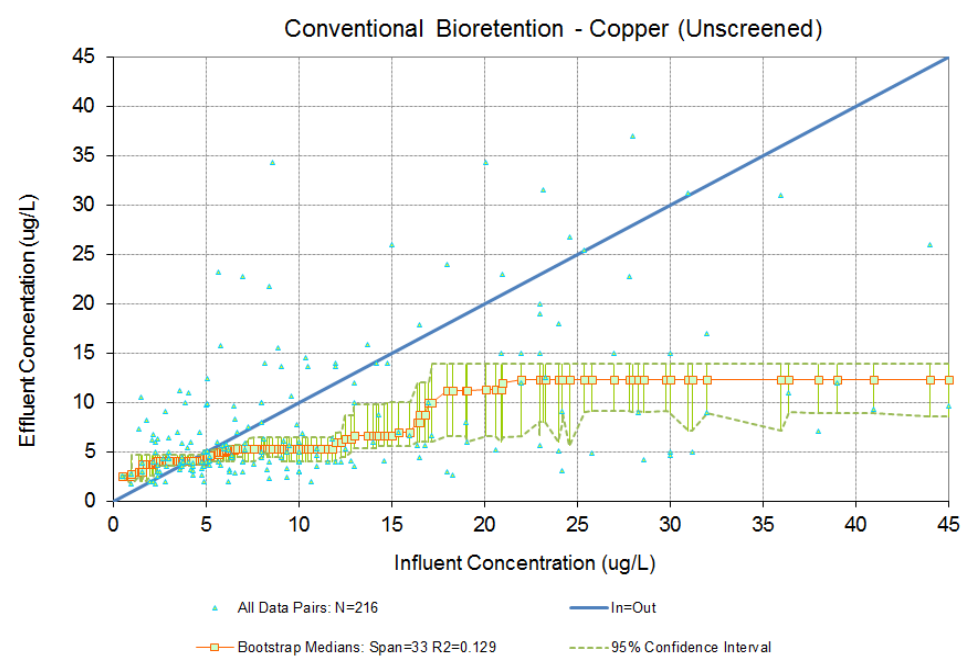
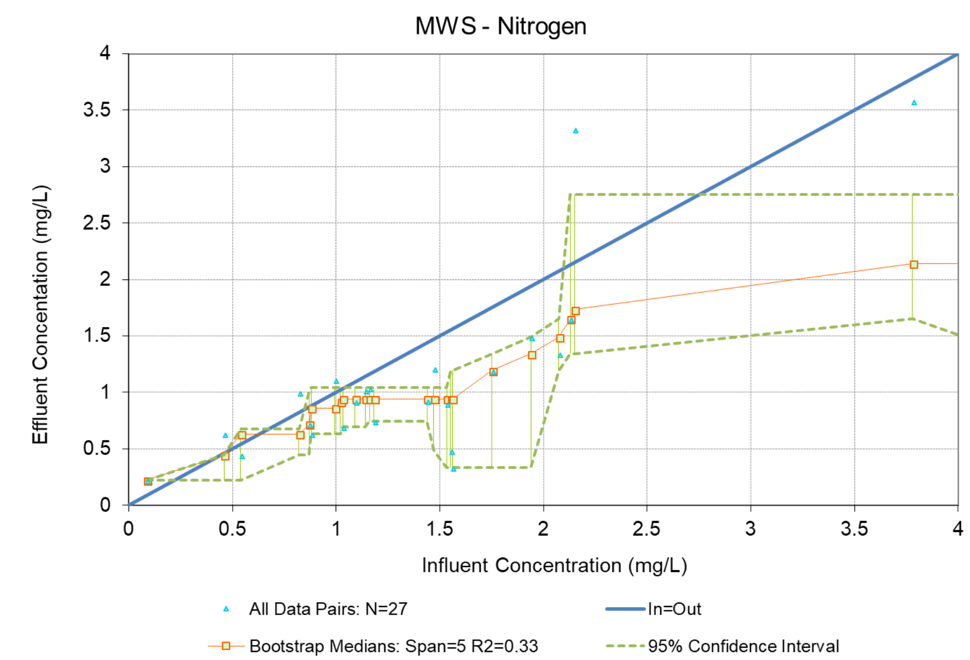




MWS Dataset



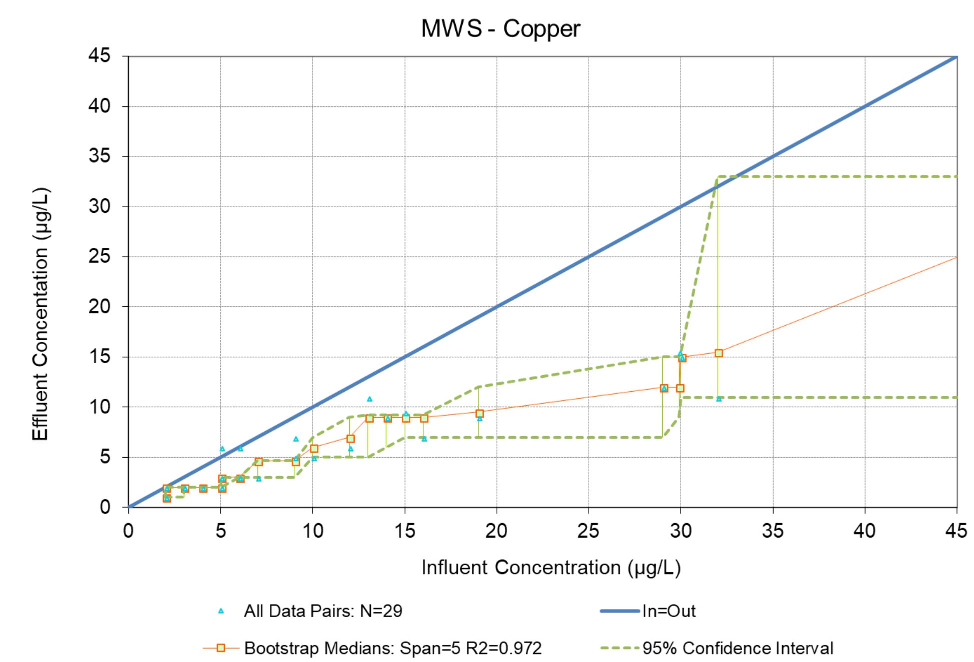


Figure D.1 Moving Window Plots of Medians (Cont.)

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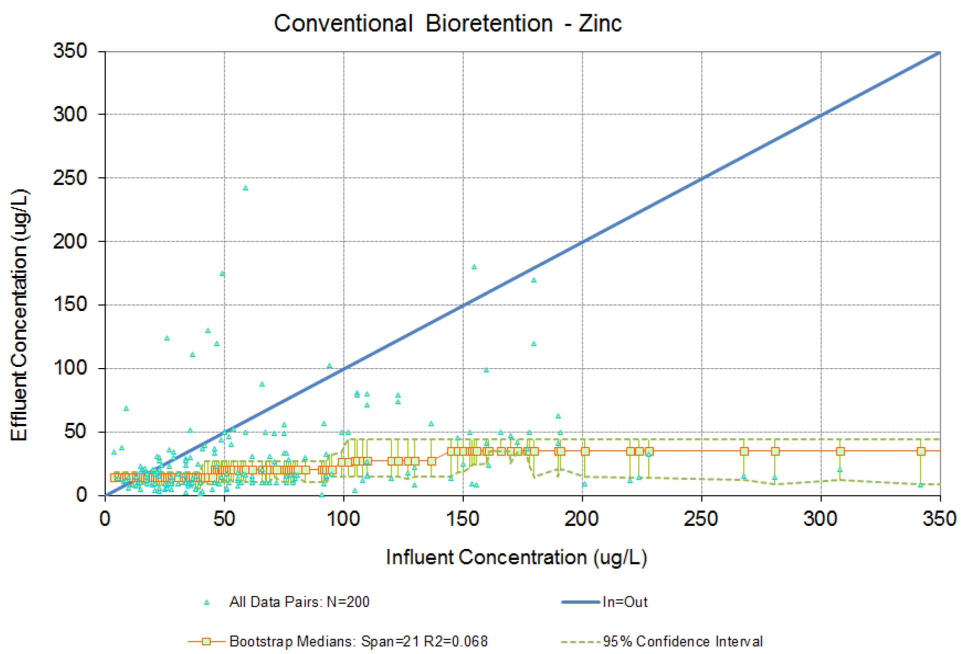

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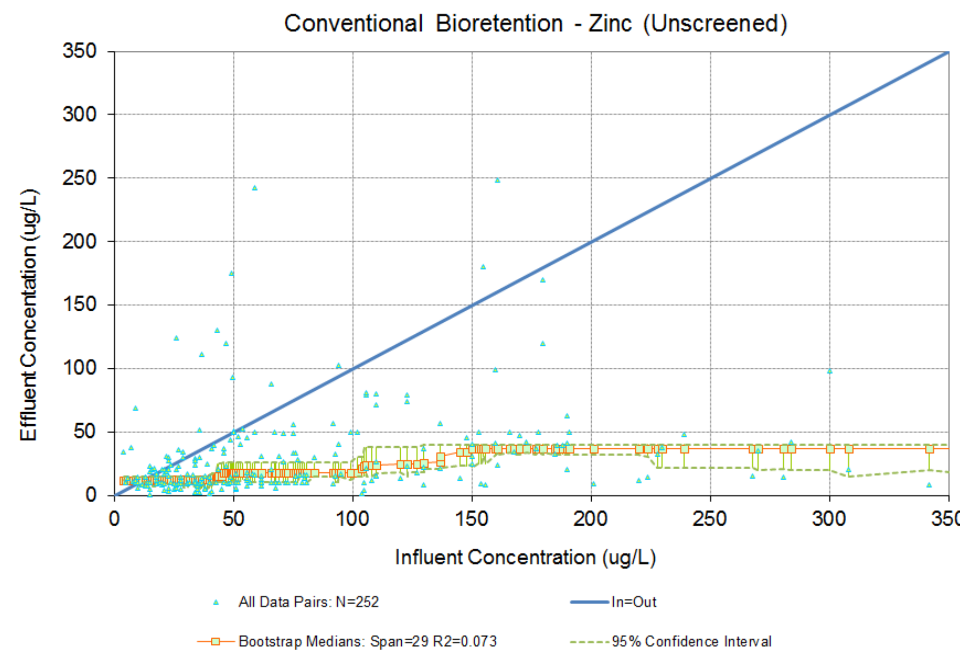

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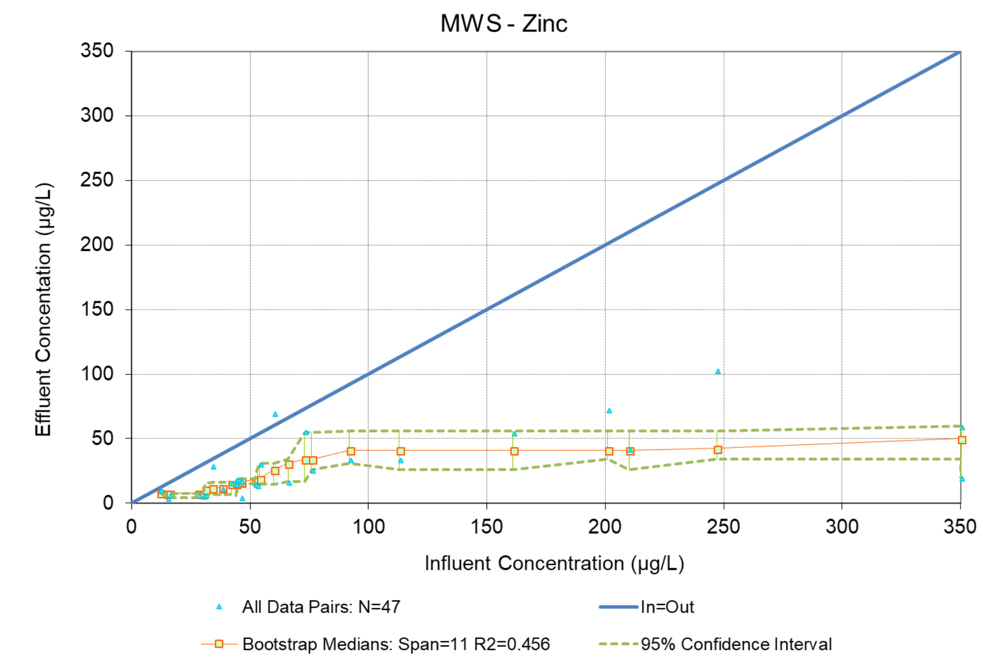
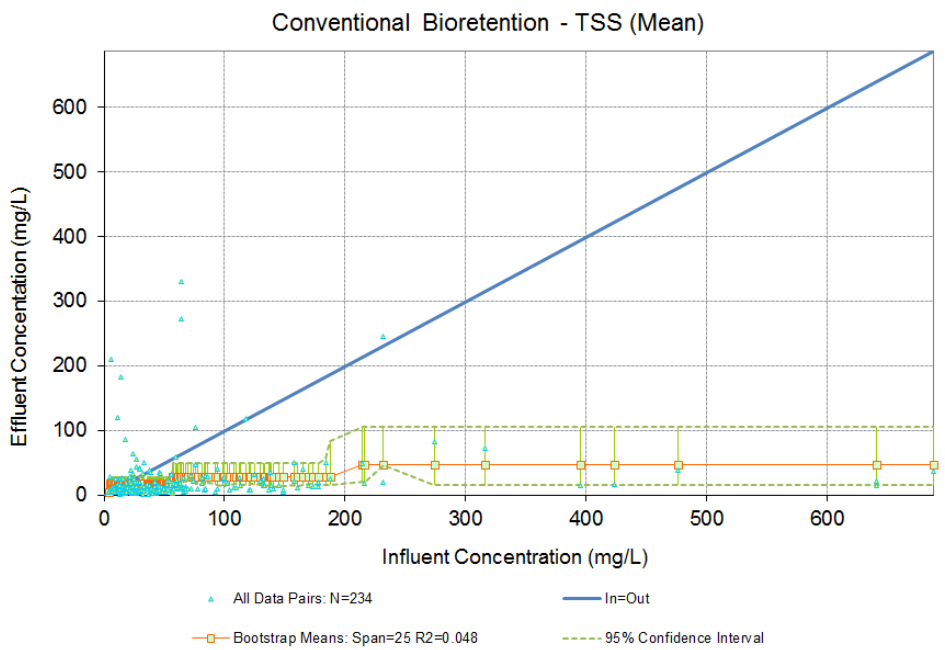
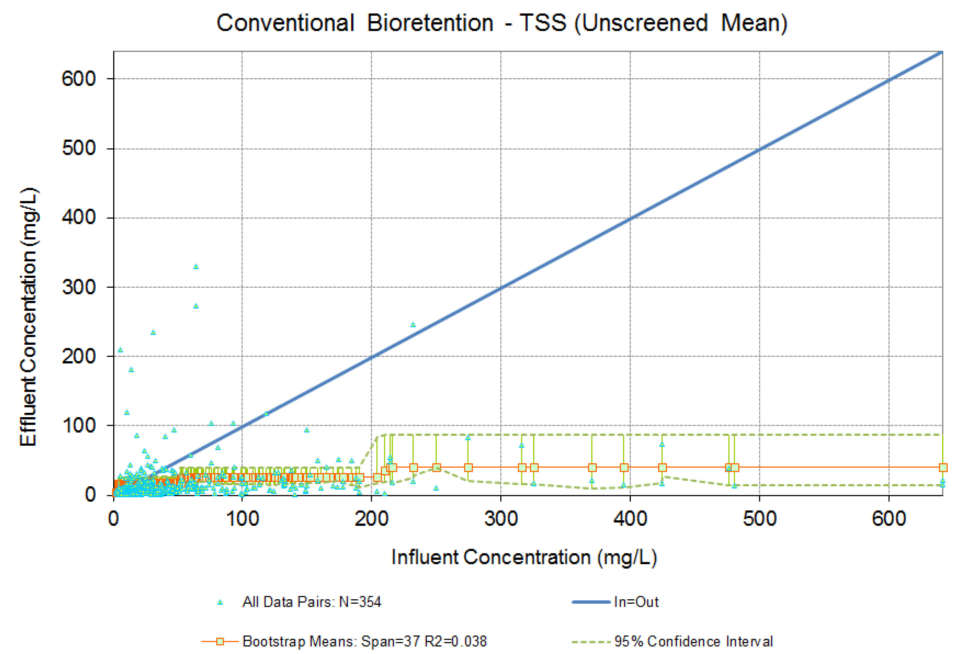
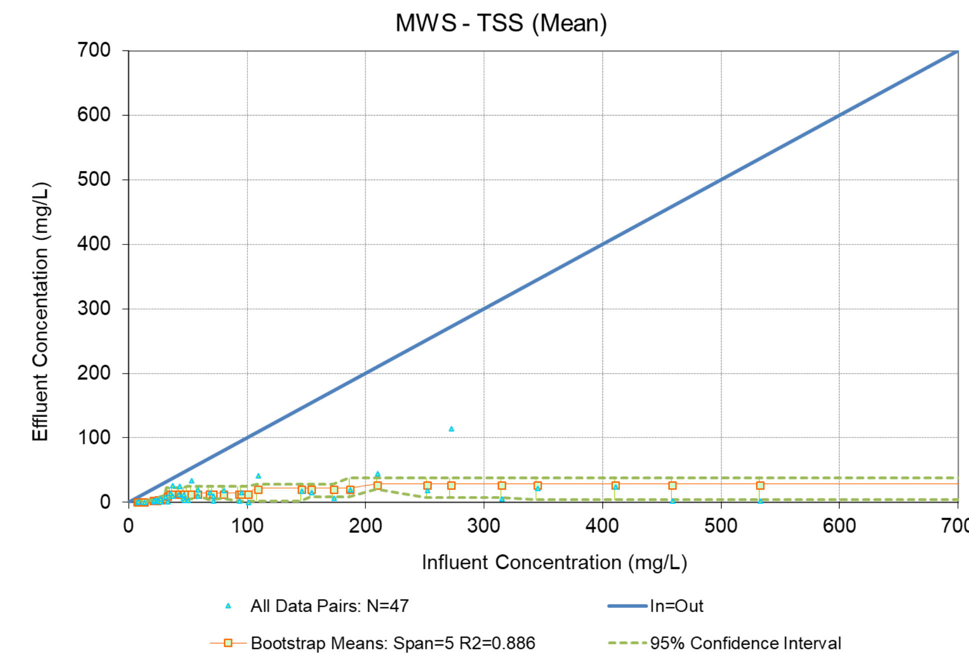


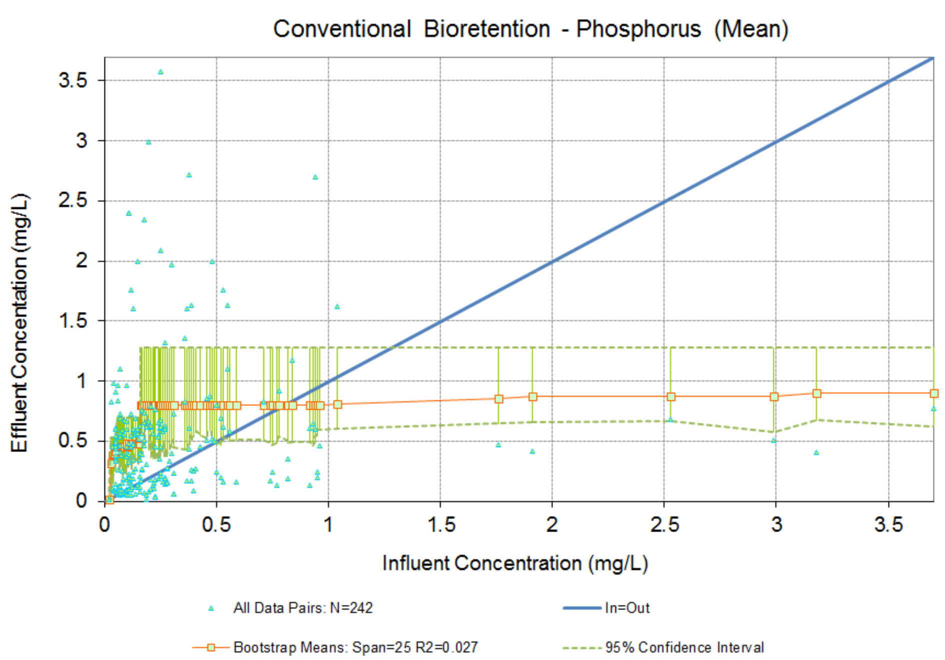
Figure D.2 Moving Window Bootstrap Plots of Means

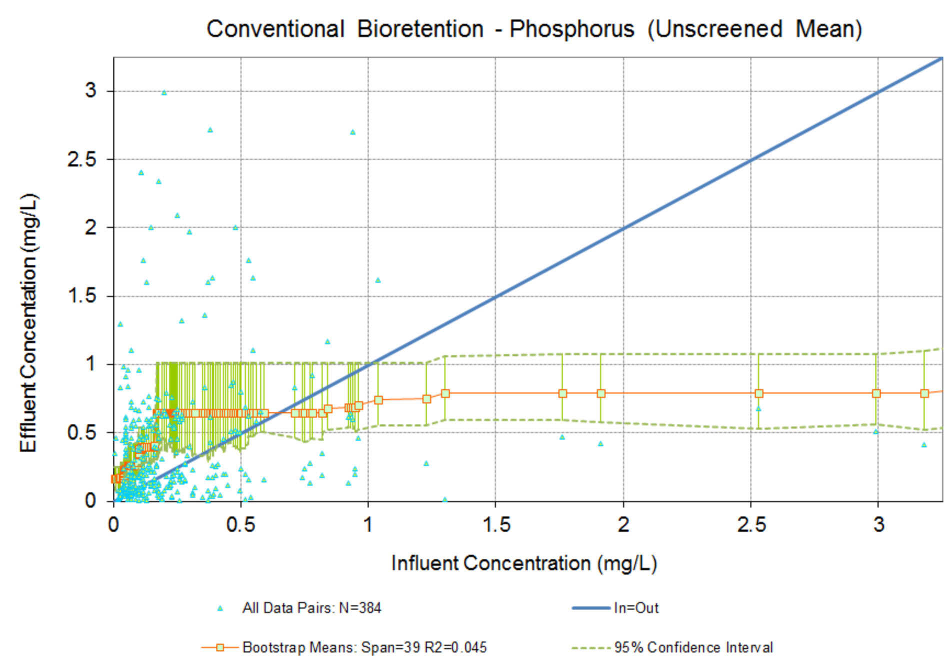
Screened Biofiltration Dataset | **Unscreened Biofiltration Dataset** | **MWS Dataset**











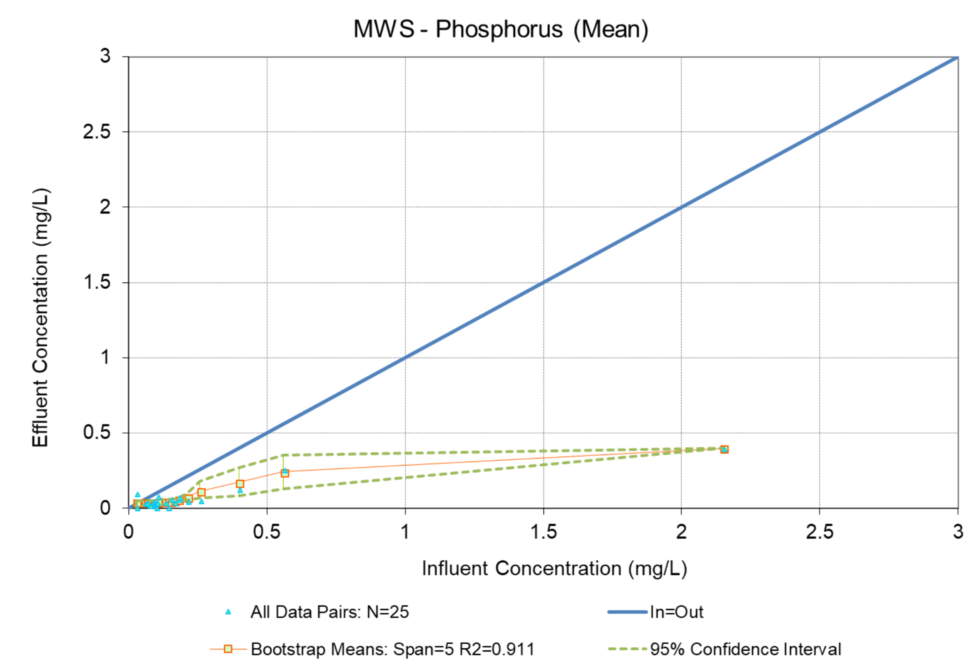
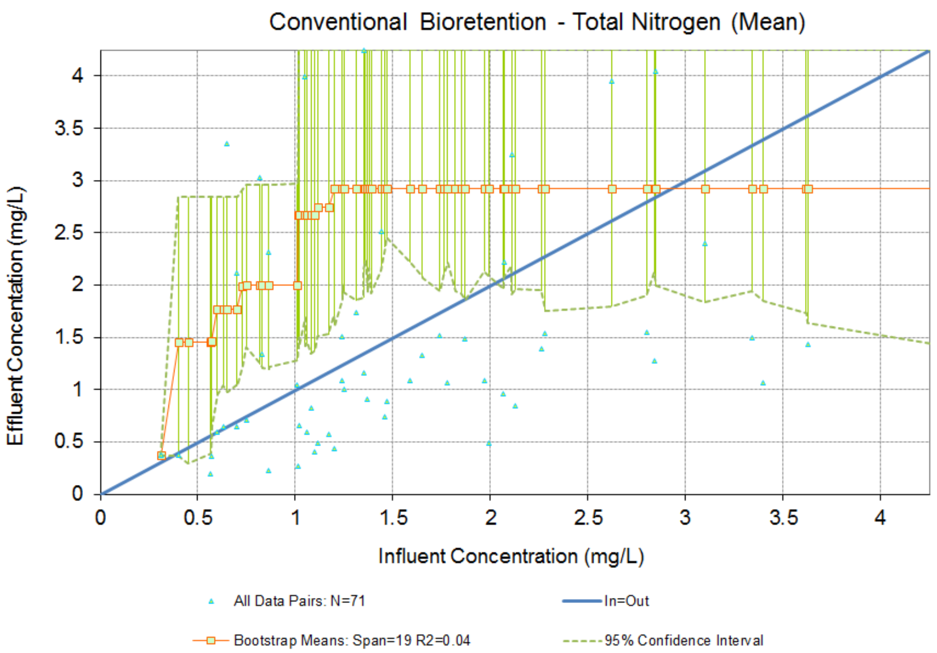


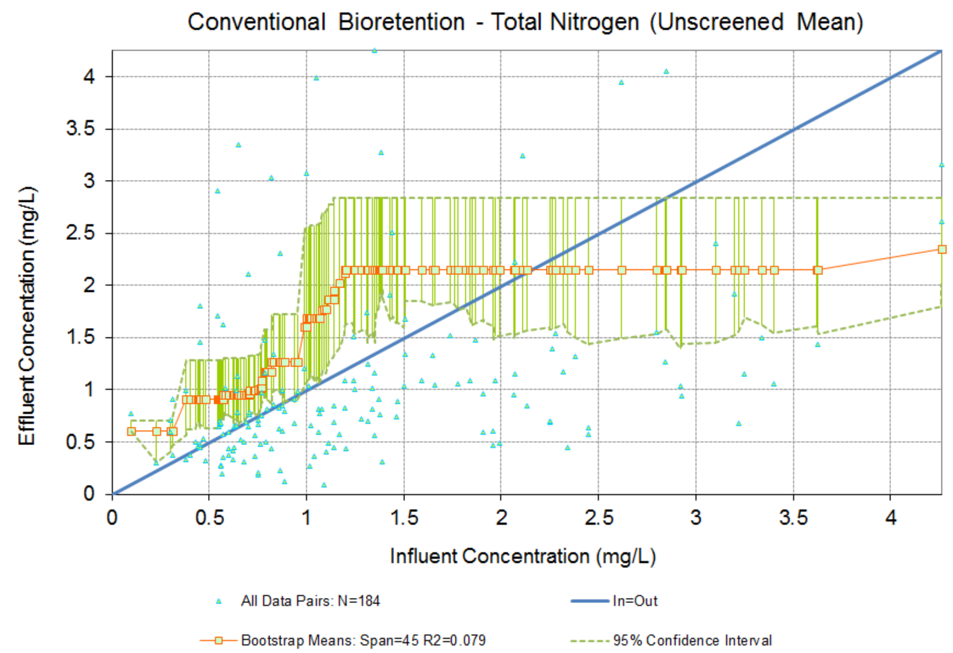
Figure D.2 Moving Window Plots of Means (Cont.)

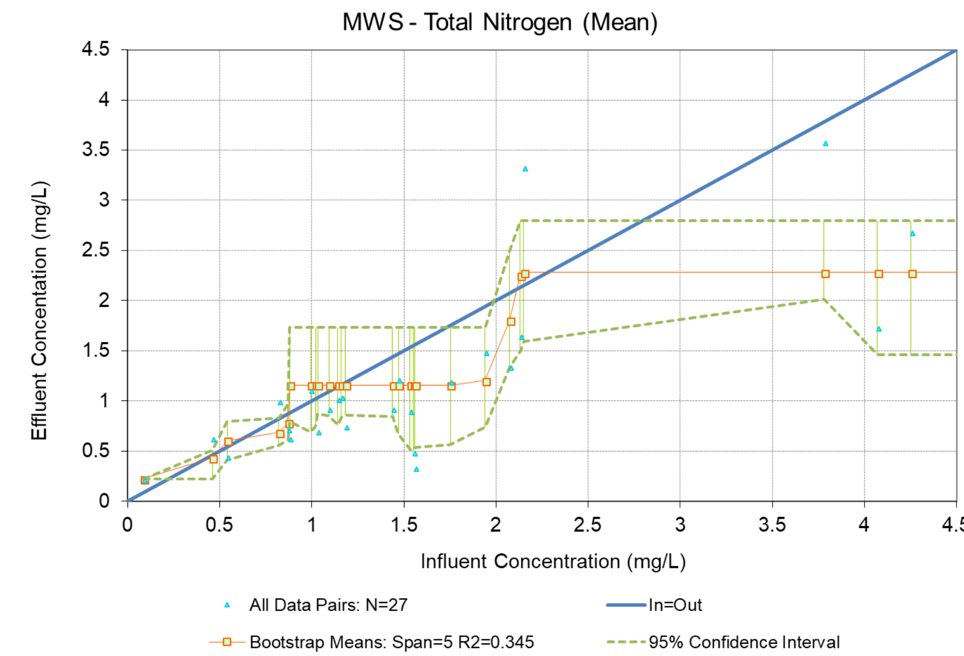
Screened Biofiltration Dataset

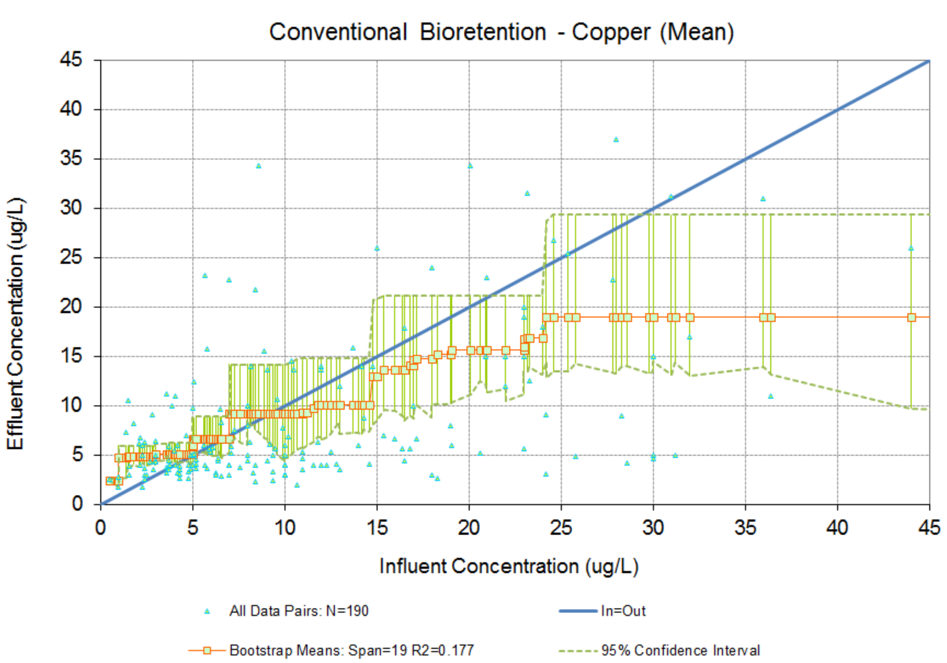
Unscreened Biofiltration Dataset

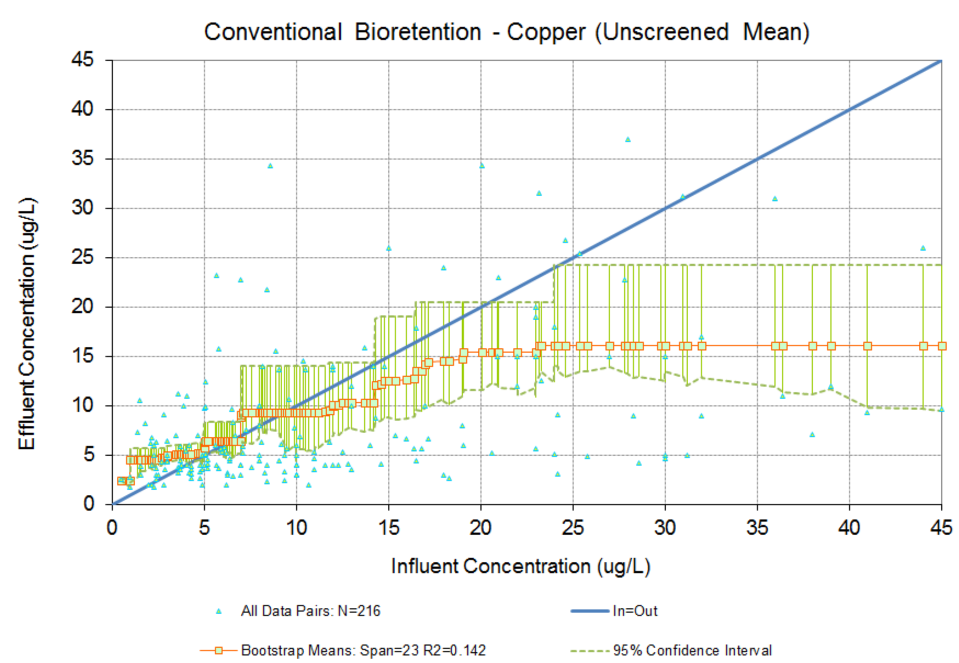
MWS Dataset











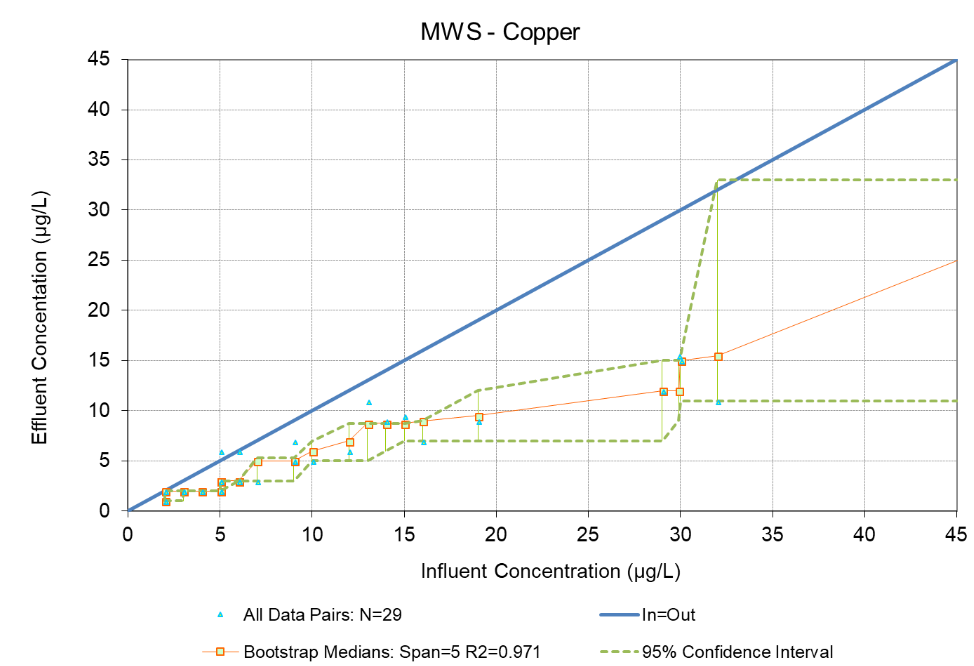


Figure D.2 Moving Window Plots of Means (Cont.)

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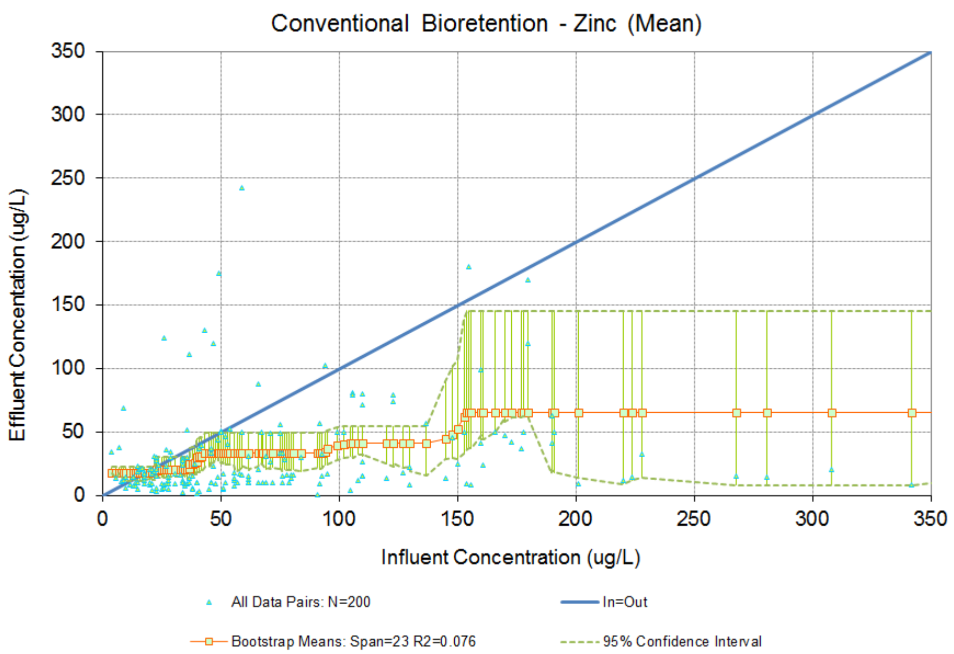

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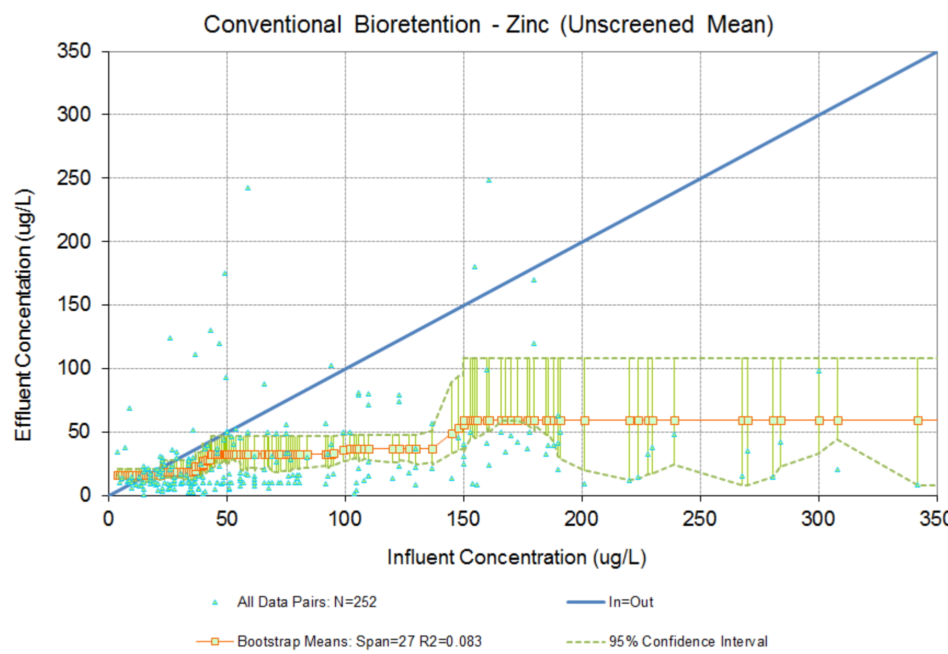
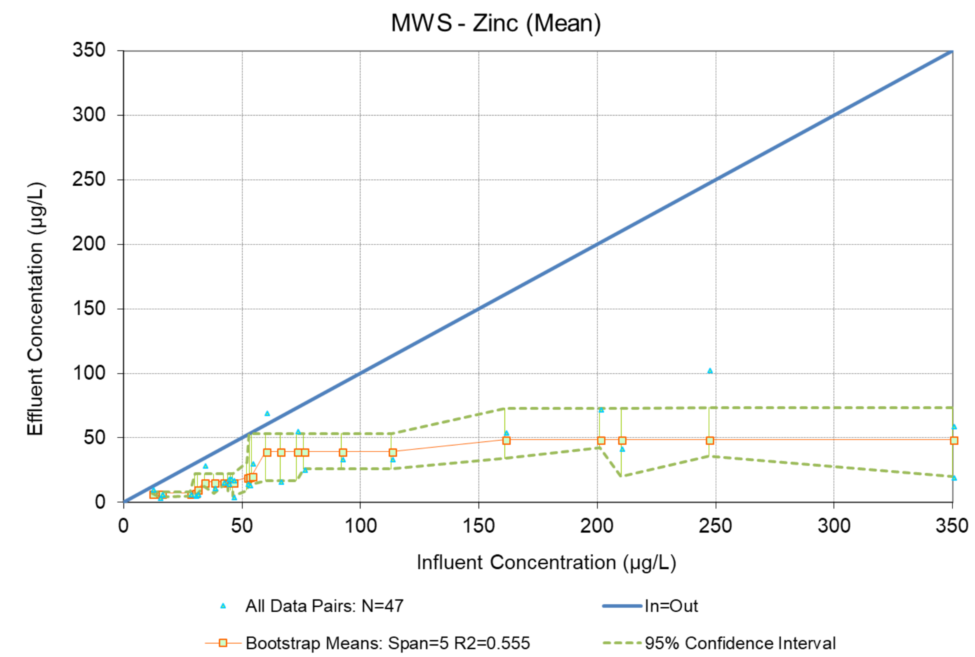


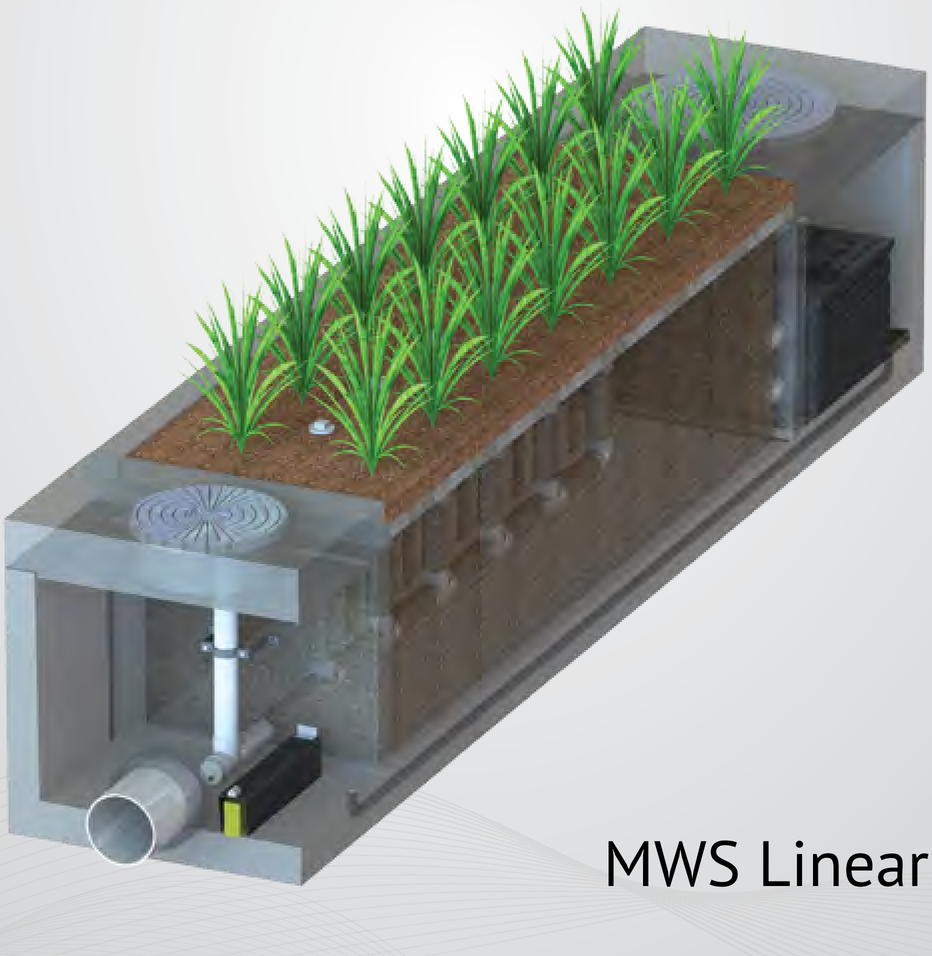
MWS Dataset



BMP Details

MODULAR WETLANDS™

*Advanced **Stormwater** Biofiltration*



MWS Linear

Contents

The Urban Impact

For hundreds of years natural wetlands surrounding our shores have played an integral role as nature's stormwater treatment system. But as our cities grow and develop, these natural wetlands have perished under countless roads, rooftops, and parking lots.

Plant A Wetland

Without natural wetlands our cities are deprived of water purification, flood control, and land stability. Modular Wetlands and the MWS Linear re-establish nature's presence and rejuvenate water ways in urban areas.

MWS Linear

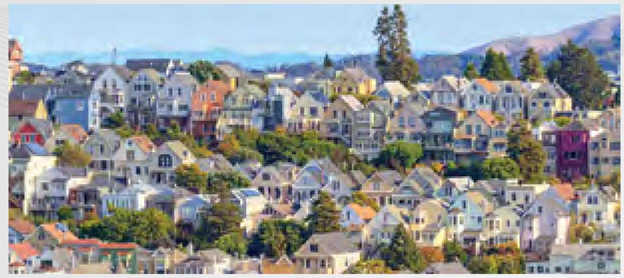
The Modular Wetland System Linear represents a pioneering breakthrough in stormwater technology as the only biofiltration system to utilize patented horizontal flow, allowing for a smaller footprint and higher treatment capacity. While most biofilters use little or no pre-treatment, the MWS Linear incorporates an advanced pre-treatment chamber that includes separation and pre-filter cartridges. In this chamber sediment and hydrocarbons are removed from runoff before it enters the biofiltration chamber, in turn reducing maintenance costs and improving performance.

Applications

The MWS Linear has been successfully used on numerous new construction and retrofit projects. The system's superior versatility makes it beneficial for a wide range of stormwater and waste water applications - treating rooftops, streetscapes, parking lots, and industrial sites.

Industrial

Many states enforce strict regulations for discharges from industrial sites. The MWS Linear has helped various sites meet difficult EPA mandated effluent limits for dissolved metals and other pollutants.



Residential

Low to high density developments can benefit from the versatile design of the MWS Linear. The system can be used in both decentralized LID design and cost-effective end-of-the-line configurations.

Streets

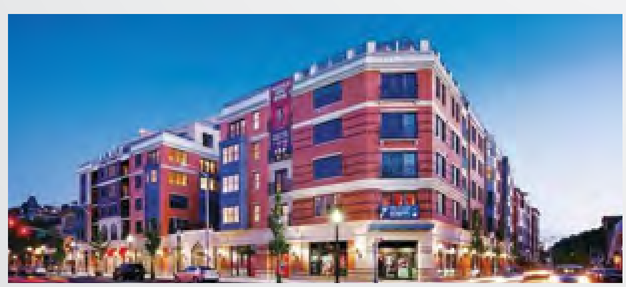
Street applications can be challenging due to limited space. The MWS Linear is very adaptable, and offers the smallest footprint to work around the constraints of existing utilities on retrofit projects.

Parking Lots

Parking lots are designed to maximize space and the MWS Linear's 4 ft. standard planter width allows for easy integration into parking lot islands and other landscape medians.

Commercial

Compared to bioretention systems, the MWS Linear can treat far more area in less space - meeting treatment and volume control requirements.



Mixed Use

The MWS Linear can be installed as a raised planter to treat runoff from rooftops or patios, making it perfect for sustainable "live-work" spaces.

More applications are available on our website: www.ModularWetlands.com/Applications

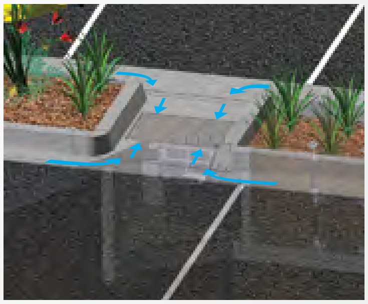
- Agriculture
- Reuse
- Low Impact Development
- Waste Water

Configurations

The MWS Linear is the preferred biofiltration system of Civil Engineers across the country due to its versatile design. This highly versatile system has available "pipe-in" options on most models, along with built-in curb or grated inlets for simple integration into your stormdrain design.

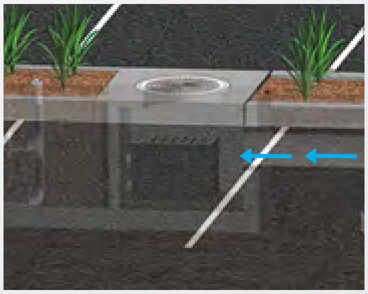
Curb Type

The *Curb Type* configuration accepts sheet flow through a curb opening and is commonly used along road ways and parking lots. It can be used in sump or flow by conditions. Length of curb opening varies based on model and size.



Grate Type

The *Grate Type* configuration offers the same features and benefits as the *Curb Type* but with a grated/drop inlet above the systems pre-treatment chamber. It has the added benefit of allowing for pedestrian access over the inlet. ADA compliant grates are available to assure easy and safe access. The *Grate Type* can also be used in scenarios where runoff needs to be intercepted on both sides of landscape islands.



Vault Type

The system's patented horizontal flow biofilter is able to accept inflow pipes directly into the pre-treatment chamber, meaning the MWS Linear can be used in end-of-the-line installations. This greatly improves feasibility over typical decentralized designs that are required with other biofiltration/bioretention systems. Another benefit of the "pipe in" design is the ability to install the system downstream of underground detention systems to meet water quality volume requirements.

Downspout Type

The *Downspout Type* is a variation of the *Vault Type* and is designed to accept a vertical downspout pipe from roof top and podium areas. Some models have the option of utilizing an internal bypass, simplifying the overall design. The system can be installed as a raised planter and the exterior can be stuccoed or covered with other finishes to match the look of adjacent buildings.

Advantages & Operation

The MWS Linear is the most efficient and versatile biofiltration system on the market, and the only system with horizontal flow which improves performance, reduces footprint, and minimizes maintenance. Figure-1 and Figure-2 illustrate the invaluable benefits of horizontal flow and the multiple treatment stages.

Featured Advantages

- Horizontal Flow Biofiltration
- Greater Filter Surface Area
- Pre-Treatment Chamber
- Patented Perimeter Void Area
- Flow Control
- No Depressed Planter Area

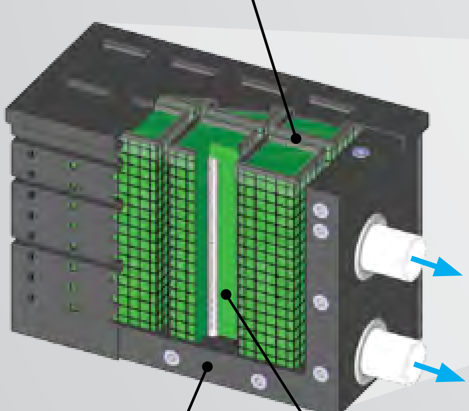
1 Pre-Treatment

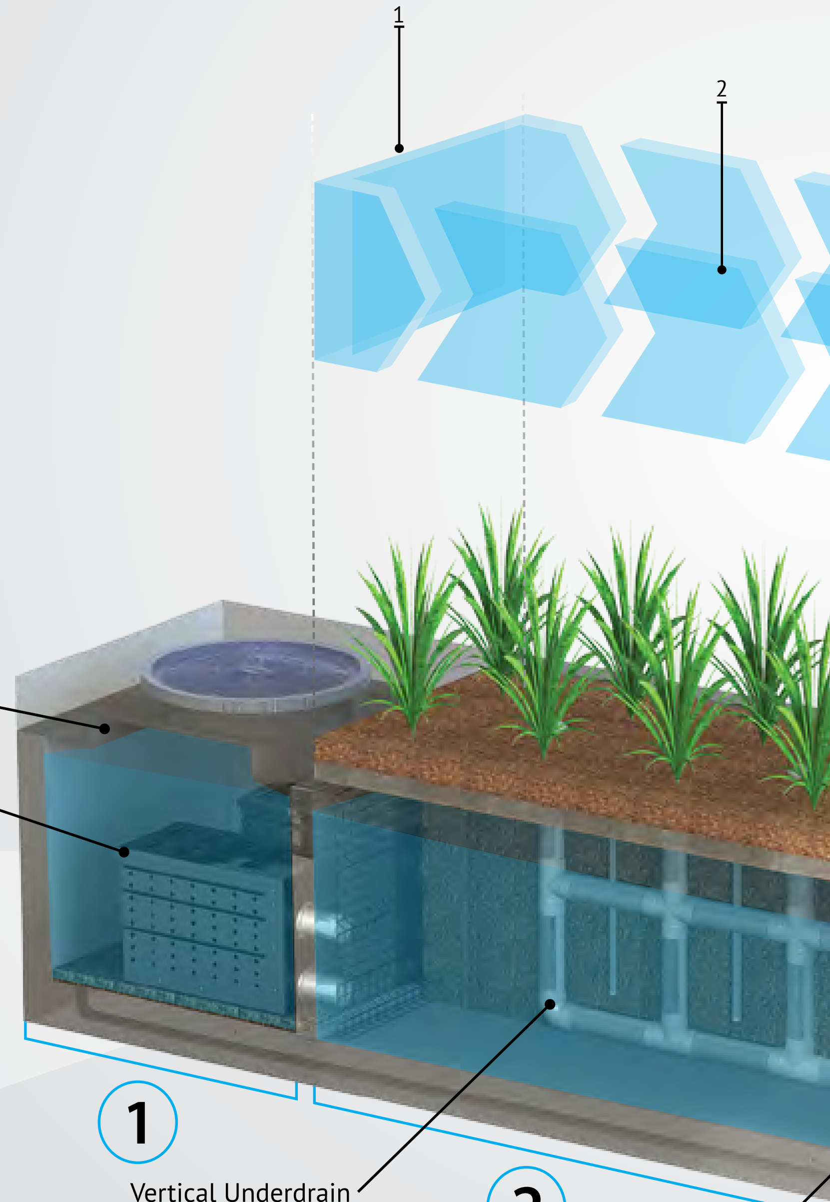
Separation

- Trash, sediment, and debris are separated before entering the pre-filter cartridges
- Designed for easy maintenance access

Pre-Filter Cartridges

- Over 25 ft^2 of surface area per cartridge
- Utilizes BioMediaGREEN filter material
- Removes over 80% of TSS & 90% of hydrocarbons
- Prevents pollutants that cause clogging from migrating to the biofiltration chamber





BioMediaGREEN

Wetland MEDIA™

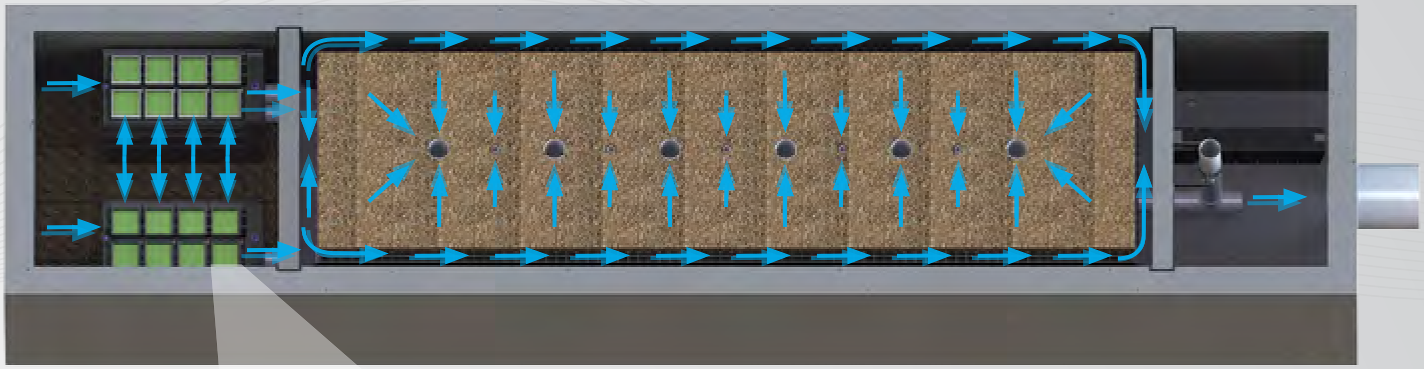


Fig. 2 - Top View

2x to 3x More Surface Area Than Traditional Downward Flow Bioretention Systems.

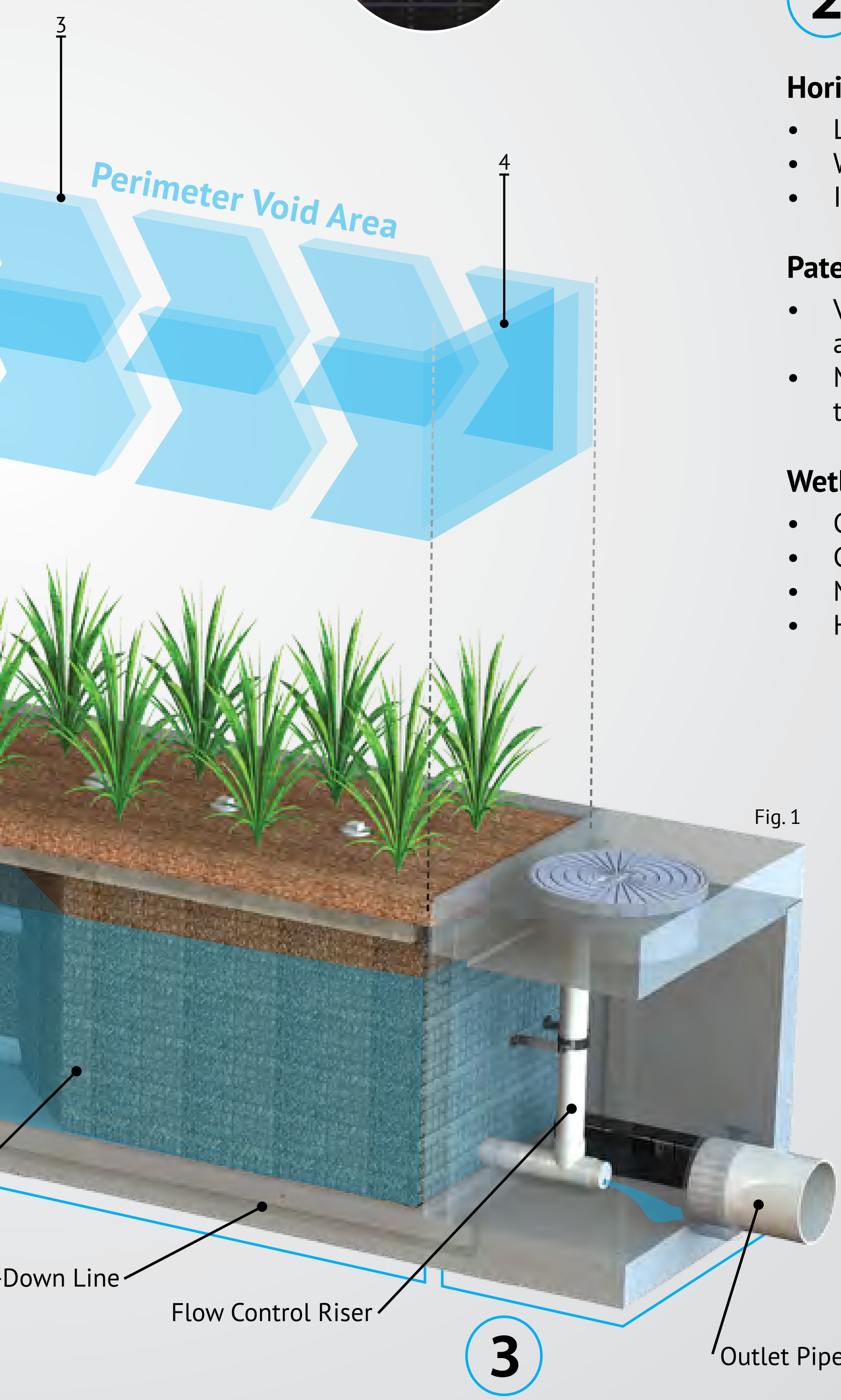


Fig. 1

2 Biofiltration

Horizontal Flow

- Less clogging than downward flow biofilters
- Water flow is subsurface
- Improves biological filtration

Patented Perimeter Void Area

- Vertically extends void area between the walls and the WetlandMEDIA on all four sides.
- Maximizes surface area of the media for higher treatment capacity

WetlandMEDIA

- Contains no organics and removes phosphorus
- Greater surface area and 48% void space
- Maximum evapotranspiration
- High ion exchange capacity and light weight

3 Discharge

Flow Control

- Orifice plate controls flow of water through WetlandMEDIA to a level lower than the media's capacity.
- Extends the life of the media and improves performance

Drain-Down Filter

- The Drain-Down is an optional feature that completely drains the pre-treatment chamber
- Water that drains from the pre-treatment chamber between storm events will be treated

Orientations

Side-By-Side

The *Side-By-Side* orientation places the pre-treatment and discharge chamber adjacent to one another with the biofiltration chamber running parallel on either side. This minimizes the system length, providing a highly compact footprint. It has been proven useful in situations such as streets with directly adjacent sidewalks, as half of the system can be placed under that sidewalk. This orientation also offers internal bypass options as discussed below.

End-To-End

The *End-To-End* orientation places the pre-treatment and discharge chambers on opposite ends of the biofiltration chamber therefore minimizing the width of the system to 5 ft (outside dimension). This orientation is perfect for linear projects and street retrofits where existing utilities and sidewalks limit the amount of space available for installation. One limitation of this orientation is bypass must be external.

Bypass

Internal Bypass Weir (Side-by-Side Only)

The *Side-By-Side* orientation places the pre-treatment and discharge chambers adjacent to one another allowing for integration of internal bypass. The wall between these chambers can act as a bypass weir when flows exceed the system's treatment capacity, thus allowing bypass from the pre-treatment chamber directly to the discharge chamber.

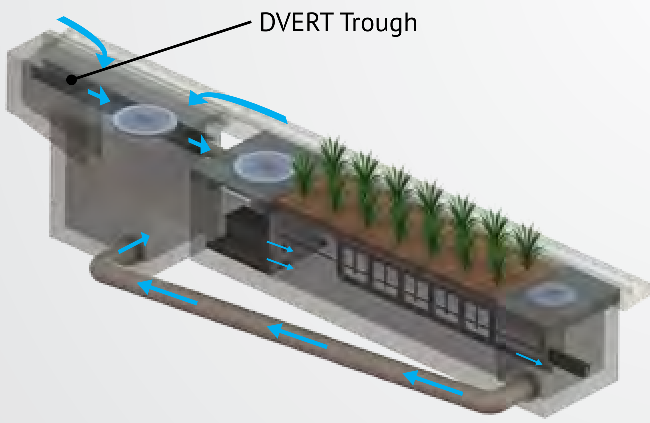
External Diversion Weir Structure

This traditional offline diversion method can be used with the MWS Linear in scenarios where runoff is being piped to the system. These simple and effective structures are generally configured with two outflow pipes. The first is a smaller pipe on the upstream side of the diversion weir - to divert low flows over to the MWS Linear for treatment. The second is the main pipe that receives water once the system has exceeded treatment capacity and water flows over the weir.

Flow By Design

This method is one in which the system is placed just upstream of a standard curb or grate inlet to intercept the first flush. Higher flows simply pass by the MWS Linear and into the standard inlet downstream.

DVERT Low Flow Diversion



This simple yet innovative diversion trough can be installed in existing or new curb and grate inlets to divert the first flush to the MWS Linear via pipe. It works similar to a rain gutter and is installed just below the opening into the inlet. It captures the low flows and channels them over to a connecting pipe exiting out the wall of the inlet and leading to the MWS Linear. The DVERT is perfect for retrofit and green street applications that allows the MWS Linear to be installed anywhere space is available.

Performance

The MWS Linear continues to outperform other treatment methods with superior pollutant removal for TSS, heavy metals, nutrients, hydrocarbons and bacteria. Since 2007 the MWS Linear has been field tested on numerous sites across the country. With it's advanced pre-treatment chamber and innovative horizontal flow biofilter, the system is able to effectively remove pollutants through a combination of physical, chemical, and biological filtration processes. With the same biological processes found in natural wetlands, the MWS Linear harnesses natures ability to process, transform, and remove even the most harmful pollutants.

Approvals

The MWS Linear has successfully met years of challenging technical reviews and testing from some of the most prestigious and demanding agencies in the nation, and perhaps the world.

WA

Washington State DOE Approved

The MWS Linear is approved for General Use Level Designation (GULD) for Basic, Enhanced, and Phosphorus treatment at 1 gpm/ft^2 loading rate. The highest performing BMP on the market for all main pollutant categories.

TSS	Total Phosphorus	Ortho Phosphorus	Nitrogen	Dissolved Zinc	Dissolved Copper	Total Zinc	Total Copper	Motor Oil
85%	64%	67%	45%	66%	38%	69%	50%	95%

VA

DEQ Assignment

The Virginia Department of Environmental Quality assigned the MWS Linear, the highest phosphorus removal rating for manufactured treatment devices to meet the new Virginia Stormwater Management Program (VSMP) Technical Criteria.

MA

MASTEP Evaluation

The University of Massachusetts at Amherst – Water Resources Research Center, issued a technical evaluation report noting removal rates up to 84% TSS, 70% Total Phosphorus, 68.5% Total Zinc, and more.

RI

Rhode Island DEM Approved

Approved as an authorized BMP and noted to achieve the following minimum removal efficiencies: 85% TSS, 60% Pathogens, 30% Total Phosphorus for discharges to freshwater systems, and 30% Total Nitrogen for discharges to saltwater or tidal systems.

Flow Based Sizing

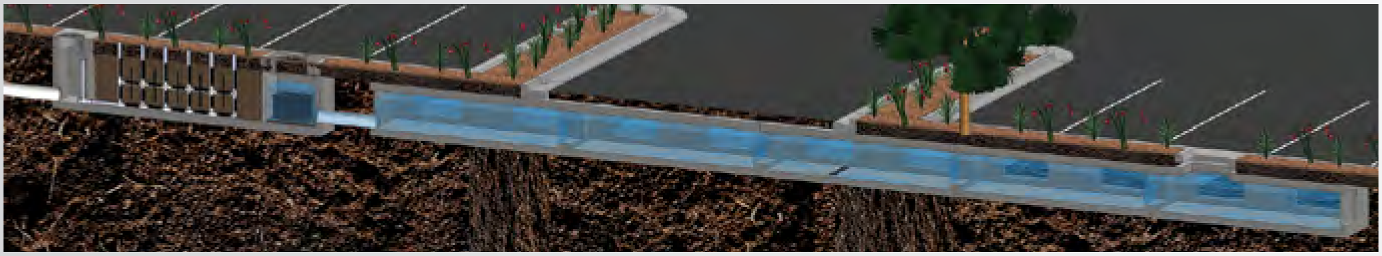
The MWS Linear can be used in stand alone applications to meet treatment flow requirements. Since the MWS Linear is the only biofiltration system that can accept inflow pipes several feet below the surface it can be used not only in decentralized design applications but also as a large central end-of-the-line application for maximum feasibility.

Treatment Flow Sizing Table

Model #	Dimensions	WetlandMedia Surface Area	Treatment Flow Rate (cfs)
MWS-L-4-4	4' x 4'	23 ft^2	0.052
MWS-L-4-6	4' x 6'	32 ft^2	0.073
MWS-L-4-8	4' x 8'	50 ft^2	0.115
MWS-L-4-13	4' x 13'	63 ft^2	0.144
MWS-L-4-15	4' x 15'	76 ft^2	0.175
MWS-L-4-17	4' x 17'	90 ft^2	0.206
MWS-L-4-19	4' x 19'	103 ft^2	0.237
MWS-L-4-21	4' x 21'	117 ft^2	0.268
MWS-L-8-8	8' x 8'	100 ft^2	0.230
MWS-L-8-12	8' x 12'	151 ft^2	0.346
MWS-L-8-16	8' x 16'	201 ft^2	0.462

Volume Based Sizing

Many states require treatment of a water quality volume and do not offer the option of flow based design. The MWS Linear and its unique horizontal flow makes it the only biofilter that can be used in volume based design installed downstream of ponds, detention basins, and underground storage systems.



Treatment Volume Sizing Table

Model #	Treatment Capacity (cu. ft.) @ 24-Hour Drain Down	Treatment Capacity (cu. ft.) @ 48-Hour Drain Down
MWS-L-4-4	1140	2280
MWS-L-4-6	1600	3200
MWS-L-4-8	2518	5036
MWS-L-4-13	3131	6261
MWS-L-4-15	3811	7623
MWS-L-4-17	4492	8984
MWS-L-4-19	5172	10345
MWS-L-4-21	5853	11706
MWS-L-8-8	5036	10072
MWS-L-8-12	7554	15109
MWS-L-8-16	10073	20145

Installation

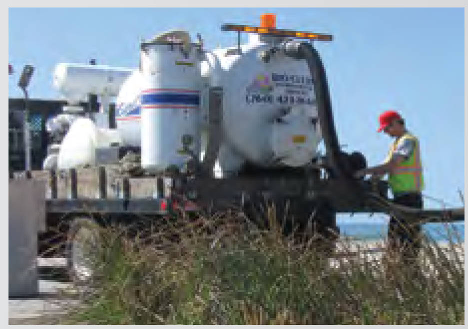
The MWS Linear is simple, easy to install, and has a space efficient design that offers lower excavation and installation costs compared to traditional tree-box type systems. The structure of the system resembles pre-cast catch basin or utility vaults and is installed in a similar fashion.

The system is delivered fully assembled for quick installation. Generally, the structure can be unloaded and set in place in 15 minutes. Our experienced team of field technicians are available to supervise installations and provide technical support.

Maintenance

Reduce your maintenance costs, man hours, and materials with the MWS Linear. Unlike other biofiltration systems that provide no pre-treatment, the MWS Linear is a self-contained treatment train which incorporates simple and effective pre-treatment.

Maintenance requirements for the biofilter itself are almost completely eliminated, as the pre-treatment chamber removes and isolates trash, sediments, and hydrocarbons. What's left is the simple maintenance of an easily accessible pre-treatment chamber that can be cleaned by hand or with a standard vac truck. Only periodic replacement of low-cost media in the pre-filter cartridges is required for long term operation and there is absolutely no need to replace expensive biofiltration media.



Plant Selection

Abundant plants, trees, and grasses bring value and an aesthetic benefit to any urban setting, but those in the MWS Linear do even more - they increase pollutant removal. What's not seen, but very important, is that below grade the stormwater runoff/flow is being subjected to nature's secret weapon: a dynamic physical, chemical, and biological process working to break down and remove non-point source pollutants. The flow rate is controlled in the MWS Linear, giving the plants more "contact time" so that pollutants are more successfully decomposed, volatilized and incorporated into the biomass of The MWS Linear's micro/macro flora and fauna.

A wide range of plants are suitable for use in the MWS Linear, but selections vary by location and climate. View suitable plants by selecting the list relative to your project location's hardy zone.

Please visit www.ModularWetlands.com/Plants for more information and various plant lists.

ATTACHMENT D OPERATION & MAINTENANCE PLAN

O&M Plan Structural BMP Inspection and Maintenance Responsibility/Frequency Matrix

BMP Inspection and Maintenance Responsibility/Frequency Matrix			
BMP	RESPONSIBILITY	INSPECTION/MAINTENANCE ACTIVITIES	MINIMUM FREQUENCY
Structural BMPs			
Storm Drain Message and Signage (S-1)	HOA	Storm drain stencils shall be inspected for legibility, at minimum, once prior to the storm season, no later than October 1st each year. Those determined to be illegible will be re-stenciled as soon as possible.	Annually
Landscape Irrigation Practices (S-8)	HOA	In conjunction with routine maintenance activities, verify that landscape design continues to function properly by adjusting properly to eliminate overspray to hardscape areas, and to verify that irrigation timing and cycle lengths are adjusted in accordance with water demands, given time of year, weather, day or night time temperatures based on system specifications and local climate patterns.	Weekly
Building Materials Selection (S-9)	HOA	In conjunction with routine maintenance activities, alternative building materials that pose minimal potential for pollutant leaching should be considered for use in maintenance and replacement projects for homeowners.	Ongoing
Non-Structural BMPs			
Education of Property Owners, Tenants and Occupants	HOA	Educational materials will be provided to homeowners at close of escrow by the owner and thereafter on an annual basis by the HOA. Materials shall include those provided in Attachment A of this Plan and any updated materials.	Close of escrow and annually.

BMP Inspection and Maintenance Responsibility/Frequency Matrix			
BMP	RESPONSIBILITY	INSPECTION/MAINTENANCE ACTIVITIES	MINIMUM FREQUENCY
Activity Restrictions	HOA	The Owner will prescribe activity restrictions to protect surface water quality, through a Covenant, Conditions and Restrictions (CC&Rs) agreement, or other equally effective measure, for the project. Upon takeover of site responsibilities by the HOA, the HOA shall be responsible for ensuring residents compliance and prescribe and implement activity restrictions required of its contractors.	Ongoing
Common Area Landscape Management	HOA	Maintenance shall be consistent with City requirements, plus fertilizer and/or pesticide usages shall be consistent with County guidelines for use of fertilizers and pesticides. Maintenance includes mowing, weeding, and debris removal on a weekly basis. Trimming, replanting and replacement of mulch shall be performed on an as-needed basis. Trimmings, clippings, and other waste shall be properly disposed of off-site in accordance with local regulations. Materials temporarily stockpiled during maintenance activities shall be placed away from water courses and drain inlets. Application of landscaping materials shall be limited to minimal amounts required and not within 48 hours prior to predicted rain events.	Weekly
Common Area Litter Control	HOA	Litter patrol, violations investigation, reporting and other litter control activities shall be performed in conjunction with maintenance activities. Litter collection and removal shall be performed on a weekly basis.	Ongoing patrols. Weekly (minimum) pick up and removal.

BMP Inspection and Maintenance Responsibility/Frequency Matrix			
BMP	RESPONSIBILITY	INSPECTION/MAINTENANCE ACTIVITIES	MINIMUM FREQUENCY
Street Sweeping Private Streets and Parking Lots	HOA	Streets and parking lots must be swept at least quarterly, including prior to the start of the rainy season (October 1st). Streets shall also be swept as needed.	Quarterly
Storm Water Quality Control Measures			
Proprietary Treatment Control Measures (T-6) Biotreatment	HOA	Inspect unit for accumulated debris and sediment and plant health; remove trash from screening device and separation chamber; trim vegetation. Remove sediment from pre-chamber, replace pre-filter cartridge media and drain down filter media. Replace wetland media.	Annually 20 years
Proprietary Treatment Control Measures (T-6) Catch Basin Screens	HOA	Inspect for accumulated trash and sediment and to ensure adequate capacity. Clean out accumulated materials as necessary via vactor truck.	Clean inserts prior to rain season and as needed.

ATTACHMENT E BMP INSPECTION MAINTENANCE RECORDS

(FOR FINAL LID PLAN)

ATTACHMENT F EDUCATIONAL MATERIALS

(FOR FINAL LID PLAN)

ATTACHMENT G SOILS REPORT

LGC Geotechnical, Inc.

January 23, 2020

Project No. 19127-01

Mr. Joe Martin
Trumark Companies
450 Newport Center Drive, Suite 300
Newport Beach, CA 92660

Subject: ***Preliminary Geotechnical Evaluation for the Proposed "Covina Bowl" Residential Development, Tentative Tract Map No. 82874, 1060 West San Bernardino Road, Covina, California***

In accordance with your request and authorization, LGC Geotechnical, Inc. has performed a preliminary geotechnical evaluation for the proposed "Covina Bowl" residential development, Tentative Tract Map No. 82874, located at 1060 West San Bernardino Road in the City of Covina, California. The purpose of our study was to evaluate the existing onsite geotechnical conditions and to provide preliminary geotechnical recommendations relative to the proposed residential development.

Should you have any questions regarding this report, please do not hesitate to contact our office. We appreciate this opportunity to be of service.

Respectfully Submitted,

LGC Geotechnical, Inc.

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1.0 INTRODUCTION

1.1 Purpose and Scope of Services

This report presents the results of our preliminary geotechnical evaluation for the proposed "Covina Bowl" residential development, Tentative Tract Map No. 82874, located at 1060 West San Bernardino Road in the City of Covina, California. Refer to the Site Location Map (Figure 1).

The purpose of our study was to provide a preliminary geotechnical evaluation relative to the proposed residential development. As part of our scope of work, we have: 1) reviewed available geotechnical background information including in-house regional geologic maps and published geotechnical literature pertinent to the site (Appendix A); 2) performed a limited subsurface geotechnical evaluation of the site consisting of the excavation of five small-diameter borings ranging in depth from approximately 25 to 50 feet below existing ground surface; 3) performed one field dry well percolation test; 4) performed laboratory testing of select soil samples obtained during our subsurface evaluation; and 5) prepared this preliminary geotechnical summary report presenting our findings, preliminary conclusions and recommendations for the development of the proposed project.

1.2 Project Description

The approximately 5.5-acre site is bound to the north by West San Bernardino Road, to the east by North Rimsdale Avenue, to the south by Badillo Street and to the west by existing residential and commercial structures. The site currently consists of a vacant bowling alley, a vacant preschool, a community church, and parking areas.

Based on concept site studies (Hunsaker, 2019), the proposed improvements include the construction of at-grade condominiums and associated alleys. The eastern portion of the existing Covina Bowl building will remain. Design cuts and fills (not including required remedial grading) are anticipated to be on the order of 2 to 5 feet. The proposed building structures are anticipated to be relatively light-weight wood construction with maximum column and wall loads of approximately 30 kips and 2 kips per linear foot, respectively.

The recommendations given in this report are based upon the estimated structural loading, grading and layout information above. We understand that the project plans are currently being developed at this time; LGC Geotechnical should be provided with updated project plans and any changes to structural loads when they become available, in order to either confirm or modify the recommendations provided herein.

1.3 Existing Conditions

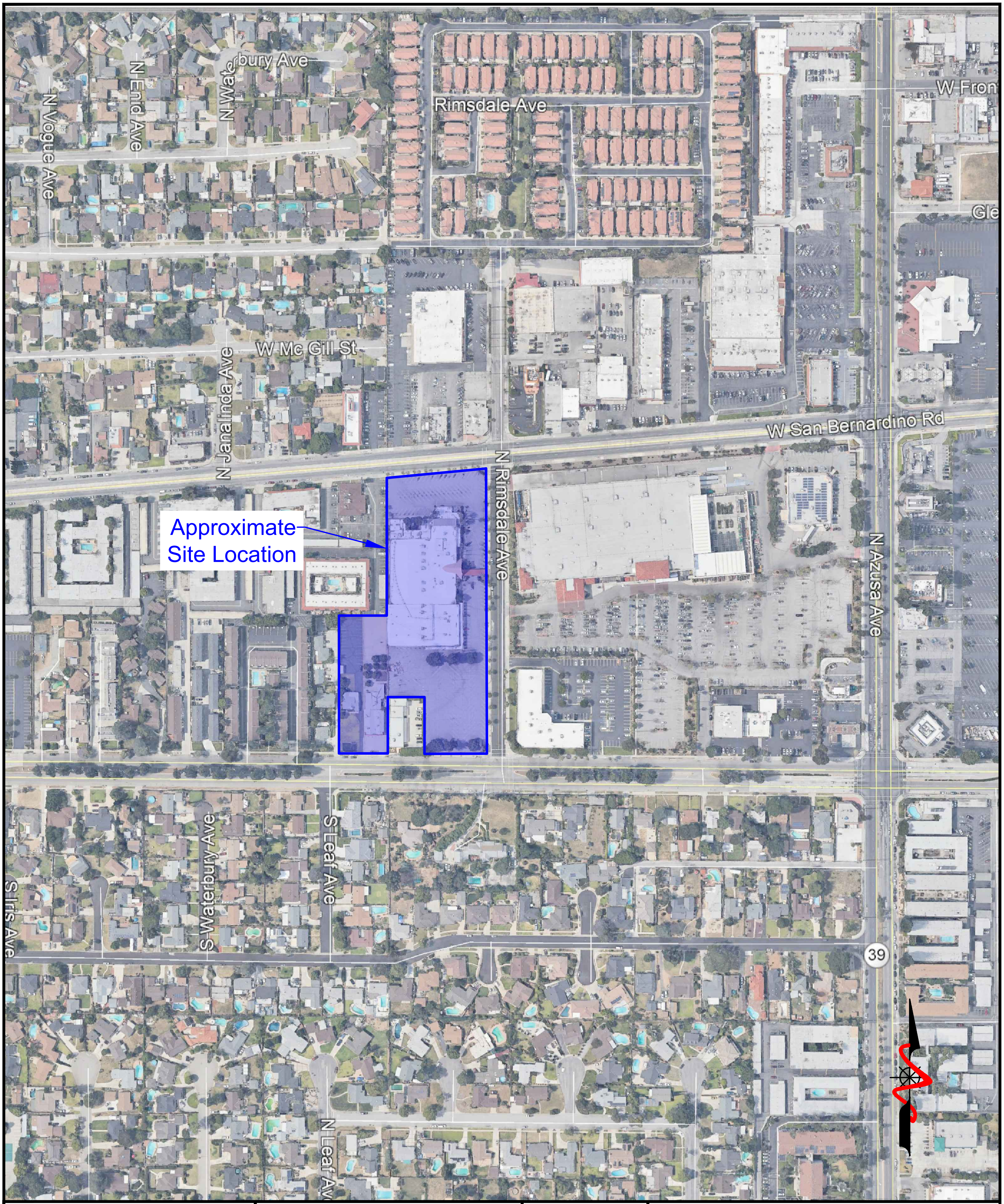
The site is a relatively flat, irregularly shaped site consisting of three adjacent parcels. The largest parcel consists of the vacant Covina Bowl building and associated parking lots. The two smaller parcels consist of a church, a non-operational preschool facility, and their associated parking lots. It is our understanding a portion of the existing bowling alley will remain intact and be repurposed and the majority of the bowling alley structure will be demolished.

The site has minor relief, with the highest being the northeastern corner of the site at an approximate elevation of 1481 feet and the lowest being the southwestern corner of the site at an approximate elevation of 1473 feet.

1.4 Background

GeoSoils Consultants (GSC) prepared a geotechnical investigation report of the site in 2017 (GSC, 2017). At that time, the site had not been extended by approximately 1.1 acre to the southwest. The field evaluation consisted of four hollow stem borings ranging in depth from approximately 10 to 50 feet below existing grade. The shallow boring was for field infiltration testing. Groundwater was not encountered to the maximum explored depth of 50 feet below existing grade. Laboratory testing included in-situ dry density and moisture content, laboratory compaction, direct shear, expansion index, consolidation/collapse and soluble sulfate. Laboratory testing of a near surface bulk sample from B-3 indicated “very low” potential for expansion. Laboratory testing of seven consolidation tests indicated the onsite soils are highly susceptible to hydro-collapse. As a result, GSC recommended deeper removals in the southern portion of the site.

Review of historic aerial photographs and topographic maps indicate that the subject site was originally part of an orange orchard and used for agricultural land in 1948, the earliest aerial photo available. Topographic maps from 1897 indicate that San Bernardino Road and Badillo Street existed near their present alignments. Between 1953 and 1954, a few farmhouses were built on the subject site while the orchard was in operation, including the current structure that was converted into the church in the southwest portion of the subject site. The 1964 aerial photograph indicates that the orchard was subdivided to its present parcels and shows the Covina Bowl and its associated parking lots. In 1964, the parcel that currently consists of the preschool facility still had one of the original farmhouses. Between 1980 and 1995, the house located on the present school site was demolished and the current structure was built.



LGC Geotechnical, Inc.

FIGURE 1
Site Location Map

PROJECT NAME	Trumark - Covina Bowl
PROJECT NO.	19127-01
ENG. / GEOL.	RLD / CNJ
SCALE	Not to Scale
DATE	January 2020

1.5 Subsurface Geotechnical Evaluation

LGC Geotechnical performed a subsurface geotechnical evaluation of the site consisting of the excavation of five hollow-stem auger borings to evaluate onsite geotechnical conditions.

Five hollow-stem borings (HS-1 through HS-4 & I-1) were drilled to depths ranging from approximately 26.5 to 50 feet below existing grade. An LGC Geotechnical representative observed the drilling operations, logged the borings, and collected soil samples for laboratory testing. The borings were excavated by 2R Drilling, Inc. under subcontract to LGC Geotechnical using a truck-mounted drill rig equipped with 8-inch-diameter hollow-stem augers. Driven soil samples were collected by means of the Standard Penetration Test (SPT) and Modified California Drive (MCD) sampler generally obtained at 2.5 to 5-foot vertical increments. The MCD is a split-barrel sampler with a tapered cutting tip and lined with a series of 1-inch-tall brass rings. The SPT sampler (1.4-inch ID) and MCD sampler (2.4-inch ID, 3.0-inch OD) were driven using a 140-pound automatic hammer falling 30 inches to advance the sampler a total depth of 18 inches. The raw blow counts for each 6-inch increment of penetration were recorded on the boring logs. Bulk samples of the near-surface soils were also collected and logged at select borings for laboratory testing. At the completion of drilling, the borings were backfilled with the native soil cuttings, tamped, and capped with asphalt cold patch or concrete. Some settlement of the backfill soils may occur over time.

Dry well percolation testing was performed in boring I-1 from depths of approximately 20 to 50 feet below existing grade. Dry well testing was performed per the County of Los Angeles testing guidelines. The location was subsequently backfilled with native soils and capped with concrete at the completion of testing.

The approximate locations of our subsurface explorations are provided on the Boring Location Map (Figure 2). The boring logs are provided in Appendix B.

1.6 Laboratory Testing

Representative bulk and driven (relatively undisturbed) samples were obtained for laboratory testing during our field evaluation. Laboratory testing included in-situ moisture content and in-situ dry density, Atterberg Limits, fines content, expansion index, consolidation, laboratory compaction, swell or collapse potential, and corrosion (sulfate, chloride, pH and minimum resistivity).

The following is a summary of the laboratory test results:

- Dry density of the samples collected ranged from approximately 94 pounds per cubic foot (pcf) to 127 pcf, with an average of 107 pcf. Field moisture contents ranged from approximately 1 to 21 percent, with an average of 7 percent.
- Two fines content tests were performed and indicated a fines content (passing No. 200 sieve) of approximately 36 and 13 percent. Based on the Unified Soils Classification System (USCS), the tested samples would be classified as "coarse-grained."
- One Atterberg Limit (liquid limit and plastic limit) test was performed. Results indicated a Plasticity Index (PI) value of 7.

- Eight collapse tests were performed. The measured hydro-collapse due to water inundation indicated up to approximately 0.75 percent. The plots are provided in Appendix C.
- One laboratory compaction test of a near surface sample indicated a maximum dry density of 128.0 pcf with an optimum moisture content of 11.5 percent.
- Expansion potential testing indicated an expansion index value of 8, corresponding to "Very Low" expansion potential.
- Corrosion testing indicated soluble sulfate contents of approximately 0.01 percent, a chloride content of 40 parts per million (ppm), pH of 6.4, and a minimum resistivity of 1,298 ohm-centimeters.

A summary of the laboratory test results is presented in Appendix C. The moisture and dry density results are presented on the boring logs in Appendix B.

1.7 Field Dry Well Percolation Testing

One 8-inch diameter, hollow-stem auger boring (I-1) was excavated and sampled to a depth of approximately 50 feet below existing grade prior to the drilling and installation of the dry well test hole. The approximate location is shown on the Boring Location Map (Figure 2). This boring was used to evaluate the subsurface soil stratigraphy, subsurface soil characteristics, and groundwater information. Data from the hollow-stem auger boring along with information provided by the dry well manufacturer team such as information regarding local soil conditions, caving potential, etc., helped us determine the target infiltration zone of 20 to 50 feet below existing grade for the dry well test.

The hollow stem auger boring was utilized for a constant head dry well infiltration test performed in general accordance with the County of Los Angeles Geotechnical and Materials Engineering Division (GMED) GS200.2 (2017) guidelines. One 3-inch diameter by 50-foot long perforated PVC pipe was placed near the center of the boring to deliver and measure water level during the test. The dry well anulus was subsequently backfilled with a crushed ¾-inch gravel from a depth of approximately 10 to 50 feet below ground surface. The remaining upper 10 feet of the dry well test was backfilled with the native sandy soil cuttings.

Water from nearby garden hoses was introduced into the pipe until the target dry well water head depth of 20 feet below existing grade was reached. The target dry well infiltration zone was tested from approximately 20 to 50 feet equating to approximately 30 feet of dry well infiltration testing. Once the target dry well water head was achieved, the water delivery flow rate was adjusted to maintain a constant head. The volume of water, in gallons, required to maintain a constant head was recorded every 30 minutes using a 5-gallon bucket.

After all testing was complete, the PVC pipe was backfilled with sand and patched with quick setting concrete. Some settlement of the backfill should be expected over time. Native soil cuttings were left onsite and spread out in the adjacent planters.

Based on the County of Los Angeles testing guidelines, the raw flow rate for the 8-inch diameter dry well test is determined by calculating the volume of water discharged into the dry well (cubic feet) in a given amount of time (seconds). The average raw flow rate over the last three consecutive readings is known as the measured stabilized flow rate. To determine the raw measured infiltration rate, the stabilized flow rate is divided by surface area of the dry well test (sum of all wetted areas including the bottom surface area of the boring and wetted sidewalls). The measured stabilized flow rate and raw measured infiltration rate are provided in Table 3 below. Please note that the values provided in Table 1 do not include any reduction factors. The dry well infiltration test was performed using relatively clean water free of particulates, silt, etc. Refer to the infiltration test data provided in Appendix D.

TABLE 1

Summary of Raw Dry Well Percolation Testing – 8-Inch Dry Well

Dry Well Test Location	**Measured Stabilized Flow Rate* ** (cfs)**	**Raw Measured Infiltration Rate* (in/hr)**	**Approximate Total Volume of Water Percolated During Test (gal)**
I-1	0.006	4.2	954

* Rates do not include required reduction factors.

** The Measured Stabilized Flow Rate is only equivalent to the results of the tested 8-inch dry well.

2.0 GEOTECHNICAL CONDITIONS

2.1 Geologic Conditions

The subject site is located within the southeastern portion of the San Gabriel Valley, within the Peninsular Ranges Geomorphic Province. It is located in a broad alluvial valley that is several miles north of the northeast-trending Covina Hills that are bounded on the north by the Walnut Creek Fault. The east-west-trending San Gabriel Mountains, located to the north of the site, are bound by the Sierra Madre Fault Zone. The region has a complex geologic history influenced by periods of uplift, folding, faulting, and alluvial deposition; however, no faults are known to transect the site.

The site is located on a laterally extensive young alluvial fan deposit interpreted to be approximately middle Holocene age (CGS, 2003). It is about approximately 3-mile southeast from the Santa Fe Dam and Recreation Area and San Gabriel River.

2.2 Generalized Subsurface Conditions

The field explorations (borings) indicate site soils primarily consist of sands with varying amounts of silts and gravels to the maximum explored depth of approximately 50 feet below ground. Soils encountered were generally slightly moist to moist sands and silty sands with isolated thinner layers of fine-grained soils (i.e., silts and clays).

It should be noted that borings are only representative of the location and time where/when they are performed and varying subsurface conditions may exist outside of the performed location. In addition, subsurface conditions can change over time. The soil descriptions provided above should not be construed to mean that the subsurface profile is uniform, and that soil is homogeneous within the project area. For details on the stratigraphy at the exploration locations, refer to Appendix B.

2.3 Groundwater

Groundwater was not encountered during our field evaluation to a maximum explored depth of approximately 50 feet below existing grade. Historic high groundwater is estimated to be over 150 feet below existing grade (CDMG, 1998).

Seasonal fluctuations of groundwater elevations should be expected over time. In general, groundwater levels fluctuate with the seasons and local zones of perched groundwater may be present due to local seepage caused by irrigation and/or recent precipitation. Local perched groundwater conditions or surface seepage may develop once site development is completed.

2.4 Faulting

Prompted by damaging earthquakes in Northern and Southern California, State legislation and policies concerning the classification and land-use criteria associated with faults have been developed. Their purpose was to prevent the construction of urban developments across the trace of active faults, resulting in the Alquist-Priolo Earthquake Fault Zoning Act. Earthquake Fault Zones have been delineated along the traces of active faults within California. Where developments for human occupation are proposed within these zones, the state requires detailed fault evaluations be performed so that engineering geologists can mitigate the hazards associated with active faulting by identifying the location of active faults and allowing for a setback from the zone of previous ground rupture.

The subject site is not located within an Alquist-Priolo Earthquake Fault Zone and no faults were identified on the site during our site evaluation. The possibility of damage due to ground rupture is considered low since no active faults are known to cross the site (CDMG, 1999).

Secondary effects of seismic shaking resulting from large earthquakes on the major faults in the Southern California region, which may affect the site, include ground lurching, shallow ground rupture, soil liquefaction and dynamic settlement. These secondary effects of seismic shaking are a possibility throughout the Southern California region and are dependent on the distance between the site and causative fault and the onsite geology. Some of the major active nearby faults that could produce these secondary effects include the Whittier, Puente Hills, and San Andreas Faults, among others (CGS, 2012). A discussion of these secondary effects is provided in the following sections.

2.4.1 Liquefaction and Dynamic Settlement

Liquefaction is a seismic phenomenon in which loose, saturated, granular soils behave similarly to a fluid when subject to high-intensity ground shaking. Liquefaction occurs when three general conditions coexist: 1) shallow groundwater; 2) low density non-cohesive (granular) soils; and 3) high-intensity ground motion. Studies indicate that saturated, loose near surface cohesionless soils exhibit the highest liquefaction potential, while dry, dense, cohesionless soils and cohesive soils exhibit low to negligible liquefaction potential. In general, cohesive soils are not considered susceptible to liquefaction, depending on their plasticity and moisture content (Bray & Sancio, 2006). Effects of liquefaction on level ground include settlement, sand boils, and bearing capacity failures below structures. Dynamic settlement of dry loose sands can occur as the sand particles tend to settle and densify as a result of a seismic event.

Based on our review of the State of California Seismic Hazard Zone for liquefaction potential (CDMG, 1999), the site is not located within a liquefaction hazard zone. Due to the absence of groundwater in the upper 50 feet, the site is not considered susceptible to liquefaction. The potential for liquefaction is considered very low to remote.

2.4.2 Lateral Spreading

Lateral spreading is a type of liquefaction-induced ground failure associated with the lateral displacement of surficial blocks of sediment resulting from liquefaction in a subsurface layer. Once liquefaction transforms the subsurface layer into a fluid mass, gravity plus the earthquake inertial forces may cause the mass to move downslope towards a free face (such as a river channel or an embankment). Lateral spreading may cause large horizontal displacements and such movement typically damages pipelines, utilities, bridges, and structures.

Due to the very low potential for liquefaction the potential for lateral spreading is also considered very low to remote.

2.5 Seismic Design Criteria

The site seismic characteristics were evaluated per the guidelines set forth in Chapter 16, Section 1613 of the 2019 California Building Code (CBC) and applicable portions of ASCE 7-16 which has been adopted by the CBC. **Please note that the following seismic parameters are only applicable for code-based acceleration response spectra and are not applicable for where site-specific ground motion procedures are required by ASCE 7-16.** Representative site coordinates of latitude 34.0866 degrees north and longitude -117.9126 degrees west were utilized in our analyses. The maximum considered earthquake (MCE) spectral response accelerations (S_{MS} and S_{M1}) and adjusted design spectral response acceleration parameters (S_{DS} and S_{D1}) for Site Class D are provided in Table 2 on the following page. Since site soils are Site Class D, additional adjustments are required to code acceleration response spectra (ARS) as outlined below and provided in ASCE 7-16. The structural designer should contact the geotechnical consultant if structural conditions (e.g., number of stories, seismically isolated structures, etc.) require site-specific ground motions.

A deaggregation of the PGA based on a 2,475-year average return period (MCE) indicates that an earthquake magnitude of 6.93 at a distance of approximately 13.3 km from the site would contribute the most to this ground motion. A deaggregation of the PGA based on a 475-year average return period (Design Earthquake) indicates that an earthquake magnitude of 6.88 at a distance of approximately 17.6 km from the site would contribute the most to this ground motion (USGS, 2008).

Section 1803.5.12 of the 2019 CBC (per Section 11.8.3 of ASCE 7) states that the maximum considered earthquake geometric mean (MCE_G) Peak Ground Acceleration (PGA) should be used for liquefaction potential. The PGA_M for the site is equal to 0.77g (SEAOC, 2019).

TABLE 2

Seismic Design Parameters

Selected Parameters from 2019 CBC, Section 1613 - Earthquake Loads	Seismic Design Values	Notes/Exceptions
Distance to applicable faults classifies the site as a "Near-Fault" site.		Section 11.4.1 of ASCE 7
Site Class	D*	Chapter 20 of ASCE 7
Ss (Risk-Targeted Spectral Acceleration for Short Periods)	1.654g	From SEAOC, 2019
S_1 (Risk-Targeted Spectral Accelerations for 1-Second Periods)	0.611g	From SEAOC, 2019
F_a (per Table 1613.2.3(1))	1.0	For Simplified Design Procedure of Section 12.14 of ASCE 7, F_a shall be taken as 1.4 (Section 12.14.8.1)
F_v (per Table 1613.2.3(2))	1.7	Value is only applicable per requirements/exceptions per Section 11.4.8 of ASCE 7
S_{MS} for Site Class D [Note: $S_{MS} = F_aS_S$]	1.654g	-
S_{M1} for Site Class D [Note: $S_{M1} = F_vS_1$]	1.039g	Value is only applicable per requirements/exceptions per Section 11.4.8 of ASCE 7
S_{DS} for Site Class D [Note: $S_{DS} = (^2/_3)S_{MS}$]	1.103g	-
S_{D1} for Site Class D [Note: $S_{D1} = (^2/_3)S_{M1}$]	0.693g	Value is only applicable per requirements/exceptions per Section 11.4.8 of ASCE 7
C_{RS} (Mapped Risk Coefficient at 0.2 sec)	0.916	ASCE 7 Chapter 22
C_{R1} (Mapped Risk Coefficient at 1 sec)	0.906	ASCE 7 Chapter 22
*Since site soils are Site Class D and S_1 is greater than or equal to 0.2, the seismic response coefficient Cs is determined by Eq. 12.8-2 for values of $T \leq 1.5T_s$ and taken equal to 1.5 times the value calculated in accordance with either Eq. 12.8-3 for $T_L \geq T > T_s$, or Eq. 12.8-4 for $T > T_L$. Refer to ASCE 7-16.		

2.6 Expansion Potential

Based on the results of previous laboratory testing by others and our recent laboratory testing, site soils have a "Very Low" expansion potential. Final expansion potential of site soils should be determined at the completion of grading. Results of expansion testing at finish grades will be utilized to confirm final foundation design.

2.7 *Soils Susceptible to Hydro-Collapse*

Soils susceptible to hydro-collapse (or collapsible soils) are predominately sand, silty sand and sandy silt held in a loose honeycomb structure. This relatively loose honeycomb structure is typically held together by small amounts clay or calcium carbonate acting as a temporary (soluble) cementing agent. If the soil remains dry the soil generally maintains its structure, however the addition of water to the soil will greatly weaken the honeycomb structure and the soil subsequently experiences immediate collapses. This collapse can result in rapid soil settlement and potential damage to any improvements which are located within the zone of influence of the collapsible soils. Fine-grained soils such as clays and silty clays are generally not considered susceptible to hydro-collapse.

Laboratory testing for hydro-collapse is typically performed per American Society for Testing and Materials (ASTM) Test Method D5333 or ASTM D 2435. The amount of collapse is commonly referred to as the collapse index (Ie). The two most common categorizations of hydro-collapse potential are ASTM D5333 and the (more pragmatic) Naval Facilities Engineering Command (NFEC, 1986) are shown in Table 3A and 3B below. As indicated in Table 3B soils with collapse potential above 5 percent are considered “trouble”.

TABLE 3A

Classification of Soil Collapsibility per ASTM D 5333

Collapse Index (Ie)	Collapse (%)	Collapse Potential
0	0	None
0.001 - 0.02	0.1 - 2	Slight
0.021 - 0.60	2.1 - 6	Moderate
0.60 - 0.10	6 - 10	Moderately Severe
> 0.10	> 10	Severe

TABLE 3B

Classification of Soil Collapsibility per NFEC, 1986

Collapse Potential (%)	Severity of Problem
0-1	No Problem
1-5	Moderate Trouble
5-10	Trouble
10-20	Severe Trouble
>20	Very Severe Trouble

A summary of the onsite soils with the most significant collapse potential are provided in Table 4 below. The measured collapse potential is up to approximately 9 percent. For example, a 10-foot thick layer of soil with a collapse potential of approximately 9 percent would result in approximately 11 inches of hydro-collapse induced settlement.

TABLE 4

Summary of Laboratory Test Results with Significant Hydro-Collapse

Boring	Measured Collapse (%)	Reference
B-2 @ 7.5 ft	6	GSC, 2017
B-2 @ 10 ft	9	GSC, 2017

3.0 CONCLUSIONS

Based on the results of our geotechnical evaluation, it is our opinion that the proposed development is feasible from a geotechnical standpoint, provided the following conclusions and recommendations are implemented.

The following is a summary of the primary geotechnical factors that may affect future development of the site:

- In general, our borings indicate primarily loose to dense sands with varying amounts of silt and gravel to the maximum explored depth of approximately 50 feet below existing grade. The near-surface soils and deeper soils in the southeastern portion of the site are not suitable for the planned improvements in their present condition (refer to Section 4.1 and Figure 2). Deeper removals are required in the southeastern portion of the site due to previous laboratory testing indicating collapsible soils (GSC, 2017). The approximate limits of the areas recommended for deeper removals are indicated on Figure 2.
- Due to the required depth of removals and proximity to exiting off-site improvements earthwork removals in portions of the site will be required to be performed in A-B-C slot cuts and/or the use of temporary shoring.
- Groundwater was not encountered during our subsurface evaluation to the maximum explored depth of approximately 50 feet below the existing ground surface. Historic high groundwater is estimated to be over 150 feet below existing grade (CDMG, 1998).
- The subject site is not located within a State of California Earthquake Fault Zone (Alquist-Priolo). The main seismic hazard that may affect the site is ground shaking from one of the active regional faults. The subject site will likely experience strong seismic ground shaking during its design life.
- Site soils are not considered susceptible to liquefaction due to the absence of groundwater in the upper 50 feet.
- Based on the results of preliminary laboratory testing, site soils are anticipated to have "Very Low" expansion potential. Final design expansion potential must be determined at the completion of grading.
- From a geotechnical perspective, the existing onsite soils are suitable material for use as general fill (not retaining wall backfill), provided that they are relatively free from rocks (larger than 8 inches in maximum dimension), construction debris, and significant organic material.
- Excavations into the existing site soils are anticipated to be feasible with heavy construction equipment in good working order. We anticipate that the on-site earth materials generated from the excavations will be generally suitable for re-use as general compacted fill, provided they are relatively free of rocks larger than 8 inches in dimension, construction debris, and significant organic material.
- Previous field evaluations have indicated the presence of soils highly susceptible to hydro-collapse (GSC, 2017). The intentional addition of water into these soils could result in significant soil settlement potentially impacting existing offsite improvements and/or proposed onsite improvements. Therefore, the intentional infiltration of stormwater is not feasible (refer to Section 4.8).

4.0 PRELIMINARY RECOMMENDATIONS

The following recommendations are to be considered preliminary and should be confirmed upon completion of grading and earthwork operations. In addition, they should be considered minimal from a geotechnical viewpoint, as there may be more restrictive requirements from the architect, structural engineer, building codes, governing agencies, or the owner.

It should be noted that the following geotechnical recommendations are intended to provide sufficient information to develop the site in general accordance with the 2019 CBC requirements. With regard to the potential occurrence of potentially catastrophic geotechnical hazards such as fault rupture, earthquake-induced landslides, liquefaction, etc. the following geotechnical recommendations should provide adequate protection for the proposed development to the extent required to reduce seismic risk to an "acceptable level." The "acceptable level" of risk is defined by the California Code of Regulations as "that level that provides reasonable protection of the public safety, though it does not necessarily ensure continued structural integrity and functionality of the project" [Section 3721(a)]. Therefore, repair and remedial work of the proposed improvements may be required after a significant seismic event. With regards to the potential for less significant geologic hazards to the proposed development, the recommendations contained herein are intended as a reasonable protection against the potential damaging effects of geotechnical phenomena such as expansive soils, fill settlement, groundwater seepage, etc. It should be understood, however, that although our recommendations are intended to maintain the structural integrity of the proposed development and structures given the site geotechnical conditions, they cannot preclude the potential for some cosmetic distress or nuisance issues to develop as a result of the site geotechnical conditions.

The geotechnical recommendations contained herein must be confirmed to be suitable or modified based on the actual as-graded conditions.

4.1 Site Earthwork

We anticipate that earthwork at the site will consist of demolition of the existing site improvements, required earthwork removals, subgrade preparation, precise grading and construction of the proposed new improvements, including the residential structures, neighborhood amenities, subsurface utilities, interior streets, etc.

We recommend that earthwork onsite be performed in accordance with the following recommendations, future grading plan review report(s), the 2019 CBC/City of Covina grading requirements, and the General Earthwork and Grading Specifications included in Appendix E. In case of conflict, the following recommendations shall supersede those included in Appendix E. The following recommendations should be considered preliminary and may be revised based upon future evaluation and review of the project plans and/or based on the actual conditions encountered during site grading/construction.

4.1.1 Site Preparation

Prior to grading of areas to receive structural fill or engineered improvements, the areas should be cleared of existing building structures, asphalt, surface obstructions, and demolition debris. Vegetation and debris should be removed and properly disposed of off-site. Holes resulting from the removal of buried obstructions, which extend below proposed finish grades, should be replaced with suitable compacted fill material. Any abandoned sewer or storm drain lines should be completely removed and replaced with properly placed compacted fill. Deeper demolition may be required in order to remove existing foundations. We recommend the trenches associated with demolition which extend below the remedial grading depth be backfilled and properly compacted prior to the demolition contractor leaving the site.

If cesspools or septic systems are encountered, they should be removed in their entirety. The resulting excavation should be backfilled with properly compacted fill soils. As an alternative, cesspools can be backfilled with lean sand-cement slurry. Any encountered wells should be properly abandoned in accordance with regulatory requirements. At the conclusion of the clearing operations, a representative of LGC Geotechnical should observe and accept the site prior to further grading.

4.1.2 Removal and Recompaction Depths and Limits

In order to provide a relatively uniform bearing condition for the planned building structures, upper loose/compressible are to be temporarily removed and recompacted as properly compacted fills. For preliminary planning purposes, the depth of required removals and recompaction may be estimated as indicated below and as shown on Figure 2. It should be noted that updated recommendations may be required based on changes to building layouts and/or grading plan.

Building Structures: Removal and recompaction should be at least 5 feet below existing grade, or 3 feet below planned footings, whichever is deeper. In the southeastern portion of the site, removal and recompaction should be a minimum of 10 feet below existing grade. Localized deeper removal and recompaction may be required. Refer to Figure 2 for approximate limits and depth of removal and recompaction.

Where adequate space is available, the base of removal and recompaction bottoms should extend laterally a minimum distance equal to the depth of overexcavation/compaction below finish grade. Specifically, soils located within a 1:1 (horizontal to vertical) projection of the bottom of footings must be compacted fill or competent natural ground.

Retaining/Free-Standing Wall Structures: For planned retaining walls removal and recompaction should extend a minimum of 5 feet below existing grade or 2 feet below proposed footings, whichever is greater. For minor structures such as free-standing and screen walls, removal and recompaction should extend at least 3 feet beneath the existing grade or 2 feet beneath the base of foundations, whichever is deeper.

Pavement and Hardscape Areas: Removal and recompaction should extend to a depth of at least 2 feet below existing grade. Removal and recompaction in any design cut areas of the pavement may be reduced by the depth of the design cut but should not be less than 1-foot below the finished subgrade (i.e., below planned aggregate base/asphalt concrete).

In general, the envelope for removal and recompaction should extend laterally a minimum lateral distance of 2 feet beyond the edges of the proposed improvements.

Local conditions may be encountered which could require additional overexcavation beyond the above-noted minimum to obtain an acceptable subgrade. The actual depths and lateral extents of removal and recompaction should be determined by the geotechnical consultant based on the subsurface conditions encountered during earthwork.

4.1.3 Temporary Excavations

Earthwork removal and recompaction adjacent to existing off-site improvements will be required. Due to the depth of required remedial grading and proximity to existing off-site improvements in portions of the site, "A-B-C" slot cuts and/or temporary shoring will be required. Geotechnical parameters for temporary shoring are provided in Section 4.5.

Temporary excavations should be performed in accordance with project plans, specifications, and all Occupational Safety and Health Administration (OSHA) requirements. Excavations should be laid back or shored in accordance with OSHA requirements before personnel or equipment are allowed to enter. Based on our field investigation, the majority of site soils are anticipated to be OSHA Type "B" soils (refer to the attached boring logs). Sandy soils are present and should be considered susceptible to caving. Raveling of the sandy soils should be anticipated for temporary slopes. Flatter slope inclinations should be considered if raveling cannot be tolerated. The exposed slope surface may be kept surficially moist (but not saturated) during construction to reduce (not eliminate) potential sloughing. Soil conditions should be regularly evaluated during construction to verify conditions are as anticipated. The contractor shall be responsible for providing the "competent person" required by OSHA standards to evaluate soil conditions. Close coordination with the geotechnical consultant should be maintained to facilitate construction while providing safe excavations. Excavation safety is the sole responsibility of the contractor.

Temporary excavations should be sloped back to 1:1 or flatter or be properly shored. As an alternative, earthwork removals may be performed in "A-B-C" slot cuts as outlined below. Vehicular traffic, stockpiles, and equipment storage should be set back from the perimeter of excavations a distance equivalent to a 1:1 projection from the bottom of the excavation. Once an excavation has been initiated, it should be backfilled as soon as practical. Prolonged exposure of temporary excavations may result in some localized instability. Excavations should be planned so that they are not initiated without sufficient time to shore/fill them prior to weekends, holidays, or forecasted rain.

The potential for impacting the existing improvements may be reduced by performing removals within 10 lateral feet of the existing off-site improvements using narrow "A-B-C" slot cuts. "A-B-C" slot cuts are defined as excavations perpendicular to sensitive property boundaries that are divided into multiple "slots" of equal width. If slots are labeled A, B, C, A, B, C, etc., then "A" slots should be excavated at the same time but must be backfilled before "B" slots can be excavated, etc. Slot cuts should be no wider than 7.5

feet and no deeper than 10 feet and should be backfilled <u>immediately</u> with properly placed compacted fill to finish grade prior to excavation of adjacent slots. Due to the presence of sands at the site which are susceptible to caving, narrower slot cuts may be required. This should be further evaluated during grading. Protection of the existing improvements during grading is the responsibility of the contractor.

4.1.4 Removal Bottoms and Subgrade Preparation

In general, removal bottoms, over-excavation bottoms and areas to receive compacted fill should be scarified to a minimum depth of 6 inches, brought to a near-optimum moisture condition (generally within optimum and 2 percent above optimum moisture content), and re-compacted per project recommendations.

Removal bottoms, over-excavation bottoms and areas to receive fill should be observed and accepted by the geotechnical consultant prior to subsequent fill placement. Soil subgrade for planned footings and improvements (e.g., slabs, etc.) should be firm and competent.

4.1.5 Material for Fill

From a geotechnical perspective, the onsite soils are generally considered suitable for use as general compacted fill, provided they are screened of organic materials, construction debris and oversized material (8 inches in greatest dimension).

From a geotechnical viewpoint, any required import soils for general fill (i.e., non-retaining wall backfill) should consist of soils of “Very Low” expansion potential (expansion index 20 or less based on American Society for Testing and Materials [ASTM] D 4829), and free of organic materials, construction debris and any material greater than 3 inches in maximum dimension. Import for any required retaining wall backfill should meet the criteria outlined in the following paragraph. <u>Source samples should be provided to the geotechnical consultant for laboratory testing a minimum of four working days prior to any planned importation.</u>

Retaining wall backfill should consist of imported sandy soils with a maximum of 35 percent fines (passing the No. 200 sieve) per ASTM Test Method D1140 (or ASTM D6913/D422) and a “Very Low” expansion potential (EI of 20 or less per ASTM D4829). Soils should also be screened of organic materials, construction debris, and any material greater than 3 inches in maximum dimension. The site contains soils that are not suitable for retaining wall backfill due to their fines content; therefore, select grading and stockpiling and/or import of soils will be required by the contractor for obtaining suitable retaining wall backfill soil.

Aggregate base (crushed aggregate base or crushed miscellaneous base) should conform to the requirements of Section 200-2 of the most recent version of the Standard Specifications for Public Works Construction (“Greenbook”) for untreated base materials (except processed miscellaneous base) and/or County of Los Angeles requirements.

The placement of demolition materials in compacted fill is acceptable from a geotechnical viewpoint provided the demolition material is broken up into pieces not larger than typically used for aggregate base (approximately 1-inch in maximum dimension) and well blended into fill soils with essentially no resulting voids. Demolition material placed in fills must be free of construction debris and reinforcing steel. If asphalt concrete fragments will be incorporated into the demolition materials, approval from an environmental viewpoint may be required and is not the purview of the geotechnical consultant. From our previous experience, we recommend that asphalt concrete fragments be limited to fill areas within planned street areas (i.e., not within building pad areas).

4.1.6 Placement and Compaction of Fills

Material to be placed as fill should be brought to near-optimum moisture content (generally within optimum and 2 percent above optimum moisture content) and recompacted to at least 90 percent relative compaction (per ASTM D1557). Moisture conditioning of site soils will be required in order to achieve adequate compaction. Drying and or mixing of very moist soils will be required prior to reusing the materials in compacted fills. Soils are also present that will require additional moisture in order to achieve the required compaction.

The optimum lift thickness to produce a uniformly compacted fill will depend on the type and size of compaction equipment used. In general, fill should be placed in uniform lifts not exceeding 8 inches in compacted thickness. Each lift should be thoroughly compacted and accepted prior to subsequent lifts. Generally, placement and compaction of fill should be performed in accordance with local grading ordinances and with observation and testing performed by the geotechnical consultant. Oversized material as previously defined should be removed from site fills.

Fill placed on any slopes greater than 5:1 (horizontal to vertical) should be properly keyed and benched into firm and competent soils as it is placed in lifts.

Aggregate base material should be compacted to at least 95 percent relative compaction at or slightly above optimum moisture content per ASTM D1557. Subgrade below aggregate base should be compacted to at least 90 percent relative compaction per ASTM D1557 at near-optimum moisture content (generally within optimum and 2 percent above optimum moisture content).

If gap-graded ¾-inch rock is used for backfill (around storm drain storage chambers, retaining wall backfill, etc.) it will require compaction. Rock shall be placed in thin lifts (typically not exceeding 6 inches) and mechanically compacted with observation by geotechnical consultant. Backfill rock shall meet the requirements of ASTM D2321. Gap-graded rock is required to be wrapped in filter fabric to prevent the migration of fines into the rock backfill.

4.1.7 Trench and Retaining Wall Backfill and Compaction

The onsite soils may generally be suitable as trench backfill, provided the soils are screened of rocks and other material greater than 6 inches in diameter and organic matter. If trenches are shallow or the use of conventional equipment may result in damage to the utilities, sand having a sand equivalent (SE) of 30 or greater (per California Test Method [CTM] 217) may be used to bed and shade the pipes. Based on our field evaluation, onsite soils will not meet this sand equivalent requirement. Sand backfill within the pipe bedding zone may be densified by jetting or flooding and then tamping to ensure adequate compaction. Subsequent trench backfill should be compacted in uniform thin lifts by mechanical means to at least the recommended minimum relative compaction (per ASTM D1557).

Retaining wall backfill should consist of sandy soils as outlined in preceding Section 4.1.5. The limits of select sandy backfill should extend at minimum ½ the height of the retaining wall or the width of the heel (if applicable), whichever is greater (Figure 3). Retaining wall backfill soils should be compacted in relatively uniform thin lifts to at least 90 percent relative compaction (per ASTM D1557). Jetting or flooding of retaining wall backfill materials should not be permitted.

In backfill areas where mechanical compaction of soil backfill is impractical due to space constraints, typically sand-cement slurry may be substituted for compacted backfill. The slurry should contain about one sack of cement per cubic yard. When set, such a mix typically has the consistency of compacted soil. Sand cement slurry placed near the surface within landscape areas should be evaluated for potential impacts on planned improvements.

A representative from LGC Geotechnical should observe, probe, and test the backfill to verify compliance with the project recommendations.

4.1.8 <u>Shrinkage and Subsidence</u>

Allowance in the earthwork volumes budget should be made for an estimated 10 to 15 percent reduction in volume of near-surface (upper approximate 5 to 10 feet) soils. It should be stressed that these values are only estimates and that an actual shrinkage factor would be extremely difficult to predetermine. Subsidence, due to earthwork operations, is expected to be on the order of 0.1 feet. These values are estimates only and exclude losses due to removal of any vegetation or debris. The effective shrinkage of onsite soils will depend primarily on the type of compaction equipment and method of compaction used onsite by the contractor and accuracy of the topographic survey.

Due to the combined variability in topographic surveys, inability to precisely model the removals and variability of on-site near-surface conditions, it is our opinion that the site will not balance at the end of grading. If importing/exporting a large volume of soils is not considered feasible or economical, we recommend a balance area be designated onsite that can fluctuate up or down based on the actual volume of soil. We recommend a "balance" area that can accommodate on the order of 5 percent (plus or minus) of the total grading volume be considered.

4.2 Preliminary Foundation Recommendations

Provided that the remedial grading recommendations provided herein are implemented, the site may be considered suitable for the support of the proposed structures using a conventional or post-tensioned foundation system. Site soils are anticipated to be "Very Low" expansion potential (EI of 20 or less per ASTM D4829) and special design considerations from a geotechnical perspective is not anticipated, however, this must be verified based on as-graded conditions. Please note that the following foundation recommendations are preliminary and must be confirmed by LGC Geotechnical. Recommended soil bearing and estimated settlement due to structural loads are provided in Section 4.3. Recommendations for a post-tensioned foundation system can be provided upon request should the owner decide to support the proposed structures on a post-tension foundation system.

The foundation designer may use a modulus of vertical subgrade reaction (k) of 200 pounds per cubic inch (pounds per square inch per inch of deflection. This value is for a 1-foot by 1-foot square loaded area and should be adjusted by the structural designer for the area of the proposed footing using the following formula:

$k = 200 \times [(B+1)/2B]^2$
k = modulus of vertical subgrade reaction, pounds per cubic inch (pci)
B = foundation width (feet)

The moisture content of near surface fill soils should be kept at optimum up to the time of concrete placement.

4.2.1 Foundation Subgrade Preparation and Maintenance

Moisture conditioning of the subgrade soils is recommended prior to trenching the foundation. The subgrade moisture condition of the building pad soils should be maintained at near-optimum moisture content up to the time of concrete placement. This moisture content should be maintained around the immediate perimeter of the slab during construction and up to occupancy of the homes.

The geotechnical parameters provided herein assume that if the areas adjacent to the foundation are planted and irrigated, these areas will be designed with proper drainage and adequately maintained so that ponding, which causes significant moisture changes below the foundation, does not occur. Our recommendations do not account for excessive irrigation and/or incorrect landscape design. Plants should only be provided with sufficient irrigation for life and not overwatered to saturate subgrade soils. Sunken planters placed adjacent to the foundation, should either be designed with an efficient drainage system or liners to prevent moisture infiltration below the foundation. Some lifting of the perimeter foundation beam should be expected even with properly constructed planters.

In addition to the factors mentioned above, future homeowners should be made aware of the potential negative influences of trees and/or other large vegetation. Roots that extend near the vicinity of foundations can cause distress to foundations. Future homeowners (and the owner's landscape architect) should not plant trees/large shrubs closer to the foundations than a distance equal to half the mature height of the tree or 20 feet, whichever is more conservative unless specifically provided with root barriers to prevent root growth below the house foundation.

It is the homeowner's responsibility to perform periodic maintenance during hot and dry periods to ensure that adequate watering has been provided to keep soils from separating or pulling back from the foundation. Future homeowners should be informed and educated regarding the importance of maintaining a constant level of soil-moisture. The homeowners should be made aware of the potential negative consequences of both excessive watering, as well as allowing potentially expansive soils to become too dry. Expansive soils can undergo shrinkage during drying and swelling during the rainy winter season or when irrigation is resumed. This can result in distress to building structures and hardscape improvements. The builder should provide these recommendations to future homeowners.

4.2.2 Slab Underlayment Guidelines

The following is for informational purposes only since slab underlayment (e.g., moisture retarder, sand or gravel layers for concrete curing and/or capillary break) is unrelated to the geotechnical performance of the foundation and thereby not the purview of the geotechnical consultant. Post-construction moisture migration should be expected below the foundation. The foundation engineer/architect should determine whether the use of a capillary break (sand or gravel layer), in conjunction with the vapor retarder, is necessary or required by code. Sand layer thickness and location (above and/or below vapor retarder) should also be determined by the foundation engineer/architect.

4.3 Soil Bearing and Lateral Resistance

Provided our earthwork recommendations are implemented, an allowable soil bearing pressure of 1,500 pounds per square foot (psf) may be used for the design of footings having a minimum width of 12 inches and minimum embedment of 12 inches below lowest adjacent ground surface. This value may be increased by 500 psf for each additional foot of embedment and 300 psf for each additional foot of foundation width to a maximum value of 2,500 psf. A post-tensioned mat foundation a minimum of 6 inches below lowest adjacent grade may be designed for an allowable soil bearing pressure of 1,200 psf. These allowable bearing pressures are applicable for level (ground slope equal to or flatter than 5H:1V) conditions only. Bearing values indicated are for total dead loads and frequently applied live loads and may be increased by ⅓ for short duration loading (i.e., wind or seismic loads).

In utilizing the above-mentioned allowable bearing capacity and provided our earthwork recommendations are implemented, foundation settlement due to structural loads is anticipated to be 1-inch or less. Differential static settlement may be taken as half of the static settlement (i.e., ½-inch over a horizontal span of 40 feet).

Resistance to lateral loads can be provided by friction acting at the base of foundations and by passive earth pressure. For concrete/soil frictional resistance, an allowable coefficient of friction of 0.35 may be assumed with dead-load forces. For slabs constructed over a moisture retarder, the allowable friction coefficient should be provided by the manufacturer. An allowable passive lateral earth pressure of 250 psf per foot of depth (or pcf) to a maximum of 2,500 psf may be used for the sides of footings poured against properly compacted fill. Allowable passive pressure may be increased to 340 pcf (maximum of 3,400 psf) for short duration seismic loading. For isolated pole footings (for items such as a deck, trellis, etc.) spaced a minimum of three diameters on-center, an allowable passive pressure of 500 pcf may be used for passive resistance. The provided passive pressure is based on an arching factor of 2 (e.g., 250 pcf x 2) and should be limited to a maximum of 10 times the value provided above (e.g., 500 pcf to a maximum of 5,000 psf). This value may be increased by one-third for short-duration seismic loading. These provided passive pressures are applicable for level (ground slope equal to or flatter than 5H:1V) conditions only. Frictional resistance and passive pressure may be used in combination without reduction. We recommend that the upper foot of passive resistance be neglected if finished grade will not be covered with concrete or asphalt. The provided allowable passive pressures are based on a factor of safety of 1.5 and 1.1 for static and seismic loading conditions, respectively.

4.4 Lateral Earth Pressures for Retaining Walls

Lateral earth pressures are provided as equivalent fluid unit weights, in pound per square foot (psf) per foot of depth or pcf. These values do not contain an appreciable factor of safety, so the retaining wall designer should apply the applicable factors of safety and/or load factors during design. A soil unit weight of 120 pcf may be assumed for calculating the actual weight of soil over the wall footing.

The following lateral earth pressures are presented on Table 5 for approved select granular soils with a maximum of 35 percent fines (passing the No. 200 sieve per ASTM D-421/422) and Very Low expansion potential (EI of 20 or less per ASTM D4829). The wall designer should clearly indicate on the retaining wall plans the required sandy soil backfill criteria. These preliminary findings should be confirmed during grading.

TABLE 5

Lateral Earth Pressures – Approved Sandy Soils

Conditions	**Equivalent Fluid Unit Weight (pcf)**	**Equivalent Fluid Unit Weight (pcf)**
	Level Backfill	**2:1 Sloped Backfill**
	Approved Sandy Soils	**Approved Sandy Soils**
Active	35	55
At-Rest	55	70

If the wall can yield enough to mobilize the full shear strength of the soil, it can be designed for "active" pressure. If the wall cannot yield under the applied load, the earth pressure will be higher. This would include 90-degree corners of retaining walls. Such walls should be designed for “at-rest.” The equivalent fluid pressure values assume free-draining conditions. Retaining wall structures should be provided with appropriate drainage and appropriately waterproofed, refer to Figure 3. Please note that waterproofing and outlet systems are not the purview of the geotechnical consultant. If conditions other than those assumed above are anticipated, the equivalent fluid pressure values should be provided on an individual-case basis by the geotechnical consultant.

Surcharge loading effects from any adjacent structures should be evaluated by the retaining wall designer. In general, structural loads within a 1:1 (horizontal to vertical) upward projection from the bottom of the proposed retaining wall footing will surcharge the proposed retaining structure. In addition to the recommended earth pressure, basement/retaining walls adjacent to streets should be designed to resist vehicular traffic if applicable. Uniform surcharges may be estimated using the applicable coefficient of lateral earth pressure using a rectangular distribution. A factor of 0.5 and 0.30 may be used for at-rest and active conditions, respectively. The vertical traffic surcharge may be determined by the structural designer. The structural designer should contact the geotechnical engineer for any required geotechnical input in estimating any applicable surcharge loads.

If required, the retaining wall designer may use a seismic lateral earth pressure increment of 10 pcf. This increment should be applied in addition to the provided static lateral earth pressure using a “normal” triangular distribution with the resultant acting at H/3 in relation to the base of the retaining structure (where H is the retained height). For the restrained, at-rest condition, the seismic increment may be added to the applicable active lateral earth pressure (in lieu of the at-rest lateral earth pressure) when analyzing short duration seismic loading. Per Section 1803.5.12 of the 2019 CBC, the seismic lateral earth pressure is applicable to structures assigned to Seismic Design Category D through F for retaining wall structures supporting more than 6 feet of backfill height. This seismic lateral earth pressure is estimated using the procedure outlined by the Structural Engineers Association of California (Lew, et al, 2010).

Soil bearing and lateral resistance (friction coefficient and passive resistance) are provided in Section 4.3. Earthwork considerations (temporary backcuts, backfill, compaction, etc.) for retaining walls are provided in Section 4.1 (Site Earthwork) and the subsequent earthwork related sub-sections.

4.5 <u>Temporary Shoring</u>

If required, the following section may be used to design temporary shoring. The design of temporary shoring, consideration should be made for required removal depths below finish grade. Typical cantilever temporary shoring, where deflection of the shoring will not impact the performance of adjacent structures, may be designed using the active equivalent fluid pressures of 35 pounds per square foot (psf) per foot of depth (or pcf) for a level backfill. Braced shoring may be used in areas where the shoring will be located close to existing structures in order to limit shoring defections or required due to the proposed depth of excavation. Braced shoring with a level backfill may be designed using a uniform soil pressure of 23H in pounds per square foot (psf), where H is equal to the depth in feet of the excavation being shored. These lateral earth pressures do not include any hydrostatic pressures and any slopes above the temporary shoring will increase the above-noted lateral earth pressures and can be provided on a case-by-case basis.

In general, any building, equipment or traffic loads located within a 1:1 (horizontal to vertical) projection from the base of the shoring should be added to the applicable lateral earth pressure. If applicable, an additional uniform lateral pressure should be added to the appropriate lateral earth pressures to account for typical vehicle traffic loading. Uniform surcharges may be estimated using the applicable coefficient of lateral earth pressure using a rectangular distribution. A factor of 0.30 may be used for the active condition. The vertical traffic surcharge may be determined by the shoring designer. For differing conditions, the above-noted lateral earth pressures can be provided on a case-by-case basis. The shoring designer should contact the geotechnical consultant for any required geotechnical input in estimating any applicable lateral surcharge loads.

For piers spaced a minimum of 2.5 pier diameters on-center, an allowable passive pressure of 500 pcf may be used for passive resistance. The provided passive pressure is based on an arching factor of 2 (e.g., 250 pcf x 2) and should be limited to a maximum of 12 times the value provided above (e.g., 500 pcf to a maximum of 6,000 psf). This passive pressure is applicable for level (ground slope equal to or flatter than 5H:1V) conditions. The concrete placed in the soldier pile excavation below the excavated level should be of adequate strength to transfer the imposed loads to the surrounding soils. The provided allowable passive pressure is based on a factor of safety of 1.5.

Continuous lagging should be provided between the soldier piles. Lagging should be placed in a timely manner during excavation in order to minimize potential spalling and sloughing. The backfill of the lagging should consist of sand-cement slurry to ensure full bearing of retained earth to the lagging. The soldier piles should be designed for the full anticipated lateral earth pressure; however, the pressure on the lagging will be less due to soil arching between the piles. The lagging can be designed for the recommended earth pressure but may be limited to a maximum value of 400 psf if surcharge loads are not present. Lagging placed behind the solider piles will negate the soil arching effect.

It is difficult to accurately predict the amount of deflection of the shoring system. It should be realized, however, that some deflection will occur. The shoring should be designed to limit deflection to within tolerable limits. If greater deflection occurs during construction, additional bracing may be necessary.

4.6 Soil Corrosivity

Although not corrosion engineers (LGC Geotechnical is not a corrosion consultant), several governing agencies in Southern California require the geotechnical consultant to determine the corrosion potential of soils to buried concrete and metal facilities. We therefore present the results of our testing with regard to corrosion for the use of the client and other consultants, as they determine necessary.

Corrosion testing of a near-surface bulk sample indicated Corrosion testing indicated soluble sulfate contents of approximately 0.01 percent, a chloride content of 40 parts per million (ppm), pH of 6.4, and a minimum resistivity of 1,298 ohm-centimeters. Previous sulfate testing indicated less than 0.01 percent (GSC, 2017). Based on Caltrans Corrosion Guidelines (Caltrans, 2015), soils are considered corrosive to structural elements if the pH is 5.5 or less, or the chloride concentration is 500 ppm or greater, or the sulfate concentration is 2,000 ppm (0.2 percent) or greater. Based on the test results, soils are not considered corrosive using Caltrans criteria.

Based on laboratory sulfate test results, the near surface soils are designated to a class "S0" per ACI 318, Table 19.3.1.1 with respect to sulfates. Concrete in direct contact with the onsite soils can be designed according to ACI 318, Table 19.3.2.1 using the "S0" sulfate classification.

Laboratory testing may need to be performed at the completion of grading by the project corrosion engineer to further evaluate the as-graded soil corrosivity characteristics. Accordingly, revision of the corrosion potential may be needed, should future test results differ substantially from the conditions reported herein. The client and/or other members of the development team should consider this during the design and planning phase of the project and formulate an appropriate course of action.

4.7 Control of Surface Water and Drainage Control

From a geotechnical perspective, we recommend that compacted finished grade soils adjacent to proposed residences be sloped away from the proposed residence and towards an approved drainage device or unobstructed swale. Drainage swales, wherever feasible, should not be constructed within 5 feet of buildings. Where lot and building geometry necessitates that the side yard drainage swales be routed closer than 5 feet to structural foundations, we recommend the use of area drains together with drainage swales. Drainage swales used in conjunction with area drains should be designed by the project civil engineer so that a properly constructed and maintained system will prevent ponding within 5 feet of the foundation. Code compliance of grades is not the purview of the geotechnical consultant.

Planters with open bottoms adjacent to buildings should be avoided. Planters should not be designed adjacent to buildings unless provisions for drainage, such as catch basins, liners, and/or area drains, are made. Overwatering must be avoided.

4.8 Subsurface Water Infiltration

Recent regulatory changes have occurred that mandate that storm water be infiltrated below grade rather than collected in a conventional storm drain system. Typically, a combination of methods is implemented to reduce surface water runoff and increase infiltration including; permeable pavements/pavers for roadways and walkways, directing surface water runoff to grass-lined swales, retention areas, and/or drywells, etc.

It should be noted that collecting and concentrating surface water for the purpose of intentional infiltration below grade, conflicts with the geotechnical engineering objective of directing surface water away from slopes, structures and other improvements. The geotechnical stability and integrity of a site is reliant upon appropriately handling surface water. In general, the vast majority of geotechnical distress issues are directly related to improper drainage. In general, distress in the form of movement of improvements could occur as a result of soil saturation and loss of soil support, expansion, internal soil erosion, collapse and/or settlement.

Geotechnical stability and integrity of the project site is reliant upon appropriate handling of surface water. In accordance with the "Site Requirements for Stormwater Infiltration" Section of the County of Los Angeles Geotechnical and Materials Engineering Division (GMED) GS200.2 (2017) guidelines, stormwater infiltration shall not increase the potential for static settlement (including hydro-collapse) of structures on or adjacent to the site. Therefore, due to the potential presence of soils highly susceptible to hydro-collapse of the subject property and/or offsite properties, the risk of causing collapse related distress to adjacent improvements is too high, and thus the intentional infiltration of stormwater is not recommended.

4.9 ***Preliminary Asphalt Concrete Pavement Sections***

The following provisional minimum asphalt concrete (AC) pavement sections are provided in Table 6 based on an assumed R-value of 40 for Traffic Indices (TI) of 5.5 and 6.0. These recommendations must be confirmed with R-value testing of representative near-surface soils at the completion of grading and after underground utilities have been installed and backfilled. Final pavement sections should be confirmed by the project civil engineer based upon the final design Traffic Index. Determination of the TI is not the purview of the geotechnical consultant If requested, LGC Geotechnical will provide sections for alternate TI values.

TABLE 6

Preliminary Asphalt Concrete Pavement Section Options

Assumed Traffic Index	≤ 5.5	6.0
R -Value Subgrade	40	40
AC Thickness	4.0 inches	4.0 inches
Aggregate Base Thickness	4.0 inches	5.0 inches

The pavement section thicknesses provided above are considered minimum thicknesses. Increasing the thickness of any or all of the above layers will reduce the likelihood of the pavement experiencing distress during its service life. The above recommendations are based on the assumption that proper maintenance and irrigation of the areas adjacent to the roadway will occur throughout the design life of the pavement. Failure to maintain a proper maintenance and/or irrigation program may jeopardize the integrity of the pavement.

Earthwork recommendations regarding underlying aggregate base and subgrade are provided in the previous Section "Site Earthwork" and the related sub-sections of this report.

4.10 ***Preliminary Concrete Vehicular Paver Sections***

The following provisional concrete vehicular paver sections provided in Table 7 are based on an assumed R-Value of 40 for Traffic Indices (TI) of 5.5 and 6.0. These recommendations must be confirmed with R-value testing of representative near-surface soils at the completion of grading and after underground utilities have been installed and backfilled. Final pavement sections should be confirmed by the project civil engineer based upon the final design Traffic Index. Determination of the TI is not the purview of the geotechnical consultant If requested, LGC Geotechnical will provide sections for alternate TI values.

Concrete pavers should be a minimum of 3 and 1/8 inches (80 mm) thick, rated for vehicular traffic and placed in a herringbone pattern. Manufacturer's specific recommendations regarding the pavers (required bedding and jointing sand, etc.) should be implemented during construction. It should be noted that pavers are typically underlain by a minimum of 1-inch of bedding sand in addition to the design sections herein. Besides the bedding sand, concrete vehicular pavers should be placed on compacted aggregate base over compacted subgrade soils. Recommended concrete vehicular paver sections are provided in Table 7 below.

TABLE 7

Preliminary Concrete Vehicular Paver Section Options

Assumed Traffic Index	≤ 5.5	6.0
R -Value Subgrade	40	40
Concrete Vehicular Paver Thickness	3.125 inches	3.125 inches
***Bedding Sand Thickness**	1.0 inch	1.0 inch
Aggregate Base Thickness	6.5 inches	8.0 inches

*Typically, a minimum of 1-inch of bedding sand is placed beneath the concrete vehicular pavers; actual thickness to be determined by others in accordance with manufacturer specifications.

Concrete bands around the perimeter of the pavers are recommended. The concrete bands should be at least 6 inches thick, with two No. 4 rebars placed longitudinally at approximately mid-height. The concrete bands should be underlain by a minimum of 4 inches of compacted crushed aggregate base.

The thicknesses above are minimum thicknesses. Increasing the thickness of any or all of the above layers will reduce the likelihood of the pavement experiencing distress during its service life. The above recommendations are based on the assumption that proper maintenance and irrigation of the areas adjacent to the roadway will occur throughout the design life of the pavement and pavers. Failure to maintain a proper maintenance and/or irrigation program may jeopardize the integrity of the pavement and pavers.

Earthwork recommendations regarding underlying aggregate base and subgrade are provided in the previous Section "Site Earthwork" and the related sub-sections of this report.

4.11 Nonstructural Concrete Flatwork

Nonstructural concrete flatwork (such as walkways, private drives, patio slabs, etc.) has a potential for cracking due to changes in soil volume related to soil-moisture fluctuations. To reduce the potential for excessive cracking and lifting, concrete may be designed in accordance with the minimum guidelines outlined in Table 8. These guidelines will reduce the potential for irregular cracking and promote cracking along construction joints but will not eliminate all cracking or lifting. Thickening the concrete and/or adding additional reinforcement will further reduce cosmetic distress.

TABLE 8

Preliminary Geotechnical Parameters for Nonstructural Concrete Flatwork Placed on Very Low to Low Expansion Potential Subgrade

	Homeowner Sidewalks	Private Drives	Patios/Entryways	City Sidewalk Curb and Gutters
Minimum Thickness (in.)	4 (nominal)	4 (full)	4 (full)	City/Agency Standard
Presoaking	Wet down prior to placing	Wet down prior to placing	Wet down prior to placing	City/Agency Standard
Reinforcement	—	No. 3 at 24 inches on centers	No. 3 at 24 inches on centers	City/Agency Standard
Thickened Edge (in.)	—	8 x 8	—	City/Agency Standard
Crack Control Joints	Saw cut or deep open tool joint to a minimum of $^1/_3$ the concrete thickness	Saw cut or deep open tool joint to a minimum of $^1/_3$ the concrete thickness	Saw cut or deep open tool joint to a minimum of $^1/_3$ the concrete thickness	City/Agency Standard
Maximum Joint Spacing	5 feet	10 feet or quarter cut whichever is closer	6 feet	City/Agency Standard
Aggregate Base Thickness (in.)	—	—	—	City/Agency Standard

To reduce the potential for driveways to separate from the garage slab, the builder may elect to install dowels to tie these two elements together. Similarly, future homeowners should consider the use of dowels to connect flatwork to the foundation.

4.12 Pre-Construction Documentation and Construction Monitoring

Due to the proximity of the existing offsite improvements and required depth of remedial grading in portions of the site, it is recommended that a program of documentation and monitoring be devised and put into practice before the onset of any groundwork. LGC Geotechnical can perform these services at your request. This should include, but not necessarily be limited to, detailed documentation of the existing improvements, buildings, and utilities around the area of proposed excavation, with particular attention to any distress that is already present prior to the start of work. Subsequent readings should be scheduled consistent with the program of work. If shoring systems are to be constructed, routine monitoring of horizontal and vertical movement should be performed for the shoring system and adjacent improvements during construction to verify that shoring deflections are within tolerable limits.

4.13 Geotechnical Plan Review

When available, grading, foundation, shoring and retaining wall plans should be reviewed by LGC Geotechnical in order to verify our geotechnical recommendations are implemented. Updated recommendations and/or additional field work may be necessary.

4.14 Boreholes for Temporary Shoring (if required)

Boreholes for temporary shoring should be plumb and free of loose or softened material. Extreme care in drilling, placement of reinforcement steel, and the pouring of concrete will be essential to avoid excessive disturbance of borehole walls. Immediately after drilling the soldier pile steel section or reinforcing cage should be installed and the concrete pumped. Where applicable, concrete placement by pumping or tremie tube to the bottom of borehole excavation is recommended. No pier borehole should be left open overnight. We recommend that pier boreholes not be drilled immediately adjacent to another pier until the concrete in the other pier has attained its initial set. A representative from LGC Geotechnical should be onsite during the drilling of piers to verify the assumptions made during the design stages.

Zones of sands with low fines content (i.e., minimal silts and clays) were encountered in site borings. These soils are considered very susceptible to caving therefore caving of drilled holes should be anticipated. The contractor should anticipate difficult drilling conditions due to dense soils and the potential presence of oversize material. The contractor should anticipate that any pier borehole left open for any extended period of time will likely experience additional caving and potential perched groundwater conditions typically from local irrigation. Refer to the boring logs provide in Appendix B. If caving occurs during CIDH pier construction, a temporary casing may be required

4.15 Footing/Foundation Excavations

Footing/foundation excavation bottoms should be firm, relatively unyielding, and free of loose material. Footing/foundation excavations should be observed and accepted by the geotechnical consultant prior to placement of steel reinforcement.

4.16 Geotechnical Observation and Testing During Construction

The recommendations provided in this report are based on limited subsurface observations and geotechnical analysis. The interpolated subsurface conditions should be checked in the field during construction by a representative of LGC Geotechnical. Geotechnical observation and testing is required per Section 1705 of the 2019 California Building Code (CBC).

Geotechnical observation and/or testing should be performed by LGC Geotechnical at the following stages:

- During grading (removal bottoms, fill placement, etc);
- Installation of temporary shoring (if applicable);
- During retaining wall backfill and compaction;
- During utility trench backfill and compaction;
- After presoaking building pads and other concrete-flatwork subgrades, and prior to placement of aggregate base or concrete;
- Preparation of pavement subgrade and placement of aggregate base;
- After building and wall footing excavation and prior to placing steel reinforcement and/or concrete; and
- When any unusual soil conditions are encountered during any construction operation subsequent to issuance of this report.

5.0 LIMITATIONS

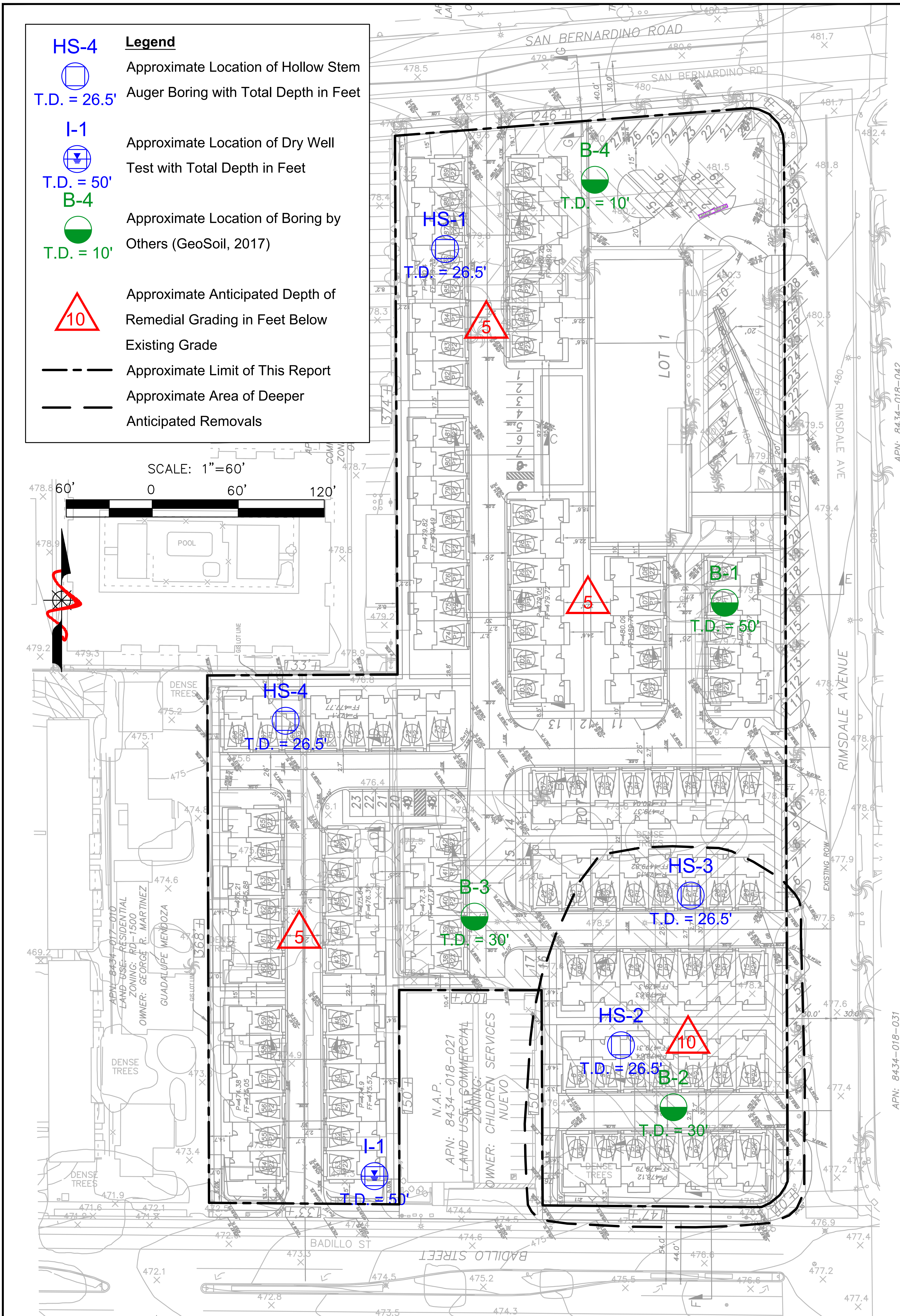
Our services were performed using the degree of care and skill ordinarily exercised, under similar circumstances, by reputable soils engineers and geologists practicing in this or similar localities. No other warranty, expressed or implied, is made as to the conclusions and professional advice included in this report.

This report is based on data obtained from limited observations of the site, which have been extrapolated to characterize the site. While the scope of services performed is considered suitable to adequately characterize the site geotechnical conditions relative to the proposed development, no practical evaluation can completely eliminate uncertainty regarding the anticipated geotechnical conditions in connection with a subject site. Variations may exist and conditions not observed or described in this report may be encountered during grading and construction.

This report is issued with the understanding that it is the responsibility of the owner, or of his/her representative, to ensure that the information and recommendations contained herein are brought to the attention of the other consultants (at a minimum the civil engineer, structural engineer, landscape architect) and incorporated into their plans. The contractor should properly implement the recommendations during construction and notify the owner if they consider any of the recommendations presented herein to be unsafe, or unsuitable.

The findings of this report are valid as of the present date. However, changes in the conditions of a site can and do occur with the passage of time, whether they be due to natural processes or the works of man on this or adjacent properties. The findings, conclusions, and recommendations presented in this report can be relied upon only if LGC Geotechnical has the opportunity to observe the subsurface conditions during grading and construction of the project, in order to confirm that our preliminary findings are representative for the site. This report is intended exclusively for use by the client, any use of or reliance on this report by a third party shall be at such party's sole risk.

In addition, changes in applicable or appropriate standards may occur, whether they result from legislation or the broadening of knowledge. Accordingly, the findings of this report may be invalidated wholly or partially by changes outside our control. Therefore, this report is subject to review and modification.



LGC Geotechnical, Inc.

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San Clemente, CA 92672
TEL (949) 369-6141 FAX (949) 369-6142

FIGURE 2
Boring Location Map

PROJECT NAME	Trumark - Covina Bowl
PROJECT NO.	19127-01
ENG. / GEOL.	RLD / CNJ
SCALE	1" = 60'
DATE	January 2020

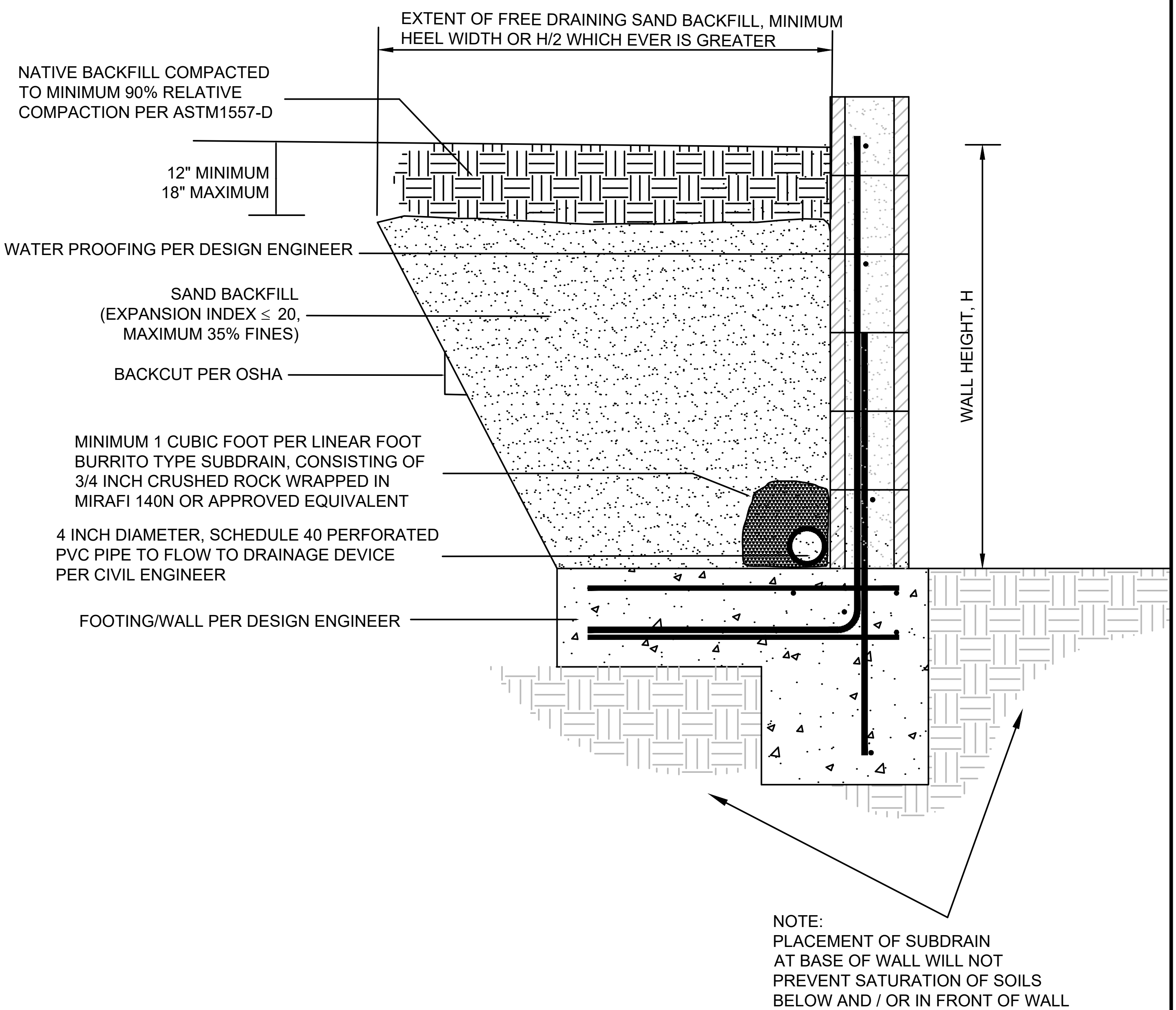

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FIGURE 3
Retaining Wall Backfill Detail

PROJECT NAME	Trumark - Covina Bowl
PROJECT NO.	19127-01
ENG.	RLD
SCALE	Not to Scale
DATE	January 2020

Appendix A
References

APPENDIX A

References

American Society of Civil Engineers (ASCE), 2017, Minimum Design Loads for Buildings and Other Structures, ASCE/SEI 7-16, 2017.

________, 2018, Standard 7-16, Minimum Design Loads for Buildings and Associated Criteria for Buildings and Other Structures, Supplement 1, effective: December 12, 2018.

California Building Standards Commission, 2019, California Building Code, California Code of Regulations Title 24, Volumes 1 and 2, dated July 2019.

Bray, J.D., and Sancio, R. B., 2006, Assessment of Liquefaction Susceptibility of Fine-Grained Soils, *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, pp. 1165-1177, dated September 2006.

California Department of Transportation (Caltrans), 2015, Corrosion Guidelines, Version 2.1, dated January 2015.

California Division of Mines and Geology (CDMG) 1997, Geologic Map of the Baldwin Park 7.5-Minute Quadrangle, Los Angeles County, California, Open File Report 98-30, dated 1997.

________, 1998, State of California Seismic Hazard Zone Report for the Baldwin Park 7.5-Minute Quadrangle, Los Angeles County, California, Seismic Hazard Zone Report 98-13, dated 1998.

________, 1999, State of California Seismic Hazard Zones, Baldwin Park Quadrangle, Official Map, scale: 1:24,000, dated March 25, 1999.

California Geological Survey [CGS], 2003, Preliminary Geologic Map of the San Bernardino 30' x 60' Quadrangle, Southern California, Version 1.0, Scale 1:100,000, Open-File Report 03-293, dated 2003.

________, 2008, California Geological Society Special Publication 117A: Guidelines for Evaluating and Mitigating Seismic Hazards in California.

________, 2012, California Geological Survey website, Interactive Fault Map: http://www.quake.ca.gov/gmaps/FAM/faultactivitymap.html

County of Los Angeles, 2017, Guidelines for Geotechnical Investigation and Reporting Low Impact Development Stormwater Infiltration, Department of Public Works Geotechnical and Materials Engineering Division, GS200.2, dated June 30, 2017.

GeoSoils Consultants Inc. (GSC), 2017, Geotechnical Engineering Investigation, Covina Bowl, 1060 West San Bernardino Road, City of Covina, California, W.O. 7043, dated May 19, 2017.

Historic Aerials, 2018, viewed January 8, 2020, Aerials viewed from: 1948, 1952, 1953, 1954, 1964, 1965, 1972, 1977, 1980, 1995, 2003, 2004, 2005, 2009, 2010, 2012, 2014, 2016 and 2012; Topographic Maps viewed from 1897, 1898, 1902, 1904, 1908, 1912, 1923, 1927, 1932, 1937, 1939, 1941, 1946, 1955, 1960, 1967, 1975, 1982, 2012, 2015, and 2018 https://www.historicaerials.com/

Hunsaker and Associates (Hunsaker), 2019, Master Site Plan, Vesting Tentative Tract Map, No. 82874 for Condominium Purposes, dated September 18, 2019.

Lew, et al, 2010, Seismic Earth Pressures on Deep Basements, Structural Engineers Association of California (SEAOC) Convention Proceedings.

Structural Engineers Association of California (SEAOC), 2019, Seismic Design Maps, Retrieved January 10, 2020, from https://seismicmaps.org/

United States Geological Survey (USGS), 2008, Unified Hazard Tool, Dynamic: Conterminous U.S. 2014 (update) (v4.2.0), Retrieved January 10, 2020, from: https://earthquake.usgs.gov/hazards/interactive/

Appendix B
Field Exploration Logs

Geotechnical Boring Log Borehole HS-1

Date: 11/19/2019	**Drilling Company:** 2R Drilling
Project Name: Trumark - Covina Bowl	**Type of Rig:** Hollow Stem Auger CME 75
Project Number: 19127-01	**Drop:** 30" **Hole Diameter:** 8"
Elevation of Top of Hole: ~479' MSL	**Drive Weight:** 140 pounds
Hole Location: See Geotechnical Map	Page 1 of 1

Logged By CNJ
Sampled By CNJ
Checked By RLD

Elevation (ft)	Depth (ft)	Graphic Log	Sample Number	Blow Count	Dry Density (pcf)	Moisture (%)	USCS Symbol	DESCRIPTION	Type of Test
	0							**@0' to T.D. - <u>Quaternary Young Alluvial Fan Deposits (Qya)</u>**	
		B-1					SP-SM	@0' - Asphalt concrete, 4" thick, over SAND with Silt: reddish brown, moist	EI, MD, CR
475									
	5		R-1	2 4 6	105.1	7.5		@5' - SAND with Silt: brown, moist, loose	
			R-2	4 4 7	103.8	7.1	SM	@7.5' - Silty SAND: brown, slightly moist to moist, medium dense; small piece of charcoal, approximately 1/4 inch in diameter; trace scattered gravel	CO, -#200
470									
	10		R-3	4 5 9	102.5	7.7		@10' - Silty SAND: brown, moist, medium dense	
465									
	15		SPT-1	10 7 6		3.8	SP	@15' - SAND with Gravel: light brown, dry to slightly moist, medium dense; gravel up to 2 inches in diameter	
460									
	20		R-4	16 28 32	121.5	1.8		@20' - SAND with Gravel: light brown, dry, very dense; friable	
455									
	25		SPT-2	12 15 10		2.4		@25' - SAND with Gravel: light brown, dry, dense; slightly friable	
								Total Depth = 26.5' Groundwater Not Encountered Backfilled with Cuttings and Capped with AC Cold Patch on 11/19/2019	
450									
	30								

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THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF THE ACTUAL CONDITIONS ENCOUNTERED. THE DESCRIPTIONS PROVIDED ARE QUALITATIVE FIELD DESCRIPTIONS AND ARE NOT BASED ON QUANTITATIVE ENGINEERING ANALYSIS.

SAMPLE TYPES:
- B BULK SAMPLE
- R RING SAMPLE (CA Modified Sampler)
- G GRAB SAMPLE
- SPT STANDARD PENETRATION TEST SAMPLE
- GROUNDWATER TABLE

TEST TYPES:
- DS DIRECT SHEAR
- MD MAXIMUM DENSITY
- SA SIEVE ANALYSIS
- S&H SIEVE AND HYDROMETER
- EI EXPANSION INDEX
- CN CONSOLIDATION
- CR CORROSION
- AL ATTERBERG LIMITS
- CO COLLAPSE/SWELL
- RV R-VALUE
- -#200 % PASSING # 200 SIEVE

Last Edited: 1/8/2020

Geotechnical Boring Log Borehole HS-2

Date: 11/19/2019	**Drilling Company:** 2R Drilling
Project Name: Trumark - Covina Bowl	**Type of Rig:** Hollow Stem Auger CME 75
Project Number: 19127-01	**Drop:** 30" **Hole Diameter:** 8"
Elevation of Top of Hole: ~478' MSL	**Drive Weight:** 140 pounds
Hole Location: See Geotechnical Map	Page 1 of 1

Logged By CNJ
Sampled By CNJ
Checked By RLD

Elevation (ft)	Depth (ft)	Graphic Log	Sample Number	Blow Count	Dry Density (pcf)	Moisture (%)	USCS Symbol	DESCRIPTION	Type of Test
	0							**@0' to T.D. - Quaternary Young Alluvial Fan Deposits (Qya)**	
475			B-1				SP-SM	@0' - Asphalt concrete, 4.5" thick, over SAND with Silt: reddish brown, slightly moist to moist	
	5		R-1	2 4 6	106.5	6.6		@5' - SAND with Silt: brown, slightly moist, loose	
470			R-2	2 4 5	104.6	4.1	SM	@7.5' - Silty SAND: dark yellowish brown, moist, loose	CO, -#200
	10		R-3	4 6 9	117.1	10.2	CL-ML	@10' - Silty CLAY: olive brown, moist, stiff	CO
465									
	15		SPT-1	2 3 4		14.0	ML	@15' - SILT with Sand: brown, moist, stiff	
460									
	20		R-4	26 39 50/5"	125.0	2.0	SM	@20' - Silty SAND with Gravel: light brown to brown, dry, very dense	
455									
	25		SPT-2	24 23 25		2.1	SP	@25' - SAND with Gravel: light brown, dry, very dense	
450								Total Depth = 26.5' Groundwater Not Encountered Backfilled with Cuttings and Capped with AC Cold Patch on 11/19/2019	
	30								

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SAMPLE TYPES:
- B BULK SAMPLE
- R RING SAMPLE (CA Modified Sampler)
- G GRAB SAMPLE
- SPT STANDARD PENETRATION TEST SAMPLE
- GROUNDWATER TABLE

TEST TYPES:
- DS DIRECT SHEAR
- MD MAXIMUM DENSITY
- SA SIEVE ANALYSIS
- S&H SIEVE AND HYDROMETER
- EI EXPANSION INDEX
- CN CONSOLIDATION
- CR CORROSION
- AL ATTERBERG LIMITS
- CO COLLAPSE/SWELL
- RV R-VALUE
- -#200 % PASSING # 200 SIEVE

Last Edited: 1/8/2020

Geotechnical Boring Log Borehole HS-3

Date: 11/19/2019	**Drilling Company:** 2R Drilling
Project Name: Trumark - Covina Bowl	**Type of Rig:** Hollow Stem Auger CME 75
Project Number: 19127-01	**Drop:** 30" **Hole Diameter:** 8"
Elevation of Top of Hole: ~478' MSL	**Drive Weight:** 140 pounds
Hole Location: See Geotechnical Map	Page 1 of 1

Elevation (ft)	Depth (ft)	Graphic Log	Sample Number	Blow Count	Dry Density (pcf)	Moisture (%)	USCS Symbol	Logged By CNJ Sampled By CNJ Checked By RLD DESCRIPTION	Type of Test
	0							**@0' to T.D. - <u>Quaternary Young Alluvial Fan Deposits (Qya)</u>**	
475							SP-SM	@0' - Asphalt concrete, 4" thick, over SAND with Silt: reddish brown, slightly moist to moist	
	5		R-1	3 5 7	107.0	4.5		@5' - SAND with Silt: brown, slightly moist, medium dense	
470			R-2	3 5 7	103.8	3.5	SM	@7.5' - Silty SAND: yellowish brown, slightly moist, medium dense	CO
	10		R-3	4 7 9	104.5	7.2	CL-ML	@10' - Silty CLAY: dark yellowish brown, slightly moist, stiff; roots	AL, CO
465									
	15		R-4	9 10 13	106.1	7.5		@15' - Silty CLAY: dark yellowish brown, slightly moist, very stiff	CO
460									
	20		SPT-1	21 31 46		1.0	SP-SM	@20' - SAND with Silt and Gravel: brown grading to white, dry, very dense	
455									
	25		R-5	33 36 50/5"				@25' - No recovery	
450								Total Depth = 26.5' Groundwater Not Encountered Backfilled with Cuttings and Capped with AC Cold Patch on 11/19/2019	
	30								

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SAMPLE TYPES:
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- GROUNDWATER TABLE

TEST TYPES:
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- S&H SIEVE AND HYDROMETER
- EI EXPANSION INDEX
- CN CONSOLIDATION
- CR CORROSION
- AL ATTERBERG LIMITS
- CO COLLAPSE/SWELL
- RV R-VALUE
- -#200 % PASSING # 200 SIEVE

Geotechnical Boring Log Borehole HS-4

Date: 11/19/2019	**Drilling Company:** 2R Drilling
Project Name: Trumark - Covina Bowl	**Type of Rig:** Hollow Stem Auger CME 75
Project Number: 19127-01	**Drop:** 30" **Hole Diameter:** 8"
Elevation of Top of Hole: ~476' MSL	**Drive Weight:** 140 pounds
Hole Location: See Geotechnical Map	Page 1 of 1

Elevation (ft)	Depth (ft)	Graphic Log	Sample Number		Blow Count	Dry Density (pcf)	Moisture (%)	USCS Symbol	Logged By CNJ Sampled By CNJ Checked By RLD DESCRIPTION	Type of Test
475	0	B-1							**@0' to T.D. - <u>Quaternary Young Alluvial Fan Deposits (Qya)</u>**	
								SP-SM	@0' - Asphalt concrete, 4" thick, over SAND with Silt: reddish brown, slightly moist to moist	
470	5		R-1		2 4 6	105.0	6.4	SP	@5' - SAND: brown, slightly moist, loose	
			R-2		3 4 6	108.4	7.3	SM	@7.5' - Silty SAND: dark yellowish brown, slightly moist to moist, loose	CO
465	10		R-3		4 4 7	106.4	9.6		@10' - Silty SAND: light reddish brown, moist, medium dense	
460	15		R-4		3 6 7	106.0	13.6		@15' - Silty SAND: brown, very moist, medium dense	
455	20		SPT-1		2 2 6		21.3	ML	@20' - SILT with Sand and Gravel: brown, very moist, stiff	
450	25		R-5		4 5 7	104.6	12.5	SM	@25' - Silty SAND: light brown, moist, medium dense; rootlets	
	30								Total Depth = 26.5' Groundwater Not Encountered Backfilled with Cuttings and Capped with AC Cold Patch on 11/19/2019	

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SAMPLE TYPES:
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- R RING SAMPLE (CA Modified Sampler)
- G GRAB SAMPLE
- SPT STANDARD PENETRATION TEST SAMPLE
- GROUNDWATER TABLE

TEST TYPES:
- DS DIRECT SHEAR
- MD MAXIMUM DENSITY
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- EI EXPANSION INDEX
- CN CONSOLIDATION
- CR CORROSION
- AL ATTERBERG LIMITS
- CO COLLAPSE/SWELL
- RV R-VALUE
- -#200 % PASSING # 200 SIEVE

Last Edited: 1/8/2020

Geotechnical Boring Log Borehole I-1

Date: 11/19/2019	**Drilling Company:** 2R Drilling
Project Name: Trumark - Covina Bowl	**Type of Rig:** Hollow Stem Auger CME 75
Project Number: 19127-01	**Drop:** 30" **Hole Diameter:** 8"
Elevation of Top of Hole: ~474' MSL	**Drive Weight:** 140 pounds
Hole Location: See Geotechnical Map	Page 1 of 2

Logged By CNJ
Sampled By CNJ
Checked By RLD

Elevation (ft)	Depth (ft)	Graphic Log	Sample Number	Blow Count	Dry Density (pcf)	Moisture (%)	USCS Symbol	DESCRIPTION	Type of Test
	0							**@0' to T.D. - <u>Quaternary Young Alluvial Fan Deposits (Qya)</u>**	
			B-1				SP-SM	@0' - Concrete, 3" thick, over SAND with Silt: light brown, slightly moist	
470									
	5		R-1	3 6 8	100.5	4.6	SM	@5' - Silty SAND: light brown, slightly moist, medium dense; scattered rootlets	
			R-2	5 7 9	101.4	3.7	ML	@7.5' - Sandy SILT: dark yellowish brown, dry, medium dense	CO
465									
	10		R-3	4 6 10	98.1	8.0	SM	@10' - Silty SAND: light brown, slightly moist, medium dense	
460									
	15		SPT-1	4 6 7		5.9	ML	@15' - Sandy SILT: light brown, slightly moist, very stiff	
455									
	20		R-4	46 48 50/4"		1.3	GP	@20' - GRAVEL with Sand: light brown and while, dry, very dense	
450									
	25		SPT-2	16 21 30		1.4	SP	@25' - SAND with Gravel: light brown, dry, very dense	
445									
	30								

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THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF THE ACTUAL CONDITIONS ENCOUNTERED. THE DESCRIPTIONS PROVIDED ARE QUALITATIVE FIELD DESCRIPTIONS AND ARE NOT BASED ON QUANTITATIVE ENGINEERING ANALYSIS.

SAMPLE TYPES:
- B BULK SAMPLE
- R RING SAMPLE (CA Modified Sampler)
- G GRAB SAMPLE
- SPT STANDARD PENETRATION TEST SAMPLE

GROUNDWATER TABLE

TEST TYPES:
- DS DIRECT SHEAR
- MD MAXIMUM DENSITY
- SA SIEVE ANALYSIS
- S&H SIEVE AND HYDROMETER
- EI EXPANSION INDEX
- CN CONSOLIDATION
- CR CORROSION
- AL ATTERBERG LIMITS
- CO COLLAPSE/SWELL
- RV R-VALUE
- -#200 % PASSING # 200 SIEVE

Geotechnical Boring Log Borehole I-1

Date: 11/19/2019	**Drilling Company:** 2R Drilling
Project Name: Trumark - Covina Bowl	**Type of Rig:** Hollow Stem Auger CME 75
Project Number: 19127-01	**Drop:** 30" **Hole Diameter:** 8"
Elevation of Top of Hole: ~474' MSL	**Drive Weight:** 140 pounds
Hole Location: See Geotechnical Map	Page 2 of 2

Logged By CNJ
Sampled By CNJ
Checked By RLD

Elevation (ft)	Depth (ft)	Graphic Log	Sample Number	Blow Count	Dry Density (pcf)	Moisture (%)	USCS Symbol	DESCRIPTION	Type of Test
	30		R-5	6 8 9	94.2	14.8	ML	@30' - SILT: brown, moist, stiff; manganese oxide staining	
440									
	35		SPT-3	4 7 10		13.6		@35' - Sandy SILT: brown, moist, very stiff	
435									
	40		R-6	6 9 11	126.7	1.7	GP	@40' - GRAVEL with Sand: gray brown, dry, medium dense	
430									
	45		SPT-4	7 11 13		7.6	SP-SM	@45' - SAND with Silt: light brown, moist, dense	
			R-7	11 17 23	105.9	7.9	SM	@48' - Silty SAND: orange brown, moist, dense	
425									
	50							Total Depth = 50' Groundwater Not Encountered 3" Perforated Pipe with Filter Sock Installed, Surrounded by Gravel, and Presoaked on 11/19/2019 Backfilled with Cuttings and Capped with Quikcrete on 11/20/2019	
420									
	55								
415									
	60								

LGC Geotechnical, Inc.

THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF THE ACTUAL CONDITIONS ENCOUNTERED. THE DESCRIPTIONS PROVIDED ARE QUALITATIVE FIELD DESCRIPTIONS AND ARE NOT BASED ON QUANTITATIVE ENGINEERING ANALYSIS.

SAMPLE TYPES:
- B BULK SAMPLE
- R RING SAMPLE (CA Modified Sampler)
- G GRAB SAMPLE
- SPT STANDARD PENETRATION TEST SAMPLE
- GROUNDWATER TABLE

TEST TYPES:
- DS DIRECT SHEAR
- MD MAXIMUM DENSITY
- SA SIEVE ANALYSIS
- S&H SIEVE AND HYDROMETER
- EI EXPANSION INDEX
- CN CONSOLIDATION
- CR CORROSION
- AL ATTERBERG LIMITS
- CO COLLAPSE/SWELL
- RV R-VALUE
- -#200 % PASSING # 200 SIEVE

GEOTECHNICAL BORING LOG

PROJECT NAME	Watt	W.O. NO.	7043
DRILLING COMPANY	Gregg Drilling	DATE STARTED:	5-12-17
BORING NO.	B-1	SHEET	1 OF 2
TYPE OF DRILL RIG	Truck	LOGGED BY	Jame Van Meter
DRILLING METHOD	Hollow Stem	HAMMER WEIGHT (LBS)	
GROUND ELEVATION (FT)			
DIAMETER OF HOLE	8	DROP (IN)	
GW ELEVATION			
BORING LOCATION:			

DEPTH (FT)	SAMPLE TYPE	BLOWS/ 6 IN.	GEOTECHNICAL DESCRIPTION	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
	Bulk Sample		4" Asphalt 4"-50' Alluvium (Qal)			
5	California Ring	3/2	@ 5' Medium brown silty fine SAND, slightly to moderately moist, slightly dense.	12.1	107.8	
	California Ring	3/4	@7.5' Medium brown very fine to fine SAND, slightly moist, slightly to moderately dense.	8.8	103.5	
10	California Ring	3/4	@10' Medium fine silty very fine to fine SAND, slightly to moderately moist, slightly to moderately dense.	21.7	97.4	
15	California Ring	3/4	@15' Medium brown clayey silty very fine SAND, moist, slightly to moderately dense.	26.4	100.3	
20	California Ring	8/11	20' Light brown fine to very coarse SAND with gravel size rock fragments, slightly moist, dense.	8.0	111.5	
25	California Ring	19/44	25' Light grayish brown fine to very coarse SAND with abundant pea sized grevel, dry to slightly moist.	2.0	126.4	
30	California Ring	28/31		13.4	104.7	

LEGEND

- Standard Penetration Test
- California Ring
- Rock Core
- Bulk Sample
- Shelby Tube
- Water Seepage
- Groundwater

SIEVE:	GRAIN SIZE ANALYSIS
MAX:	MAXIMUM DRY DENSITY
DS:	DIRECT SHEAR
CONS:	CONSOLIDATION
HYDR:	HYDROMETER ANALYSIS
EXPAN:	EXPANSION INDEX
CHEM:	CHEMICAL TESTS

PLATE A-1

GeoSoils Consultants, Inc.
GEOTECHNICAL * GEOLOGIC * ENVIRONMENTAL

GEOTECHNICAL BORING LOG

PROJECT NAME Watt
W.O. NO. 7043
DRILLING COMPANY Gregg Drilling
DATE STARTED: 5-12-17
BORING NO. B-1
TYPE OF DRILL RIG Truck
LOGGED BY Jame Van Meter
SHEET 2 OF 2
DRILLING METHOD Hollow Stem
HAMMER WEIGHT (LBS)
GROUND ELEVATION (FT)
DIAMETER OF HOLE 8
DROP (IN)
GW ELEVATION
BORING LOCATION:

DEPTH (FT)	SAMPLE TYPE	BLOWS/ 6 IN.	GEOTECHNICAL DESCRIPTION	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
	California Ring	21/18	35' Lightl gray fine to very coarse SAND with rock fragments, dry dense medium brown clayey silty CLAY fine SAND, moderately dense.	10.7	108.7	
40	California Ring	10/13	40' Medium brown silty very fine to fine SAND, slightly moist dense.	9.3	97.1	
45	California Ring	9/12	45' Medium brown silty very fine to fine SAND, slightly moist, dense.	4.9	107.5	
			50' Light to medium brown very fine to fine SAND, slightly moist, dense.			
50	California Ring	12/15	Total Depth 50' No Ground Water Hole Backfilled.			
55						
60						
65						

LEGEND

- Standard Penetration Test
- California Ring
- Rock Core
- Bulk Sample
- Shelby Tube
- Water Seepage
- Groundwater

SIEVE: GRAIN SIZE ANALYSIS
MAX: MAXIMUM DRY DENSITY
DS: DIRECT SHEAR
CONS: CONSOLIDATION
HYDR: HYDROMETER ANALYSIS
EXPAN: EXPANSION INDEX
CHEM: CHEMICAL TESTS

PLATE A-2

GeoSoils Consultants, Inc.
GEOTECHNICAL * GEOLOGIC * ENVIRONMENTAL

GEOTECHNICAL BORING LOG

PROJECT NAME Watt W.O. NO. 7043
DRILLING COMPANY Gregg Drilling DATE STARTED: 5-12-17 BORING NO. B-2
TYPE OF DRILL RIG Truck LOGGED BY Jame Van Meter SHEET 1 OF 1
DRILLING METHOD Hollow Stem HAMMER WEIGHT (LBS) GROUND ELEVATION (FT)
DIAMETER OF HOLE 8 DROP (IN) GW ELEVATION
BORING LOCATION:

DEPTH (FT)	SAMPLE TYPE	BLOWS/ 6 IN.	GEOTECHNICAL DESCRIPTION	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
			5" Asphalt **5"-30' Alluvium (Qal)**			
5	Bulk Sample; California Ring	3/3	@5' Medium brown silty fine sand, slightly moist, slightly dense	6.2	99.4	
	California Ring	4/5	7.5 Light to medium brown very fine to fine SAND, slightly moist, slightly to moderately dense.	4.1	100.0	
10	California Ring	7/10	@10' Light to medium brown very fine to fine SAND, medium brown silty very fine SAND, slightly moist, moderately dense.	8.2	100.5	
15	California Ring	7/12	@15' Light brown silty very fine SAND, slightly moist, dense.	7.3	100.5	
20	California Ring	15/37	@20' Light brown to light gray brown fine to very coarse SAND with gravel, dry, dense.	1.5	125.6	
25	California Ring	15/32	@25' Light gray fine to medium SAND, dry, dense.	1.9	102.4	
			@30' Light gray fine to course SAND with gravel and medium brown silty fine SAND, moist, dense.			
30	California Ring	9/10		17.1	150.0	
			Total Depth 30' No Ground Water Hole Backfilled.			

LEGEND

- Standard Penetration Test
- California Ring
- Rock Core
- Bulk Sample
- Shelby Tube
- Water Seepage
- Groundwater

SIEVE: GRAIN SIZE ANALYSIS
MAX: MAXIMUM DRY DENSITY
DS: DIRECT SHEAR
CONS: CONSOLIDATION
HYDR: HYDROMETER ANALYSIS
EXPAN: EXPANSION INDEX
CHEM: CHEMICAL TESTS

PLATE A-3

GeoSoils Consultants, Inc.
GEOTECHNICAL ★ GEOLOGIC ★ ENVIRONMENTAL

GEOTECHNICAL BORING LOG

PROJECT NAME Watt
W.O. NO. 7043
DRILLING COMPANY Gregg Drilling
DATE STARTED: 5-12-17
BORING NO. B-3
TYPE OF DRILL RIG Truck
LOGGED BY Jame Van Meter
SHEET 1 OF 1
DRILLING METHOD Hollow Stem
HAMMER WEIGHT (LBS)
GROUND ELEVATION (FT)
DIAMETER OF HOLE 8
DROP (IN)
GW ELEVATION
BORING LOCATION:

DEPTH (FT)	SAMPLE TYPE	BLOWS/ 6 IN.	GEOTECHNICAL DESCRIPTION	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
			3" Asphalt 3"-30' Alluvium (Qal)			
5	Bulk Sample / California Ring	2/2	@5' Medium brown silty fine SAND, moderately moist, slightly dense.	9.3	104.2	
	California Ring	3/5	@7.5' Medium brown silty fine SAND, moderately moist slightly to moderately dense.	7.6	103.7	
10	California Ring	5/6	@10' Mediium brown fine SAND, slightly moist, moderately dense.	6.2	102.9	
15	California Ring	6/7	15' Medium brown silty fine to medium SAND, moderately moist, moderately dense.	11.0	115.1	
20	California Ring	27/44	20' Light brown fine to very coarse SAND with rock fragments, slightly moist, dense.	2.4	128.2	
25	California Ring	44/50 for 4"	25' Partial sample, light gray fine to very coarse SAND with rock fragment, dry, dense.			
			30' Medium brown silty fine SAND and fine to medium SAND, moderately moist, moderately dense.			
30	California Ring	6/18		10.4	97.7	
			Total Depth 30' No Groung Water Hole Backfilled.			

LEGEND

- Standard Penetration Test
- California Ring
- Rock Core
- Bulk Sample
- Shelby Tube
- Water Seepage
- Groundwater

SIEVE: GRAIN SIZE ANALYSIS
MAX: MAXIMUM DRY DENSITY
DS: DIRECT SHEAR
CONS: CONSOLIDATION
HYDR: HYDROMETER ANALYSIS
EXPAN: EXPANSION INDEX
CHEM: CHEMICAL TESTS

PLATE A-4

GeoSoils Consultants, Inc.
GEOTECHNICAL * GEOLOGIC * ENVIRONMENTAL

GEOTECHNICAL BORING LOG

PROJECT NAME Watt			W.O. NO. 7043
DRILLING COMPANY Gregg Drilling	DATE STARTED: 5-12-17		BORING NO. B-4
TYPE OF DRILL RIG Truck	LOGGED BY Jame Van Meter		SHEET 1 OF 1
DRILLING METHOD Hollow Stem	HAMMER WEIGHT (LBS)		GROUND ELEVATION (FT)
DIAMETER OF HOLE 8	DROP (IN)		GW ELEVATION

BORING LOCATION:

DEPTH (FT)	SAMPLE TYPE	BLOWS/ 6 IN.	GEOTECHNICAL DESCRIPTION	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
			<u>0-6" Asphalt</u> <u>6"-10' Alluvium (Qal)</u>			
5	California Ring	3/4	@5' Medium brown silty fine sand, moderately moist, slightly dense.	8.7	106.5	
	California Ring	4/5	@7.5' Medium brown silty fine SAND, moderatley moist, lightly to moderateley dense.	7.2	103.1	
10	California Ring	4/7	@10' Medium brown silty fine SAND, moderatly moist, moderateley dense.	9.5	96.6	
			Total Dept 10' Pipe/gravel installed No Ground Water.			
15						
20						
25						
30						

LEGEND

- Standard Penetration Test
- California Ring
- Rock Core
- Bulk Sample
- Shelby Tube
- Water Seepage
- Groundwater

SIEVE: GRAIN SIZE ANALYSIS
MAX: MAXIMUM DRY DENSITY
DS: DIRECT SHEAR
CONS: CONSOLIDATION
HYDR: HYDROMETER ANALYSIS
EXPAN: EXPANSION INDEX
CHEM: CHEMICAL TESTS

PLATE A-5

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Appendix C
Laboratory Test Results

APPENDIX C

Laboratory Test Results

The laboratory testing program was directed towards providing quantitative data relating to the relevant engineering properties of the soils. Samples considered representative of site conditions were tested in general accordance with American Society for Testing and Materials (ASTM) procedure and/or California Test Methods (CTM), where applicable. The following summary is a brief outline of the test type and a table summarizing the test results.

Moisture and Density Determination Tests: Moisture content (ASTM D2216) and dry density determinations (ASTM D2937) were performed on driven samples obtained from the test borings. The results of these tests are presented in the boring logs. Where applicable, only moisture content was determined from undisturbed or disturbed samples.

Grain Size Distribution/Fines Content: Representative samples were dried, weighed, and soaked in water until individual soil particles were separated (per ASTM D421) and then washed on a No. 200 sieve (ASTM D1140). Where applicable, the portion retained on the No. 200 sieve was dried and then sieved on a U.S. Standard brass sieve set in accordance with ASTM D6913 (sieve) or ASTM D422 (sieve and hydrometer).

Sample Location	**Description**	**% Passing # 200 Sieve**
HS-1 @ 7.5 ft	Silty Sand	35.5
HS-2 @ 7.5 ft	Silty Sand	12.7

Atterberg Limits: The liquid and plastic limits ("Atterberg Limits") were determined per ASTM D4318 for engineering classification of fine-grained material and presented in the table below. The USCS soil classification indicated in the table below is based on the portion of sample passing the No. 40 sieve and may not necessarily be representative of the entire sample. The plots are provided in this Appendix.

Sample Location	**Liquid Limit (%)**	**Plastic Limit (%)**	**Plasticity Index (%)**	**USCS Soil Classification**
HS-3 @ 10 ft	21	14	7	CL-ML

Laboratory Test Results

Expansion Index: The expansion potential of a selected representative sample was evaluated by the Expansion Index Test per ASTM D4829. The result is presented in the table below.

Sample Location	Expansion Index	Expansion Potential*
HS-1 @ 2-5 ft	8	Very Low

* Per ASTM D4829

Collapse/Swell Potential: Collapse tests were performed per ASTM D4546. Samples (2.4 inches in diameter and 1 inch in height) were placed in a consolidometer and loaded to their approximate in-situ effective stress. The curves are presented in this Appendix.

Laboratory Compaction: The maximum dry density and optimum moisture content of typical materials were determined in accordance with ASTM D1557. The results are presented in the table below.

Sample Location	Sample Description	Maximum Dry Density (pcf)	Optimum Moisture Content (%)
HS-1 @ 2-5 ft	Silty Sand	128.0	11.5

Soluble Sulfates: The soluble sulfate contents of selected samples were determined by standard geochemical methods (CTM 417). The test results are presented in the table below.

Sample Location	Sulfate Content, %
HS-1 @ 2-5 ft	0.01

Chloride Content: Chloride content was tested per CTM 422. The results are presented below.

Sample Location	Chloride Content, ppm
HS-1 @ 2-5 ft	4

Laboratory Test Results

<u>Minimum Resistivity and pH Tests</u>: Minimum resistivity and pH tests were performed in general accordance with CTM 643 and standard geochemical methods. The results are presented in the table below.

Sample Location	pH	Minimum Resistivity (ohms-cm)
HS-1 @ 2-5 ft	6.4	1,298

ATTERBERG LIMITS

ASTM D 4318

Project Name:	Covina	Tested By:	A. Santos	Date:	12/02/19
Project No. :	19127-01	Input By:	G. Bathala	Date:	12/03/19
Boring No.:	HS-3	Checked By:	J. Ward		
Sample No.:	R-3	Depth (ft.)	10.0		
Soil Identification:	Dark yellowish brown silty clay (CL-ML)				

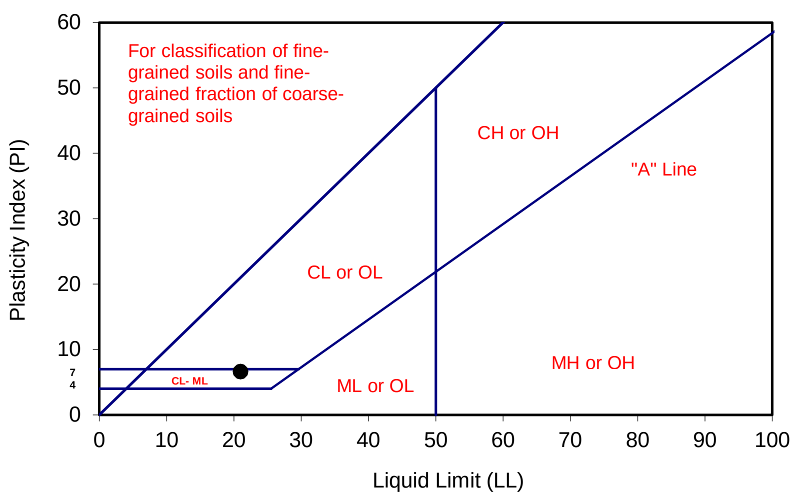
TEST	PLASTIC LIMIT		LIQUID LIMIT			
NO.	1	2	1	2	3	4
Number of Blows [N]			32	24	19	
Wet Wt. of Soil + Cont. (g)	11.31	10.25	19.19	21.43	22.00	
Dry Wt. of Soil + Cont. (g)	10.01	9.10	16.13	17.91	18.30	
Wt. of Container (g)	1.02	1.06	1.03	1.10	1.01	
Moisture Content (%) [Wn]	14.46	14.30	20.26	20.94	21.40	

Liquid Limit	21
Plastic Limit	14
Plasticity Index	7
Classification	CL-ML

PI at "A" - Line = 0.73(LL-20) | 0.73

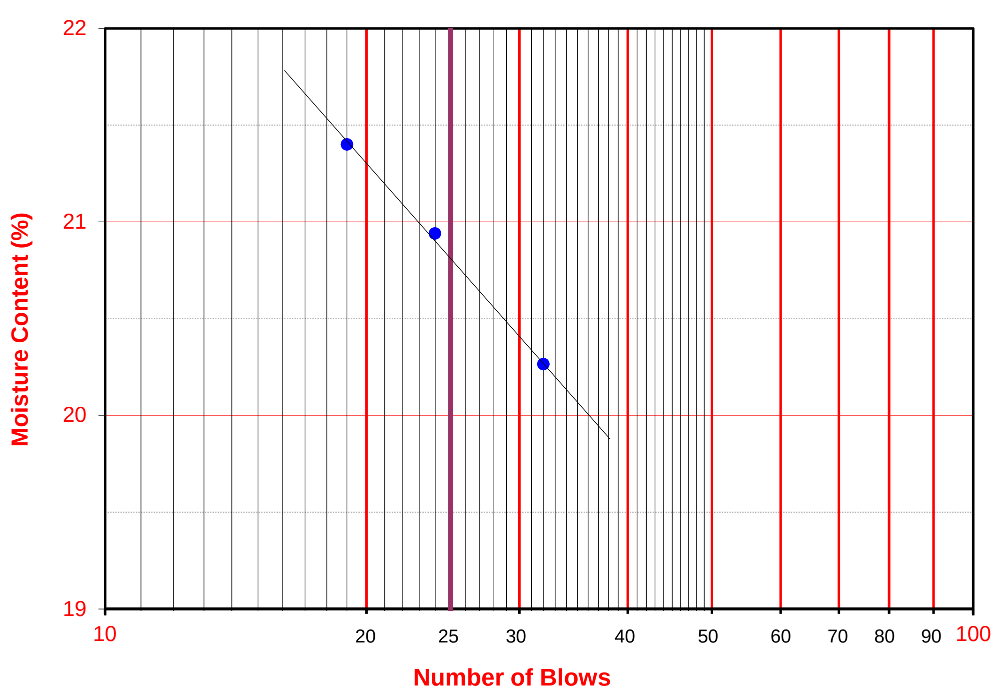
One - Point Liquid Limit Calculation

$$LL = Wn(N/25)^{0.121}$$



PROCEDURES USED

- [ ] Wet Preparation Multipoint - Wet
- [X] Dry Preparation Multipoint - Dry
- [X] Procedure A Multipoint Test
- [ ] Procedure B One-point Test



ONE-DIMENSIONAL SWELL OR SETTLEMENT POTENTIAL OF COHESIVE SOILS

ASTM D 4546

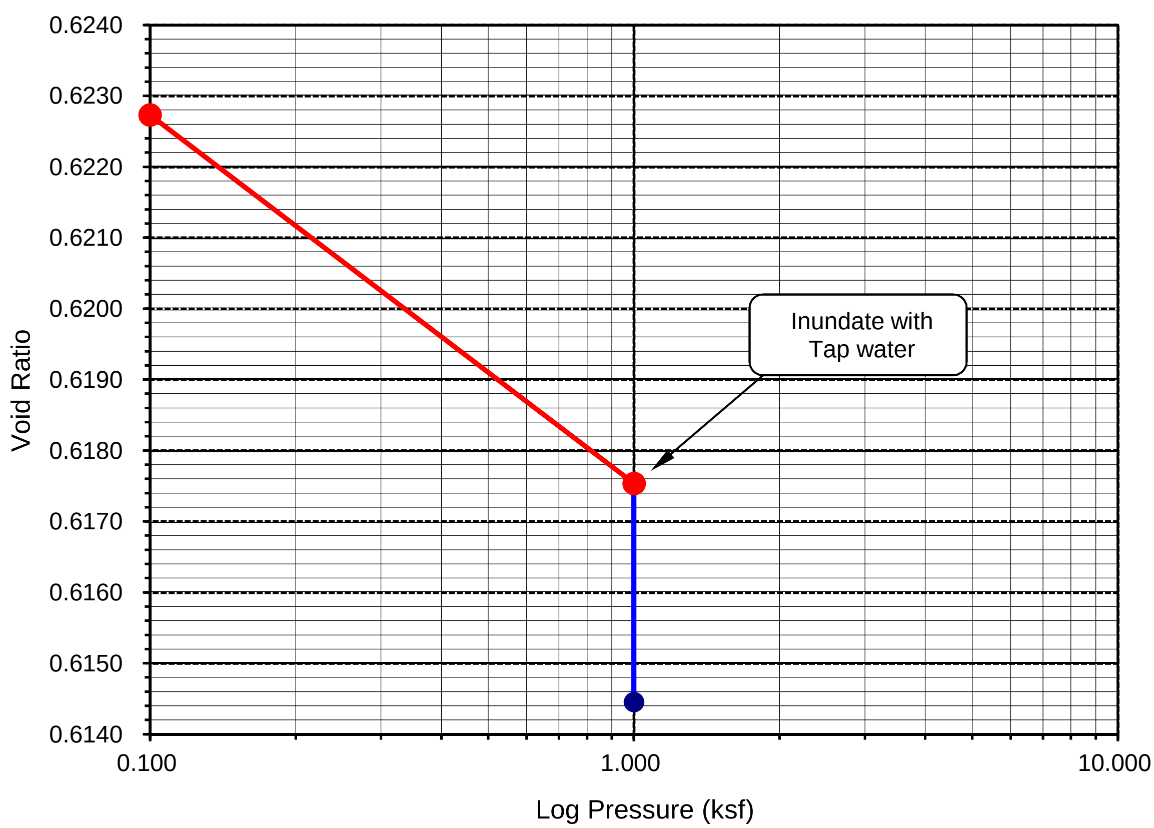
Project Name:	Covina	Tested By:	G. Bathala	Date:	11/23/19
Project No.:	19127-01	Checked By:	J. Ward	Date:	12/12/19
Boring No.:	HS-1	Sample Type:	Ring		
Sample No.:	R-2	Depth (ft.)	7.5		
Sample Description:	Dark yellowish brown silty sand (SM)				

Initial Dry Density (pcf):	103.8	Final Dry Density (pcf):	104.4
Initial Moisture (%):	7.09	Final Moisture (%) :	19.3
Initial Length (in.):	1.0000	Initial Void Ratio:	0.6232
Initial Dial Reading:	0.2403	Specific Gravity(assumed):	2.70
Diameter(in):	2.415	Initial Saturation (%)	30.7

Pressure (p) (ksf)	Final Reading (in)	Apparent Thickness (in)	Load Compliance (%)	Swell (+) Settlement (-) % of Sample Thickness	Void Ratio	Corrected Deformation (%)
0.100	0.2400	0.9997	0.00	-0.03	0.6227	-0.03
1.000	0.2357	0.9954	0.11	-0.46	0.6175	-0.35
H2O	0.2338	0.9935	0.11	-0.65	0.6145	-0.54

Percent Swell (+) / Settlement (-) After Inundation = -0.19

Void Ratio - Log Pressure Curve



ONE-DIMENSIONAL SWELL OR SETTLEMENT POTENTIAL OF COHESIVE SOILS
ASTM D 4546

Project Name:	Covina	Tested By:	G. Bathala	Date:	11/23/19
Project No.:	19127-01	Checked By:	J. Ward	Date:	12/12/19
Boring No.:	HS-2	Sample Type:	Ring		
Sample No.:	R-2	Depth (ft.)	7.5		

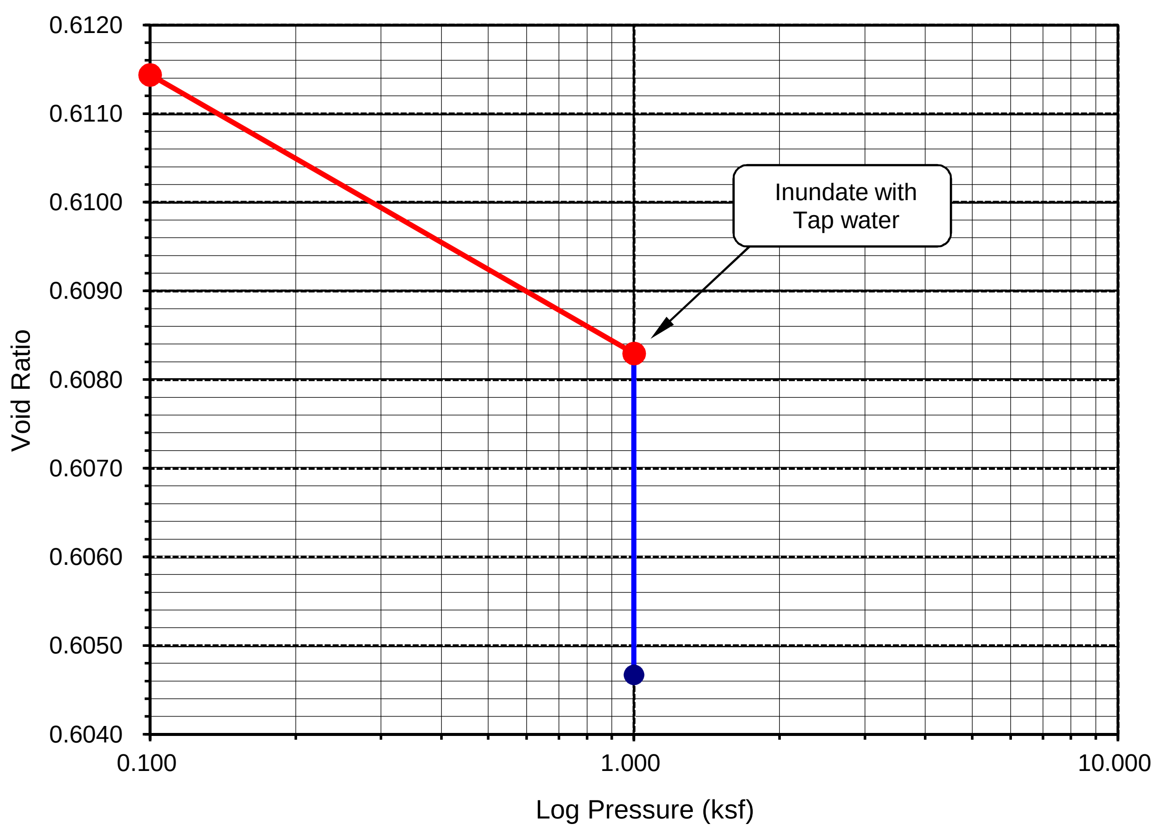
Sample Description: Dark yellowish brown silty sand (SM)

Initial Dry Density (pcf):	104.6	Final Dry Density (pcf):	105.0
Initial Moisture (%):	4.08	Final Moisture (%) :	18.7
Initial Length (in.):	1.0000	Initial Void Ratio:	0.6118
Initial Dial Reading:	0.2760	Specific Gravity(assumed):	2.70
Diameter(in):	2.415	Initial Saturation (%)	18.0

Pressure (p) (ksf)	Final Reading (in)	Apparent Thickness (in)	Load Compliance (%)	Swell (+) Settlement (-) % of Sample Thickness	Void Ratio	Corrected Deformation (%)
0.100	0.2758	0.9998	0.00	-0.03	0.6114	-0.03
1.000	0.2717	0.9957	0.21	-0.43	0.6083	-0.22
H2O	0.2695	0.9935	0.21	-0.66	0.6047	-0.45

Percent Swell (+) / Settlement (-) After Inundation = -0.23

Void Ratio - Log Pressure Curve



ONE-DIMENSIONAL SWELL OR SETTLEMENT POTENTIAL OF COHESIVE SOILS

ASTM D 4546

Project Name:	Covina	Tested By:	G. Bathala	Date:	11/24/19
Project No.:	19127-01	Checked By:	J. Ward	Date:	12/12/19
Boring No.:	HS-2	Sample Type:	Ring		
Sample No.:	R-3	Depth (ft.)	10.0		
Sample Description:	Olive brown silty clay (CL-ML)				

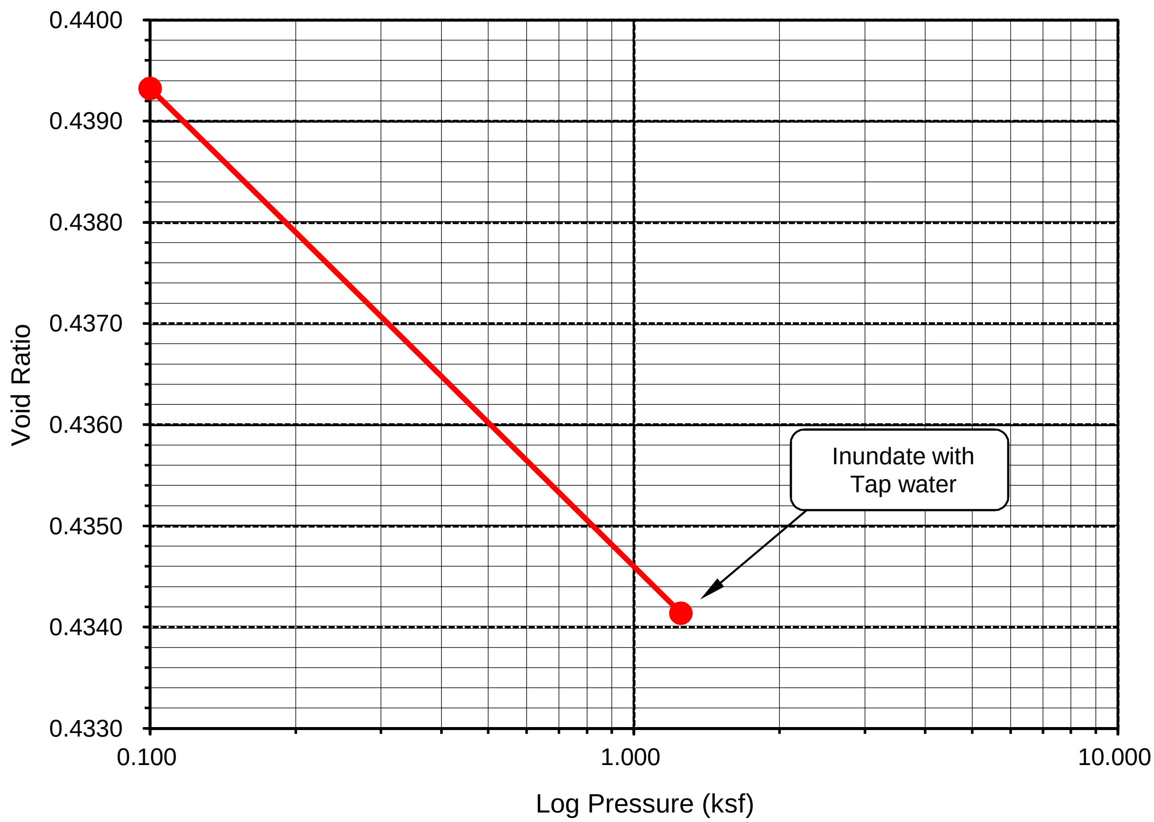
Initial Dry Density (pcf):	117.1
Initial Moisture (%):	10.18
Initial Length (in.):	1.0000
Initial Dial Reading:	0.2351
Diameter(in):	2.415

Final Dry Density (pcf):	117.5
Final Moisture (%) :	16.4
Initial Void Ratio:	0.4400
Specific Gravity(assumed):	2.70
Initial Saturation (%)	62.4

Pressure (p) (ksf)	Final Reading (in)	Apparent Thickness (in)	Load Compliance (%)	Swell (+) Settlement (-) % of Sample Thickness	Void Ratio	Corrected Deformation (%)
0.100	0.2346	0.9995	0.00	-0.05	0.4393	-0.05
1.250	0.2297	0.9946	0.13	-0.54	0.4341	-0.41
H2O	0.2297	0.9946	0.13	-0.54	0.4341	-0.41

Percent Swell (+) / Settlement (-) After Inundation = 0.00

Void Ratio - Log Pressure Curve



ONE-DIMENSIONAL SWELL OR SETTLEMENT POTENTIAL OF COHESIVE SOILS

ASTM D 4546

Project Name: Covina
Project No.: 19127-01
Boring No.: HS-3
Sample No.: R-2
Sample Description: Yellowish brown silty sand (SM)

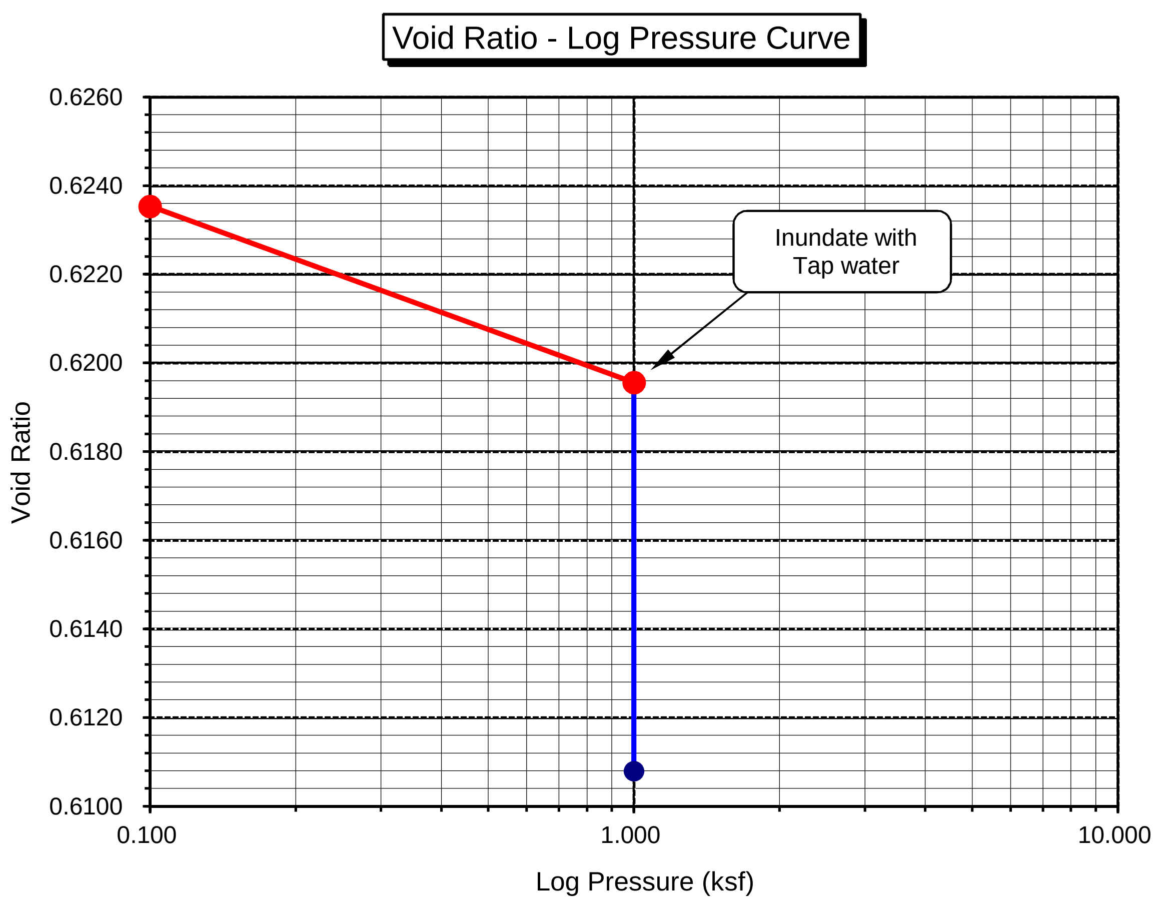
Tested By: G. Bathala   Date: 11/24/19
Checked By: J. Ward   Date: 12/12/19
Sample Type: Ring
Depth (ft.) 7.5

Initial Dry Density (pcf):	103.8
Initial Moisture (%):	3.47
Initial Length (in.):	1.0000
Initial Dial Reading:	0.1971
Diameter(in):	2.415

Final Dry Density (pcf):	104.6
Final Moisture (%) :	18.0
Initial Void Ratio:	0.6240
Specific Gravity(assumed):	2.70
Initial Saturation (%)	15.0

Pressure (p) (ksf)	Final Reading (in)	Apparent Thickness (in)	Load Compliance (%)	Swell (+) Settlement (-) % of Sample Thickness	Void Ratio	Corrected Deformation (%)
0.100	0.1968	0.9997	0.00	-0.03	0.6235	-0.03
1.000	0.1923	0.9952	0.21	-0.49	0.6196	-0.28
H_2O	0.1869	0.9898	0.21	-1.03	0.6108	-0.81

Percent Swell (+) / Settlement (-) After Inundation = -0.54



ONE-DIMENSIONAL SWELL OR SETTLEMENT POTENTIAL OF COHESIVE SOILS
ASTM D 4546

Project Name:	Covina	Tested By:	G. Bathala	Date:	11/25/19
Project No.:	19127-01	Checked By:	J. Ward	Date:	12/12/19
Boring No.:	HS-3	Sample Type:	Ring		
Sample No.:	R-3	Depth (ft.)	10.0		

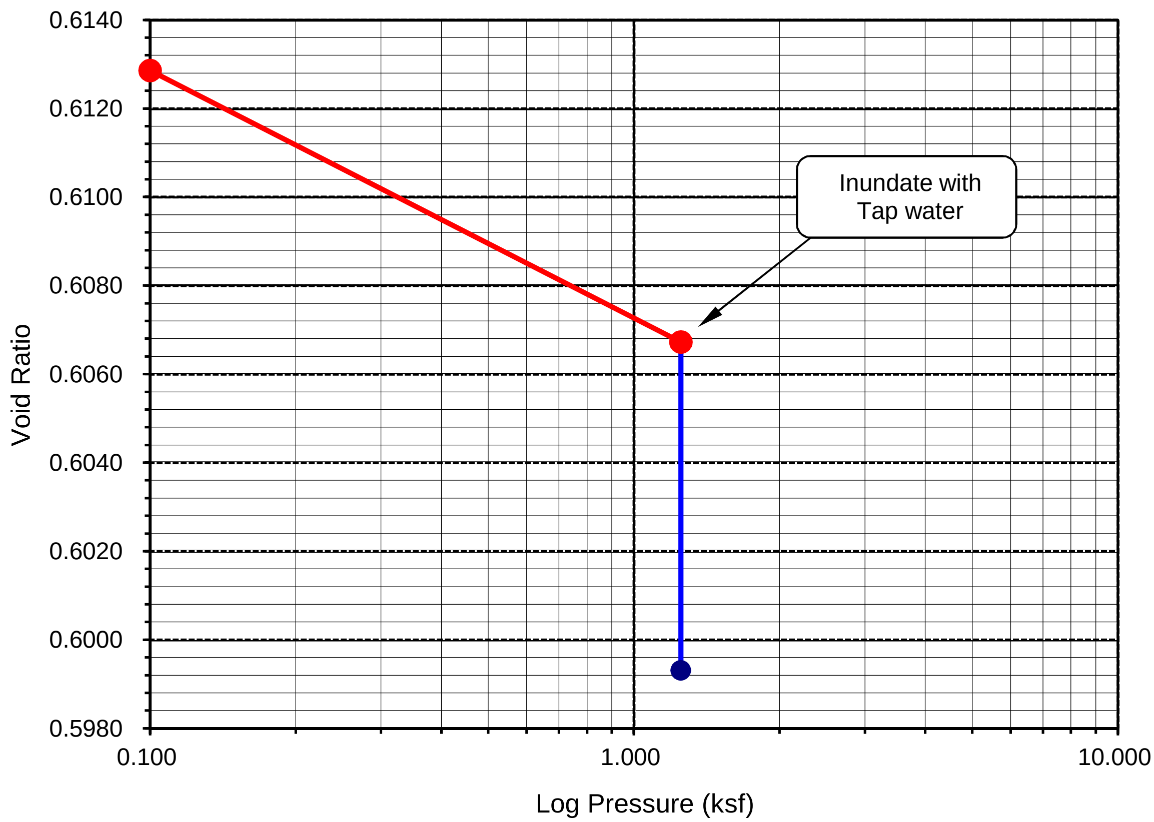
Sample Description: Dark yellowish brown silty clay (CL-ML)

Initial Dry Density (pcf):	104.5	Final Dry Density (pcf):	105.4
Initial Moisture (%):	7.22	Final Moisture (%) :	20.0
Initial Length (in.):	1.0000	Initial Void Ratio:	0.6132
Initial Dial Reading:	0.3012	Specific Gravity(assumed):	2.70
Diameter(in):	2.415	Initial Saturation (%)	31.8

Pressure (p) (ksf)	Final Reading (in)	Apparent Thickness (in)	Load Compliance (%)	Swell (+) Settlement (-) % of Sample Thickness	Void Ratio	Corrected Deformation (%)
0.100	0.3010	0.9998	0.00	-0.02	0.6129	-0.02
1.250	0.2959	0.9947	0.13	-0.53	0.6067	-0.40
H2O	0.2913	0.9901	0.13	-0.99	0.5993	-0.86

Percent Swell (+) / Settlement (-) After Inundation = -0.46

Void Ratio - Log Pressure Curve



ONE-DIMENSIONAL SWELL OR SETTLEMENT POTENTIAL OF COHESIVE SOILS

ASTM D 4546

Project Name:	Covina	Tested By:	G. Bathala	Date:	11/25/19
Project No.:	19127-01	Checked By:	J. Ward	Date:	12/12/19
Boring No.:	HS-3	Sample Type:	Ring		
Sample No.:	R-4	Depth (ft.)	15.0		
Sample Description:	Dark yellowish brown silty clay (CL-ML)				

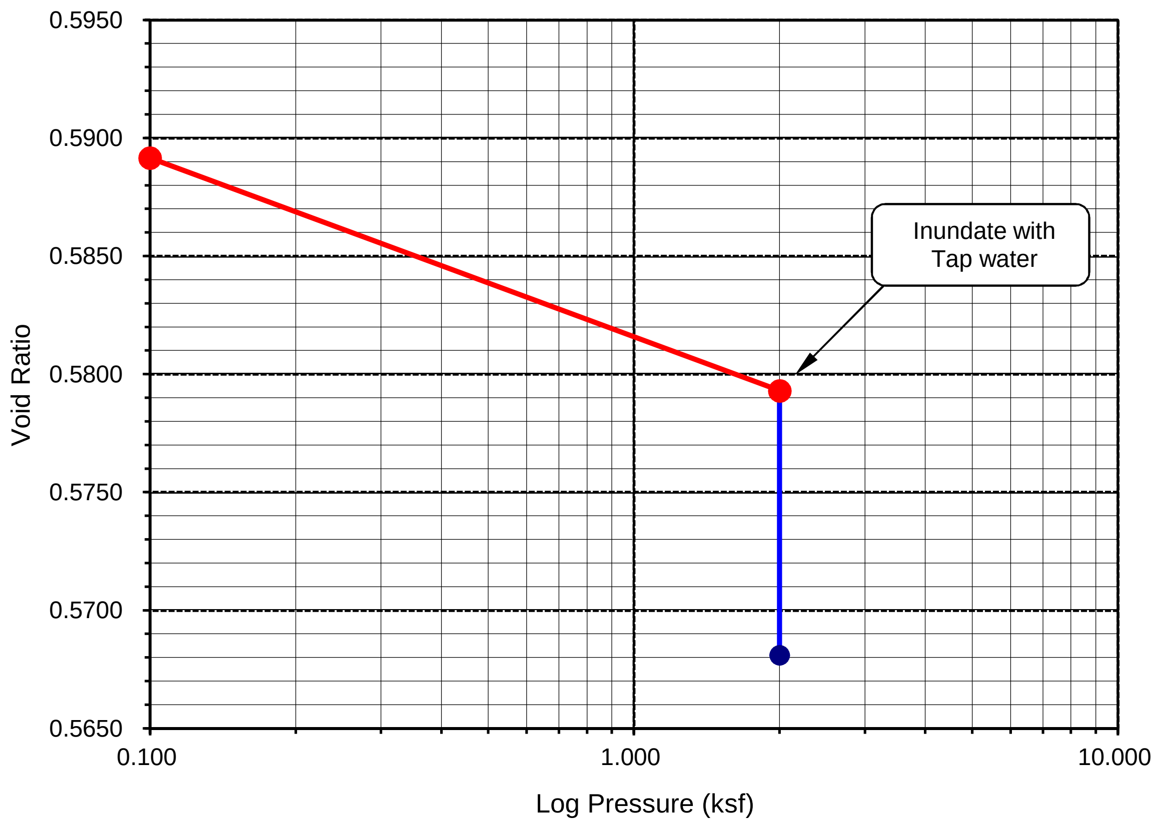
Initial Dry Density (pcf):	106.1
Initial Moisture (%):	7.47
Initial Length (in.):	1.0000
Initial Dial Reading:	0.2699
Diameter(in):	2.415

Final Dry Density (pcf):	107.5
Final Moisture (%) :	19.6
Initial Void Ratio:	0.5893
Specific Gravity(assumed):	2.70
Initial Saturation (%)	34.2

Pressure (p) (ksf)	Final Reading (in)	Apparent Thickness (in)	Load Compliance (%)	Swell (+) Settlement (-) % of Sample Thickness	Void Ratio	Corrected Deformation (%)
0.100	0.2698	0.9999	0.00	-0.01	0.5891	-0.01
2.000	0.2603	0.9904	0.33	-0.96	0.5793	-0.63
H_2O	0.2533	0.9834	0.33	-1.67	0.5681	-1.34

Percent Swell (+) / Settlement (-) After Inundation = -0.71

Void Ratio - Log Pressure Curve



ONE-DIMENSIONAL SWELL OR SETTLEMENT POTENTIAL OF COHESIVE SOILS

ASTM D 4546

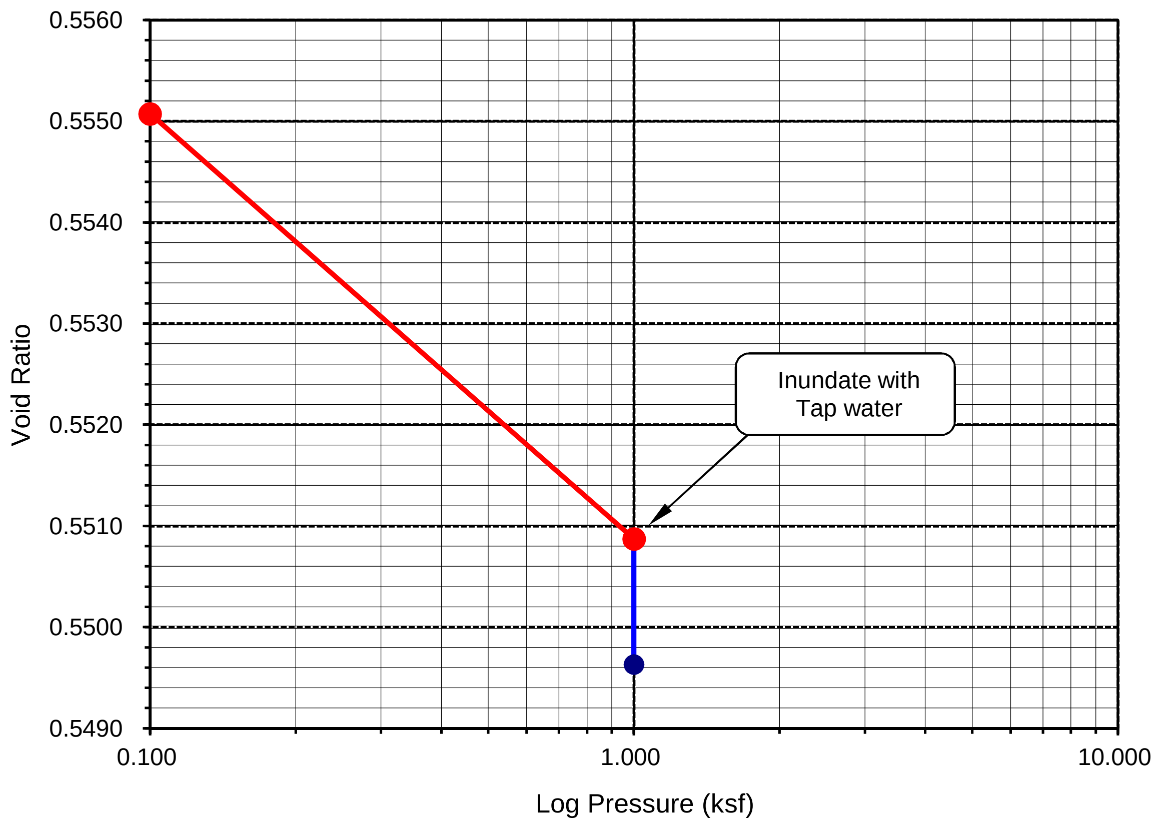
Project Name:	Covina	Tested By:	G. Bathala	Date:	11/26/19
Project No.:	19127-01	Checked By:	J. Ward	Date:	12/12/19
Boring No.:	HS-4	Sample Type:	Ring		
Sample No.:	R-2	Depth (ft.)	7.5		
Sample Description:	Dark yellowish brown silty sand (SM)				

Initial Dry Density (pcf):	108.4	Final Dry Density (pcf):	108.8
Initial Moisture (%):	7.25	Final Moisture (%) :	17.2
Initial Length (in.):	1.0000	Initial Void Ratio:	0.5554
Initial Dial Reading:	0.2613	Specific Gravity(assumed):	2.70
Diameter(in):	2.415	Initial Saturation (%)	35.3

Pressure (p) (ksf)	Final Reading (in)	Apparent Thickness (in)	Load Compliance (%)	Swell (+) Settlement (-) % of Sample Thickness	Void Ratio	Corrected Deformation (%)
0.100	0.2611	0.9998	0.00	-0.02	0.5551	-0.02
1.000	0.2573	0.9960	0.11	-0.40	0.5509	-0.29
H2O	0.2565	0.9952	0.11	-0.48	0.5496	-0.37

Percent Swell (+) / Settlement (-) After Inundation = -0.08

Void Ratio - Log Pressure Curve



ONE-DIMENSIONAL SWELL OR SETTLEMENT POTENTIAL OF COHESIVE SOILS

ASTM D 4546

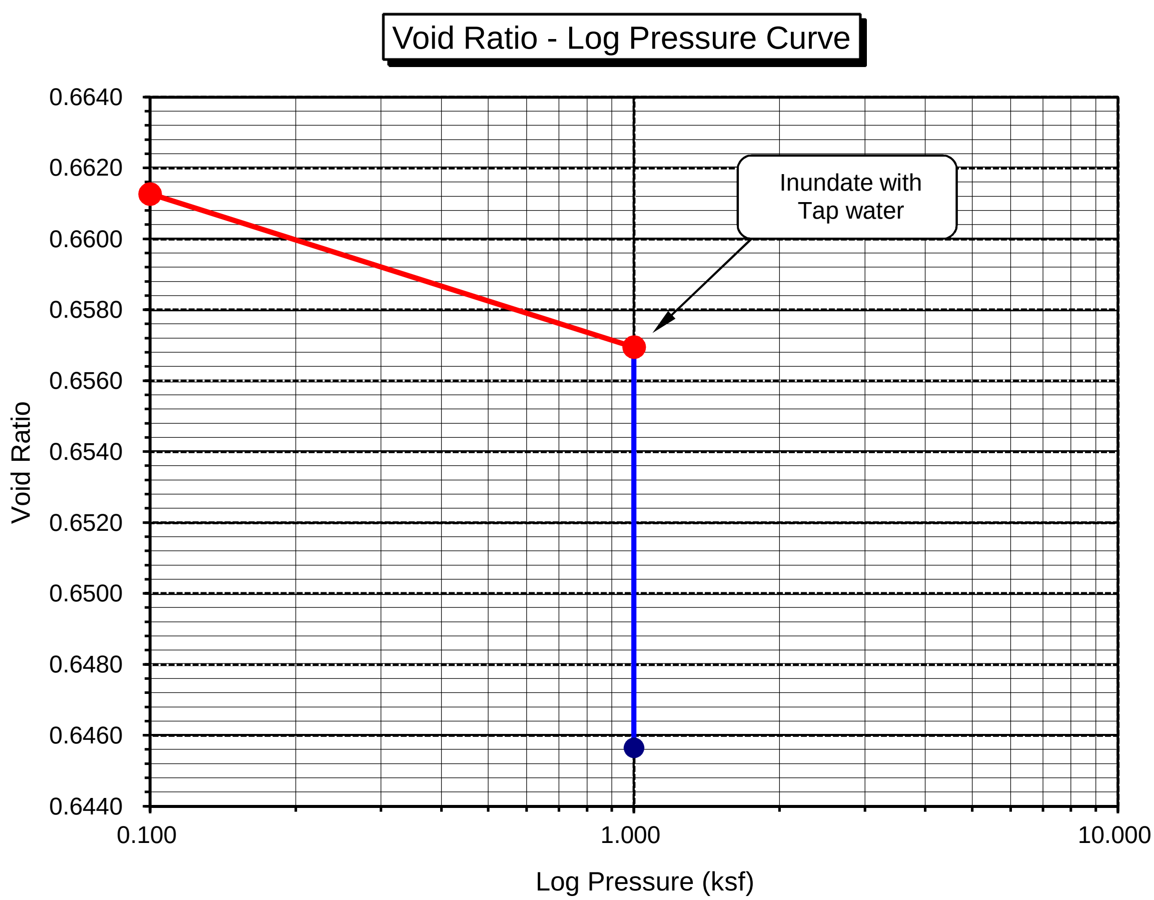
Project Name:	Covina	Tested By:	G. Bathala	Date:	11/26/19
Project No.:	19127-01	Checked By:	J. Ward	Date:	12/12/19
Boring No.:	I-1	Sample Type:	Ring		
Sample No.:	R-2	Depth (ft.)	7.5		

Sample Description: Dark yellowish brown sandy silt s(ML)

Initial Dry Density (pcf):	101.4	Final Dry Density (pcf):	102.4
Initial Moisture (%):	3.70	Final Moisture (%) :	20.6
Initial Length (in.):	1.0000	Initial Void Ratio:	0.6618
Initial Dial Reading:	0.2595	Specific Gravity(assumed):	2.70
Diameter(in):	2.415	Initial Saturation (%)	15.1

Pressure (p) (ksf)	Final Reading (in)	Apparent Thickness (in)	Load Compliance (%)	Swell (+) Settlement (-) % of Sample Thickness	Void Ratio	Corrected Deformation (%)
0.100	0.2592	0.9997	0.00	-0.03	0.6613	-0.03
1.000	0.2545	0.9950	0.21	-0.50	0.6569	-0.29
H2O	0.2477	0.9882	0.21	-1.18	0.6456	-0.97

Percent Swell (+) / Settlement (-) After Inundation = -0.68



APPENDIX B

LABORATORY TEST PROCEDURES AND TEST RESULTS

Moisture-Density

The in-situ moisture content and dry unit weights were determined for each of the undisturbed ring samples. The data obtained are shown on the boring logs.

Compaction Tests

One compaction test was performed to determine to moisture density relationships of the typical surficial soils encountered on the site. The laboratory standard used was in accordance with ASTM Test Designation D-1557-12. Summaries of the compaction test results are shown in Table B-2.

TABLE B-2
COMPACTION TEST RESULTS

Borings No. and Sample Depth	Description	Maximum Dry Density (pcf)	Optimum Moisture (%)
B-3 @ 3.5-6'	Dark brown, silty SAND	128.5	9.5

Consolidation Tests

Seven consolidation tests were performed on selected ring samples. The samples were inundated at an approximate load of one ton per square foot to monitor the hydroconsolidation. Loads were applied to the samples in several increments in geometric progression and resulting deformations were recorded at selected time intervals. Results of the consolidation tests are presented on Plates C-1 through C-7.

Appendix B

Direct Shear Tests

Natural and remolded (90 percent of the material's maximum density) samples were sheared in a strain-control type Direct Shear Machine. The sample was sheared under varying confining loads in order to determine the Coulomb shear strength parameters: cohesion (c), and angle of internal friction (ϕ) for peak and residual strength conditions. The samples were tested in an artificially-saturated condition. The results are plotted and a linear approximation is drawn of the failure curve. Results are shown on the Shear Test Diagrams, Plates SH-1 and SH-2 included in this appendix.

Expansion Index Test

To determine the expansion potential of the on-site soils, one expansion index test was conducted in accordance with the ASTD D-4829 on a sample from B-3 @ 3.5-6 feet. The ranges for expansion index potential are as follows:

0–20	Very Low
21–50	Low
51–90	Medium
91–130	High
>130	Very High

Table B-3 below presents the results.

TABLE B-3 EXPANSION INDEX TEST RESULTS		
Sample	**Expansion Index**	**Expansion Potential**
B-3@3.5-6'	Very low	3

Appendix B

Sulfates

Soluble sulfates react chemically with the hydrated lime and calcium aluminate of hardened cement to form calcium aluminate and calcium sulfo-aliminate. The effect is disintegration of the concrete. In addition to the potential detrimental effects of high concentrations of sulfate to certain admixtures of concrete, sulfates may catalyze reaction of certain clay minerals in soil columns which then undergo large, isolated volume changes which prove detrimental to some structures. Type V cement is normally used where sulfates are present.

Testing for soluble sulfates was performed on one representative sample of the material concentrated within the subject site by American Analytics (see Plate AA-1 this appendix). The results indicate that the soluble sulfate content is 39 ppm within the soil sample; therefore, the soils will have a negligible impact on the cement used at the site.

SULFATE EXPOSURE	RECOMMENDATIONS FOR CONCRETE IN SULFATE ENVIRONMENTS (AFTER TABLE 19-A-4)				
	SOLUBLE SULFATES IN SOIL, %	SULFATES IN WATER, PPM	CEMENT TYPE	MAXIMUM WATER/CEMENT RATIO	MINIMUM CEMENT CONTENT, LBS
Negligible	0-0.10	0-150			
Moderate	0.0.10-0.20	150-1,500	II	0.55	470
Severe	0.20-2.0	1,500-10,000	V	0.45	660
Very Severe	Over 2.0	Over 10,000	V + Pozzolan	0.45	660

Watt - Covina
W.O.: 7043

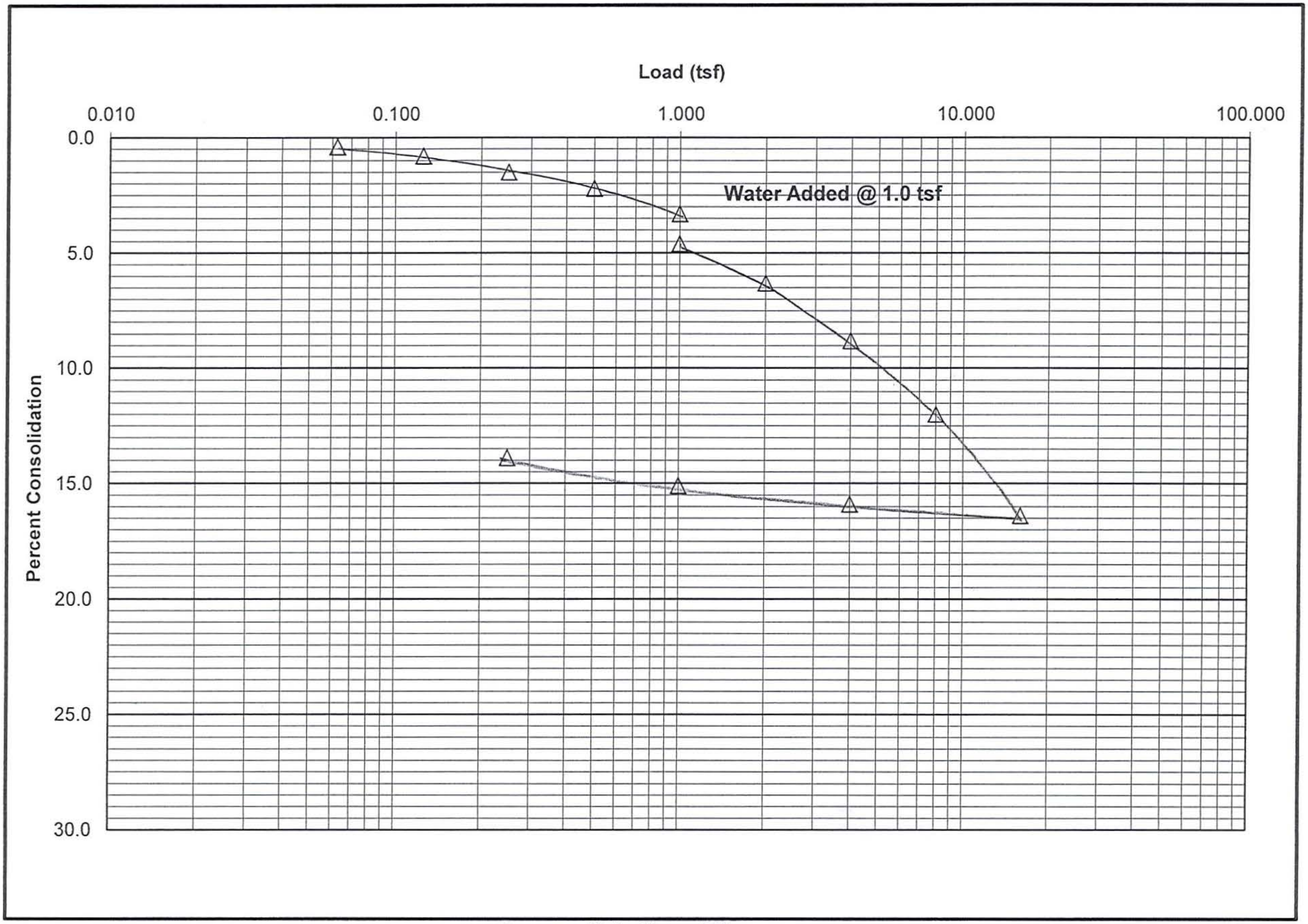
Date of Test: 5/17

GeoSoils Consultants, Inc.

Geotechnical Engineering * Engineering Geology

Moisture(%)
Before: 8.8 After: 20.7

Sample(in.)
Height: 1.00 Diameter: 2.36



Consolidation Diagram

B-1 @ 7.5'
Brown, slightly sandy SILT.

C7043.1.xls

Plate C-1

Watt - Covina
W.O.: 7043

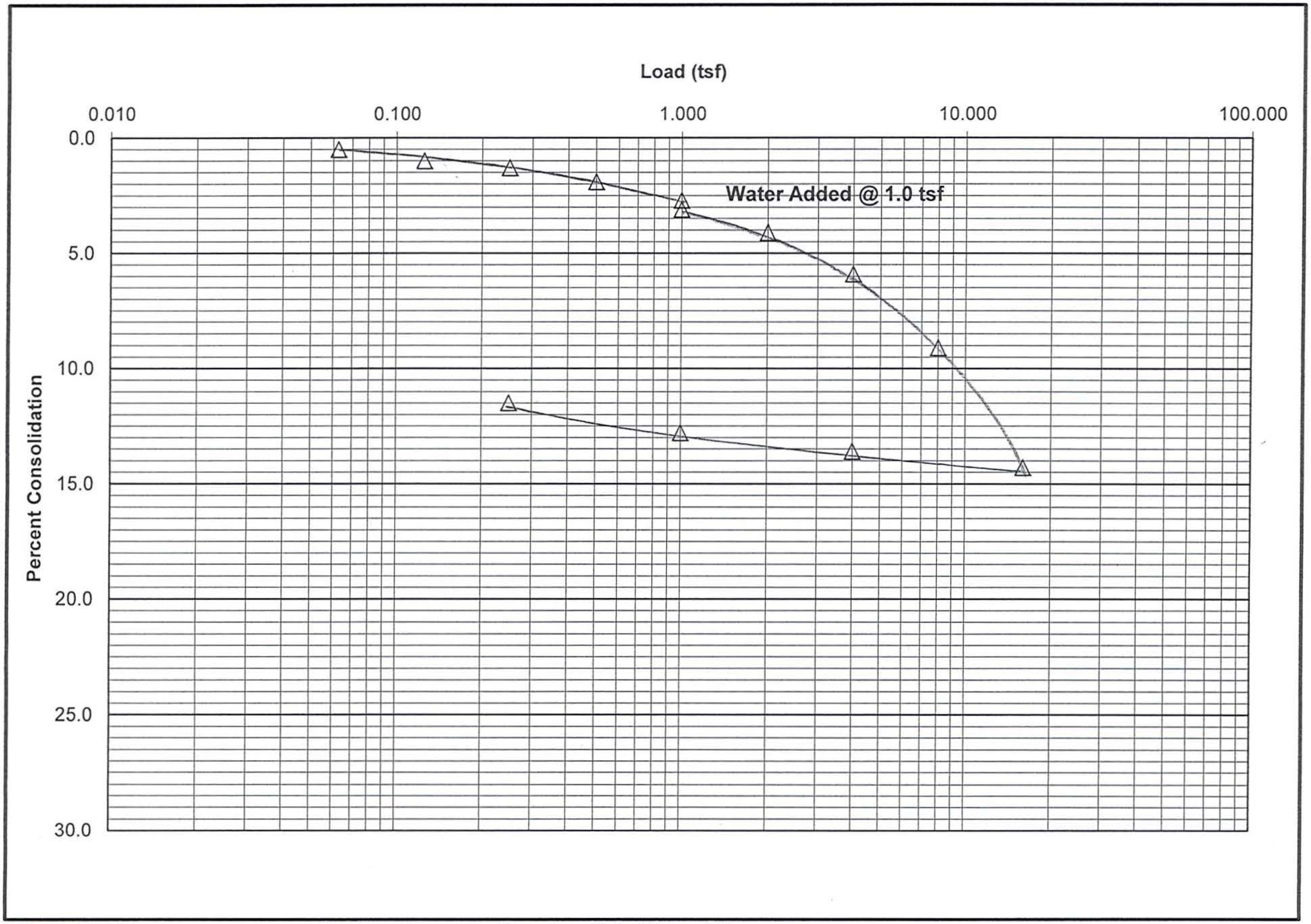
Date of Test: 5/17

GeoSoils Consultants, Inc.

Geotechnical Engineering * Engineering Geology

Moisture(%)
Before: 21.7 After: 19.9

Sample(in.)
Height: 1.00 Diameter: 2.36



B-1 @ 10.0'
Brown, clayey SILT.

Consolidation Diagram

C7043.2.xls

Plate C-2

Watt - Covina
W.O.: 7043

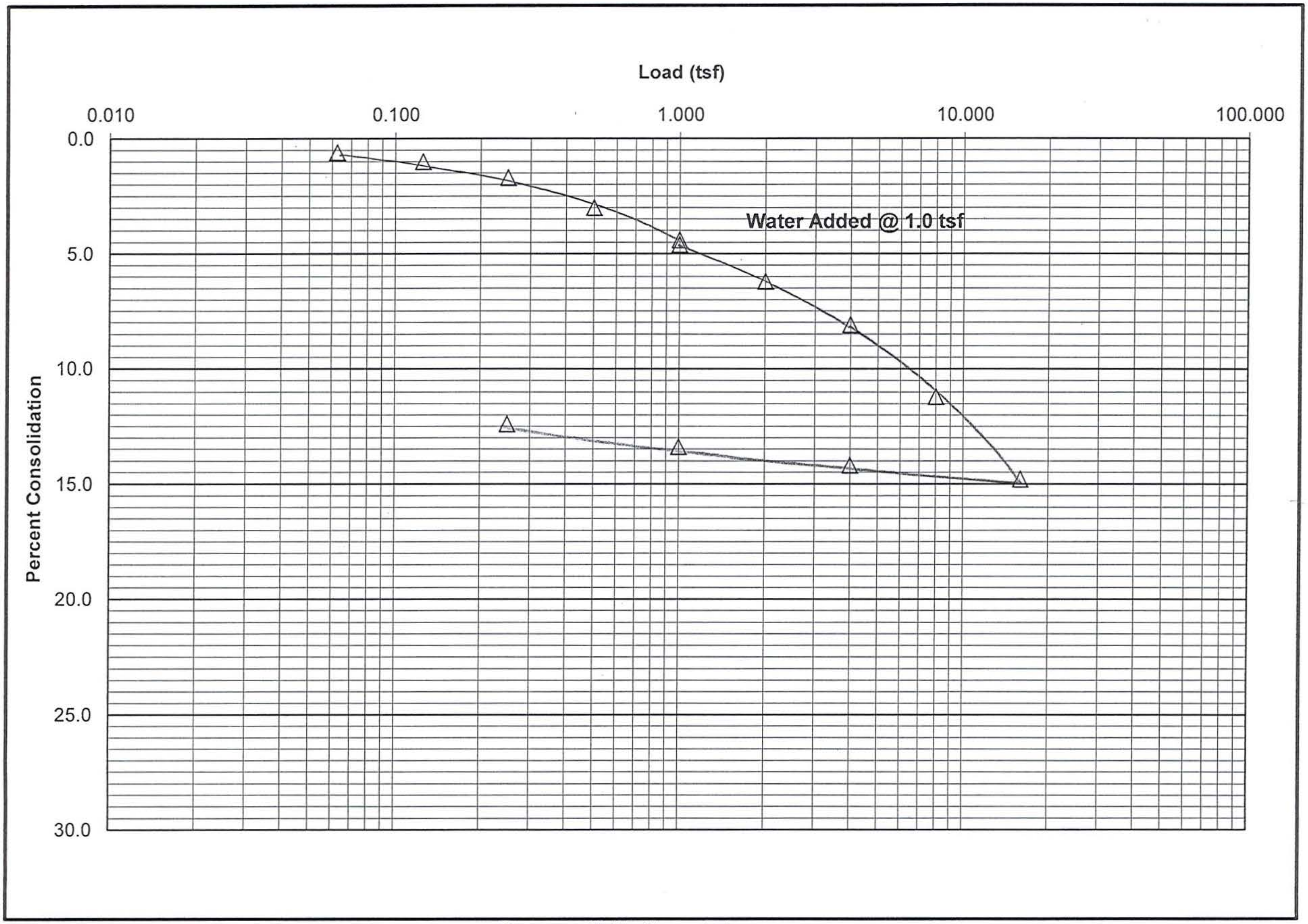
Date of Test: 5/17

GeoSoils Consultants, Inc.

Geotechnical Engineering * Engineering Geology

Moisture(%)
Before: 26.4 After: 14.5

Sample(in.)
Height: 1.00 Diameter: 2.36



B-1 @ 15.0'
Brown, clayey SILT.

Consolidation Diagram

C7043.3.xls

Plate C-3

Watt - Covina
W.O.: 7043

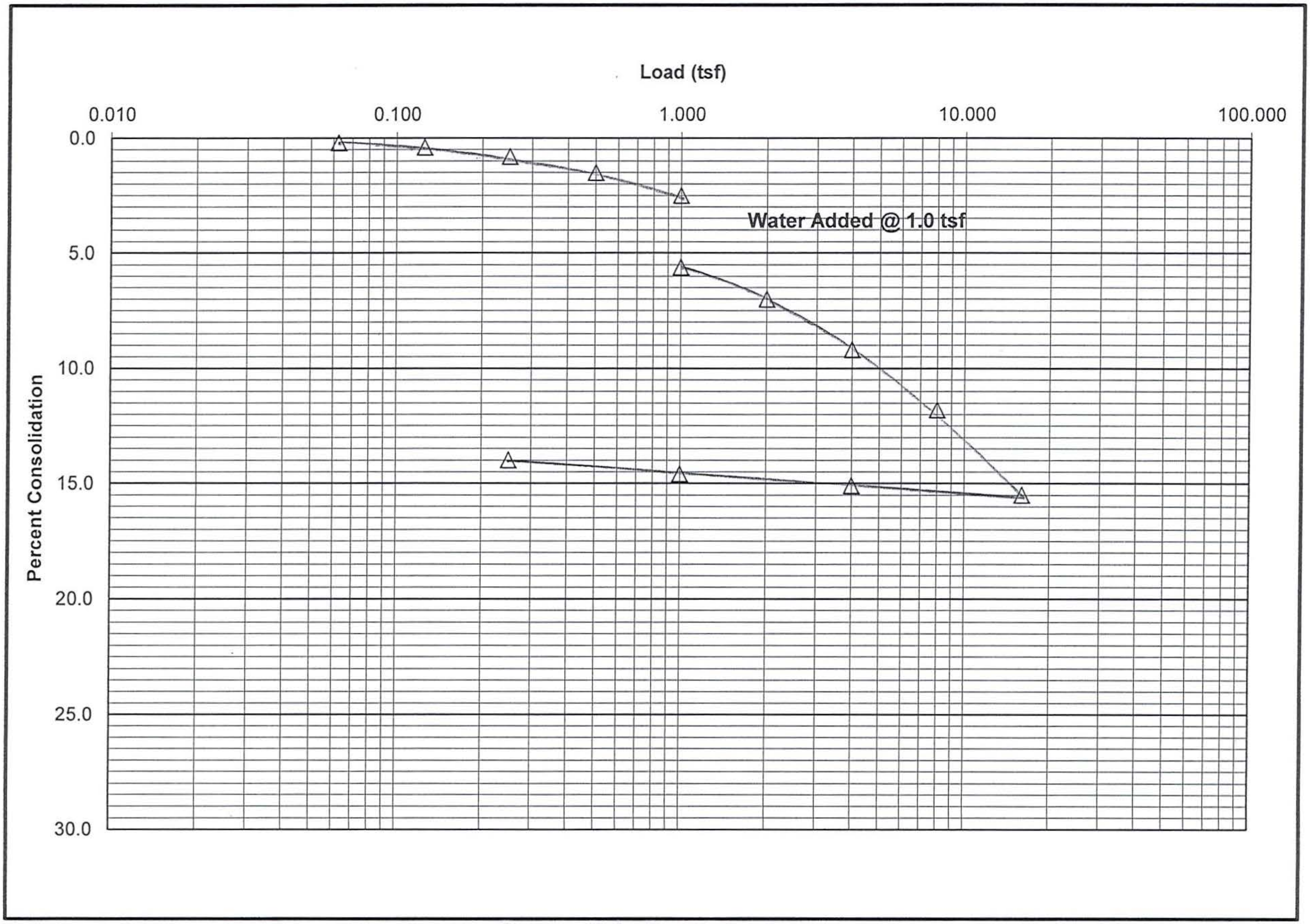
Date of Test: 5/17

GeoSoils Consultants, Inc.

Geotechnical Engineering * Engineering Geology

Moisture(%)
Before: 4.1 After: 19.3

Sample(in.)
Height: 1.00 Diameter: 2.36



B-2 @ 7.5'
Brown, silty SAND.

Consolidation Diagram

C7043.4.xls

Plate C-4

Watt - Covina
W.O.: 7043

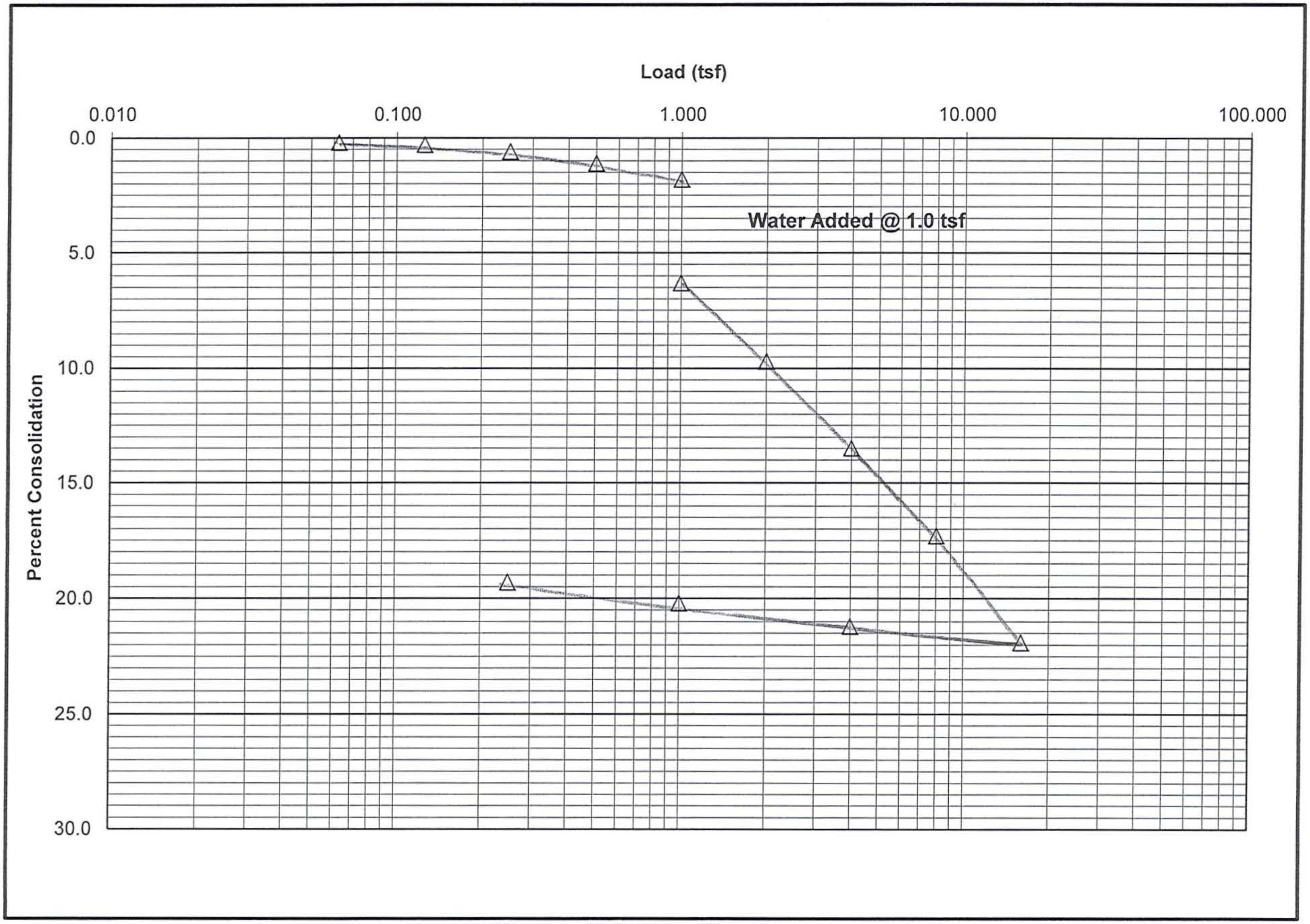
Date of Test: 5/17

GeoSoils Consultants, Inc.

Geotechnical Engineering * Engineering Geology

Moisture(%)
Before: 8.2 After: 16.7

Sample(in.)
Height: 1.00 Diameter: 2.36



B-2 @ 10.0'
Orange-brown, silty, slightly clayey SAND.

Consolidation Diagram

C7043.5.xls

Plate C-5

Watt - Covina
W.O.: 7043

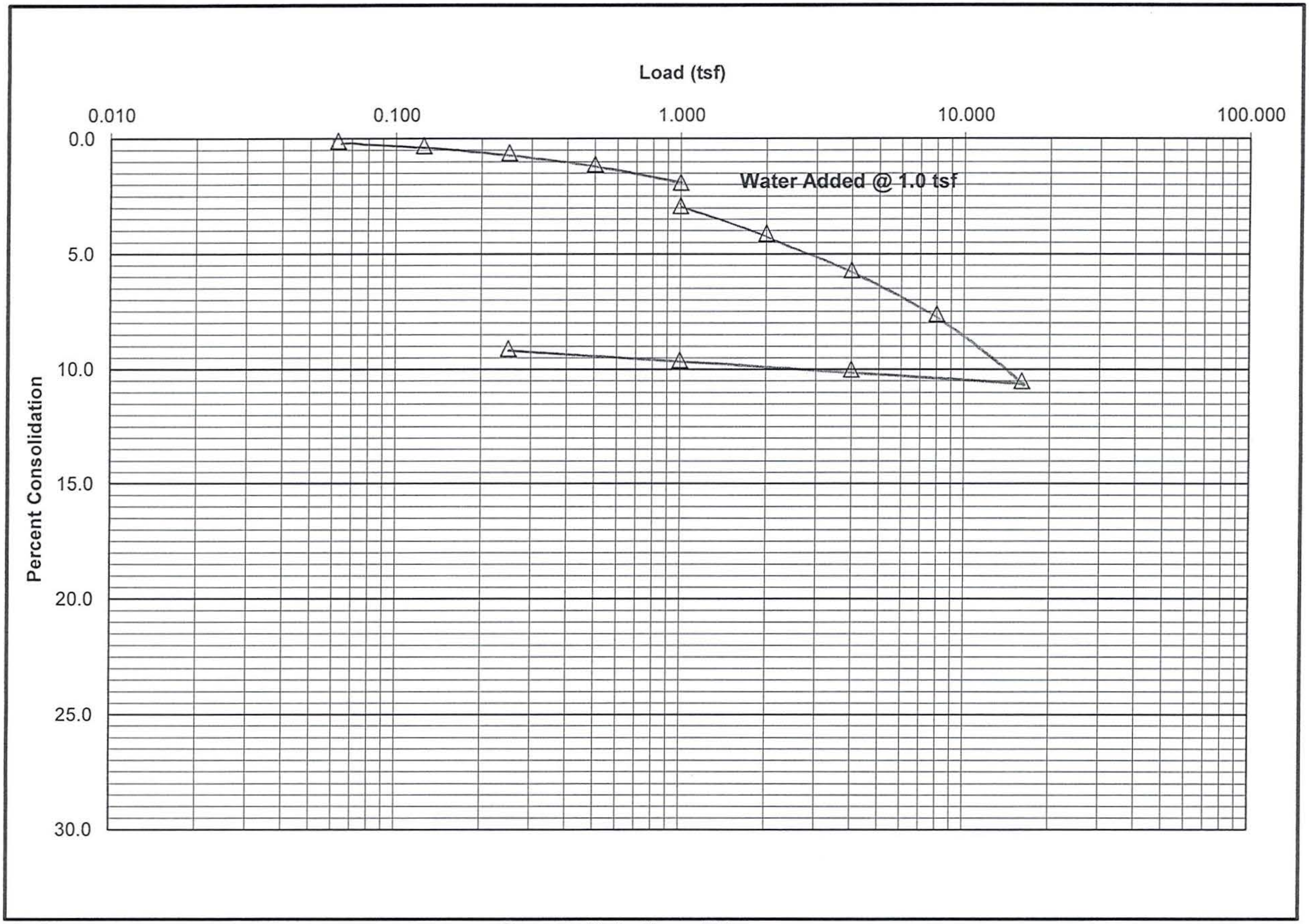
Date of Test: 5/17

GeoSoils Consultants, Inc.

Geotechnical Engineering * Engineering Geology

Moisture(%)
Before: 6.2 After: 20.4

Sample(in.)
Height: 1.00 Diameter: 2.36



B-3 @ 10.0'
Brown, silty SAND.

Consolidation Diagram

C7043.6.xls

Plate C-6

Watt - Covina
W.O.: 7043

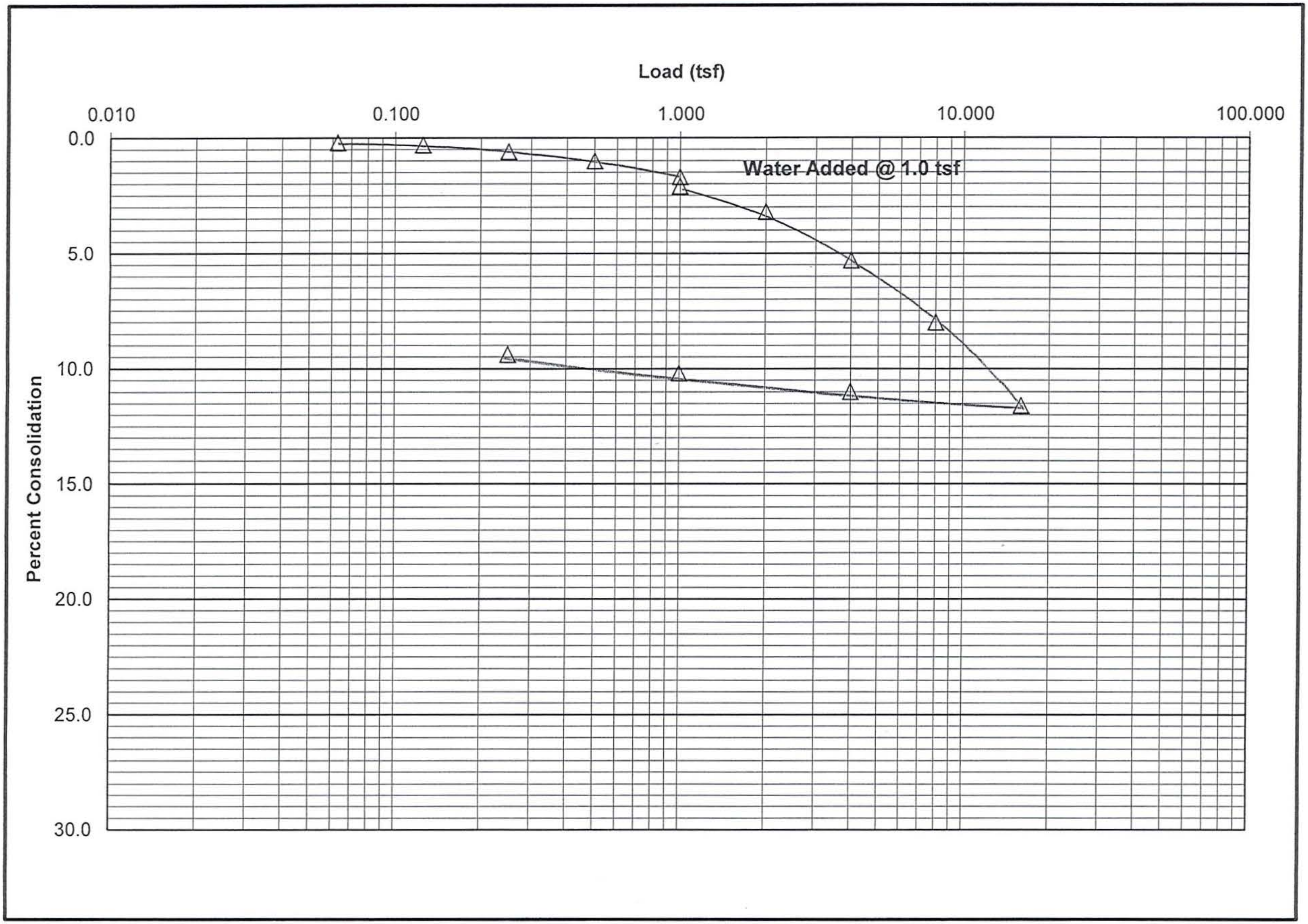
Date of Test: 5/17

GeoSoils Consultants, Inc.

Geotechnical Engineering * Engineering Geology

Moisture(%)
Before: 11.0 After: 14.1

Sample(in.)
Height: 1.00 Diameter: 2.36



B-2 @ 15.0'
Brown, silty SAND.

Consolidation Diagram

C7043.7.xls

Plate C-7

Watt - Covina
W.O.: 7043

Date of Test: 5/17

Sample: **B-2 @ 5.0'**

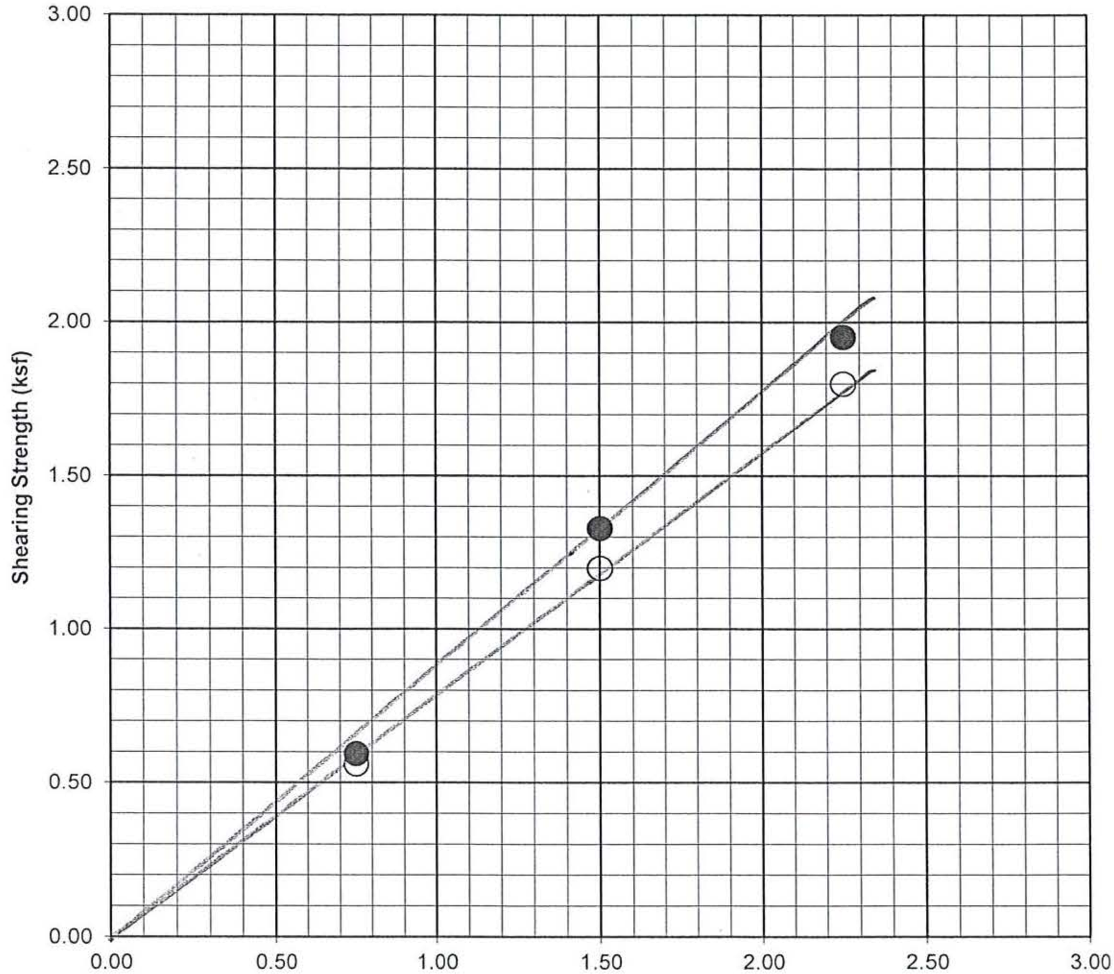
GeoSoils Consultants, Inc.

Geotechnical Engineering * Engineering Geology

PLATE SH-1

Shear Test Diagram
Peak
C(psf): 0 Phi (degrees): 40.0

Reshear
C(psf): 0 Phi (degrees): 37.0



Normal Pressure (ksf)
Direct Shear, Peak / Reshear Speed: .005 in./min.

● Peak Values ○ Reshear Values

Undisturbed **Natural** Shear-Saturated

Brown, silty SAND.

23.5% Saturated Moisture Content

7043.1.xls

Watt - Covina
W.O.: 7043

Date of Test: 5/17

Sample: **B-3 @ 3.5'-6.0'**

PLATE SH-1

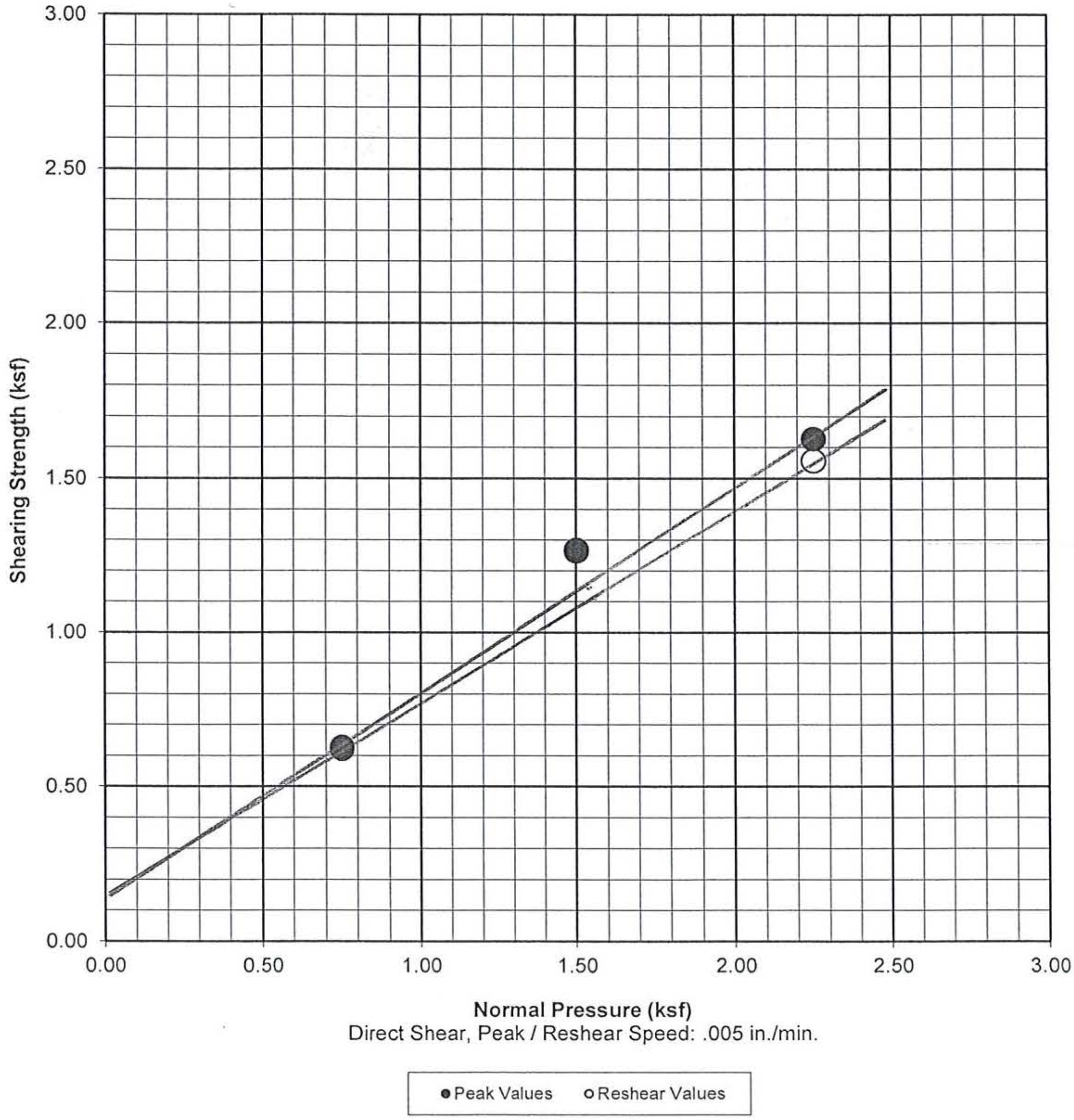
GeoSoils Consultants, Inc.

Geotechnical Engineering * Engineering Geology

Shear Test Diagram

Peak
C(psf): **150** Phi (degrees): **33.0**

Reshear
C(psf): **150** Phi (degrees): **32.0**



Direct Shear, Peak / Reshear Speed: .005 in./min.

Sample **Remolded** to 90% Relative Density, saturated.
Remolded Dry Density = 115.7 PCF

Dark brown silty sand.

MAX: 128.5 PCF: 9.5%
18.8% Saturated Moisture Content
7043.1.xls

AMERICAN ANALYTICS

LABORATORY ANALYSIS RESULTS

Client: Geosoils Consultants, Inc.
Project No: NA
Project Name: 7043

AA Project No: A61017/8
Date Received: 05/15/17
Date Reported: 05/22/17

ANALYTICAL DATA SUMMARY

Analyte	Sample Name	Result	MRL	Units	Dilution	Prepared	Analyzed	Method
		Sulfate by Ion Chromatography						
Sulfate	7043 B-2@5-7.5	**39**	5.0	mg/kg	1	05/19/17	05/19/17	EPA 300.0

Allen Aminian

Allen Aminian
QA/QC Manager

Plate AA-1

Appendix D
Infiltration Data

LA County Dry Well Constant Head Percolation Test Data Sheet

LGC Geotechnical, Inc
131 Calle Iglesia Suite A, San Clemente, CA 92672 tel. (949) 369-6141

Project Name:	**Trumark - Covina Bowl**
Project Number:	**19127-01**
Date:	**11/21/2019**
Location:	**I-1**
Approximate Test Duration:	**6 Hours**

Test hole dimensions (if circular)	
Boring Depth (feet)*:	49.5
Boring Diameter (inches):	8
Perforated Pipe Dia. (in):	3
3/4" Rock Backfill: (y/n)	y
Filter Sock: (y/n)	y

*measured at time of test

Main Test Data

Trial No.	Start Time (24:HR)	Avg Head of Water Above Bottom of Dry Well, H (feet)	Time Interval, Δt (min)	Volume of Water Per Reading (gal)	Time of Reading (sec)	Volume of Water per Time Interval (gal/Δt)	Volume of Water per Time Interval (ft^3/Δt)	Observed Field Flow Rate (ft^3/s)	Infiltration Surface Area (ft^2)	Raw Measured Infiltration Rate (in/hr)
1	9:15:00 AM			5	94					
2	9:30:00 AM	29.2	15	5	99	45.5	6.1	0.007	61.5	4.7
3	10:00:00 AM	29.2	30	5	122	73.8	9.9	0.005	61.5	3.8
4	10:30:00 AM	29.0	30	5	116	77.6	10.4	0.006	61.1	4.1
5	11:00:00 AM	29.0	30	5	113	79.6	10.6	0.006	61.1	4.2
6	11:30:00 AM	28.9	30	5	116	77.6	10.4	0.006	60.9	4.1
7	12:00:00 PM	28.9	30	5	105	85.7	11.5	0.006	60.9	4.5
8	12:30:00 PM	28.8	30	5	113	79.6	10.6	0.006	60.7	4.2
9	1:00:00 PM	28.8	30	5	119	75.6	10.1	0.006	60.7	4.0
10	1:30:00 PM	28.7	30	5	112	80.4	10.7	0.006	60.5	4.3
11	2:00:00 PM	28.7	30	5	112	80.4	10.7	0.006	60.5	4.3
12	2:30:00 PM	28.7	30	5	116	77.6	10.4	0.006	60.5	4.1
13	3:00:00 PM	28.6	30	5	111	81.1	10.8	0.006	60.2	4.3
14	3:15:00 PM	28.5	15	5	114	39.5	5.3	0.006	60.0	4.2
					Total Gallons	**954**				

Measured Stabilized Flow Rate (ft^3/s) (Including NO Reduction Factors): **0.006**

Raw Measured Infiltration Rate (in/hr) (Including NO Reduction Factors): **4.2**

Sketch:

Notes:

Based on Guidelines from: LA County dated 06/2017
Spreadsheet Revised on: 11/22/2019

Appendix E
General Earthwork and Grading Specifications

General Earthwork and Grading Specifications for Rough Grading

1.0 General

1.1 Intent

These General Earthwork and Grading Specifications are for the grading and earthwork shown on the approved grading plan(s) and/or indicated in the geotechnical report(s). These Specifications are a part of the recommendations contained in the geotechnical report(s). In case of conflict, the specific recommendations in the geotechnical report shall supersede these more general Specifications. Observations of the earthwork by the project Geotechnical Consultant during the course of grading may result in new or revised recommendations that could supersede these specifications or the recommendations in the geotechnical report(s).

1.2 The Geotechnical Consultant of Record

Prior to commencement of work, the owner shall employ a qualified Geotechnical Consultant of Record (Geotechnical Consultant). The Geotechnical Consultant shall be responsible for reviewing the approved geotechnical report(s) and accepting the adequacy of the preliminary geotechnical findings, conclusions, and recommendations prior to the commencement of the grading.

Prior to commencement of grading, the Geotechnical Consultant shall review the "work plan" prepared by the Earthwork Contractor (Contractor) and schedule sufficient personnel to perform the appropriate level of observation, mapping, and compaction testing.

During the grading and earthwork operations, the Geotechnical Consultant shall observe, map, and document the subsurface exposures to verify the geotechnical design assumptions. If the observed conditions are found to be significantly different than the interpreted assumptions during the design phase, the Geotechnical Consultant shall inform the owner, recommend appropriate changes in design to accommodate the observed conditions, and notify the review agency where required.

The Geotechnical Consultant shall observe the moisture-conditioning and processing of the subgrade and fill materials and perform relative compaction testing of fill to confirm that the attained level of compaction is being accomplished as specified. The Geotechnical Consultant shall provide the test results to the owner and the Contractor on a routine and frequent basis.

1.3 The Earthwork Contractor

The Earthwork Contractor (Contractor) shall be qualified, experienced, and knowledgeable in earthwork logistics, preparation and processing of ground to receive fill, moisture-conditioning and processing of fill, and compacting fill. The Contractor shall review and accept the plans, geotechnical report(s), and these Specifications prior to commencement of grading. The Contractor shall be solely responsible for performing the grading in accordance with the project plans and specifications. The Contractor shall prepare and submit to the owner and the Geotechnical Consultant a work plan that indicates the sequence of earthwork grading, the number of “equipment” of work and the estimated quantities of daily earthwork

contemplated for the site prior to commencement of grading. The Contractor shall inform the owner and the
Geotechnical Consultant of changes in work schedules and updates to the work plan at least 24 hours in advance of such changes so that appropriate personnel will be available for observation and testing. The Contractor shall not assume that the Geotechnical Consultant is aware of all grading operations.

The Contractor shall have the sole responsibility to provide adequate equipment and methods to accomplish the earthwork in accordance with the applicable grading codes and agency ordinances, these Specifications, and the recommendations in the approved geotechnical report(s) and grading plan(s). If, in the opinion of the Geotechnical Consultant, unsatisfactory conditions, such as unsuitable soil, improper moisture condition, inadequate compaction, insufficient buttress key size, adverse weather, etc., are resulting in a quality of work less than required in these specifications, the Geotechnical Consultant shall reject the work and may recommend to the owner that construction be stopped until the conditions are rectified. It is the contractor's sole responsibility to provide proper fill compaction.

2.0 Preparation of Areas to be Filled

2.1 Clearing and Grubbing

Vegetation, such as brush, grass, roots, and other deleterious material shall be sufficiently removed and properly disposed of in a method acceptable to the owner, governing agencies, and the Geotechnical Consultant.

The Geotechnical Consultant shall evaluate the extent of these removals depending on specific site conditions. Earth fill material shall not contain more than 1 percent of organic materials (by volume). Nesting of the organic materials shall not be allowed.

If potentially hazardous materials are encountered, the Contractor shall stop work in the affected area, and a hazardous material specialist shall be informed immediately for proper evaluation and handling of these materials prior to continuing to work in that area.

As presently defined by the State of California, most refined petroleum products (gasoline, diesel fuel, motor oil, grease, coolant, etc.) have chemical constituents that are considered to be hazardous waste. As such, the indiscriminate dumping or spillage of these fluids onto the ground may constitute a misdemeanor, punishable by fines and/or imprisonment, and shall not be allowed. The contractor is responsible for all hazardous waste relating to his work. The Geotechnical Consultant does not have expertise in this area. If hazardous waste is a concern, then the Client should acquire the services of a qualified environmental assessor.

2.2 Processing

Existing ground that has been declared satisfactory for support of fill by the Geotechnical Consultant shall be scarified to a minimum depth of 6 inches. Existing ground that is not satisfactory shall be over-excavated as specified in the following section. Scarification shall continue until soils are broken down and free of oversize material and the working surface is reasonably uniform, flat, and free of uneven features that would inhibit uniform compaction.

2.3 *Over-excavation*

In addition to removals and over-excavations recommended in the approved geotechnical report(s) and the grading plan, soft, loose, dry, saturated, spongy, organic-rich, highly fractured or otherwise unsuitable ground shall be over-excavated to competent ground as evaluated by the Geotechnical Consultant during grading.

2.4 *Benching*

Where fills are to be placed on ground with slopes steeper than 5:1 (horizontal to vertical units), the ground shall be stepped or benched. Please see the Standard Details for a graphic illustration. The lowest bench or key shall be a minimum of 15 feet wide and at least 2 feet deep, into competent material as evaluated by the Geotechnical Consultant. Other benches shall be excavated a minimum height of 4 feet into competent material or as otherwise recommended by the Geotechnical Consultant. Fill placed on ground sloping flatter than 5:1 shall also be benched or otherwise over-excavated to provide a flat subgrade for the fill.

2.5 *Evaluation/Acceptance of Fill Areas*

All areas to receive fill, including removal and processed areas, key bottoms, and benches, shall be observed, mapped, elevations recorded, and/or tested prior to being accepted by the Geotechnical Consultant as suitable to receive fill. The Contractor shall obtain a written acceptance from the Geotechnical Consultant prior to fill placement. A licensed surveyor shall provide the survey control for determining elevations of processed areas, keys, and benches.

3.0 *Fill Material*

3.1 *General*

Material to be used as fill shall be essentially free of organic matter and other deleterious substances evaluated and accepted by the Geotechnical Consultant prior to placement. Soils of poor quality, such as those with unacceptable gradation, high expansion potential, or low strength shall be placed in areas acceptable to the Geotechnical Consultant or mixed with other soils to achieve satisfactory fill material.

3.2 *Oversize*

Oversize material defined as rock, or other irreducible material with a maximum dimension greater than 8 inches, shall not be buried or placed in fill unless location, materials, and placement methods are specifically accepted by the Geotechnical Consultant. Placement operations shall be such that nesting of oversized material does not occur and such that oversize material is completely surrounded by compacted or densified fill. Oversize material shall not be placed within 10 vertical feet of finish grade or within 2 feet of future utilities or underground construction.

3.3 *Import*

If importing of fill material is required for grading, proposed import material shall meet the requirements of the geotechnical consultant. The potential import source shall be given to the Geotechnical Consultant at least 48 hours (2 working days) before importing begins so that its suitability can be determined and appropriate tests performed.

4.0 *Fill Placement and Compaction*

4.1 *Fill Layers*

Approved fill material shall be placed in areas prepared to receive fill (per Section 3.0) in near-horizontal layers not exceeding 8 inches in loose thickness. The Geotechnical Consultant may accept thicker layers if testing indicates the grading procedures can adequately compact the thicker layers. Each layer shall be spread evenly and mixed thoroughly to attain relative uniformity of material and moisture throughout.

4.2 *Fill Moisture Conditioning*

Fill soils shall be watered, dried back, blended, and/or mixed, as necessary to attain a relatively uniform moisture content at or slightly over optimum. Maximum density and optimum soil moisture content tests shall be performed in accordance with the American Society of Testing and Materials (ASTM Test Method D1557).

4.3 *Compaction of Fill*

After each layer has been moisture-conditioned, mixed, and evenly spread, it shall be uniformly compacted to not less than 90 percent of maximum dry density (ASTM Test Method D1557). Compaction equipment shall be adequately sized and be either specifically designed for soil compaction or of proven reliability to efficiently achieve the specified level of compaction with uniformity.

4.4 *Compaction of Fill Slopes*

In addition to normal compaction procedures specified above, compaction of slopes shall be accomplished by backrolling of slopes with sheepsfoot rollers at increments of 3 to 4 feet in fill elevation, or by other methods producing satisfactory results acceptable to the Geotechnical Consultant. Upon completion of grading, relative compaction of the fill, out to the slope face, shall be at least 90 percent of maximum density per ASTM Test Method D1557.

4.5 *Compaction Testing*

Field tests for moisture content and relative compaction of the fill soils shall be performed by the Geotechnical Consultant. Location and frequency of tests shall be at the Consultant's discretion based on field conditions encountered. Compaction test locations will not necessarily be selected on a random basis. Test locations shall be selected to verify adequacy of compaction levels in areas that are judged to be prone to inadequate compaction (such as close to slope faces and at the fill/bedrock benches).

4.6 Frequency of Compaction Testing

Tests shall be taken at intervals not exceeding 2 feet in vertical rise and/or 1,000 cubic yards of compacted fill soils embankment. In addition, as a guideline, at least one test shall be taken on slope faces for each 5,000 square feet of slope face and/or each 10 feet of vertical height of slope. The Contractor shall assure that fill construction is such that the testing schedule can be accomplished by the Geotechnical Consultant. The Contractor shall stop or slow down the earthwork construction if these minimum standards are not met.

4.7 Compaction Test Locations

The Geotechnical Consultant shall document the approximate elevation and horizontal coordinates of each test location. The Contractor shall coordinate with the project surveyor to assure that sufficient grade stakes are established so that the Geotechnical Consultant can determine the test locations with sufficient accuracy. At a minimum, two grade stakes within a horizontal distance of 100 feet and vertically less than 5 feet apart from potential test locations shall be provided.

5.0 Subdrain Installation

Subdrain systems shall be installed in accordance with the approved geotechnical report(s), the grading plan, and the Standard Details. The Geotechnical Consultant may recommend additional subdrains and/or changes in subdrain extent, location, grade, or material depending on conditions encountered during grading. All subdrains shall be surveyed by a land surveyor/civil engineer for line and grade after installation and prior to burial. Sufficient time should be allowed by the Contractor for these surveys.

6.0 Excavation

Excavations, as well as over-excavation for remedial purposes, shall be evaluated by the Geotechnical Consultant during grading. Remedial removal depths shown on geotechnical plans are estimates only. The actual extent of removal shall be determined by the Geotechnical Consultant based on the field evaluation of exposed conditions during grading. Where fill-over-cut slopes are to be graded, the cut portion of the slope shall be made, evaluated, and accepted by the Geotechnical Consultant prior to placement of materials for construction of the fill portion of the slope, unless otherwise recommended by the Geotechnical Consultant.

7.0 Trench Backfills

7.1 The Contractor shall follow all OHSA and Cal/OSHA requirements for safety of trench excavations.

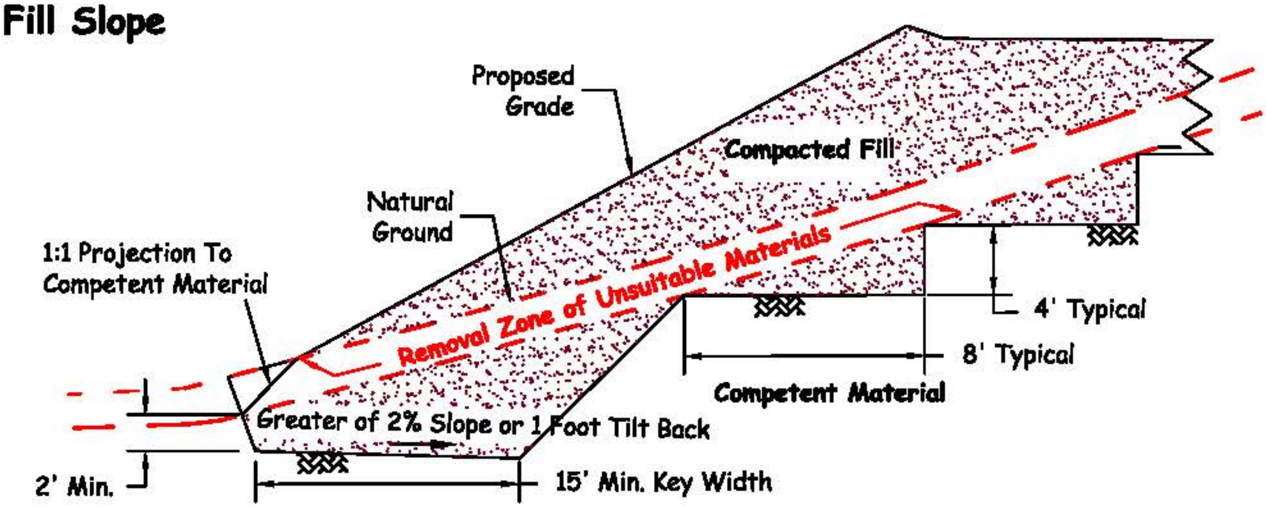
7.2 All bedding and backfill of utility trenches shall be done in accordance with the applicable provisions of Standard Specifications of Public Works Construction. Bedding material shall have a Sand Equivalent greater than 30 (SE>30). The bedding shall be placed to 1 foot over the top of the conduit and densified by jetting. Backfill shall be placed and densified to a minimum of 90 percent of maximum from 1 foot above the top of the conduit to the surface.

7.3 The jetting of the bedding around the conduits shall be observed by the Geotechnical Consultant.

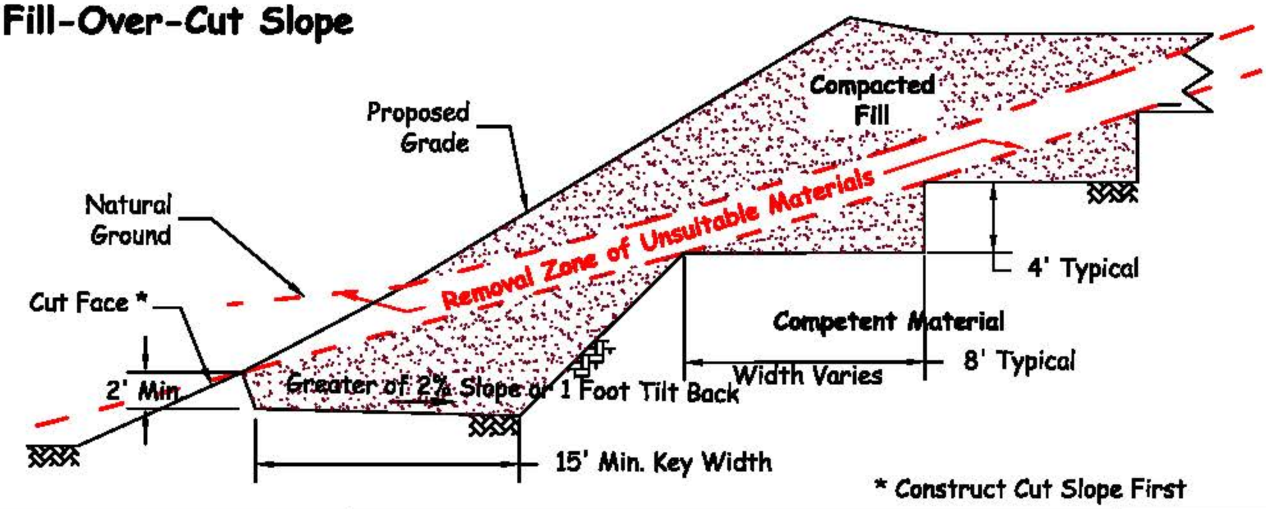
7.4 The Geotechnical Consultant shall test the trench backfill for relative compaction. At least one test should be made for every 300 feet of trench and 2 feet of fill.

7.5 Lift thickness of trench backfill shall not exceed those allowed in the Standard Specifications of Public Works Construction unless the Contractor can demonstrate to the Geotechnical Consultant that the fill lift can be compacted to the minimum relative compaction by his alternative equipment and method.

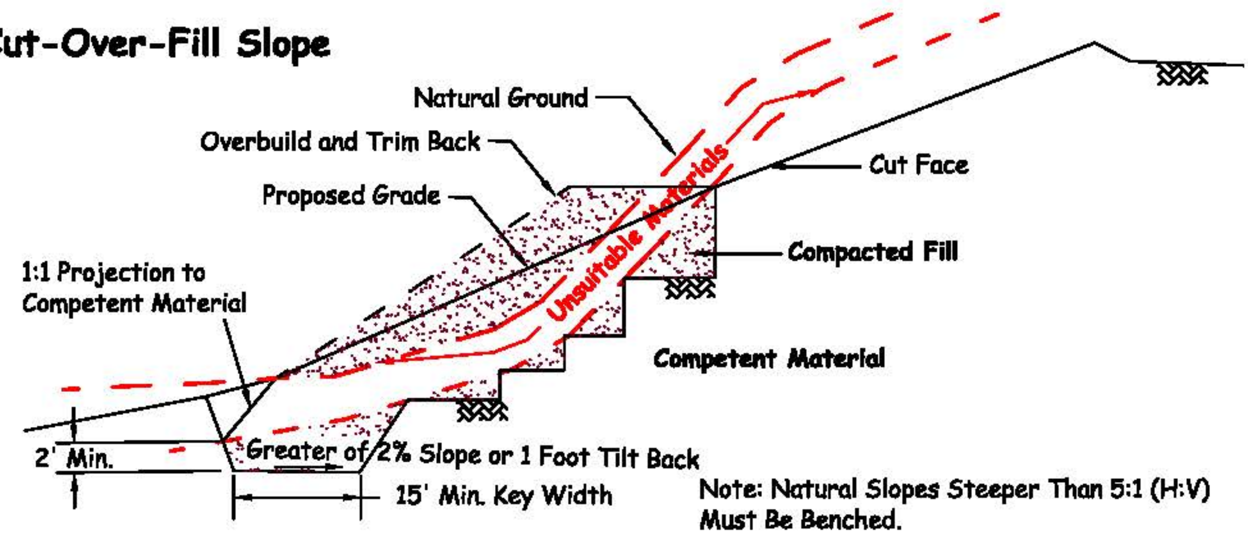
Fill Slope



Fill-Over-Cut Slope



Cut-Over-Fill Slope



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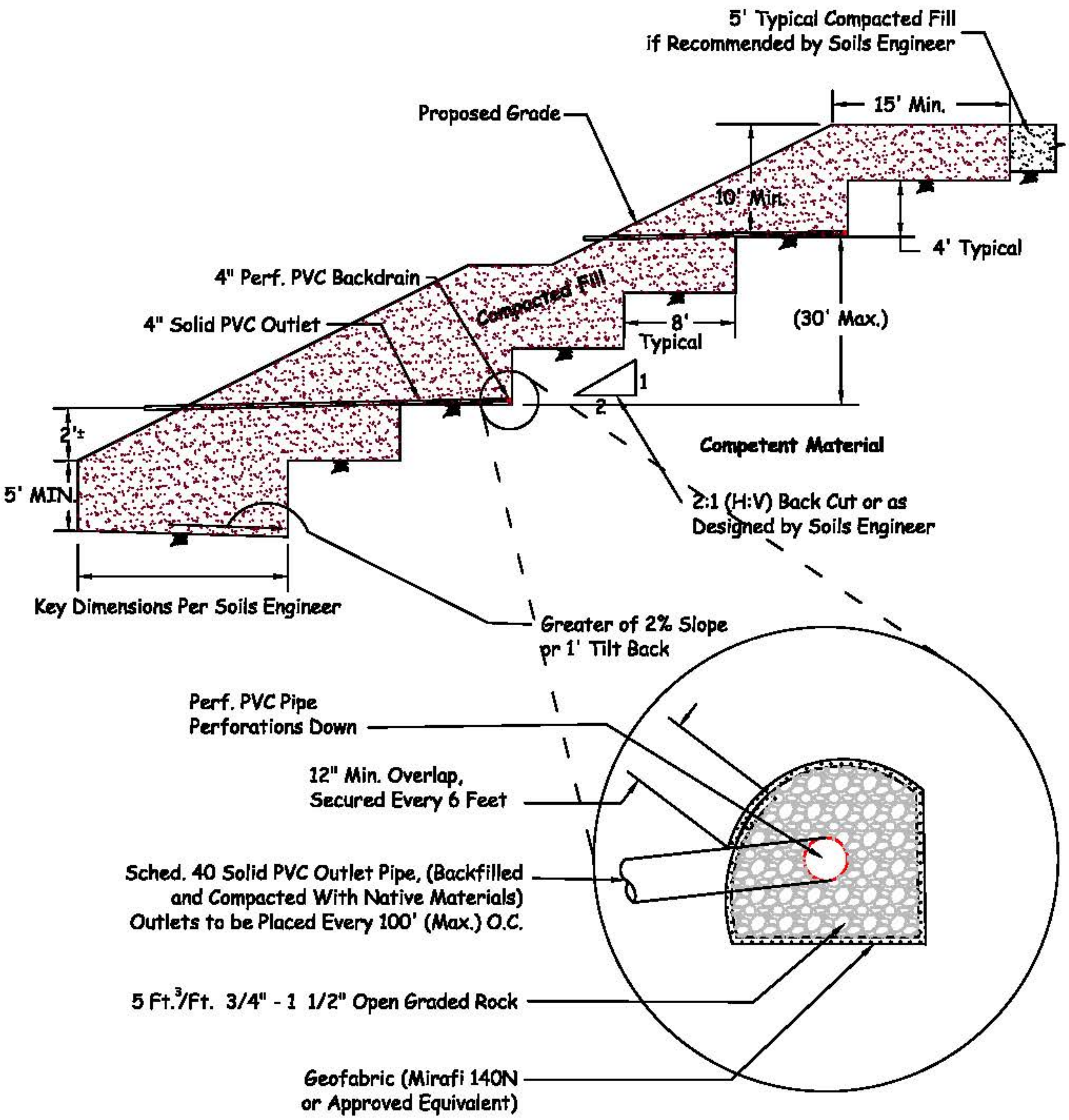
KEYING AND BENCHING



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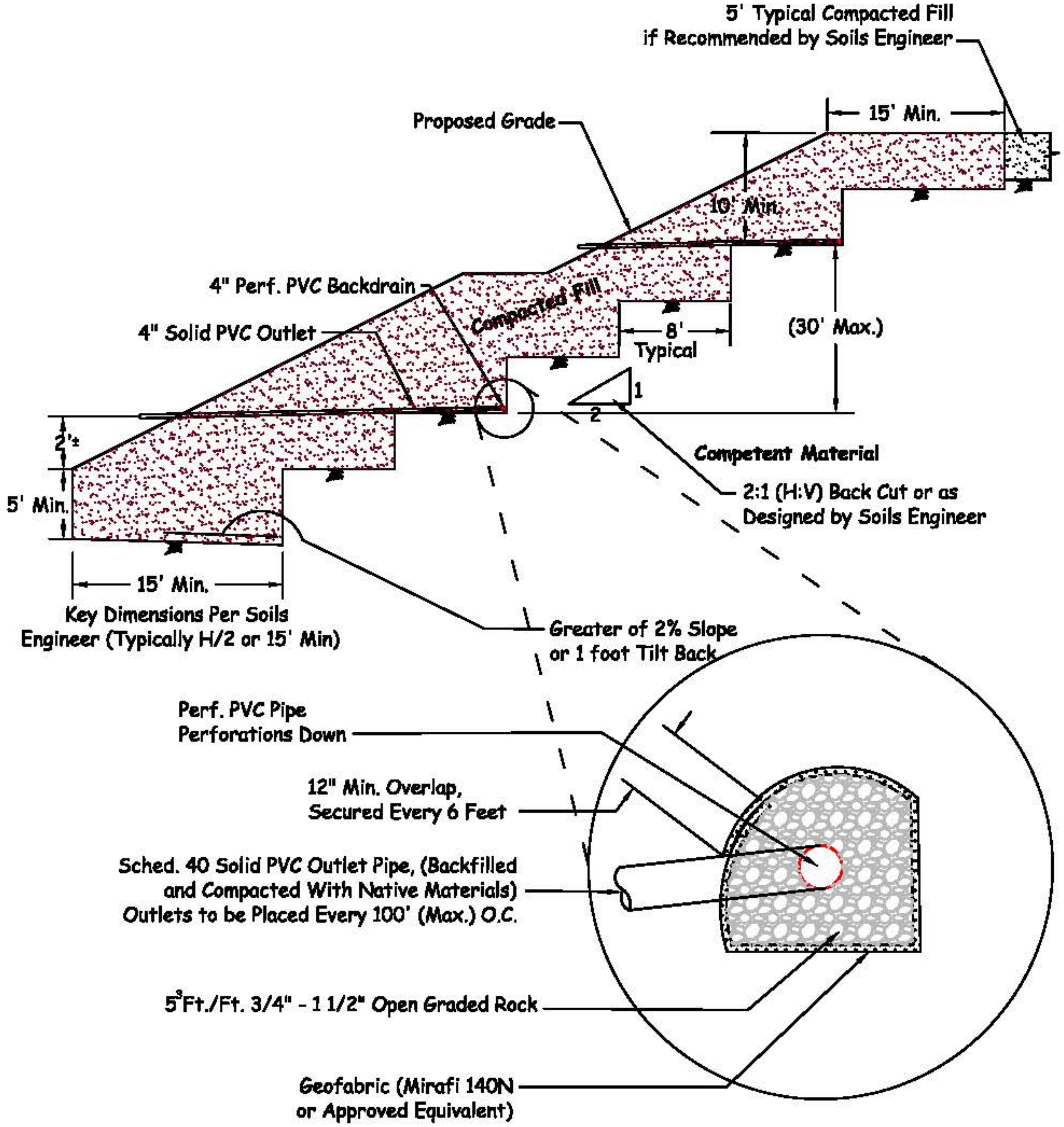
TYPICAL BUTTRESS DETAIL



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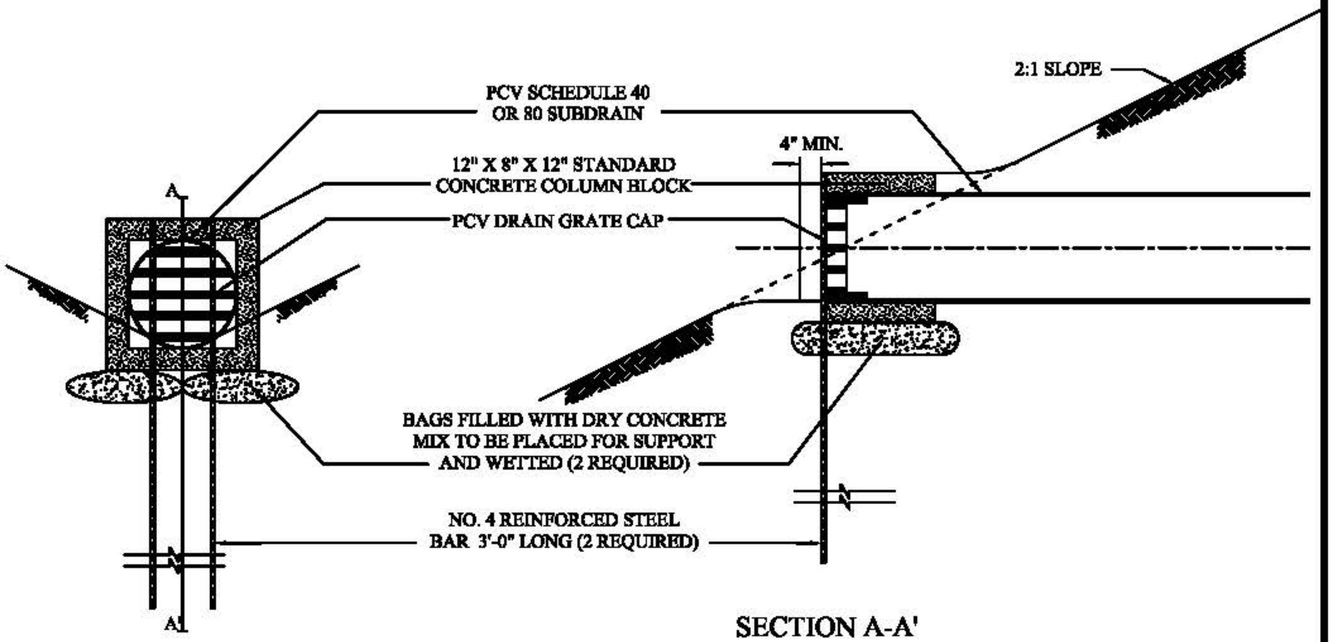
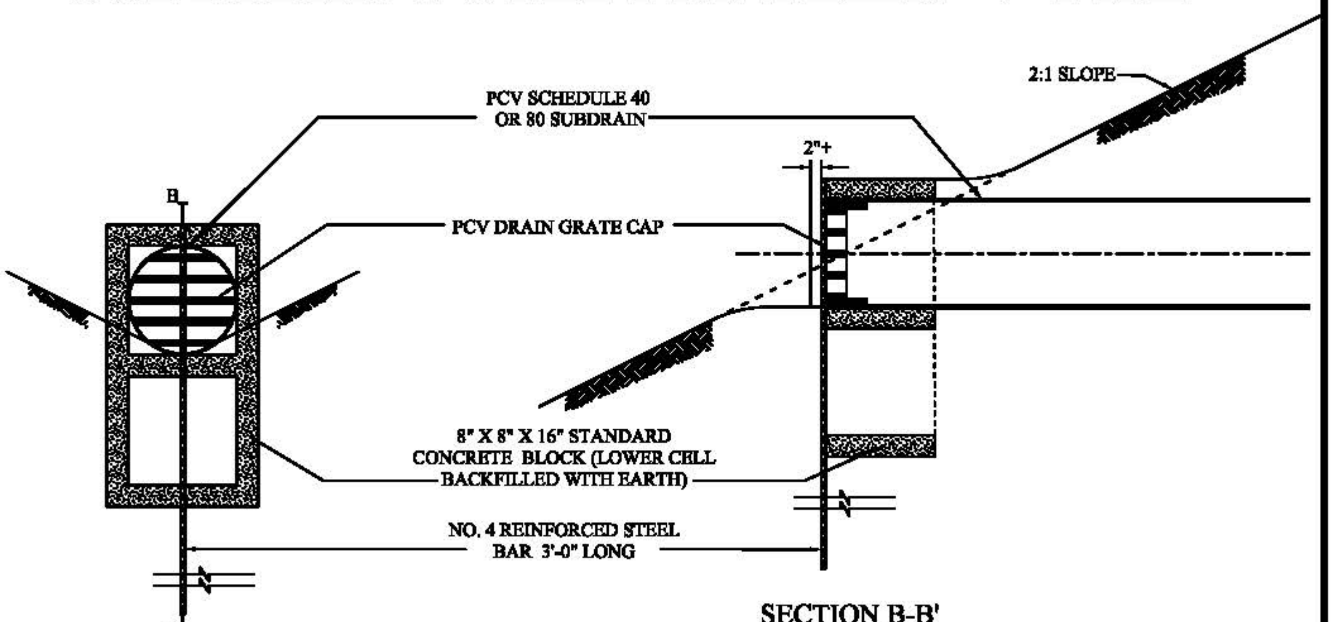
TYPICAL STABILIZATION FILL DETAIL

SUBDRAIN OUTLET MARKER -6" & 8" PIPE



SUBDRAIN OUTLET MARKER -4" PIPE



NOT TO SCALE

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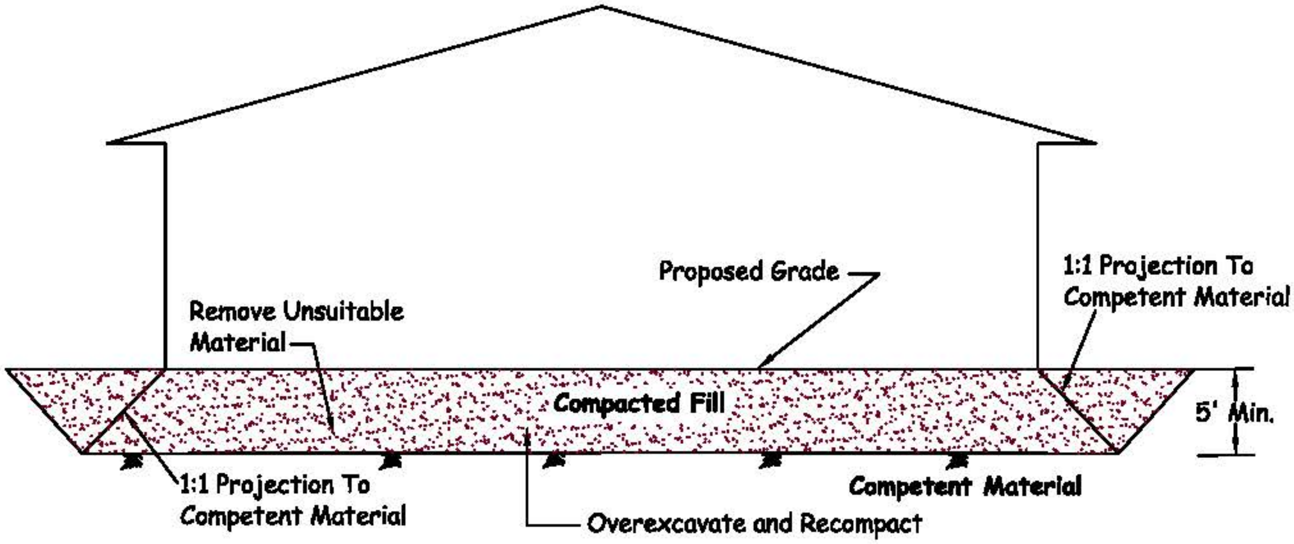
SUBDRAIN OUTLET MARKER DETAIL

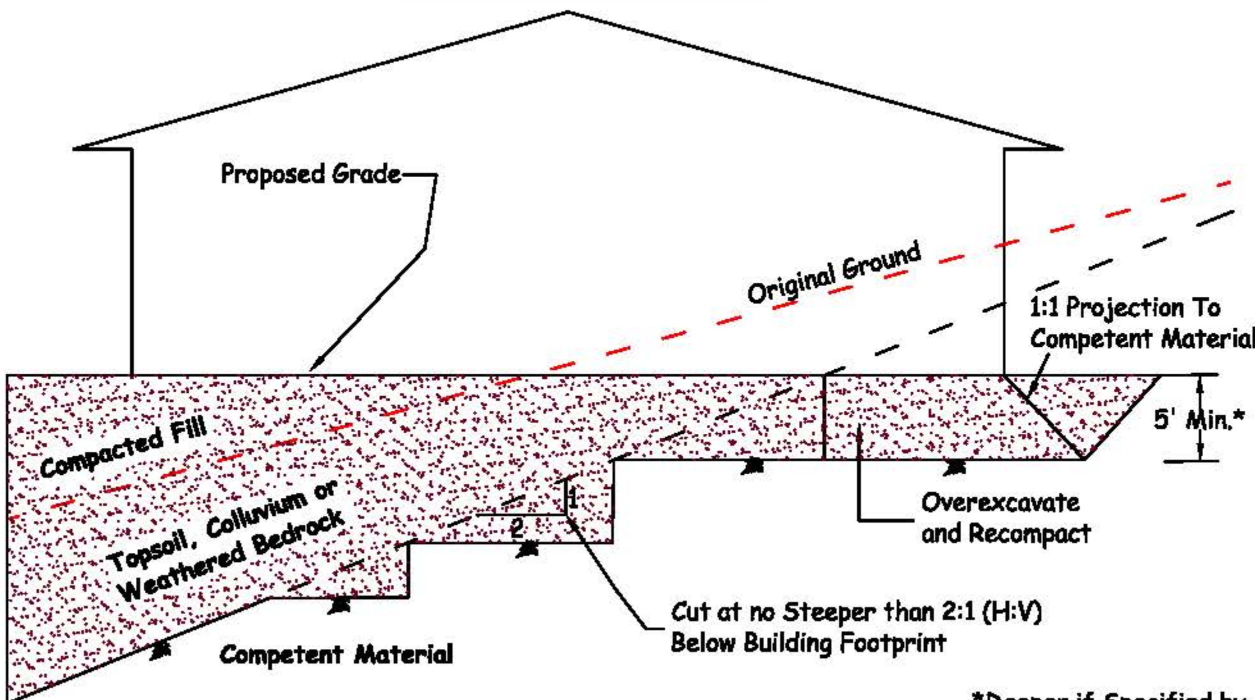
Cut Lot
(Exposing Unsuitable Soils at Design Grade)



Note 1: Removal Bottom Should be Graded With Minimum 2% Fall Towards Street or Other Suitable Area (as Determined by Soils Engineer) to Avoid Ponding Below Building

Note 2: Where Design Cut Lots are Excavated Entirely Into Competent Material, Overexcavation May Still be Required for Hard-Rock Conditions or for Materials With Variable Expansion Characteristics.

Cut/Fill Transition Lot



*Deeper if Specified by Soils Engineer

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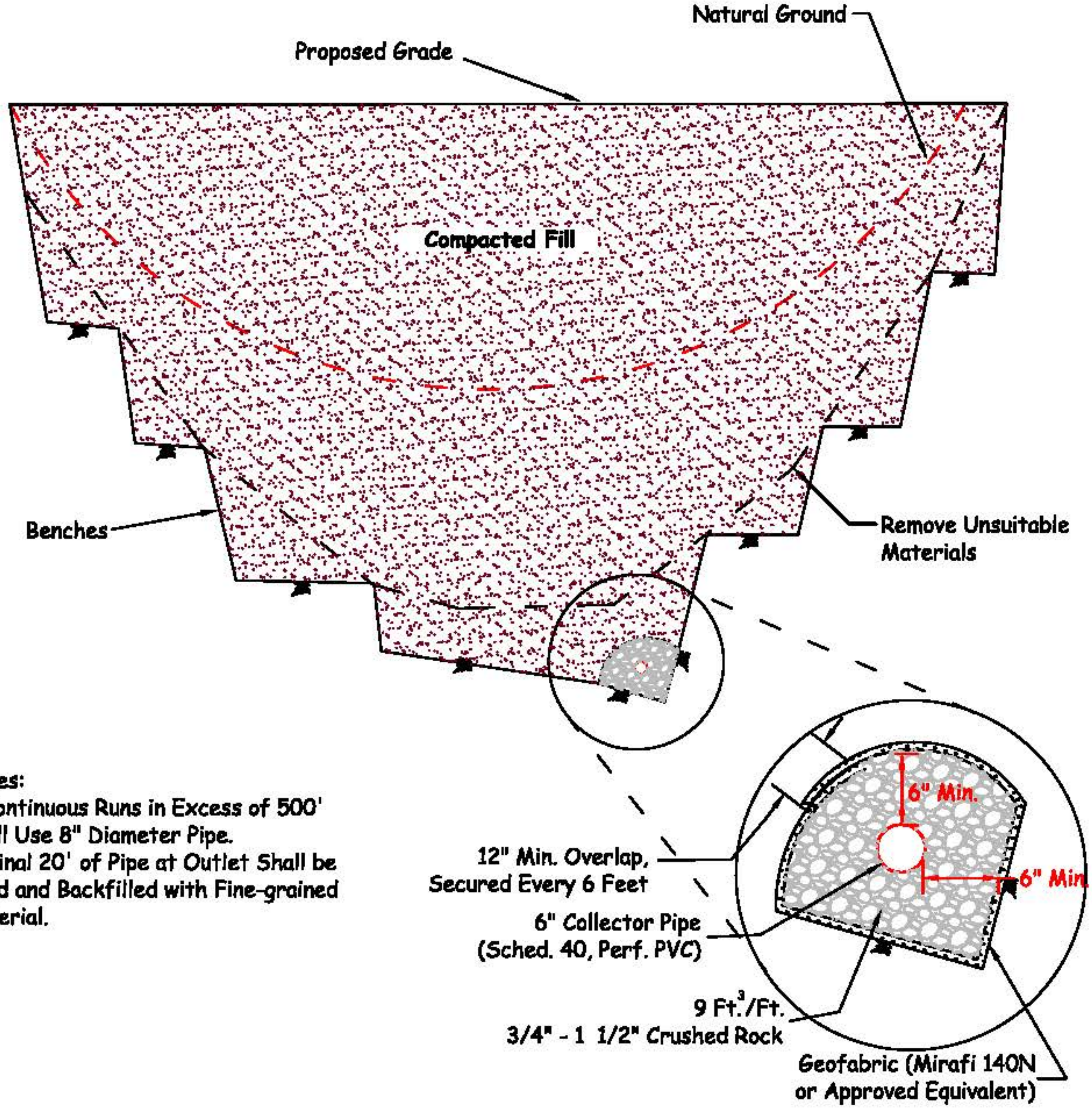
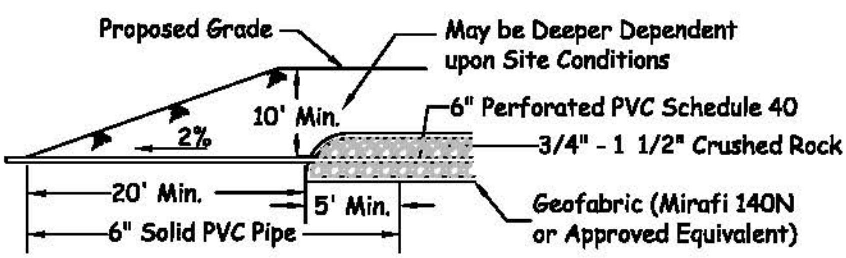
CUT AND TRANSITION LOT OVEREXCAVATION DETAIL



Notes:
1) Continuous Runs in Excess of 500' Shall Use 8" Diameter Pipe.
2) Final 20' of Pipe at Outlet Shall be Solid and Backfilled with Fine-grained Material.

Proposed Outlet Detail



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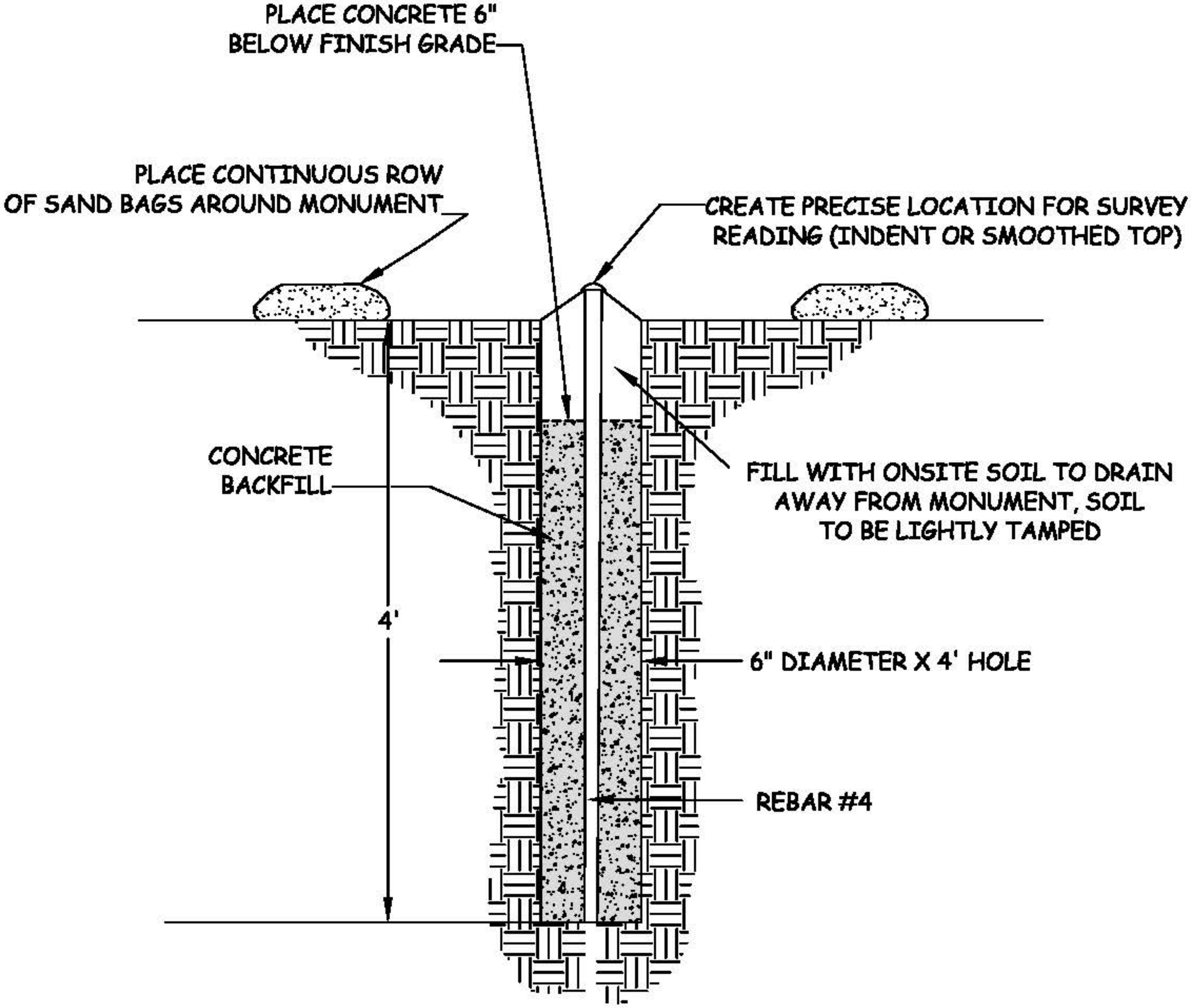
CANYON SUBDRAINS



NO CONSTRUCTION EQUIPMENT WITHIN 25 FEET
OF ANY INSTALLED SETTLEMENT MONUMENTS

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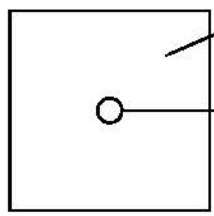
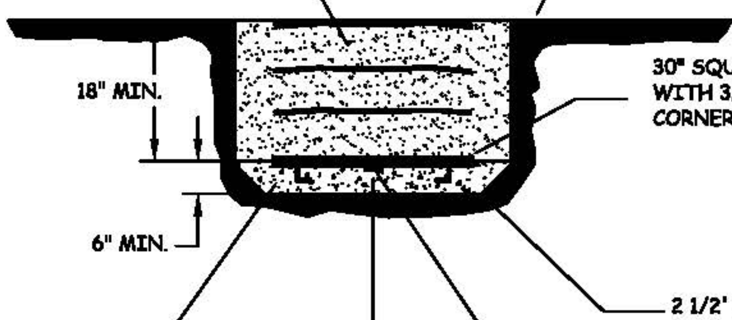
TYPICAL SURFACE SETTLEMENT MONUMENT





1. SURVEY FOR HORIZONTAL AND VERTICAL LOCATION TO NEAREST .01 INCH PRIOR TO BACKFILL USING KNOW LOCATIONS THAT WILL REMAIN INTACT DURING THE DURATION OF THE MONITORING PROGRAM. KNOW POINTS EXPLICITELY NOT ALLOWED ARE THOSE LOCATED ON FILL OR THAT WILL BE DESTROYED DURING GRADING.
2. IN THE EVENT OF DAMAGE TO SETTLEMENT PLATE DURING GRADING, CONTRACTOR SHALL IMMEDIATELY NOTIFY THE GEOTECHNICAL ENGINEER AND SHALL BE RESPONSIBLE FOR RESTORING THE SETTLEMENT PLATES TO WORKING ORDER.
3. DRILL TO RECOVER AND ATTACH RISER PIPE.

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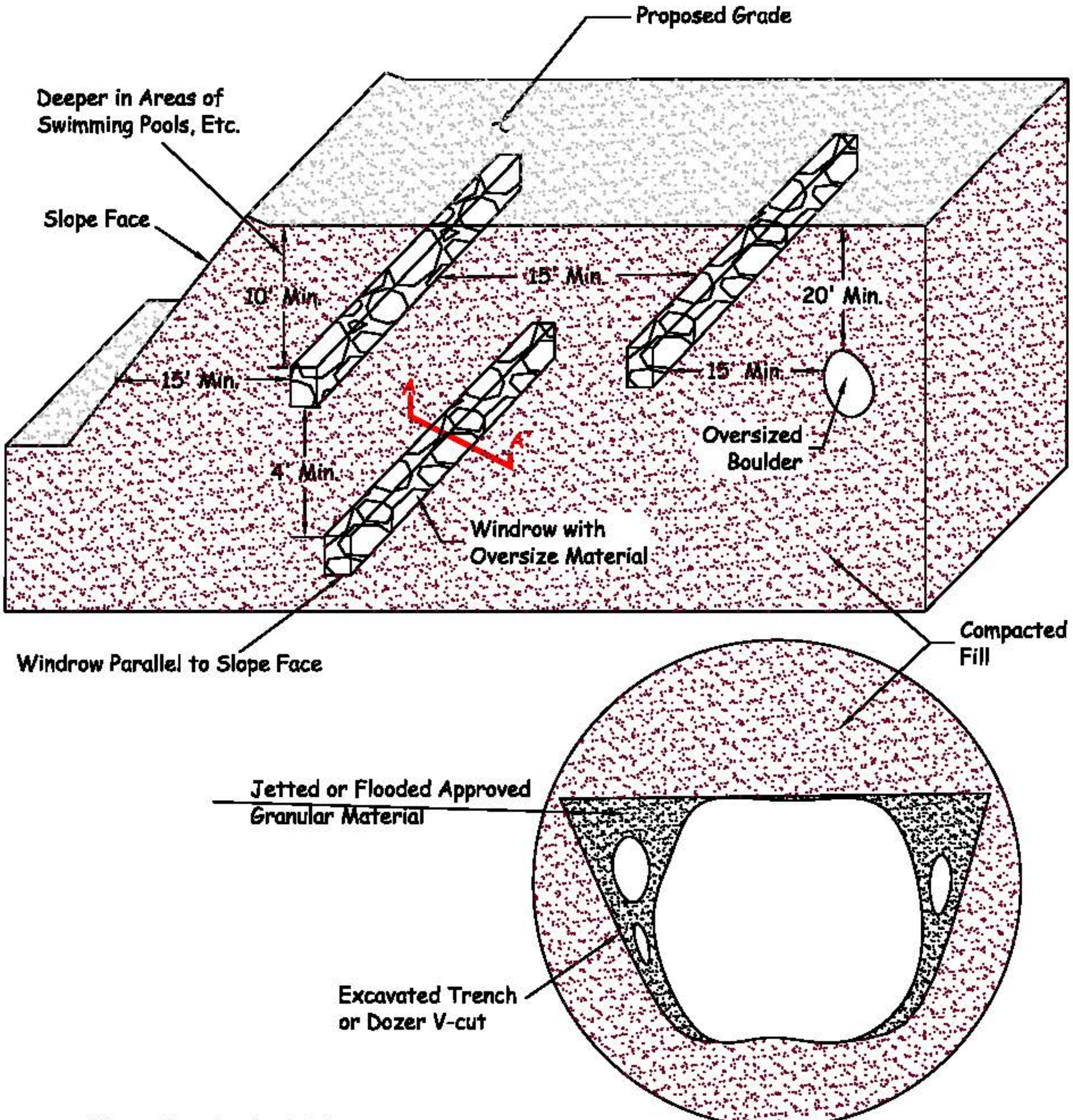
TYPICAL SETTLEMENT PLATE AND RISER



Note: Oversize Rock is Larger than 8" in Maximum Dimension.

Section A-A'

LGC Geotechnical, Inc.

OVERSIZE ROCK DISPOSAL DETAIL

ATTACHMENT H RWQCB APPROVAL LETTER

October 4, 2019

Sandy Costandi
Environmental Services Analyst
City of Covina
125 East College Street
Covina, CA 91723

VIA EMAIL

APPROVAL OF ALTERNATIVE BIOFILTRATION SPECIFICATION PURSUANT TO PART VI.D.7.c.iii.(1)(b)(i) OF THE LOS ANGELES COUNTY MUNICIPAL SEPARATE STORM SEWER SYSTEM (MS4) PERMIT (NPDES PERMIT NO. CAS004001; ORDER NO. R4-2012-0175 AS AMENDED BY STATE WATER BOARD ORDER WQ 2015-0075 AND LOS ANGELES WATER BOARD ORDER R4-2012-0175-A01)

Dear Ms. Costandi:

On July 30, 2019 the Los Angeles Regional Water Quality Control Board (Los Angeles Water Board) received a letter from the City of Covina (City) requesting approval for the use of Bio Clean Modular Wetlands System (MWS Linear) manufactured by Bio Clean as an alternative biofiltration design specification.

The City's request includes an attachment, entitled "Equivalency Analysis and Design Criteria for Modular Wetlands Systems" (Equivalency Analysis), that details a proposed design approach and equivalency criteria for MWS Linear installations to achieve equivalent performance to the biofiltration design specifications defined in the Los Angeles County MS4 Permit.

Pursuant to Part VI.D.7.c.iii.(1)(b)(i) of the Los Angeles County MS4 Permit, projects using biofiltration as an alternative compliance measure may use alternative design specifications for on-site biofiltration systems if approved by the Los Angeles Water Board Executive Officer.

Background

Part VI.D.7 of the Los Angeles County MS4 Permit requires Permittees to implement a Planning and Land Development Program. As part of this program, Permittees shall require all New Development and Redevelopment projects identified in Part VI.D.7.b (hereinafter "new projects") to control pollutants, pollutant loads, and runoff volume emanating from the project site. Except as provided in Part VI.D.7.c.ii (Technical Infeasibility or Opportunity for Regional Ground Water Replenishment), Part VI.D.7.d.i (Local Ordinance Equivalence), or Part VI.D.7.c.v (Hydromodification), each Permittee shall require new projects to retain on-site the Stormwater Quality Design Volume (SWQDv).

Pursuant to Part VI.D.7.c.iii.(1) of the Los Angeles County MS4 Permit, Permittees may allow new projects to use on-site biofiltration when the project applicant has demonstrated that it is technically infeasible to retain 100 percent of the Stormwater Quality Design Volume (SWQDv) on-site. If a Permittee conditions a project using biofiltration due to demonstrated technical infeasibility, then the new project must biofiltrate 1.5 times the portion of the SWQDv that is not reliably retained on-site, as calculated by the following equation:

$$Bv = 1.5\,[SWQDv - Rv]$$

Where: *Bv = biofiltration volume*
SWQDv = the stormwater runoff from a 0.75 inch, 24-hour storm or the 85th percentile storm, whichever is greater
Rv = volume reliably retained on-site

As a condition for on-site biofiltration, bioretention/biofiltration systems shall meet the design specifications provided in Attachment H of the Los Angeles County MS4 Permit unless otherwise approved by the Los Angeles Board Executive Officer.

Public Review

On August 19, 2019, the Los Angeles Water Board provided public notice and a 30-day period to allow for public review and written comment on the proposed use of the Bio Clean Modular Wetlands System alternative biofiltration design specification. No comments were received.

Alternative Biofiltration Specification Approval

I hereby approve the City's proposal for the use of the MWS Linear as an alternative on-site biofiltration design specification pursuant to Part VI.D.7.c.iii(1)(b)(i) of the Los Angeles County MS4 Permit, provided the following conditions are met:

1. **Vegetative Treatment**: Systems must include vegetation and must be designed such that there is effective treatment due to vegetation (e.g. uptake, chemical transformation, transpiration, treatment from associated microbial activity, etc.).

2. **Review**: The City shall ensure that the data relied upon and the conclusions presented in the Equivalency Analysis are appropriate.

3. **Sizing**: Systems must be designed and sized following the methodology in Section 4 of the July 2018 Equivalency Analysis document.

4. **O&M**: Operation and maintenance of the MWS Linear must be conducted consistent with the recommendations in the maintenance manual provided by the manufacturer and any revisions thereto.

5. **Media**: MWS Linear proprietary media must be provided by the manufacturer. No substitution of these materials/media is allowed.

6. **Hydromodification**: There is no presumption by this approval that a Permittee's implementation of the abovementioned design parameters and use specifications of the MWS Linear system meet the separate hydromodification requirements of Part VI.D.7.c.iv of the Los Angeles County MS4 Permit. Hydromodification requirements apply regardless of the type of biofiltration system used.

This approval only applies to the use of MWS Linear as an alternative on-site biofiltration design in situations where a project applicant has demonstrated that it is technically infeasible to retain 100 percent of the SWQDv on-site. Furthermore, this approval does not constitute certification or verification of the performance of the MWS Linear since the Los Angeles Water Board does not have a testing and certification program for treatment control BMPs. This approval is given based on the supporting documentation provided in the request and relies on the City's review of the system.

The City shall comply with Maintenance Agreement and Transfer requirements outlined in Part VI.D.7.d.iii of the Los Angeles County MS4 Permit. These requirements include:

1. Part VI.D.7.d.iii – prior to issuing approval for final occupancy, the City shall require new development and redevelopment projects subject to post-construction BMP requirements to provide an operation and maintenance plan; monitoring plan, where required; and verification of ongoing maintenance provisions for LID practices, treatment control BMPs, and hydromodification control BMPs.

2. Part VI.D.7.d.iii.(1)(a) – verification of post-construction BMP maintenance agreement shall include all the documents included in this provision.

3. Part VI.D.7.d.iii.(1)(b) – the City shall ensure a plan is developed for the operation and maintenance of all structural and treatment controls. The City shall examine the plan for relevance to keeping the BMPs in proper working order. Furthermore, operation and maintenance plans for private BMPs shall be kept on-site for periodic review by City inspectors.

4. Part VI.D.7.d.iv.(c) – the City shall verify proper maintenance and operation of post-construction BMPs operated by the City.

5. Part VI.D.7.d.iv.(d) – for post-construction BMPs operated and maintained by parties other than the City, the City shall require the other parties to document proper maintenance and operations.

6. Part VI.D.7.d.iv.(e) – the City shall undertake any enforcement as appropriate per the established progressive enforcement policy.

If you have any questions, please contact Ms. Susana Vargas of the Storm Water Permitting Unit at Susana.Vargas@waterboards.ca.gov or by phone at (213) 576-6688. Alternatively, you may also contact Ivar Ridgeway, Chief of the Storm Water Permitting Unit, at Ivar.Ridgeway@waterboards.ca.gov or by phone at (213) 620-2150.

Sincerely,

Renee Purdy
Executive Officer

W.O. 3593-42