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U.S. Department of Transportation
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TechBrief

DECEMBER 2012 | FHWA-HIF-13-006

Pervious Concrete

This TechBrief presents an overview of pervious concrete and its use in pavement applications. General information on the composition of pervious concrete is provided, along with a summary of its benefits, limitations, and typical properties and characteristics. Important considerations in mix proportioning, hydrological design, structural design, construction, and maintenance are also described.

Introduction

Pervious concrete, sometimes referred to as no-fines, gap-graded, permeable, or enhanced porosity concrete, is an innovative approach to controlling, managing, and treating stormwater runoff. When used in pavement applications, pervious concrete can effectively capture and store stormwater runoff, thereby allowing the runoff to percolate into the ground and recharge groundwater supplies.

Pervious concrete contains little or no fine aggregate (sand) and carefully controlled amounts of water and cementitious materials. The paste coats and binds the aggregate particles together to create a system of highly permeable, interconnected voids that promote the rapid drainage of water (Tennis et al. 2004; ACI 2010). Typically, between 15 and 25 percent voids are achieved in the hardened concrete, and flow rates for water through the pervious concrete are generally in the range of 2 to 18 gal/min/ft^2 (81 to 730 L/min/m^2), or 192 to 1,724 inch/hr (488 to 4,379 cm/hr) (ACI 2010). Figure 1 shows a typical cross section of a pervious concrete pavement.

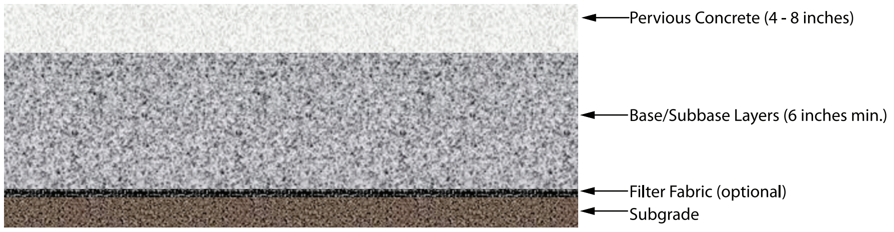

FIGURE 1. Typical pervious concrete pavement cross section (adapted from EPA 2010).

Benefits and Limitations

Table 1 summarizes some of the major benefits and limitations associated with pervious concrete. As described above, perhaps the most significant benefit provided by pervious concrete is in its use as a stormwater management tool. Stormwater runoff in developed areas (often the result of or exacerbated by the presence of conventional impervious pavement) has the potential to pollute surface and groundwater supplies, as well as contribute to flooding and erosion (Leming et al. 2007).

Pervious concrete can be used to reduce stormwater runoff, reduce contaminants in waterways, and renew groundwater supplies. With high levels of permeability, pervious concrete can effectively capture the "first flush" of rainfall (that part of the runoff with a higher contaminant concentration) and allow it to percolate into the ground where it is filtered and "treated" through soil chemistry and biology (Tennis et al. 2004; ACI 2010).

Other major benefits provided by pervious concrete include reduction in heat island effects (water percolating through the pavement can exert a cooling effect through evaporation, and convective airflow can also contribute to cooling (Cambridge 2005)), reductions in standing water on pavements (and associated hydroplaning and splash/spray potential), and reduced tire–pavement noise emissions (due to its open structure that helps absorb noise at the tire–pavement interface) (ACI 2010). In addition, pervious concrete can contribute toward credits in the LEED® (Leadership in Energy and Environmental Design) rating system for sustainable building construction (Ashley 2008).

Along with its many benefits, there are some limitations associated with the use of pervious concrete. First and foremost, pervious concrete has typically been used on lower trafficked roadways, although there are a number of installations on higher volume facilities, and research is being conducted on the structural behavior of pervious concrete slabs (see, for example, Suleiman et al. 2011; Vancura et al. 2011). In addition, pervious concrete exhibits material characteristics (primarily lower paste contents and higher void contents) and produces hardened properties (notably density and strength) that are significantly different from conventional concrete; as a result, the current established methods of quality control/quality assurance (e.g., slump, strength, air content) are in many

TABLE 1. Summary of Pervious Concrete Benefits and Limitations (Tennis et al. 2004; ACI 2010)

Benefits/Advantages	Limitations/Disadvantages
• Effective management of stormwater runoff, which may reduce the need for curbs and the number and sizes of storm sewers. • Reduced contamination in waterways. • Recharging of groundwater supplies. • More efficient land use by eliminating need for retention ponds and swales. • Reduced heat island effect (due to evaporative cooling effect of water and convective airflow). • Elimination of surface ponding of water and hydroplaning potential. • Reduced noise emissions caused by tire–pavement interaction. • Earned LEED® credits.	• Limited use in heavy vehicle traffic areas. • Specialized construction practices. • Extended curing time. • Sensitivity to water content and control in fresh concrete. • Lack of standardized test methods. • Special attention and care in design of some soil types such as expansive soils and frost-susceptible ones. • Special attention possibly required with high groundwater.

cases not applicable (ACI 2010). Moreover, a number of special practices, described later, are required for the construction of pervious concrete pavements. And, while there have been concerns about the use of pervious concrete in areas of the country subjected to severe freeze–thaw cycles, available field performance data from a number of projects indicate no signs of freeze–thaw damage (Delatte et al. 2007; ACI 2010).

Applications

Pervious concrete has been used in pavement applications ranging from driveways and parking lots to residential streets, alleys, and other low-volume roads (Tennis et al. 2004). Within these applications, pervious concrete has been used as the surface course, as a drainable base course (often in conjunction with edge drains to provide subsurface drainage), or as a drainable shoulder (to help provide lateral drainage to a pavement and prevent pumping). The focus in recent years has been on its use as a surface course as a means of providing stormwater management.

Typical Properties and Characteristics

As noted previously, many of the properties of pervious concrete are different from those of conventional concrete. These properties are primarily a function of the porosity (air void content) of the pervious concrete, which in turn depends on the cementitious content, the water-to-cementitious materials (w/cm) content, the compaction level, and the aggregate gradation and quality (ACI 2010). Table 2 summarizes some of the typical material properties associated with pervious concrete. These properties and characteristics must be considered during the structural design and pavement construction.

The cost of pervious concrete may be 15 to 25 percent higher than conventional concrete, but cost can vary significantly depending on the region, the type of application, the size of the project, and the inclusion of admixtures.

Mixture Proportioning

Like conventional concrete, pervious concrete is a mixture of cementitious materials, water, coarse aggregate, and possibly admixtures, but it contains little or no fines; however, note that a small amount of fine aggregate, typically 5 to 7 percent, is required for freeze–thaw durability (Schaefer et al. 2006; Kevern et al. 2008). Table 3 shows the typical range of materials proportions that have been used in pervious concrete. Commentary on the components of a pervious concrete is provided below (Tennis et al. 2004; Delatte et al. 2007; ACI 2010):

Cementitious materials. As with conventional concrete mixtures, conventional portland cements or blended cements are used as the primary binder in pervious concrete, although supplementary cementitious materials may also be used.

TABLE 2. Typical Pervious Concrete Properties (Tennis et al. 2004; Obla 2007)

Property	Common Value / Range
Plastic Concrete	
Slump	N/A
Unit weight	70% of conventional concrete
Working time	1 hour
Hardened Concrete	
In-place density	100 to 125 lb/ft^3
Compressive strength	500 to 4,000 lbf/in^2 (typ. 2,500 lbf/in^2)
Flexural strength	150 to 550 lbf/in^2
Permeability	2 to 18 gal/ft^2/min (384 to 3,456 ft/day)

1 in = 25.4 mm; 1 lb/ft^3 = 16 kg/m^3; 1 lbf/in^2 = 6.89 kPa; 1 gal/ft^2/min = 40.8 L/m^2/min

Coarse aggregate. Coarse aggregate is kept to a narrow gradation, with the most common gradings of coarse aggregate used in pervious concrete meeting the requirements of ASTM C33/C33M—aggregate sizes of 7, 8, 67, and 89. Coarse aggregate size 89 (top size 0.375 inch (9.5 mm)) has been used extensively for parking lot and pedestrian applications. Rounded and crushed aggregates, both normal and lightweight, have been used to make pervious concrete.

Water. The control of water is important in the development of pervious concrete mixtures, and the selection of an appropriate w/cm value is important for obtaining desired strength and void structure in the concrete. A high w/cm can result in the cement paste flowing off of aggregate and filling the void structure, whereas a low w/cm can result in mixing and placement difficulties and reduced durability. Commonly, w/cm values between 0.27 and 0.34 are used.

Admixtures. As with conventional concrete, chemical admixtures can be used in pervious concrete to obtain or enhance specific properties of the mixture. In particular, set retarders and hydration stabilizers are commonly used to help control the rapid setting associated with many pervious concrete mixtures. Air-entraining admixtures are required in freeze–thaw environments although no current method exists to quantify the amount of entrained air in the fresh paste. Air entrainment can be determined on hardened samples according to ASTM C457.

TABLE 3. Typical Pervious Concrete Materials Proportions (ACI 2010)

Mix Constituent or Design Parameter	Range
Coarse aggregate	2,000 to 2,500 lb/yd³
Cementitious materials	450 to 700 lb/yd³
Water-to-cementitious ratio	0.27 to 0.34
Aggregate-to-cementitious ratio (by mass)	4 to 4.5:1

1 lb/yd³ = 0.59 kg/m³

Mix proportioning for pervious concrete is based on striking a balance between voids, strength, paste content, and workability (ACI 2010). As such, the development of trial batches is essential to determining effective mix proportions using locally available materials. Detailed information on mix proportioning is available from ACI (2010).

Some limited work has been done investigating the freeze–thaw characteristics of pervious concrete and mix design for cold weather climates (NRMCA 2004; Schaefer et al. 2006). The freeze–thaw resistance of pervious concrete appears to be dependent on the saturation level of the voids; consequently a drainable base layer with a minimum thickness of 6 inches (150 mm) is recommended to help keep the pervious concrete layer from becoming saturated. Furthermore, as previously noted, the freeze–thaw resistance of pervious concrete has been shown to improve when sand is included in the pervious concrete mixture (Schaefer et al. 2006; Kevern et al. 2008).

Design of Pervious Pavements

Two primary considerations enter into the determination of the thickness of pervious concrete pavements: 1) hydrologic design to meet environmental requirements and 2) structural design to withstand the anticipated traffic loading applications (Leming et al. 2007; ACI 2010). These design considerations are briefly described below.

Hydrologic Design

In evaluating the hydrologic design capabilities of a pervious pavement, the approach is to determine whether the characteristics of the pervious concrete pavement system are sufficient to infiltrate, store, and release the expected inflow of water (which

includes direct rainfall and may also include excess runoff from adjacent impervious surfaces). As such, information required in a hydrologic analysis includes the precipitation intensity levels, the thickness and permeability characteristics of the pervious concrete pavement, cross slopes and geometrics, and permeability properties and characteristics of the underlying base, subbase, and subgrade materials.

Many hydrological design methods exist that can be used when designing pervious concrete pavement systems, including the Natural Resources Conservation Service Curve Number Method and the Rational Method (Leming et al. 2007). In essence, the hydrologic design of pervious concrete pavements should consider two possible conditions to ensure that excess surface runoff does not occur (Leming et al. 2007):

1. Low permeability of the pervious concrete material that is inadequate to capture the “first flush” of a rainfall event.
2. Inadequate retention provided in the pervious concrete structure (slab and subbase).

Often, the thickness of a pervious concrete pavement is first determined based on structural requirements and then analyzed to determine its suitability to meet the hydrologic needs of the project site. If the thickness is found to be insufficient, adjustments can be made to the thickness of the pervious pavement or the underlying base course. Details on hydrologic design are beyond the scope of this document but are available in the literature (Leming et al. 2007; Wanielista et al. 2007; Rodden et al. 2011).

Structural Pavement Design

Pervious concrete pavements can be designed using virtually any standard concrete pavement procedure (e.g., American Association of State Highway and Transportation Officials, Portland Cement Association, StreetPave) (Delatte 2007). The American Concrete Pavement Association has recently developed a comprehensive program, PerviousPave, that can be used to develop both structural and hydrological designs for pervious pavements (Rodden et al. 2011). Regardless of the procedure used, there are critical factors to consider in the design of pervious concrete pavements (ACI 2010):

Subgrade and subbase. In the design of pervious pavements, foundation support is typically characterized by a composite modulus of subgrade reaction, which should account for the effects of both the subgrade and the subbase. An open-graded subbase is commonly used beneath pervious concrete pavements not only to provide an avenue for vertical drainage of water to the subgrade, but also to provide storage capabilities. Special subgrade conditions (such as frost susceptibility or expansive soils) may require direct treatment.

Concrete flexural strength. The flexural strength of concrete is an important input in concrete pavement structural design. However, testing to determine the flexural strength of pervious concrete may be subject to high variability; therefore, it is common to measure compressive strengths and to use empirical relationships to estimate flexural strengths for use in design (Tennis et al. 2004).

Traffic loading applications. The anticipated traffic to be carried by a pervious pavement is commonly characterized in terms of equivalent 18,000-lb (80 kN) single-axle load repetitions, which many procedures compute directly based on assumed truck-traffic distributions. Most pervious concrete pavements are used in low-truck-traffic applications.

Currently there are no thickness standards for pervious concrete pavements, but many pervious pavements for parking lots are constructed 6 inches (150 mm) thick, whereas pervious pavements for low-volume streets have been

constructed between 6 and 12 inches (150 and 300 mm) thick (ACI 2010).

Construction Considerations

Because of its unique material characteristics, pervious concrete has a number of special construction requirements. Key aspects of pervious concrete construction include the following (Tennis et al. 2004; ACI 2010):

Placement and consolidation. Most pervious concrete is placed using fixed-form construction. For smaller projects, a hand-held straightedge or vibrating screed may be acceptable for placement, whereas for larger projects an A-frame, low-frequency, vibrating screed may be used. A few projects have used laser screeds and concrete slipform equipment. Consolidation is generally accomplished by rolling the concrete with a steel roller. Overall, the low water content and porous nature of pervious concrete require that delivery and placement be completed as quickly as possible.

Finishing. Pervious concrete pavements are not finished in the same manner as conventional pavements. In essence, the final surface finish is achieved as part of the consolidation process, which leaves an open surface. Normal concrete finishing procedures, such as with bull floats and trowels, should not be performed.

Jointing. Jointing is commonly done on pervious concrete to control random crack development. These joints are commonly formed (using a specially designed compacting roller-jointer) to a depth between one-fourth and one-third of the slab thickness.

Curing and protection. After the concrete has been jointed, it is important that the concrete be effectively cured; this is commonly achieved through the placement of thick (typically 6 mil (0.15mm)) plastic sheeting over all exposed surfaces. The plastic sheeting should be applied no later than 20 minutes following discharge of the concrete, and should remain in place for at least 7 days (longer times may be required under cold weather placement conditions or if supplementary cementitious materials are used in the mix). Liquid membrane curing compounds are not commonly used because they prevent surface moisture loss and do nothing to prevent evaporation from within the pervious concrete (Kevern et al. 2009).

Inspection and testing. The American Concrete Institute has prepared a summary of recommended inspection and testing activities that should be performed during construction of pervious concrete pavements (ACI 2010), as well as a specification for pervious concrete construction (ACI 2008). Acceptance testing for pervious concrete is typically limited to density (ASTM C1688) and thickness (ASTM C42). Test methods specific to pervious concrete are listed below:

- ASTM C1688, *Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete.*
- ASTM C1701, *Standard Test Method for Infiltration Rate of In Place Pervious Concrete.*
- ASTM C1747, *Standard Test Method for Determining Potential Resistance to Degradation of Pervious Concrete by Impact and Abrasion.*
- ASTM C1754, *Standard Test Method for Density and Void Content of Hardened Pervious Concrete.*

In recognition of the special construction requirements of pervious concrete, the National Ready Mixed Concrete Association has developed a program designed to educate, train, and certify contractors in pervious concrete placement (see http://nrmca.org/Education/Certifications/Pervious_Contractor.htm).

Maintenance

Over time, sand, dirt, vegetation, and other debris can collect in pervious concrete's voids and reduce its porosity, which can negatively affect

the functionality of the system. Thus, periodic maintenance may be needed to remove surface debris and restore infiltration capacity. Two common maintenance methods are pressure washing and power vacuuming (ACI 2010).

Performance

The performance of pervious concrete pavements may be assessed in a number of ways, including monitoring changes in the permeability/porosity of the system (which would indicate clogging of the void structure), the presence of distress (both structural and surficial), and resistance to freeze–thaw damage. Unfortunately, there are limited long-term performance data on pervious concrete, but generally performance is considered satisfactory. For example, a study in Florida indicated that pervious concrete pavements that were 10 to 15 years old were operating in a satisfactory manner without significant amounts of clogging (Wanielista et al. 2007). In another study, field inspections of 22 projects located in freeze areas were conducted, with reported good performance and no visual signs of freeze–thaw damage (although all projects were less than 4 years old at the time of inspection) (Delatte et al. 2007).

Where the performance of pervious concrete pavements has not been satisfactory, poor performance is often attributed to contractor inexperience, higher compaction of soil than specified, and improper site design (ACI 2010).

Summary and Future Needs

The use of pervious concrete has increased significantly in the last several years, perhaps largely because it is considered an environmentally friendly, sustainable product. The use of pervious concrete provides a number of benefits, most notably in the effective management of stormwater runoff. Other significant benefits include reducing contaminants in waterways, recharging groundwater supplies, reducing heat island effects, and reducing pavement–tire noise emissions.

Still, there are a number of areas that need additional developmental work to improve or enhance the capabilities of pervious concrete pavements. One area is the continued monitoring of the performance of pervious concrete so that long-term performance trends can be documented; this will also help in evaluating the suitability of pervious concrete for other applications, such as overlays. Tied in with this is the assessment of the suitability of current structural design approaches to provide competent designs, particularly regarding the fatigue behavior of pervious concrete. Finally, a third area is in the testing and evaluation of pervious concrete, as current test methods for conventional concrete are not generally applicable to pervious concrete.

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Contact—For more information, contact the following:

Federal Highway Administration (FHWA)
Office of Pavement Technology
Sam Tyson, P.E.—sam.tyson@dot.gov

ACPT Implementation Team
Shiraz Tayabji, Ph.D., P.E., Fugro Consultants, Inc.—
stayabji@aol.com

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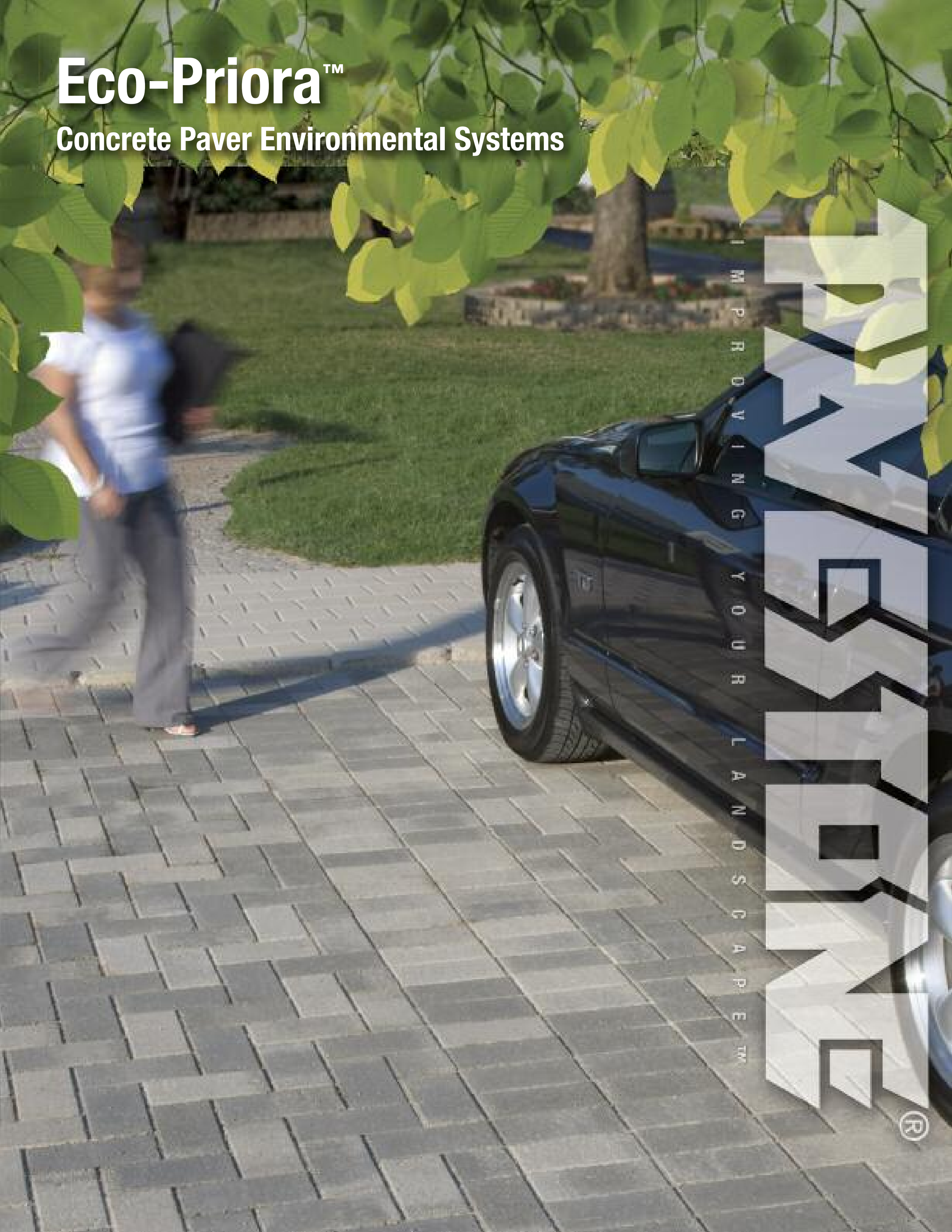
Key Words—concrete pavement construction, design, drainage, LEED® credit, maintenance, pavement design, pavement construction, permeability, pervious concrete, porous concrete, stormwater, sustainability

DECEMBER 2012 **FHWA-HIF-13-006**

Eco-Priora™

Concrete Paver Environmental Systems



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Eco-Priora™

Pavestone Eco-Priora™ is the sustainable solution for permeable pavements. Eco-Priora™ is produced in a 120mm x 240mm rectangular module that is 80mm in thickness with a patented interlocking joint and a micro-chamfered top edge profile. This ingenuity is singular to the Pavestone Eco-Priora™ product and insures optimum pavement performance unequaled in the permeable paver industry. The unique Eco-Priora™ joint profile allows surface water to infiltrate into the pavement and its sub-layers. With initial permeability average flow rates of over 100 inches per hour, the Eco-Priora™ product, even with a clogging factor, will still meet the majority of current storm water management plans (SWMP). The structural interlocking capability is achieved by the paving unit having interlocking joints with a minimum of two vertically aligned horizontal interlocking spacer bars on each of its sides. These spacer bars interlock throughout the depth of the block and nest adjacently with neighboring paving units. This interlocking function resists lateral and vertical displacement when the unit is exposed to load. The dynamics of pavement stress are better distributed providing a structurally superior permeable paving system.

The micro-chamfered top edge profile produces a horizontal edge to edge dimension that is nominally 7mm including installation gapping. This small joint complies dimensionally with current ADA requirements for walking surfaces with spaces no greater than 1/2 inch. This narrow jointed surface diminishes vibration for wheelchairs and shopping carts when compared to all other permeable paving products. Eco-Priora™ can assist in meeting current EPA storm water regulations and LEED certification. The Eco-Priora™ product best achieves the balance of aesthetic segmental paving and the function of permeable pavement.

APPLICATIONS

Parking Lots • Driveways • Patios • Entrance Areas • Sidewalks
Terraces Garden Pathways • Pool Decks • Pedestrian Malls • Roof Gardens • Streets

COMPOSITION AND MANUFACTURE

Eco-Priora™ is available in one size. Height = 80mm. Eco-Priora™ is made from a "no slump" concrete mix made under extreme pressure and high frequency vibrations. Eco-Priora™ has a compressive strength greater than 8000 psi, a water absorption maximum of 5% and will meet or exceed ASTM C-936. Note: Requires modifying the ASTM C 140 - Paver Annex A4 - "The test specimen shall be 60 ± 3 mm thick and, if necessary, cut to a specimen size having a Height/Thickness (width) [H/T] aspect ratio of 0.6 ± 0.1

INSTALLATION

1. Excavate unsuitable, unstable or unconsolidated subgrade material. Compact the area, which has been cleared as per the engineer's of record (EOR) requirements. Backfill and level with open graded aggregates as per the EOR's structural and hydraulic design.
2. Place bedding course of hard and angular material conforming to the grading requirements of ASTM No. 8 or No. 9 to a uniform minimum depth of 1 1/2" -2". (38mm) screeded to the grade and profile required.
3. Install Eco-Priora™ with joints approximately 1/4". (7mm).
4. Where required, cut pave stones with an approved cutting device to fit accurately, neatly and without damaged edges.
5. Tamp pave stones with a plate compactor, uniformly level, true to grade and free of movement.
6. Spread a thin layer of hard angular material conforming to the grading requirements of ASTM No. 8 or No. 9 aggregate over entire paving area.
7. Make one more pass with plate compactor to nest the aggregate and fill joints to the top.
8. Sweep and remove surplus joint material.

Complete installation & specification details are available by contacting your Pavestone Sales Representative.

Note: ✔ Permeable pavements require both civil and hydraulic engineering. All final pavements design shall be approved by a licensed engineer familiar with local site conditions, building codes and storm water management plans.

PRODUCT INFORMATION

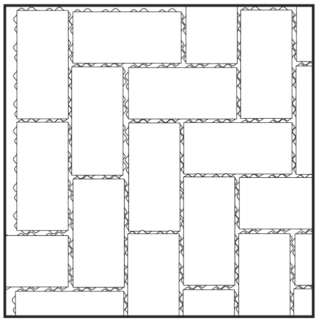
Eco-Priora™ is available in one size. Height = 80mm

ECO-PRIORA™
(120mm x 240mm)

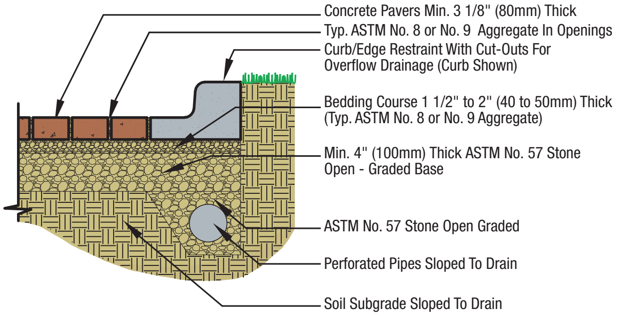
Eco-Priora™

Dimensions:	4 3/4" W x 9 7/16" L x 3 1/8" H
Wt./Stone:	11.5 lbs.
Stones/Pallet:	280
Approx. Wt./Pallet:	3,255 lbs.
Sq. Ft./Pallet:	88
Product Number:	699

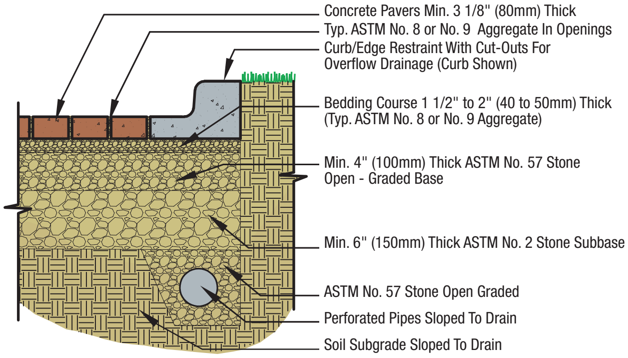
INSTALLATION PATTERN

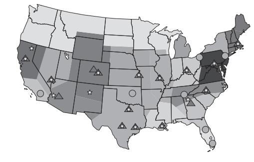


PERMEABLE PAVERS TREATMENT



PERMEABLE PAVERS TREATMENT AND DETENTION





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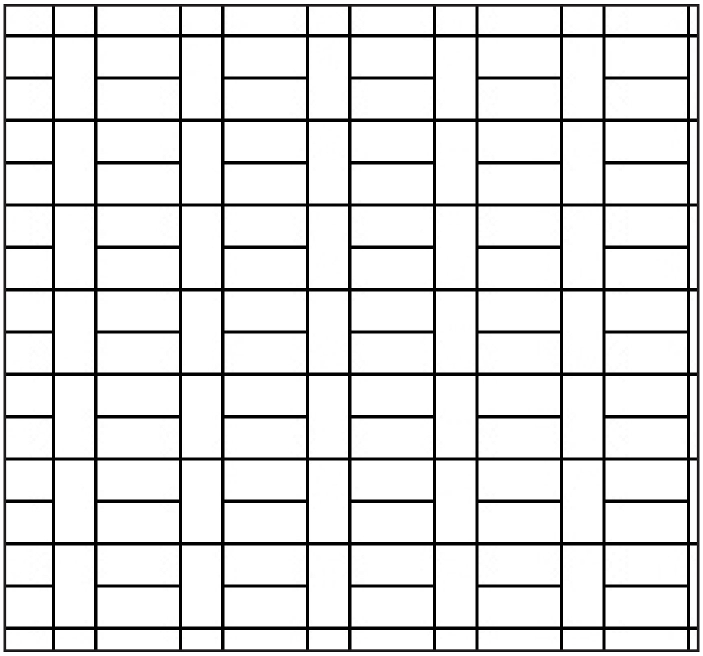
• Denver, CO:	(303) 287-3700
• Hagerstown, MD:	(240) 420-3780
• Houston, TX:	(281) 391-7283
• Kansas City, MO:	(816) 524-9900
• Las Vegas, NV:	(702) 221-2700
• New Orleans, LA:	(985) 882-9111
• Phoenix, AZ:	(602) 257-4588
• St. Louis/ Cape Girardeau, MO:	(573) 332-8312
• Sacramento/ Winters, CA:	(530) 795-4400

Eco-Priora™ - Is a trademark of F. von Langsdorff Protected by one or more of the following patents: U.S. Patent 5,902,069 U.S. Patent 6,857,244.

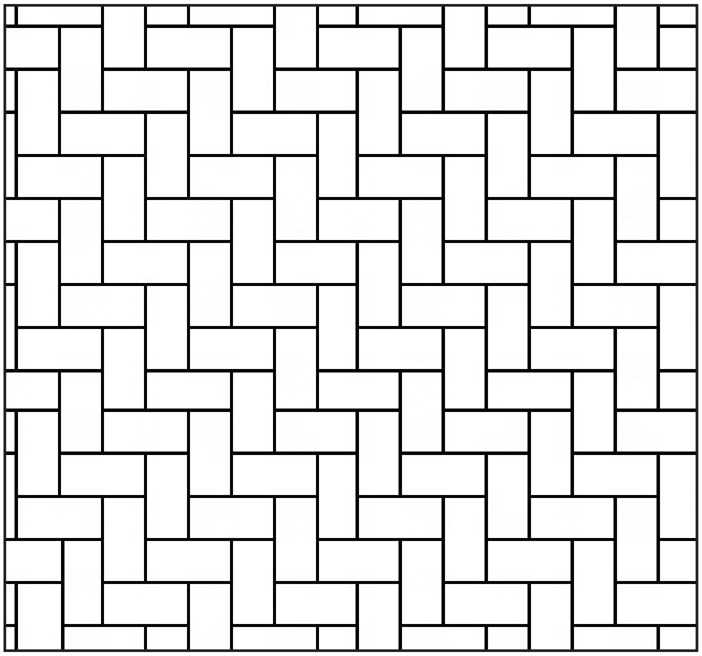
Member of ASLA and NCMA   ICPI Charter Member   World Wide Pavers

SKU# CDC 266V4 5/10

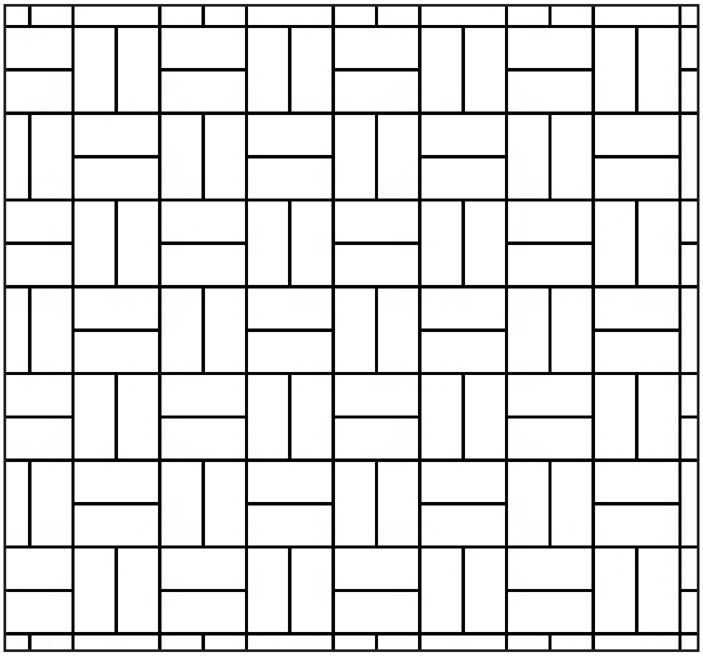
Eco-Priora™ 699 Installation Patterns



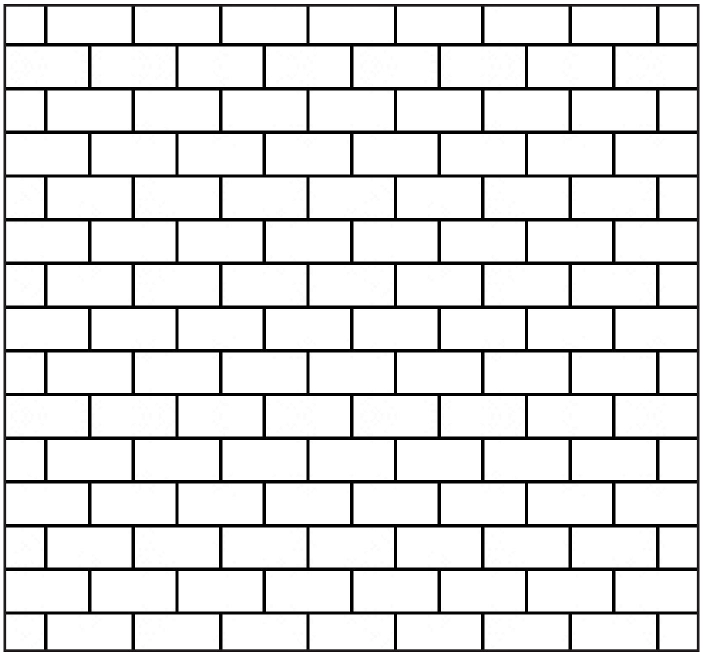
BASKETWEAVE (1)



HERRINGBONE (2)



PARQUET (5)

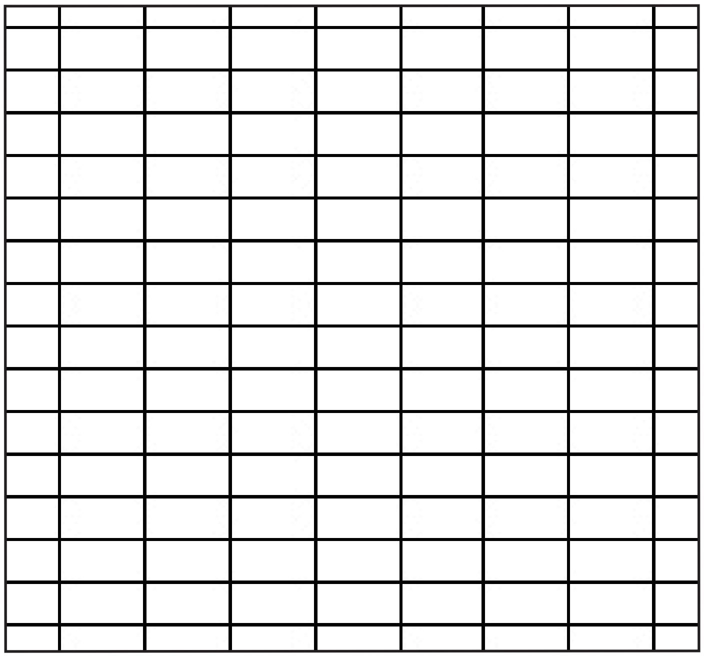


RUNNER BOND (7)

PAVESTONE®

CREATING BEAUTIFUL LANDSCAPES℠

Eco-Priora™ 699 Installation Patterns



STACK (8)

CREATING BEAUTIFUL LANDSCAPES℠

Belgard Environmental Product

BELGARD®
COMMERCIAL
belgardcommercial.com

AquaLine™ L-stone Multi-Cobble
Environmental Collection

Beauty, functionality and quality are hallmarks of the Belgard® Commercial AquaLine™ paver series, while the innovative design features of L-shape make it the perfect pavement choice for plazas, sidewalks, parking lots, alleys and small roadways. It is available in a variety of nationally offered colors, finishes and surface textures, including Texturgard™ - an ultra-durable wearing course that virtually eliminates the appearance of aging.

ADA COMPLIANT ♿ *HEAVY VEHICULAR—100MM* *VEHICULAR—80MM* *MECHANICAL INSTALLATION*

Designed to provide an aesthetically pleasing large format permeable surface that is pedestrian friendly and functional for vehicular traffic. AquaLine combines structural joints and infiltrating voids to optimize system performance. Easier to install due to the additional interlock provided by the L-shape. It is the result of years of research on existing permeable paver products.

Benefits of AquaLine™ L-stone Multi-Cobble

STRENGTH

Manufactured to exceed the minimum standards specified in ASTM C936. Test results from an independent third party are available upon request.

ECOLOGICAL SOLUTIONS

Engineered to infiltrate up to 140 inches per hour which greatly exceeds even the heaviest storms. Where water quality improvements are required, select aggregates can be used in the voids to optimize contaminant removal.

ECONOMICAL

Permeable Pavement Systems serve as both the driving surface and stormwater management system, eliminating the need for traditional infrastructure, allowing more property to be used for revenue generation. Pavers have also been proven to last in excess of 50 years, greatly benefitting life cycle costs.

LOW MAINTENANCE

Maintenance is similar to what is commonly required for other pavement surfaces. If voids become plugged, aggregate and debris can be vacuum extracted and new aggregate material inserted, restoring the original infiltration rate.

AFFORDABILITY

Packaged for mechanical installation, resulting in a cost effective installed price.

COMFORT

ADA compliant walking surface that is high-heel and pedestrian friendly. Causes low-vibration for strollers, bikes, shopping carts and wheelchairs.

LEED POINTS

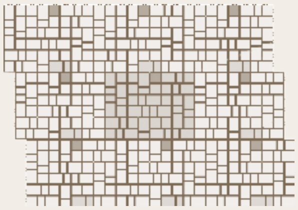
Can contribute to credits for stormwater quality and quantity, recycled materials, heat island effect, and innovation in design, among others.

AquaLine™ L-stone Multi-Cobble

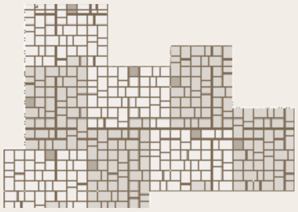
Size: 12" x 12" x 3 1/8" (or 12" x 12" x 4")
Colors: 9 national colors, local custom colors available upon request
Finishes: Smooth, Shot Blast, Ground Face
Processes: Colorgard, Texturgard
Chamfer: 2mm
Spacers: Dual positive-interlocking integrated bars
Joint/Void: Maximum 8 mm non-structural voids
Appearance: Random 3 size cobble

BELGARD AQUALINE™ L-SHAPE	
Dimensions	12" x 12" x 80mm
sold by	sf
sf/plt	96
lbs/plt	3380
layers/plt	8
lf/plt	96*
units/plt	128
sf/layer	12
sf/unit	0.75
lf/unit	0.75
lbs/unit	26.4

*Linear feet measured when used as 12" soldier course installed in pairs (see front photo).



Stitched Pattern



Non-Stitched Pattern

Sierra an Oldcastle Company
10714 Poplar Avenue
Fontana, CA 92337
PH: 909.355.6422
Toll Free: 866.749.3838

For more info visit: www.belgardcommercial.com

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BELGARD®
COMMERCIAL

Eco Dublin™
Environmental Collection

Beauty, functionality and quality are hallmarks of the Belgard® Commercial brand, and our Environmental Collection of permeable pavers is no exception. Belgard permeable pavers combine the best of Belgard with innovative stormwater management for a superior product line that provides sustainable solutions and aesthetically appealing designs.

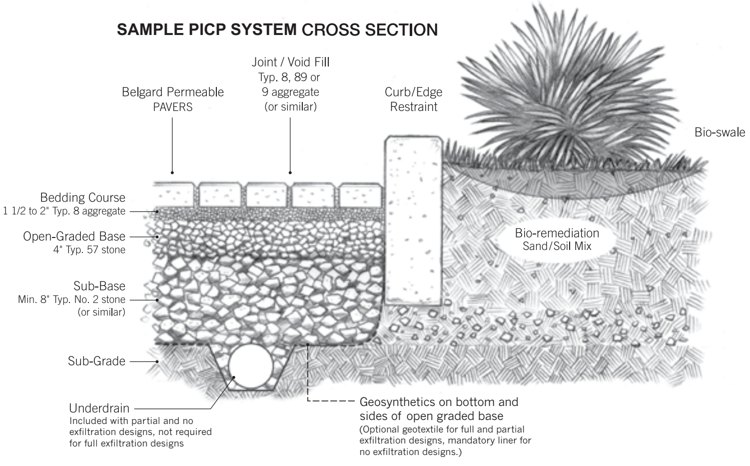
ADA COMPLIANT ♿ LT. VEHICULAR—80MM 🚗 MECHANICAL INSTALLATION

Eco Dublin™

Smart-looking style meets smart science. The classic look of cut stone and contemporary materials technology combine in Eco Dublin™, the latest addition to Belgard's Environmental Series of permeable pavers.

Benefits of Belgard® Permeable Paving Stone Systems

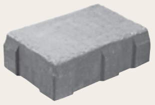
- On the US Environmental Protection Agency's (EPA) menu for structural Low Impact Development (LID) BMPs
- Can contribute toward several LEED NC-2009 points
- Reduces stormwater runoff by up to 100%
- Can be used to achieve total maximum daily load (TMDL) limits for a range of pollutants
- Certified SRI colors reduce heat island effect
- Can reduce or eliminate the need for traditional drainage and detention requirements, saving space and money
- Can be designed to accommodate all native soil types
- 50-year design life based on proven field performance


SAMPLE PICP SYSTEM CROSS SECTION

The availability of specific aggregate will often vary from region to region. In cases where it becomes necessary to substitute a similar size, your project engineer should always be consulted.

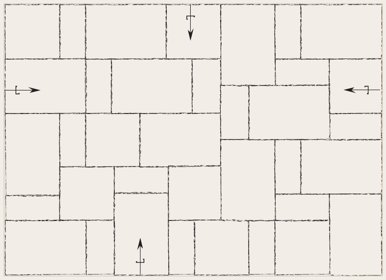

3 7/16″ x 6 7/8″ x 3 1/8″
(87.78mm x 174.57mm x 80mm)


6 7/8″ x 6 7/8″ x 3 1/8″
(174.57mm x 174.57mm x 80mm)


Large Rectangle
6 7/8″ x 10 1/4″ x 3 1/8″
(174.57mm x 261.35mm x 80mm)

Shapes

(All three shapes come in each bundle.)



Mechanical Installation Laying Pattern

Sierra an Oldcastle Company
10714 Poplar Avenue
Fontana, CA 92337
PH: 909.355.6422
Toll Free: 866.749.3838

For more info visit: www.belgardcommercial.com

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BELGARD®
COMMERCIAL

Aqua Roc™
Environmental Collection

Beauty, functionality and quality are hallmarks of the Belgard® Commercial brand, and our Environmental Collection of permeable pavers is no exception. Belgard permeable pavers combine the best of Belgard with innovative stormwater management for a superior product line that provides sustainable solutions and aesthetically appealing designs.

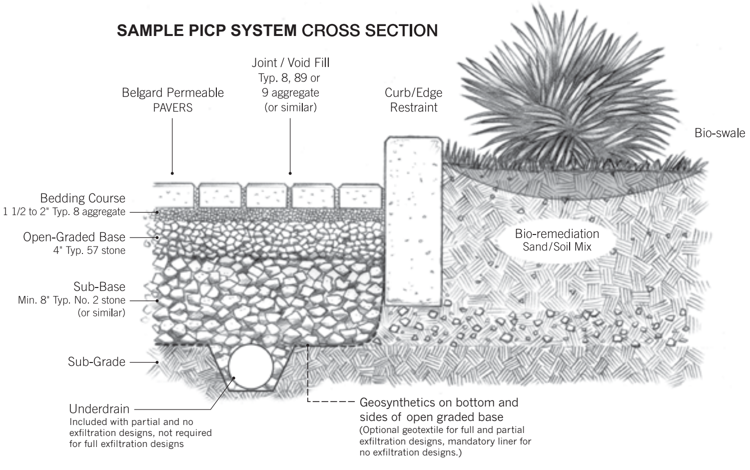
ADA COMPLIANT ♿ VEHICULAR—80MM LT. VEHICULAR—80MM MECHANICAL INSTALLATION

Aqua Roc™

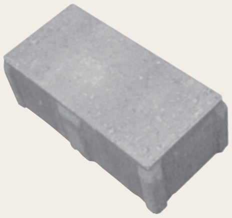
Aqua Roc is a versatile paver featuring not only the environmentally-friendly benefits of a permeable paver, but also high visual appeal, low maintenance, and proven durability. Aqua Roc's versatile pattern range allows for flexible design options, making it an excellent choice for vehicular use.

Benefits of Belgard® Permeable Paving Stone Systems

- On the US Environmental Protection Agency's (EPA) menu for structural Low Impact Development (LID) BMPs
- Can contribute toward several LEED NC-2009 points
- Reduces stormwater runoff by up to 100%
- Can be used to achieve total maximum daily load (TMDL) limits for a range of pollutants
- Certified SRI colors reduce heat island effect
- Can reduce or eliminate the need for traditional drainage and detention requirements, saving space and money
- Can be designed to accommodate all native soil types
- 50-year design life based on proven field performance

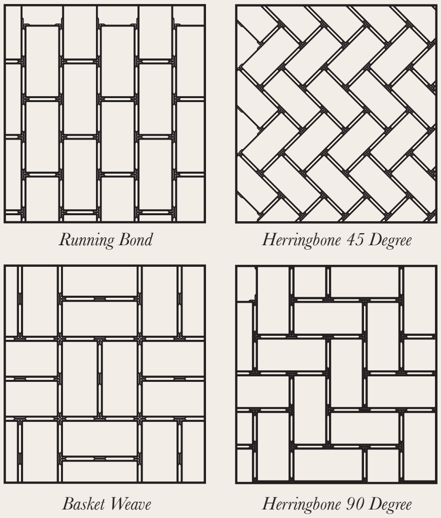


The availability of specific aggregate will often vary from region to region. In cases where it becomes necessary to substitute a similar size, your project engineer should always be consulted.



Shape

4 1/2" x 9" x 3 1/8"
(114.3mm x 228.6mm x 80mm)



Running Bond *Herringbone 45 Degree*

Basket Weave *Herringbone 90 Degree*

Laying Patterns

BELGARD®
COMMERCIAL

Sierra an Oldcastle Company
10714 Poplar Avenue
Fontana, CA 92337
PH: 909.355.6422
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For more info visit: www.belgardcommercial.com

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Interlocking Concrete Pavement Institute Certified Installer	City	State
California Outdoor Living	Anaheim	CA
Marina Landscape, Inc.	Anaheim	CA
VERSAI Design and Development, Pavers Division	Beverly Hills	CA
Pacific Coast Pavers	Brea	CA
Peterson Brothers Construction	Brea	CA
AJ's Landscaping	Brentwood	CA
Paver Decor Masonry, Inc.	Calimesa	CA
System Pavers - San Diego	Carlsbad	CA
OLVERA MASONRY INC.	Carpinteria	CA
Landmark Site Contractors	Corona	CA
Stepping Stone Landscape	Coronado	CA
Castlelite Block, LLC	Dixon	CA
Paver Plus, Inc.	Downey	CA
Paving Stone of San Diego, Inc.	El Cajon	CA
Coyote Construction - Pavers	Escondido	CA
Claddagh Paving	Fallbrook	CA
Aloha Pavers, Inc.	Huntington Beach	CA
I.M. Masonry Construction, Inc.	Lancaster	CA
Precision Contractors, Inc.	Lancaster	CA
Earth Shelter Developers	Lodi	CA
Go Pavers	Los Angeles	CA
Stowe Contracting, Inc.	Marina	CA
Stowe General Construction	Modesto	CA
Sierra Madre Landscape	Monrovia	CA
Systems Paving - Dallas	Newport Beach	CA
System Pavers - Novato	Novato	CA
Haney Landscape Inc.	Ojai	CA
System Pavers - Inland Impire	Ontario	CA
Alan Smith Pools	Orange	CA
Farley Interlocking Paving	Palm Desert	CA
Sunshine Landscape	Palm Desert	CA
DMA Construction	Paso Robles	CA
Edsons Pavers, Inc.	Perris	CA
Viking Pavers Inc.	Point Richmond	CA
System Pavers - Sacramento	Rancho Cordova	CA
McEntire Landscaping, Inc.	Redding	CA
INSTALL IT DIRECT	San Diego	CA
Landscapes West	San Diego	CA
Pavers 4 Less	San Diego	CA
Bauman Landscape and Construction	San Francisco	CA
Black Diamond Paver Stone and Landscape, Inc	San Jose	CA
European Paving Designs, Inc.	San Jose	CA
JCMS Landscaping	Santee	CA
Prime Gardens, Inc.	Sherman Oaks	CA
Alford's English Gardens INC	Signal Hill	CA
JFK Pavestone, Inc.	Simi Valley	CA

Tahoe Outdoor Living DBA Tahoe Paving Stones	South Lake Tahoe	CA
Pacific Pavingstone, Inc.	Sun Valley	CA
Weiland & Associates, Inc.	Swall Meadows	CA
System Pavers - Northern California	Union City	CA
System Pavers - Northern California	Union City	CA
Scarlett's Landscape, Inc.	Ventura	CA
System Pavers - Ventura	Ventura	CA
Southwest Specialties of California, Inc.	Walnut	CA
Southwest Specialties of California, Inc.	Walnut	CA

First Name	Intial	Last Name	Suffix	Company	City	State	ZIP	Cert Type	Expiration Date
Anthonie		Smith		T.B. Penick	San Diego	CA	92128	Pervious Concrete Craftsman	6/3/2016
Bill		Beeson		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Craftsman	2/5/2019
Danny		Stewart		T.B. Penick	San Diego	CA	92128	Pervious Concrete Craftsman	6/3/2016
David		Liguori		Bay Area Pervious Concrete	San Carlos	CA	94070	Pervious Concrete Craftsman	11/14/2019
Dennis	M.	Collins		Enviro-Crete, Inc.	Orangevale	CA	95662	Pervious Concrete Craftsman	10/1/2017
Guy		Collignon		Enviro-Crete, Inc.	Orangevale	CA	95662	Pervious Concrete Craftsman	6/13/2016
Steven	J.	Carrera		S 7 J Carrera Construction, Inc.	Watsonville	CA	95076	Pervious Concrete Craftsman	2/24/2016
Wayne		Jenness		T.B. Penick	San Diego	CA	92120	Pervious Concrete Craftsman	6/3/2016

First Name	Intial	Last Name	Suffix	Company	City	State	ZIP	Cert Type	Expiration Date
Alejandro		Ruiz Villalobos		Robert A. Bothman	Salinas	CA		Pervious Concrete Installer	10/26/2017
Alexander		Renteria		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
Arturo		Rosas		Beeson Masonry	Lake Hughes	CA	93532	Pervious Concrete Installer	8/6/2019
Daniel		Rodriguez Avalos		Robert A. Bothman, Inc.	Salinas	CA		Pervious Concrete Installer	10/26/2017
Edward		Ramirez		GPF Concrete	Perris	CA	92574	Pervious Concrete Installer	1/16/2017
Hector		Vela Villagrana		Robert A. Bothman Inc.	Antioch	CA	94509	Pervious Concrete Installer	10/26/2017
Humberto		Tovalin		T.B. Penick	San Diego	CA	92128	Pervious Concrete Installer	6/3/2016
Isaias		Ruiz		Melo Concrete Construction	Gilroy	CA		Pervious Concrete Installer	10/26/2017
Jaime		Sanitillan		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
Jaime		Villegas		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
James		Lamping		T.B. Penick	San Diego	CA	92128	Pervious Concrete Installer	6/3/2016
Joey		Lankford		Beeson Masonry	Lake Hughes	CA	93532	Pervious Concrete Installer	8/6/2019
Jose		Ceron		Bay Area Pervious Concrete	San Carlos	CA	94070	Pervious Concrete Installer	11/8/2015
Juan		Munoz		Galvan's Place and Finish	Perris	CA	92574	Pervious Concrete Installer	1/16/2017
Luis		Castellanos		Robet A. Bothman Inc.	San Jose	CA		Pervious Concrete Installer	10/26/2017
Mario		Ortiz		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
Michael		Orosz		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
Mike		Beczak		T.B. Penick	San Diego	CA	92128	Pervious Concrete	6/3/2016

First Name	Intial	Last Name	Suffix	Company	City	State	ZIP	Cert Type	Expiration Date
								Installer	
Piedad		Menchara Solorio		Robert A. Bothman Inc.	Salinas	CA	93905	Pervious Concrete Installer	10/26/2017
Ricardo	R.	Galvan		Galvan's Place and Finish	Perris	CA	92571	Pervious Concrete Installer	1/16/2017
Robert		Estrada		Bay Area Pervious Concrete	San Carlos	CA	95040	Pervious Concrete Installer	5/4/2017
Ron		Parietti			Pilot Hill	CA	95664	Pervious Concrete Installer	6/30/2015
Salvador		Rosas		Robert A. Bothman Inc.	San Jose	CA	95116	Pervious Concrete Installer	10/26/2017
Sergio		Grageda		Bay Area Pervious Concrete	San Carlos	CA	94070	Pervious Concrete Installer	11/8/2015
Victor		Santana		Robert A. Bothman Inc.	Salinas	CA	93906	Pervious Concrete Installer	10/26/2017

Appendix F – Soil Report

99.0300004

BORING LOG

GeoSoils, Inc.

W.O. 4633A-VN

PROJECT: S & V VAN NUYS ASSOCIATES

BORING B- 4 SHEET 1 OF 1

DATE EXCAVATED 2-19-97

SAMPLE METHOD: 8" Hol/140lb/30" Drop

■ SPT

▨ Ring

∿ Water Seepage

Depth (feet)	Sample			USCS Symbol	Dry Unit Wt. (pcf)	Moisture (%)	Description of Material
	Bulk	Undisturbed	Blows/6 in.				
							<u>0 - 30' ALLUVIUM</u> @ 0 - 9', Dark brown, very silty, very fine SAND, slightly moist, loose, slightly porous.
		▨	3/ 5	SM	101.7	17.2	
5		▨	7/ 13	SM	104.0	16.3	
10		▨	2/ 9	ML	99.8	14.2	@ 9 - 12', Brown, slightly sandy SILT, moist, slightly porous, moderately stiff.
		▨	7/ 14	ML	101.8	18.2	@ 12 - 18', Brown, sandy SILT, moist, slightly stiff.
15							
		▨	8/ 12	SM	97.9	19.5	@ 18 - 25', Brown, silty very fine SAND, moist, moderately dense.
20							
		▨	7/ 10	CL	99.7	14.9	
25							@ 25 - 30', Dark brown, sandy CLAY, with silty SAND layers, moist, slightly stiff.
30		▨	14/ 18	SM	97.0	17.4	@ 30-1/2', Red-brown, slightly silty very fine to fine SAND, moderately dense. Total Depth 30' No Groundwater
35							

GeoSoils, Inc.

PLATE A-4

BORING LOG

GeoSoils, Inc.

W.O. 4633A-VN

PROJECT: S & V VAN NUYS ASSOCIATES

BORING B-34 SHEET 1 OF 1

DATE EXCAVATED 2-24-97

SAMPLE METHOD: Rings/SPT Hammer

■ SPT

▨ Ring

∿ Water Seepage

970830034

Depth (feet)	Sample			USCS Symbol	Dry Unit Wt. (pcf)	Moisture (%)		Description of Material
	Bulk	Undisturbed	Blows/8 in.					
								0 - 11' ALLUVIUM Sandy SILT, medium to large amounts and fine SAND, grey-brown, damp, firm, trace small rounded GRAVEL. Moist, loose to moderately firm with depth.
5		▨	6/ 9	ML/ SM	107.6	11.1		
10		▨	6/ 8	ML/ SM	112.3	12.9		
								Total Depth @ 11' No Groundwater
15								
20								
25								
30								
35								

PINNACLE
ENVIRONMENTAL TECHNOLOGIES
#2 Santa Maria, Foothill Ranch, CA
Tel: (949) 470-3691 Fax: (949) 595-0459

BORING LOG

9910500H1

SITE: Former GM Assembly Plant
ADDRESS: Van Nuys Blvd. & Arminta Street
Van Nuys, California
DRILLING METHOD: GeoProbe Direct Push
DRILLING COMPANY: Vironex, Inc.

BORING No.: B-1
DATE: 12/3/99
GEOLOGIST: W. Malvey
REVIEWED: K. Thompson, R.G.
ELEVATION: Not Measured

Time	PID	LEL/H2S	Depth	Sample	DESCRIPTION	Graphic Log	Well Const
					Unpaved dirt at surface.		
1425	0	0/0			Silty Clay (CL), trace sand, dark brown, firm, damp, no odors		
1430	0	0/0	5		Silty Clay (CL), trace sand, dark brown, firm, damp, no odors		
1435	0	0/0	10		Sand (SP), some silt, grayish-tan, loose, damp, very fine-grained, no odors		
1445	0	0/0	15		Sand (SP), some silt, grayish-tan, loose, damp, very fine-grained, no odors		
1450	0	0/0	20		No Recovery		
1500	0	0/0	25		Silt (ML), trace sand, trace clay, dark brown, loose, damp, very fine-grained, no odors		
1515	0	0/0	30		Silt (ML), trace sand, trace clay, dark brown, loose, damp, very fine-grained, no odors		
					Boring terminated at 30 feet below ground surface		

991050042

BORING LOG

PINNACLE
ENVIRONMENTAL TECHNOLOGIES
#2 Santa Maria, Foothill Ranch, CA
Tel: (949) 470-3691 Fax: (949) 595-0459

SITE: Former GM Assembly Plant
ADDRESS: Van Nuys Blvd. & Arminta Street
Van Nuys, California
DRILLING METHOD: GeoProbe Direct Push
DRILLING COMPANY: Vironex, Inc.

BORING No.: B-2
DATE: 12/3/99
GEOLOGIST: W. Malvey
REVIEWED: K. Thompson, R.G.
ELEVATION: Not Measured

Time	PID	LEL/H2S	Depth	Sample	DESCRIPTION	Graphic Log	Well Const
					Unpaved dirt at surface.		
0720	0	0/0			Silty Clay (CL), trace sand, dark brown, firm, damp, no odors		
0725	0	0/0	5		No Recovery		
0735	0	0/0	10		Sand (SP), some silt, grayish-tan, loose, damp, very fine-grained, no odors		
0740	0	0/0	15		Sand (SP), some silt, grayish-tan, loose, damp, very fine-grained, no odors		
0755	0	0/0	20		Silt (ML), trace sand, trace clay, dark brown, loose, damp, very fine-grained, no odors		
0800	0	0/0	25		Silt (ML), trace sand, trace clay, dark brown, loose, damp, very fine-grained, no odors		
0840	0	0/0	30		Silt (ML), trace sand, trace clay, dark brown, loose, damp, very fine-grained, no odors		
					Boring terminated at 30 feet below ground surface		

GeoSoils, Inc.

BORING LOG

W.O. 4633A-VN

PROJECT: S & V VAN NUYS ASSOCIATES

BORING B- 4 SHEET 1 OF 1

DATE EXCAVATED 2-19-97

SAMPLE METHOD: 8" Hol/140lb/30" Drop

■ SPT

▨ Ring

∿ Water Seepage

970830004

Depth (feet)	Sample		Blows/6 in.	USCS Symbol	Dry Unit Wt. (pcf)	Moisture (%)	Description of Material
	Bulk	Undisturbed					
							0 - 30' ALLUVIUM @ 0 - 9', Dark brown, very silty, very fine SAND, slightly moist, loose, slightly porous.
		▨	3/ 5	SM	101.7	17.2	
5		▨	7/ 13	SM	104.0	16.3	
10		▨	2/ 9	ML	99.8	14.2	@ 9 - 12', Brown, slightly sandy SILT, moist, slightly porous, moderately stiff.
		▨	7/ 14	ML	101.8	18.2	@ 12 - 18', Brown, sandy SILT, moist, slightly stiff.
15							
		▨	8/ 12	SM	97.9	19.5	@ 18 - 25', Brown, silty very fine SAND, moist, moderately dense.
20							
		▨	7/ 10	CL	99.7	14.9	
25							@ 25 - 30', Dark brown, sandy CLAY, with silty SAND layers, moist, slightly stiff.
30		▨	14/ 18	SM	97.0	17.4	@ 30-1/2', Red-brown, slightly silty very fine to fine SAND, moderately dense. Total Depth 30' No Groundwater
35							

Appendix 4.D.2

Upgrades to Pump Plants and Associated Stormwater Treatment Opportunities in the City of Los Angeles Upper Los Angeles River Watershed

Implementation Strategy for Pump Plant 622

Upgrades to Pump Plants and Associated Stormwater Treatment Opportunities in the City of Los Angeles Upper Los Angeles River Watershed

Implementation Strategy for Pump Plant 622

Jointly prepared by:

Tetra Tech
3475 East Foothill Boulevard
Pasadena, CA 91107

Black & Veatch Corporation
800 Wilshire Blvd, #600
Los Angeles, CA 90017

City of Los Angeles
LA Sanitation
Watershed Protection Division
1149 S Broadway, 10th Floor
Los Angeles, CA 90015-2213

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1. Introduction

Multiple pollutants currently impair the beneficial uses of the Los Angeles River. To address these impairments, the City of Los Angeles (City) must comply with the water quality requirements presented in the Municipal Separate Storm Sewer System (MS4) Permit) and State-mandated total maximum daily loads (TMDLs). Recently prepared Enhanced Watershed Management Programs (EWMPs) prescribe collaborative and adaptive strategies for the City to attain compliance with these requirements; however, the scale of implementation is extraordinary.

The EWMPs currently forecast implementation of over 3,000 acre-feet of green infrastructure and regional control measures by the City (totaling $3.8 billion in capital cost) in the Upper Los Angeles River (ULAR) watershed alone. At this scale, cost-effective implementation will be challenging in many locations, particularly when the suitable opportunities for stormwater treatment are *not* located near runoff and pollutant sources. One solution is divert runoff to the highest efficiency opportunities using existing infrastructure.

EWMP Requirement:
Implement >3,000 acre-feet of BMPs in the ULAR basin before 2037

There are multiple aging pump plants located strategically throughout the City of Los Angeles – each intended to alleviate or prevent flooding in low lying areas where gravity flow is not feasible (Figure 1). If upgrades to these pumps can be leveraged to provide water quality benefits (Figure 2), the advantages are two-fold:

1. ***Creating* High-Efficiency Treatment Opportunities:** The efficiency (pollutant reduction per dollar) is maximized by routing runoff to areas with high treatment potential and maximizing the treated drainage area using existing infrastructure.
2. **Improving Resilience:** Control measures sited upstream from pumps can reduce pump cycle frequency, energy use, and maintenance burden by intercepting and retaining runoff volume from small storm events.

This conceptual design describes recommended upgrades to the aging infrastructure at Pump Plant 622 along with integrating multi-benefit stormwater treatment strategies into the plant upgrades. A cost-effective solution that addresses Permit water quality requirements in tandem with flood control functions will be recommended. These solutions would also provide multiple other benefits for residents and businesses in the area, and promote a greener, healthier, and more sustainable urban landscape. The concepts will justify incorporating water quality components into future infrastructure upgrades, and will have wider implications when considering leveraging existing infrastructure to support integrated water planning (One Water) in the Los Angeles region.

EXISTING CONDITIONS

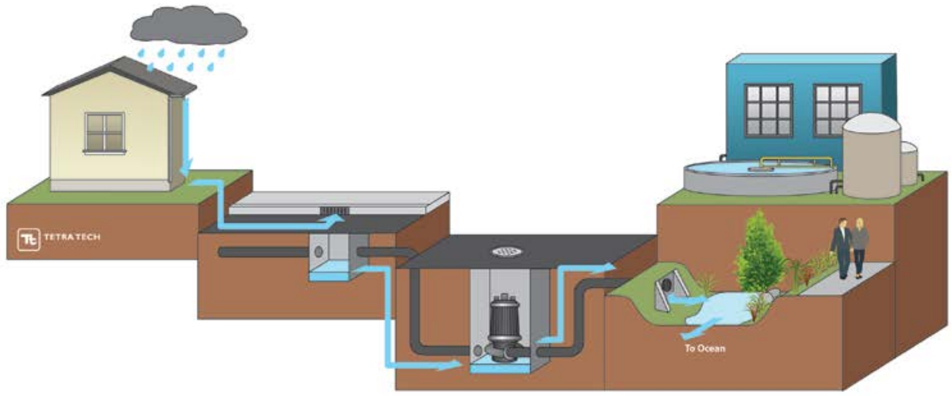

Figure 1. Conceptual diagram illustrating a typical infrastructure design. Pumps in low-lying areas use energy to convey runoff directly to the receiving water without treatment. In some instances, dry weather flows are diverted to the sanitary sewer for treatment.

PROPOSED SYNERGY: LEVERAGING INFRASTRUCTURE UPGRADES

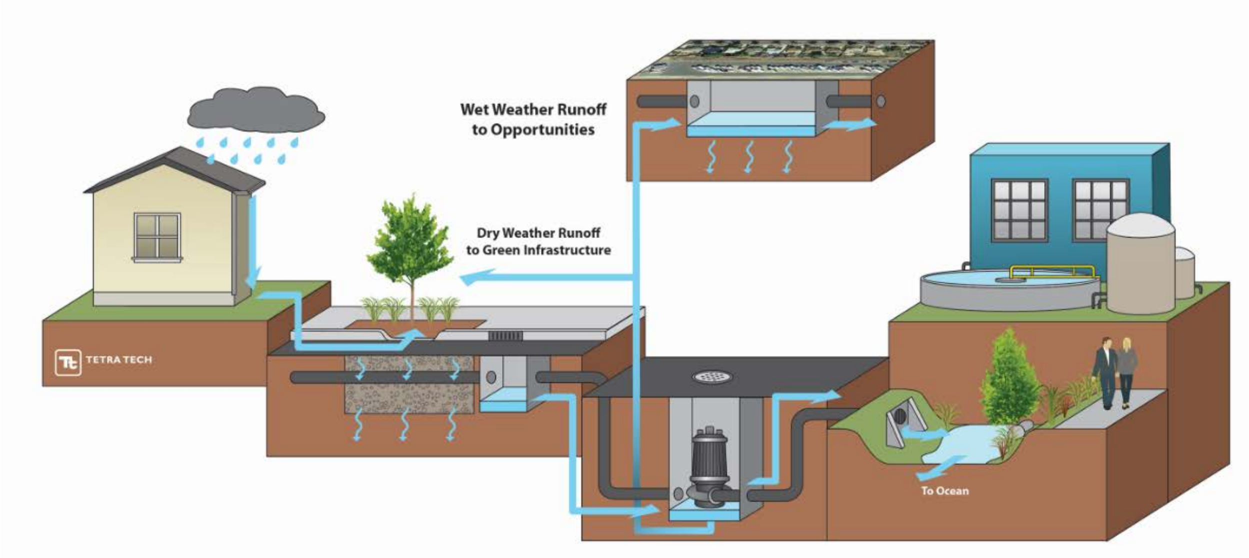

Figure 2. Conceptual diagram illustrating the potential benefits of integrating water quality design into future upgrades. Integrating water quality and flood control can lead to cost-effective treatment by taking advantage of existing facilities to move runoff to BMP opportunities. Upstream control measures can also reduce the burden on pumps by intercepting runoff near the source.

2. Background

This conceptual design focuses on the rehabilitation and green infrastructure modification of Pump Plant 622. Key background information, such as regulatory context and a description of the project site is provided in the following paragraphs.

2.1. Stormwater Regulations and Work to Date

The LA River is on the *Clean Water Act 303(d) List of Water Quality Limited Waterbodies* for ammonia, bacteria, zinc, copper, lead, algae, oil, and trash. To address these impairments, the State has developed TMDLs for metals, nitrogen, and trash, which contain compliance schedules for the City to reduce impacts from stormwater discharges. The LA River Metals TMDL has a final compliance date of 2028 for wet weather. The LA River Bacteria TMDL, perhaps the most challenging TMDL faced by the City, has a wet-weather compliance date of 2037. Moreover, compliance of these TMDLs would also address the pollutant reduction requirements of the 2012 MS4 (MS4) Permit (Order No. R4-2012-0175; NPDES Permit No. CAS004001). The stormwater project described herein would be a key component of the metals and bacteria Load Reduction Strategies for Segment D-Reach 4 of the LA River, and would address many other stormwater pollutants from the targeted subwatershed during wet weather.

2.2. Project Location and Site Description

The targeted subwatershed, SWS 685149 in the R4-LAR-Sepulveda subwatershed, is bordered by the 405 freeway to the west, Pacoima Wash to the east, Rayen Street to the north, and the Van Nuys Metrolink is immediately south of the pump station as shown in Figure 3. SWS 685149 is serviced by approximately 98 catch basins that drain to a network of both city and county storm drains that discharge to the Pacoima Wash and ultimately to the Los Angeles River (Figure 3 and Table 1). Pump Plant 622 dewaters the sag below a bridge and receives stormwater runoff from an approximately 13-acre subwatershed.

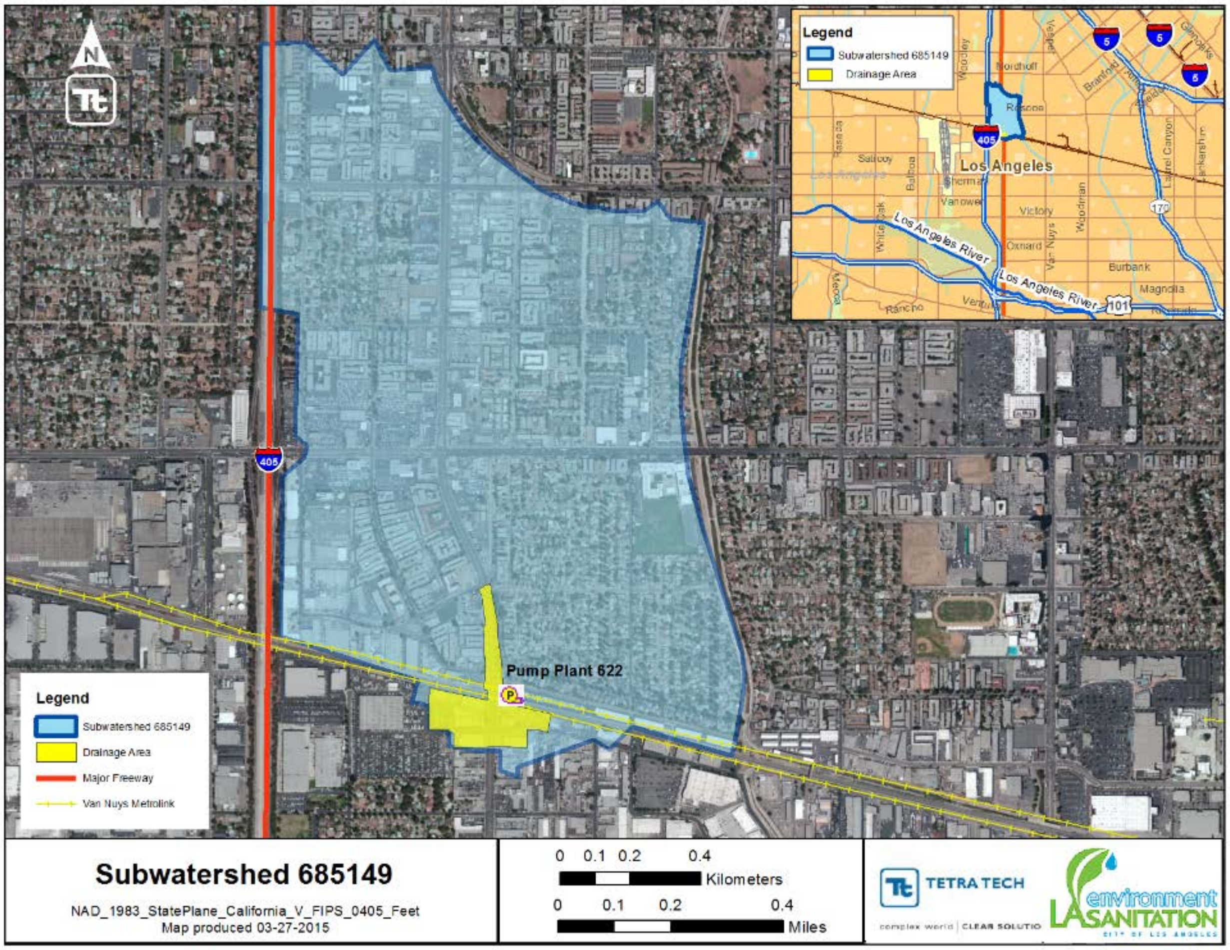

Figure 3. SWS 685149 in The R4-LAR-Sepulveda subwatershed.

Table 1. Site summary

Site attribute	Value
Watershed	Upper Los Angeles River
Subwatershed	SWS 685149
Total Pump Plant Drainage Area	12.7 acres

3.Proposed Pump Plant Upgrades

Pump Plant 622 is intended to provide flood protection to Sepulveda Boulevard south of Roscoe Boulevard in the Van Nuys area of the City. It does so by lifting storm water flows from the sump in Sepulveda Boulevard below the Metrolink railroad tracks up to a double box culvert storm drain located parallel and to the north of the Metrolink railroad tracks east of Sepulveda Boulevard. This double box culvert generally flows southeast and eventually ties into the Los Angeles County drainage system and the Los Angeles River. The current configuration of the pumping station is shown in Figure 4.

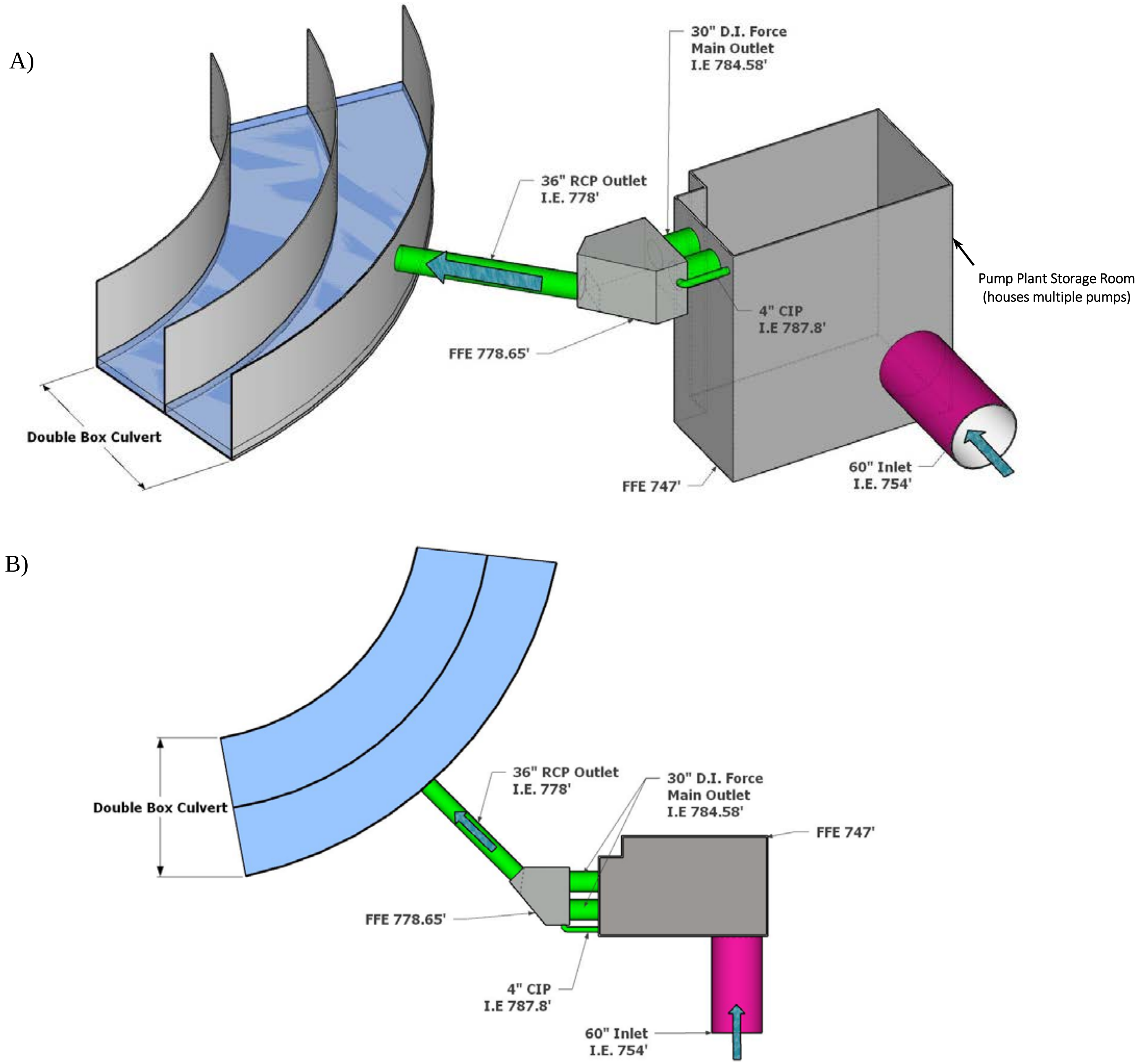

Figure 4. A) Isometric Configuration of Pump Plant 622. B) Plan Configuration of Pump Plant 622.

The characteristics of the Pump Plant 622 are summarized in the following sections. This information was obtained through a review of the as-built plans, a site visit to the plant, and other information obtained from LA Sanitation.

3.1. General Description of Pump Plant No. 622 (Sepulveda)

- Street address: 15266 Cabrito Road, Van Nuys, CA.
- Constructed in 1968.

- Underground reinforced concrete structure with three levels: a motor/electrical room level, a bar screen room level, and a storage room level.
- Reinforced concrete stairs provide access to the interior of the pump plant from the ground surface and between levels.
- Miscellaneous metal items are damaged including railings, ladders, bar screens, and ventilation louvers.
- Lighting is original and inadequate for many maintenance operations.
- The plant incorporates three pumps: two service pumps and one sump pump.
- The plant wet well storage is approximately 45,700 gallons.
- Inlet pipe is a 60” ID RCP with an invert elevation of 754.0.
- Main outlets are dual 30” DIP force mains (one for each pump) with an invert elevation of 784.58.
- Sump pump outlet is 4” CIP with an invert elevation of 787.2
- A 350 KW Onan trailer mounted portable backup generator is located on site. The original design included a permanent natural gas powered 150 KW backup generator located in the motor room of the pump plant. The original permanent generator has been removed.
- The fenced area around the plant is about 7,300 square feet.
- Security problems were noted at the site – the chain link fence has a large hole in it and there is evidence of intruders (graffiti, garbage, etc.).
- Based on discussions with maintenance staff, flooding on Sepulveda Boulevard, making it impassable to vehicles, occurred at least once in the last 30 years.

3.2. Existing Pumps and Proposed Upgrades

This section describes the existing and proposed pump types and capacities for Pump Plant 622.

3.2.1. Existing Duty Pumps

Based upon information provided by operations staff, the two duty pumps are Lane Bowler vertical turbine pumps each with a pumping capacity of 15,500 gpm (34.5 cfs) at a static head of 32’. These pumps are each powered by a single speed, 150 HP motor manufactured by US Motors. One pump operates at a time, providing 100% back-up redundancy.

Per the City of Los Angeles Storm Drain Design Manual, sump areas like this are to be sized for the 50-year storm. The 50-year storm for this this area was calculated to be approximately 40 cfs in Appendix B. The pump capacity of Plant 622 is 34.5 cfs, approximately 15% less than the 50-year storm.

The Pump # 2 motor was noted to leak oil and the breaker tripped when it was turned on during the site visit. A hole in the housing of Pump 2 appears to have been repaired with a sleeve wrap around the pump.

3.2.2. Existing Sump Pump

Based upon information provided by operations staff, the sump pump is a Yeomans submersible pump with a single speed 15 HP motor with a rated flow rate of 500 gpm. The purpose of this pump is to slowly drain the storage room from the low water level to the sump level after a storm is over. Based upon discussions with maintenance staff, this pump is not operational.

3.2.3. Proposed Duty Pumps

Due to the age, condition, and flow capacity, the two main duty pumps should be replaced and upgraded to meet the 50-year storm of 40 cfs. This would provide 100% redundancy for the station. Because of the flow requirements and available space within the existing station, vertical turbine solids handling pumps (similar to the existing ones) are considered.

The preliminary pumps selected for this application are Fairbanks Morse model 30” VTSH LH solids handling pump with 200 HP motors. To reduce the power load demand on motor start-up, solid state soft starters should be considered for the motor control center. The pump system curve for the duty pumps is included in Appendix C.

3.2.4. Proposed Sump Pump

The existing sump pump is rated at 500 gpm and has a 15 HP motor, but is not currently operational and should be replaced. To replace this pump, a submersible pump with integral motor is considered.

To meet the BMP 85th percentile flow of 2.5 cfs (as discussed in Section 4), the preliminary pump selected for this application is a Fairbanks Morse model 6” 5434 M&W submersible pump with 25 HP motor. The pump system curve for the sump pump is included in Appendix C.

3.2.5. Pump System Summary

The existing and proposed pump system for Pump Plant 622 is summarized in Table 2.

Table 2. Existing and proposed pump system components.

Existing Conditions				
Pump	Pump Type	Pump Capacity (gpm)	Static Head (feet)	Power (HP)
Duty Pump #1	Lane Bowler vertical turbine	15,500	32	150
Duty Pump #2	Lane Bowler vertical turbine	15,500	32	150
Sump Pump	Yeomans submersible	500	N/A	15
Proposed Conditions				
Duty Pump #1	Fairbanks Morse model 30” VTSH LH solids handling	17,900	32	200
Duty Pump #2	Fairbanks Morse model 30” VTSH LH solids handling	17,900	32	200
Sump Pump	Fairbanks Morse model 6” 5434 M&W	1,200	N/A	25

3.3. Structural Integrity

Based upon a cursory visual inspection of the pump plant, which was limited to those portions that were exposed to view (top of roof slab and pump plant interior), the structure appeared to generally be in good to very good condition. There are relatively minor concrete cracks in various locations throughout the structure, which is not uncommon for conventionally reinforced concrete. In the Motor Room, there is a damaged louvered vent at the ventilation and exhaust well. Also in the Motor Room, adjacent to the electrical panels, there are abandoned embedded metal items in the floor slab that are corroded. The current condition of the motor room is shown in Figure 5.

According to the Design Data on the General Plan of the as-built drawings, the Motor Room was designed for a lateral earth pressure of 143 pounds per cubic foot (PCF), while the Bar Screen Room and Storage

Room were designed for a uniform lateral earth pressure of 2000 pounds per square foot (PSF), equivalent to 143 PCF at 14 feet of depth. There are no seismic design parameters shown in the Design Data.

Figure 5. Pump Plant 622 Motor Room.

3.3.1. Proposed Structural Upgrades

The condition of the structure appears to be satisfactory. The replacement of the louvered vent and monitoring of the embedded metal items in the motor room for further corrosion should be considered. Additionally, a more detailed structural evaluation should be conducted during the pre-design phase of the project. If a current Code analysis/evaluation of the structure is desired, a geotechnical investigation should be performed to determine if the design lateral earth pressures are appropriate, and to determine if seismic earth pressure should be considered.

Due to the proposed modifications noted below, minor structural modifications may be required to accommodate the new equipment.

3.4. Miscellaneous Upgrades

Based upon site observations and discussions with maintenance staff, the following miscellaneous repairs and upgrades should be considered:

- Upgrade the Motor Control Center.
- Upgrade the SCADA / Instrumentation and Control Equipment.
- Replace pump discharge piping and valves.
- Install level control through ultrasonic sensors (primary) with float backup.
- Upgrade railings and ladders.
- Replace damaged bar screens.
- Replace the damaged louver in the motor room.
- Repair or replace the chain-link fence around the site.
- Sand blast and paint the interior and exterior of the building.

- Replace the ventilation system.
- Upgrade the interior and exterior lighting.
- Replace the on-site portable generator with new generator in plant (the original pump plant had an interior generator).
- Implement recommendations from the Arc Flash Study (to be determined).

3.4.1. Conceptual Layout and Design

The concept elements of the Pump Plant are as follows:

- Replace and upgrade the duty pumps, sized to convey the 50-year storm.
- Replace the existing sump pump with a new submersible pump.
- Perform miscellaneous upgrades.

3.4.2. Power Requirements

This section describes the power requirements needed to supply Pump Plant 622.

3.4.2.1. Electrical Supply

The pump plant has an existing 480V/500A service. A preliminary review indicates that if the replacement pumps include a solid state soft starter (instead of the existing magnetic starter) the existing service appears to be adequate for the upgraded pumps.

3.4.2.2. Backup Power Supply

The existing 350 KW backup generator is of sufficient size to power the replacement pumps. However, the generator is aging and it is not known if it is complies with current regulations. Additionally, since the generator is located outside, it is subject to damage from the elements and vandalism. As an alternate to this generator, a new 250 KW natural gas powered backup generator could be installed within the motor room of the existing pump plant building.

3.4.3. Operations and Maintenance

Operations and maintenance (O&M) procedures will be very similar to those currently conducted at Pump Plant 622. Major O&M items include monthly exercising of pumps and generator, as well as annual in-depth inspection, lubrication, and scheduled/worn-out part replacement.

3.5. Preliminary Opinion of Cost

Including a 25% contingency, the preliminary opinion of cost to complete the Pump Plant upgrades is approximately $2.0 million. A more detailed breakdown of costs is included in Section 8.

Due to the preliminary level of this study, this preliminary opinion of cost should be considered suitable for the early planning stage of the project. As the work becomes more defined in the subsequent project stages, it is expected that the opinion of cost will be revised.

4. Green Infrastructure Alternative Analysis Evaluation for Wet Weather Treatment

Integrating green infrastructure improvements into the rehabilitation of Pump Plant 622 can enhance the overall performance of the system and expand the benefit of the Pump Plant beyond its original function as a flood control mechanism. By linking the "gray infrastructure" (i.e. the physical pump plant) with the green infrastructure, multiple objectives can be achieved within a seamless system, reducing the overall cost to achieve each individual objective separately. In addition to the flood control function, this integration can help to achieve EWMP water quality improvement objectives while simultaneously providing the numerous advantages that green infrastructure brings to the City, such as an improvement to the community's overall well-being, increased property values, enhanced aesthetics, and recreational opportunities.

According to the ULAR EWMP, right-of-way along streets are the most extensive opportunity to implement BMPs on public land. In developed areas, curb and gutter in the road provide an opportunity to intercept both dry and wet weather runoff prior to entering the storm drain system and treat it within the extents of the public right-of-way. Green streets have been demonstrated to provide "complete streets" benefits in addition to stormwater management, including pedestrian safety and traffic calming, street tree canopy and heat island effect mitigation. The City of Los Angeles is planning to implement a Great Streets Initiative that seeks to enhance various areas of the City by making changes with temporary treatments such as plazas and parklets, and permanent changes to curbs, street lighting, and street trees (www.lamayor.org/greatstreets). The Great Streets Initiative is being implemented in aims of activating public spaces, providing economic revitalization, increasing public safety, and enhancing local culture. One setback for this area is narrow sidewalks, preventing the street from reaching its full potential. Because bicycle riding is permitted on sidewalks in the City of Los Angeles, a potential solution to narrow sidewalks would be to create a bicycle lane, decreasing sidewalk traffic In addition to the Great Streets initiative, the City of Los Angeles 2010 Bicycle Plan (LDCP 2010) proposes a bike lane for Sepulveda Boulevard from Rinaldi Street to Sherman Oaks Avenue. The plan notes that bicycle lanes along streets has been shown to have multiple economics, social, and environmental benefits such as, improvement to the businesses, increased number of riders, and enhanced safety. Utilizing permeable pavement in the bike lane can add an enhancement to water quality to the long list of benefits.

Localized flooding can result from insufficient capacity to drain a site and/or from excessive (and often unanticipated) offsite flows. Many causes of localized flooding can be remedied by repairing or replacing the existing infrastructure; however, it is often more practical to reduce the peak discharge and volume of runoff that are conveyed to the existing storm drainage network. As suggested in Alternative 2 below, retrofitting the study area with green infrastructure could provide a viable strategy to regulate runoff and alleviate localized flooding.

Implementing the green infrastructure concepts presented in the following sections provides an opportunity to integrate multiple initiatives currently proposed and in various stages of implementation across the City, the EWMP, Great Streets Initiative, and the 2010 Bicycle Plan. Combining all of these initiatives into one approach is a key component of the One Water plan approach.

There are two alternatives for incorporating treatment for wet weather flow into the pump station upgrades that could be implemented in tandem or independently. Water from the pump plant could be diverted into an underground infiltration basin (post-pump treatment) or stormwater flows could be treated before flowing into the pump plant (pre-pump treatment), using green infrastructure concepts suited for implementation in a protected bicycle lane and right-of-way, including permeable pavement and bioretention. Each alternative proposes incorporating treatment through green infrastructure in an attempt to improve the water quality of stormwater prior to discharge into the Los Angeles River (Segment D-Reach 4) and ultimately into the Pacific Ocean. Both alternatives incorporate diverting stormwater runoff from the street and the surrounding lands through a series of BMPs and allowing stormwater to infiltrate.

Alternative 1, referred to as "**Post-Pump Treatment**", includes two different scenarios that are designed to either pump or divert stormwater runoff into a underground infiltration basin underneath W. Cabrito Road on the east side of Sepulveda Blvd (Figure 6). Stormwater runoff is routed from two catch basins under the railroad bridge crossing Sepulveda Blvd into a wet well in the pump plant. The runoff will be pumped out of the wet well and into the City of LA owned culvert at a rate of approximately 40 cfs, once the pumps have been upgraded. There is also a sump pump that is allocated to slowly drain the storage room with the rate of 1.1 cfs from the low water level to the sump level after a storm is over. Scenario 1 proposes a gravity diversion structure sized to divert a portion of the flow from the bottom of the existing pump outfall junction structure into a proposed underground infiltration basin and scenario 2 proposes upgrading the existing sump pump to pump stormwater runoff directly from the existing wet well into the proposed underground infiltration basin.

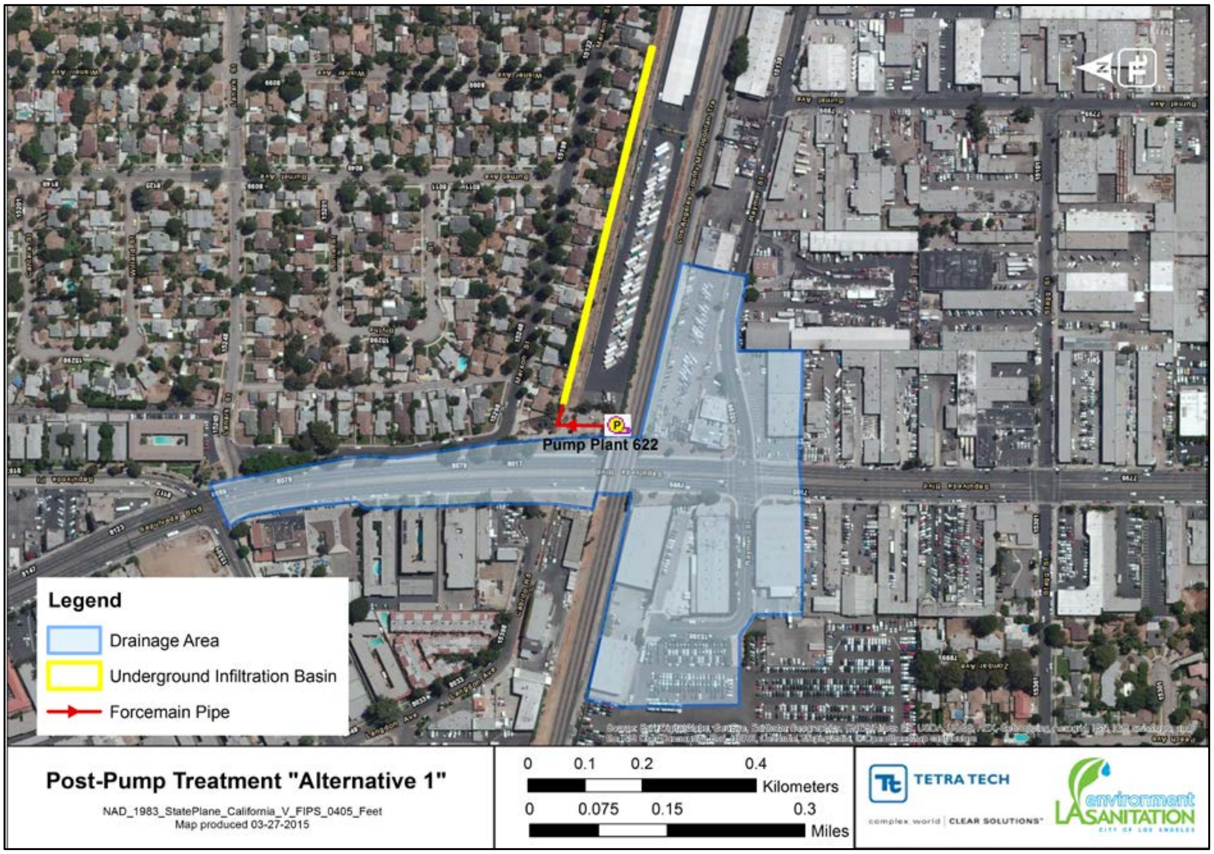

Figure 6. Alternative 1 potential BMP location.

Alternative 1-Scenario 1: Under this Scenario, it is assumed that the wet weather runoff would be pumped out at a rate of 40 cfs, once the pumps have been upgraded, from the storage room and discharge to the existing pump outfall junction structure. The existing structure would be retrofit with a gravity diversion weir capable of diverting flow at a maximum diversion rate of 20 cfs (half of the pumping rate and half of the approximate peak flow rate for 50-year storm design) from the bottom of the existing pump outfall junction structure into the proposed underground infiltration basin through the proposed 36-inch outlet pipe (Figure 7). The rest of the flows that are higher than the diversion capacity will drain to the existing 36-inch storm drain that discharges to a double box culvert resulting in approximately half of the flow reaching the pump plant being diverted into the BMP.

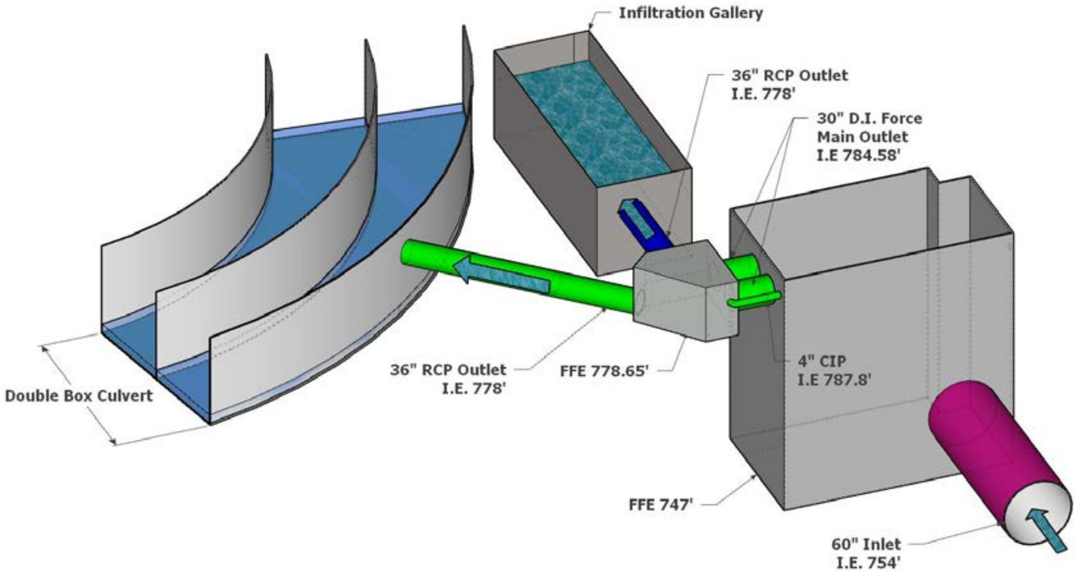

Figure 7. Weir-based Gravity Diversion System for Alternative 1-Scenario 1.

Alternative 1-Scenario 2: In this scenario, the wet weather runoff from the existing storage room would be pumped out at a constant rate of 2.5 cfs. To achieve this flow would require that the existing sump pump be upgraded to allow pumping of the peak flow rate for the 85th percentile storm design. A 4-inch outlet pipe would be connected to the existing 4 inch pipe and routed through the top of the existing pump outfall junction structure to divert the water from the sump pump to the proposed infiltration gallery Treatment of the 85th-percentile runoff volume would constitute compliance with all water quality requirements for the tributary drainage area (based on current interpretation of the MS4 Permit, as discussed in the EWMPs). This flow would be pumped into a underground infiltration basin underneath of W Cabrito Road on the east side of Sepulveda Blvd similar to the one proposed in scenario 1 (Figure 8). Utilizing the sump pump to pump runoff to the underground infiltration basin not only can significantly improve water quality but also, could greatly reduce the need for the main pumps to turn on during small storm events and decrease the operation time considerably during larger storm events.

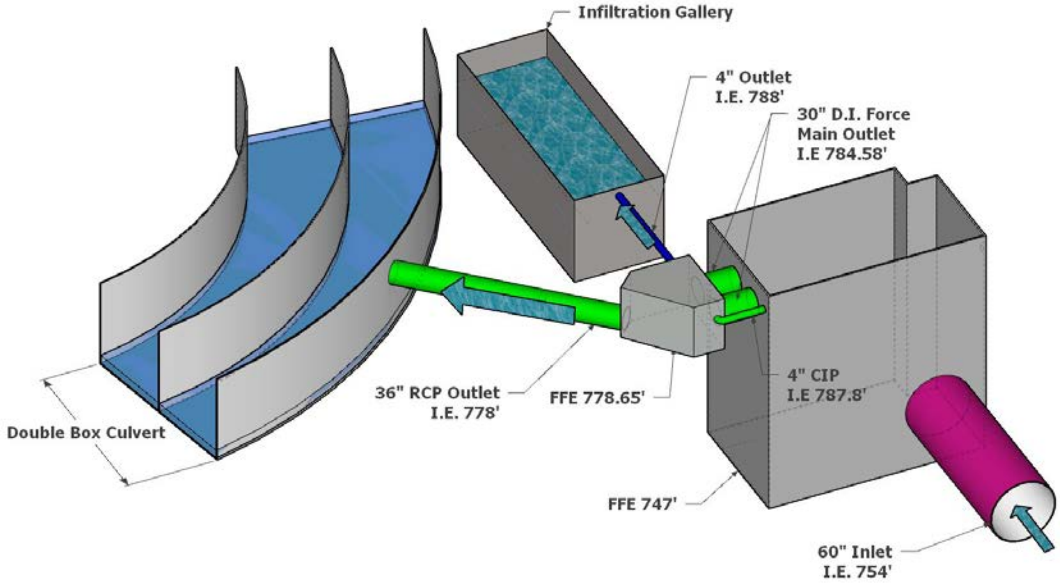

Figure 8. Direct Pumping System for Alternative 1-Scenario 2.

Alternative 2, referred to as “**Pre-Pump Treatment**”, is intended to treat the wet weather runoff from a 12.7-acre drainage area through permeable pavement and bioretention areas implemented within the bicycle lane and the right-of-way of Sepulveda Boulevard (Figure 9) prior to its arrival at the pump plant. To treat this runoff, bioretention areas could be implemented along the east side of Sepulveda Blvd. and along the outside edge of a newly created bicycle lane on the west side of Sepulveda Blvd. Overflow from bioretention and additional runoff should be treated in permeable pavement implemented within the newly created bicycle lane on the West side of Sepulveda Boulevard.

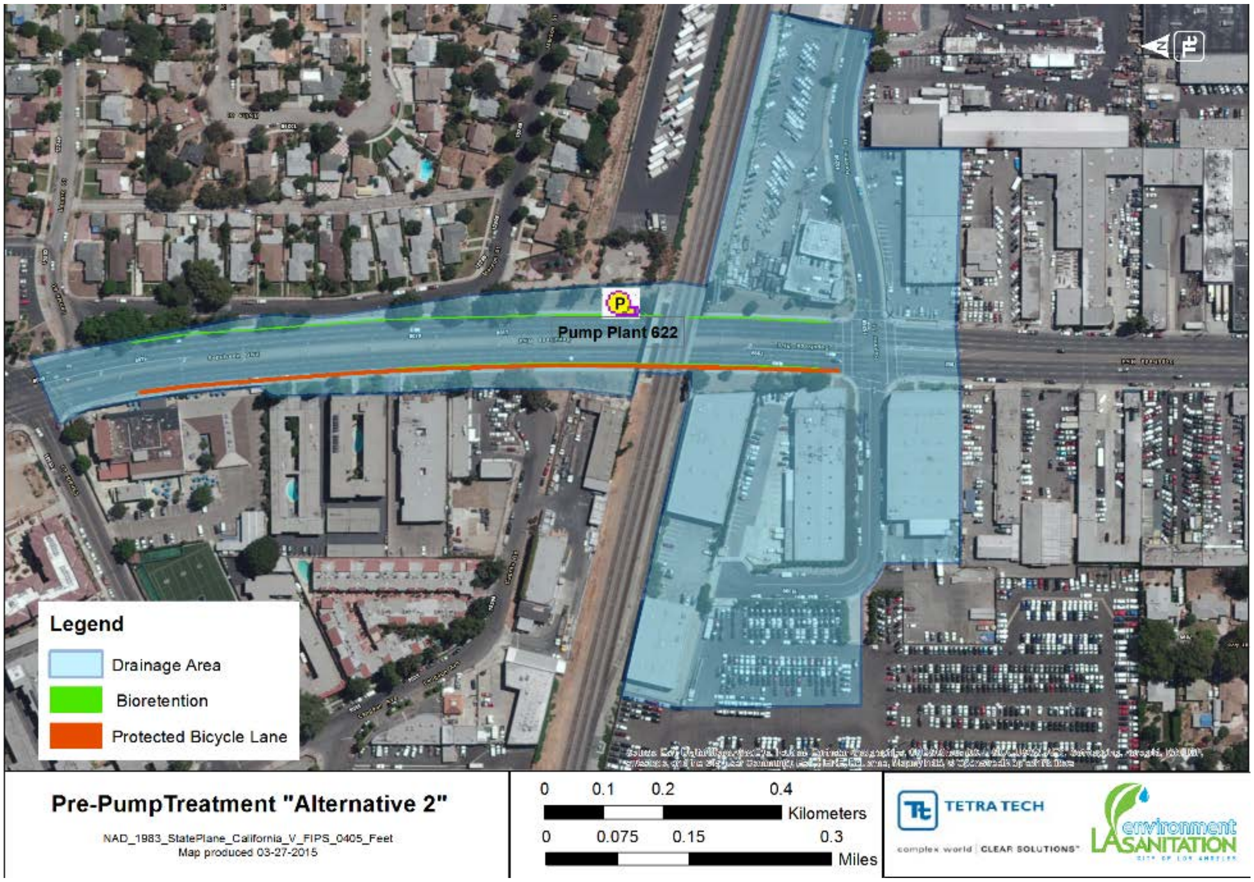

Figure 9. Alternative 2 recommended areas for BMP implementation.

Table 3 presents a comparison of the configuration of each alternative. Details for the sizing and evaluation of each alternative is presented in Section 3.5

Table 3. Comparison of Alternatives.

Alternative	Scenario	Sump Pump Flow Rate (cfs)	Diversion Rate (cfs)	BMP Area (ac)			Annual Volumetric Treatment (ft^3)
				Bioretention	Permeable Pavement	Underground Infiltration Basin	
Post-Pump Treatment	1	N/A	20	N/A	N/A	0.17	216,839
	2	2.5	N/A	N/A	N/A	0.17	302,604
Pre-Pump Treatment	N/A	N/A	N/A	0.12	0.19	N/A	310,157

4.1. BMP Sizing and Evaluation

The entire drainage area primarily encompasses industrial and secondary roadway land uses, and contains approximately 90 percent impervious surface. Table 4 and Table 5 illustrate the predominant soil texture and the land use types within SWS 685149. The details of the two proposed alternatives are outlined below.

Table 4. SWS 685149 soils summary.

Soil Series	Infiltration Rate (in/hr) (Source: USDA)	Hydrologic Soil Group (Source: USDA/ LA Soils GIS Layer)	Percentage of Watershed
Yolo loam	0.57 to 1.98	A/B	100%

Table 5. SWS 685149 distribution of land use types.

Landuse type	Acres	Percent
High Density Single Family Residential	0.03	0.2%
Multi-family Residential	0.02	0.2%
Commercial	0.15	1.2%
Institutional	0.03	0.2%
Industrial	7.31	57.6%
Secondary Roads	5.14	40.6%
Total	**12.7**	**100%**

4.1.1. Wet Weather Flow

Wet weather flow can vary significantly from storm to storm and from year to year. To analyze the proposed system and determine the potential inflow, a 10-year continuous simulation period from January 1, 2002 to December 31, 2011 was used. Hourly wet weather runoff time series for each contributing land use were obtained from the calibrated Watershed Management Modeling System (WMMS; Tetra Tech 2010a and Tetra Tech 2010b).

4.1.2. Existing Pollutant Loading Assessment

According to the ULAR EWMP, for the Sepulveda Boulevard study area, zinc is found to be the limiting pollutant among metals and bacteria, and the initial EWMP suggested that a 34% reduction of zinc throughout the Los Angeles River Reach 4 watershed would be necessary for final compliance. Therefore for this study area, zinc was used as the basis for removal comparison. The zinc load entering the storm drain varies depending on the size of the storm and the number of dry days between storms. A 10-year continuous simulation period from January 1, 2002 to December 31, 2011 was used to analyze the zinc removal and water quality improvement. The long-term time series for zinc load across the watershed was obtained from the calibrated WMMS at an hourly time step (Tetra Tech 2010a and Tetra Tech 2010b). Other pollutants including copper, lead, nitrogen, phosphorous, and pathogens, long-term time series from the calibrated WMMS were used to analyze the comprehensive water quality benefits for the recommended alternative.

4.1.3. Geotechnical Literature Review

A geotechnical literature review was performed to identify potential geologic or subsurface issues that could affect BMP implementation or configuration. According to the City of LA Bureau of Standards soil report adjacent to the pump plant 622, the first 10.5 feet of the site soils consist of brown fine to medium-grained poorly graded sand (SP) with a trace of clay fines. Below that layer, there is 2.5 feet of brown clayey sand (SC) following by 2 feet of brownish tan fine to medium-grained poorly graded sand with some clay fines (SP). No water table is detected up to the depth of 15 feet from the surface. Based on the United State Department of Agriculture (USDA) sandy soil has a moderate water storage capacity of about 8.3 inches which indicates the maximum amount of plant available water a soil can provide. This is an important factor which supports plant growth and soil biological activity. The infiltration rates of the sandy soils can vary from 0.5 inches per hour to 1 inches per hour. Soil borings from the area around the pump plant are include in Appendix F.

This review was limited to existing data and should be supplemented with a full, site-specific geotechnical and seismic investigation prior to preliminary designs. Infiltration rates and other subsurface conditions must be verified to ensure project success and public safety.

4.1.4. BMP Optimization and Performance

To optimize the size of the proposed BMPs, a range of possible BMPs sizes for both alternatives were modeled in the EPA’s System for Urban Stormwater Treatment and Analysis Integration (SUSTAIN) using the 10-year, continuous simulation data to measure the overall impact on the water quality. SUSTAIN was developed by the EPA Office of Research and Development to facilitate selection and placement of BMPs and green infrastructure techniques at strategic locations in urban watersheds. It assists to develop, evaluate, and select optimal BMP combinations at various watershed scales on the basis of cost and effectiveness. In this study, the BMP’s effectiveness was measured by its ability to remove total zinc. Total zinc was determined to be the limiting pollutant, indicating that if total zinc is controlled, other pollutants would have similar or greater removal rates.

In addition, identifying appropriate numeric targets is necessary to evaluate and optimize performance of the stormwater facilities. One common hydrologic criterion for integrated water quality, flow reduction, and resources management is retention of the runoff volume generated by the 85th percentile storm event. At the study area, the 85th percentile storm event depth is 0.94 inch, according to the Los Angeles County isohyetal map. As a result, an additional analysis was performed to identify the size required to capture and treat the 85th percentile, 24-hour design storm event. The 10-year continuous time period (from 2002 to 2011) was then modeled through the identified BMP size to measure the overall, long-term expected water quality impacts. Three sets of analyses were performed for different solutions including Alternative 1”Post-Pump Treatment” (Scenario 1, and 2) and Alternative 2 “Pre-Pump Treatment”.

Figure 10 shows the 85th percentile 24-hour hydrograph for the drainage area (12.7 acres), derived from the HydroCalc (Version 0.3.0 beta). The peak flow for the 85th percentile storm for the 12.7-acre study area was calculated to be 2.3 cfs, as illustrated in Figure 10.

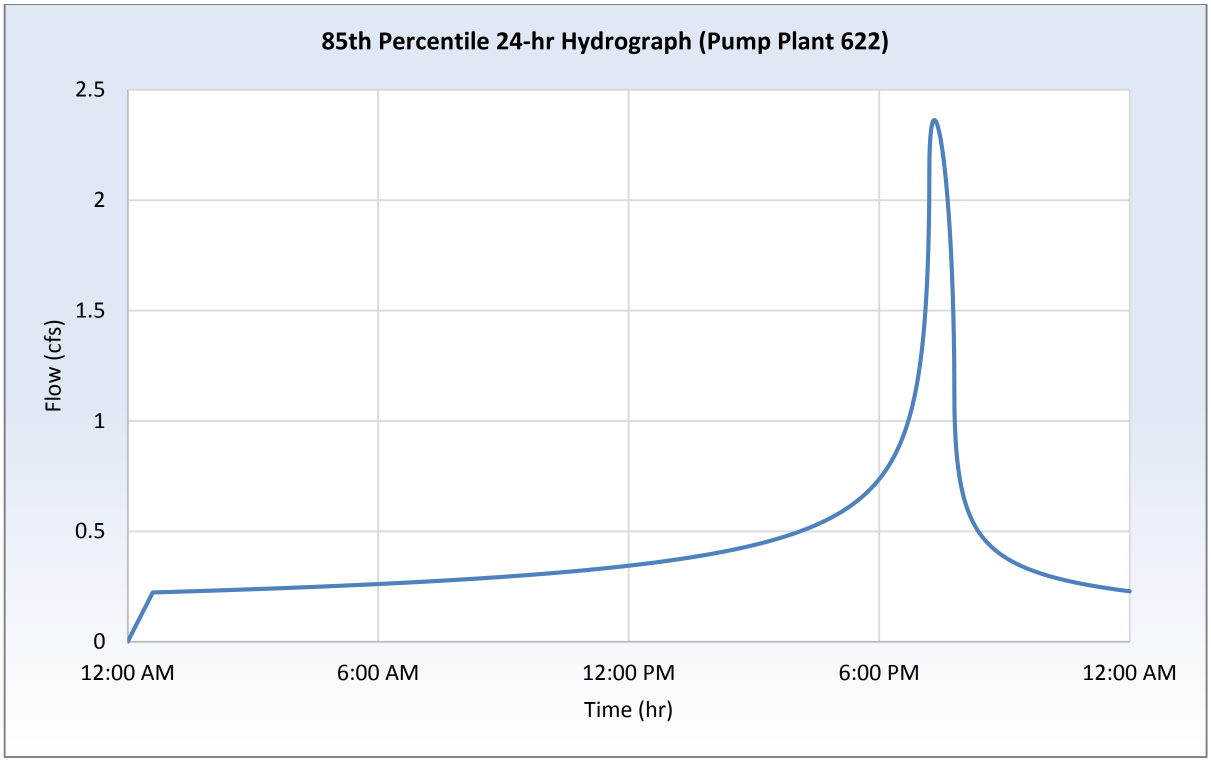

Figure 10. 85th Percentile 24-Hour Hydrograph for the 12.7- acre drainage area with 0.94 inch Rainfall Depth.

For alternative 1, scenario 1 it is assumed that the main pumps cycle on when the wet well reaches a certain level. At that point, all of the volume in the wet well is pumped out at a rate of 40 cfs. This pumping scheme results in the pump cycling on and off multiple times throughout the duration of the storm event. It may not be feasible to assume that all of the 40 cfs flow can be diverted into a BMP. For the purpose of this analysis it was assume that a portion of the flow is diverted to the BMP at a diversion rate of 20 cfs. This would result in approximately half of the volume that reaches the pumping plant being diverted into the BMP. For comparison purposes, a BMP capable of treating the volume of runoff produced by the 85th percentile storm was evaluated for both scenario 1 and scenario 2. A BMP foot print of 7,600 ft^2 with a capacity of approximately 30,400 ft^3 would provide a 37% reduction in volume (Figure 11) and a 44% reduction in zinc (Figure 12).

For alternative 1, scenario 2, the smaller sump pump would be utilized to pump all of the flow entering the pump plant at a rate of 2.5 cfs or less. This pump would operate throughout the duration of the storm providing a more consistent flow into the BMP, ultimately diverting a higher volume than in scenario 1 despite the much lower flow rate. Diverting flow into a similar sized BMP would results in a 52 percent reduction in volume (Figure 11) and a 61 percent reduction in zinc (Figure 12).

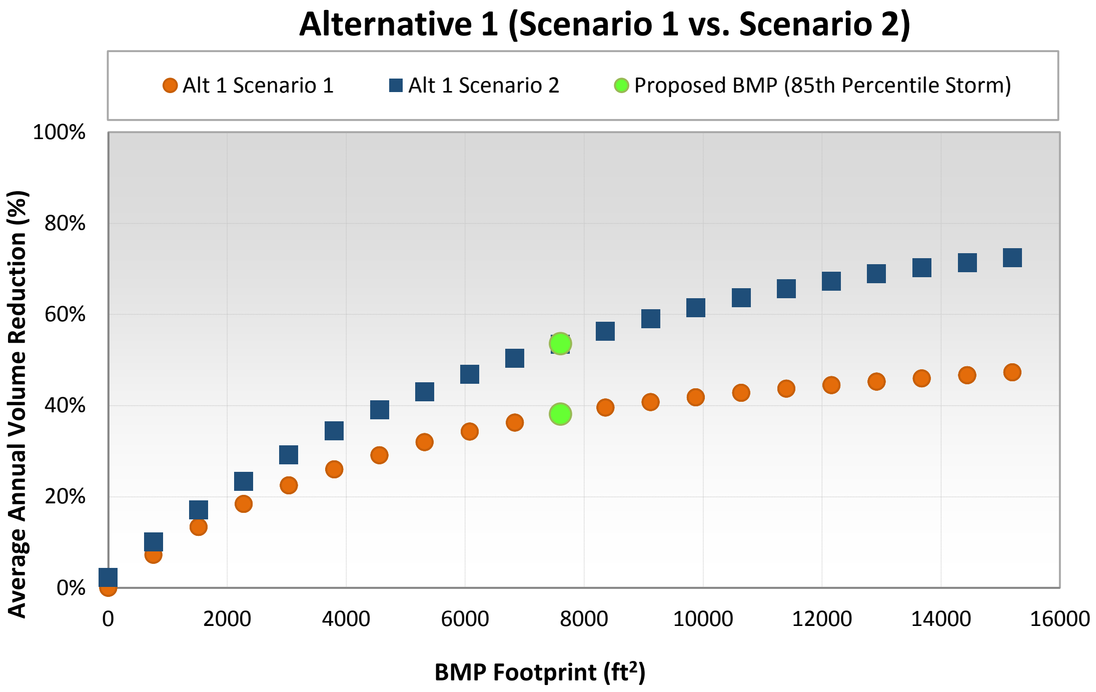

Figure 11. Comparison of 20 cfs diversion versus 2.5 cfs direct pumping for Alternative 1 (Post-Pump Treatment).

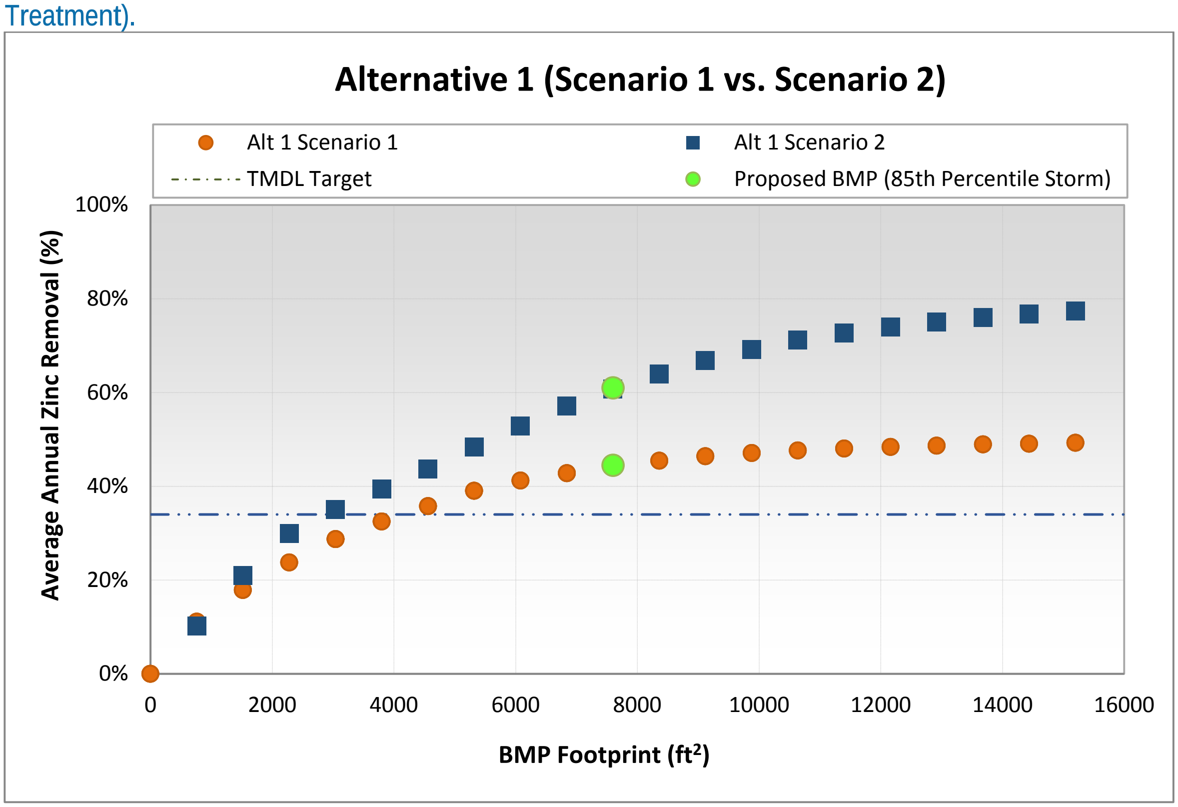

Figure 12. Comparison of water quality benefit for scenario 1 and scenario 2 (Post-Pump Treatment).

Upgrading the sump pump, while requiring some extra cost, will provide a higher level of treatment efficiency in the system (see Section 8 pump plant upgrade cost estimates).

For alternative 2 the BMPs opportunities would be implemented along Sepulveda Boulevard to treat wet weather runoff from a 12.7-acre drainage before reaching the Pumping Plant. The 10-year continuous time period (from 2002 to 2011) is modeled to generate the cost-effectiveness curve and measure the overall, long-term expected water quality impacts (Figure 13 and Figure 14). Relative cost is presented in Figure 13 and Figure 14 (instead of BMP footprints like those shown in Figure 11 and Figure 12) because a combination of multiple BMPs were modeled. The result of the analysis showed that the combination of permeable pavement and bioretention with the sizes of 8,400 and 5,000 square feet and retention volumes of 12,600 and 14,465 cubic feet respectively provide the capacity to treat the 85th percentile storm event. The respective BMPs sizes would result in 53 percent flow volume removal and 54 percent zinc.

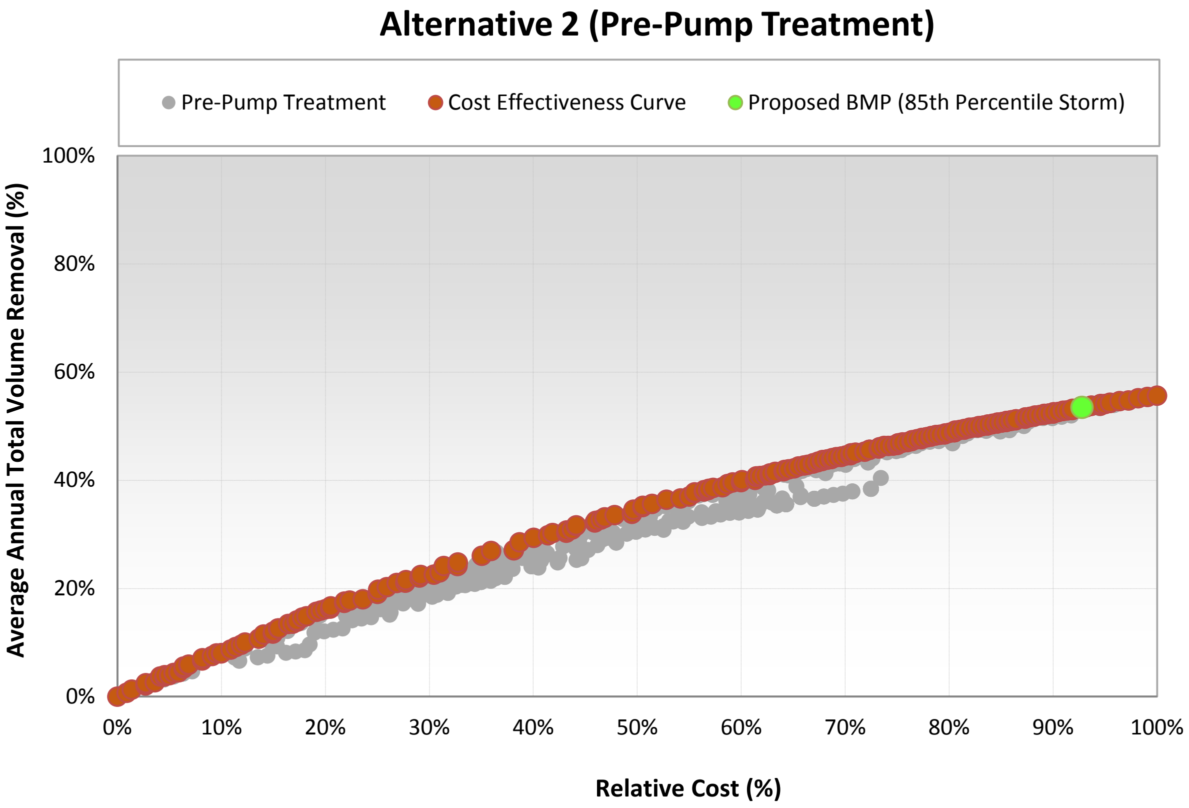

Figure 13. Relative Cost vs Average Annual Total Volume reduction.

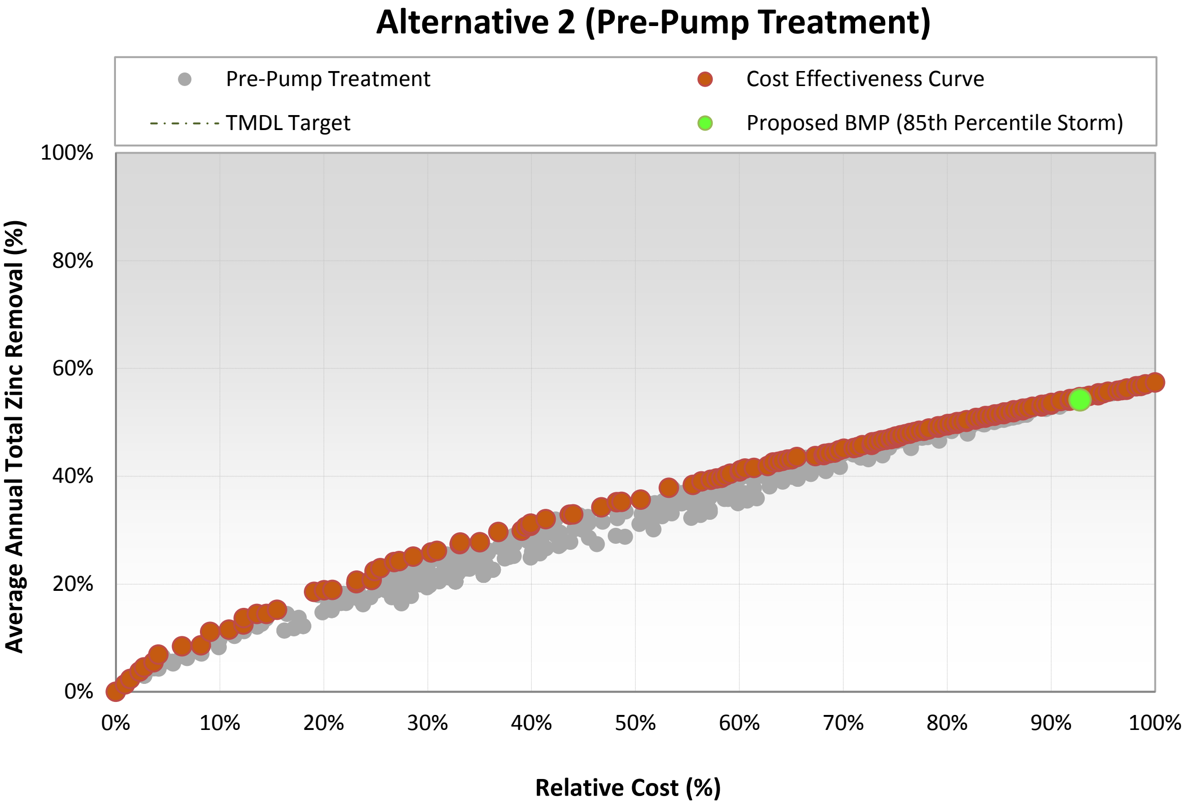

Figure 14. Relative Cost vs Average Annual Total Zinc Reduction.

4.1.5. Treatment Alternative Comparison and Conclusions

Based on the comparison of the two alternatives presented in Table 6, Alternative-1-Scenario 1 (20 cfs gravity diversion) will provide the reasonable volume and associated pollutant load reduction however, that benefit comes at a cost. The high construction cost associated with Alternative 1-Senario 1 is due to the deep excavation required for the gravity diversion of the flow to the underground infiltration basin (See Section 5).

Table 6. Average annual expected pollutant reductions and cost.

Constituent	Average annual loads	Average annual reduction					
		Post-Pump Treatment				Pre-Pump Treatment	
		Scenario 1		Scenario 2		Alternative 2	
	Pre-BMP	Reduction	Percentage	Reduction	Percentage	Reduction	Percentage
Volume, (ft^3)	579,619	216,839	37%	30,2604	52%	310,157	54%
TSS, (lbs)	2471	1090	44%	1490	60%	1316	53%
TN,(lbs)	72.4	28.3	39%	39.7	55%	39.0	54%
TP, (lbs)	42.7	16.7	39%	23.4	55%	22.9	54%
Copper, (lbs)	0.7	0.3	45%	0.4	61%	0.4	55%
Lead, (lbs)	0.6	0.3	45%	0.4	62%	0.3	57%
Zinc, (lbs)	7.6	3.4	44%	4.6	61%	4.1	54%
Fecal counts	3.8E+11	1.5E+11	40%	2.2E+11	57%	2.1E+11	54%
Cost		$1,287,340		$1,079,200		$944,940	

Implementing Alternative 1, scenario 1 will require the least impact to the existing function and performance of the pump plant but also has the lowest performance for stormwater treatment. The excavation cost of this scenario for the BMP implementation is also more costly because of the depth of excavation required to divert flows from the pump plant by gravity. Alternative 1, scenario 2 will require a small upgrade to the current pump plant configuration to provide a larger sump pump. This cost will be offset by the cost saving from excavation since the BMP can be implemented closer to the surface and flow would be pumped out. This scenario also provides some resiliency for the large and more costly main pumps. By using the sump pump to divert flows to the BMP, the main pumps will not have to operate as often. Among all solutions, Alternative 2 is recommended since it requires no alteration to the current sump pump configuration. This alternative provides maximum resiliency for the main pumps. Treating the volume produced by the 85th percentile storm before entering the pump plant significantly reduces the amount of time that the main pumps have to operate, approximately 70%, reducing the strain on the pumps and the required maintenance to make sure the pumps remain operational.

5. BMP Conceptual Layout, Design, and Performance Specifications

5.1. Post Pumping Alternative 1

The recommended BMP for alternative 1 is an underground infiltration basin. An infiltration basin is typically an excavated area containing amended soils functions like a bioretention area but is implemented at a larger scale. Infiltration basins can be designed as surface or subsurface units allowing for implementation around paved streets, parking lots, and buildings to provide initial stormwater detention and treatment of runoff. Such applications offer an ideal opportunity to minimize directly connected impervious areas in highly urbanized areas. In addition to stormwater management benefits, surface infiltration galleries provide green space and improve natural aesthetics in urban environments (Figure 15).

Figure 15. Subsurface Infiltration Gallery. (Source: www.oldcastlestormwater.com)

Typically, runoff percolates through the bottom of the gallery and an approximately 1-foot amended, tilled native soil layer, which has an infiltration rate capable of draining the infiltration gallery within a specified design drawdown time (usually up to 72 hours). After the stormwater infiltrates through the amended surface, it percolates into the subsoil, if site conditions allow for adequate infiltration and slope protection. If site conditions do not allow for adequate infiltration or slope protection, filtered water is directed toward a stormwater conveyance system or other stormwater runoff BMP via underdrain pipes. Observation ports and cleanouts should be included at the inlet of the infiltration gallery and along the length of the system to allow maintenance access and observation of any potential sediment accumulation. Infiltration galleries can be designed to help meet hydromodification criteria and also for conveyance of higher flows.

There are multiple systems available designed to provide storage for underground systems. Most systems are intended to provide void space; however, some systems provide greater void space than others. One product that provides adequate voice space is the StormTrap system (Figure 16).

Source: www.stormtrap.com Source: City of Los Angeles

Figure 16. Typicall StormTrap System.

5.1.1. Scenario 1

Because of the elevation of the diversion structure, the surface of the infiltration basin will be at approximately 778 feet (approximately 12 feet below ground surface). This will required a significant amount of excavation. Figure 17 shows the relative configuration of the pump station, the diversion, and the underground infiltration basin.

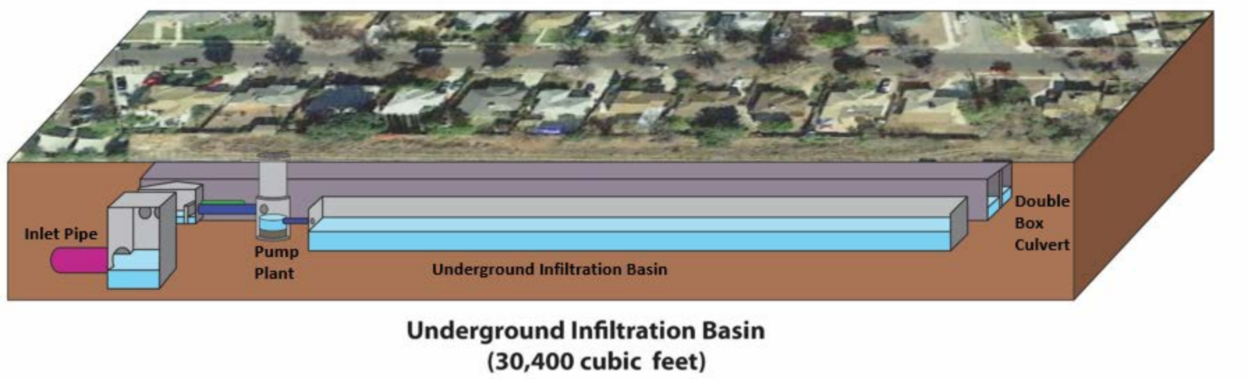

Figure 17. BMP configuration for Alternative 1, scenario 1.

5.1.2. Scenario 2

Utilizing the sump pump to divert flow into the BMP will allow some flexibility in the configuration and depth of the BMP allowing the underground infiltration basin to be close to the surface (approximately two feet below ground surface). Figure 18 shows the relative configuration of the diversion and underground infiltration basin.

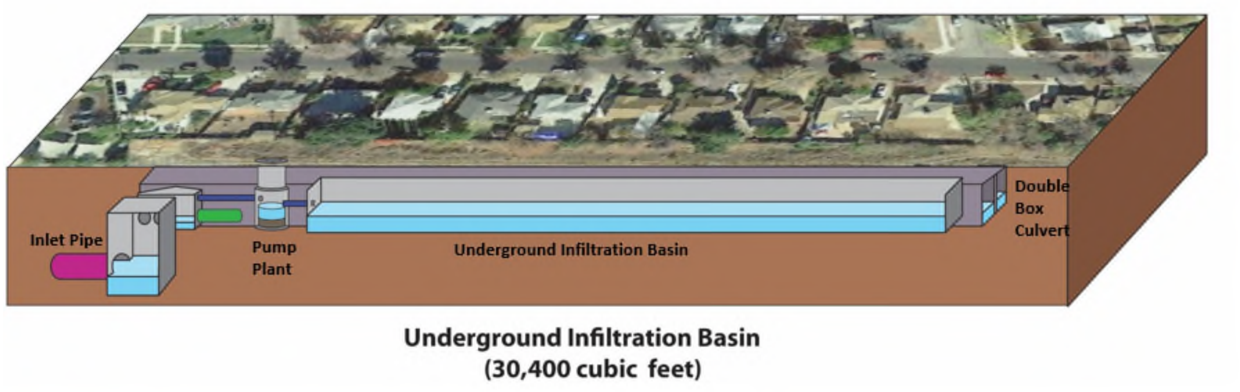

Figure 18. BMP configuration for Alternative 1, scenario 2.

For both scenarios observation ports and cleanouts are recommended for the purpose of maintenance.

5.2. Pre-Pumping Alternative 2

For alternative 2, the conceptual configuration of the BMPs providing the optimum level of treatment is intended to divert and treat water flowing from the street and surrounding parcels. Sepulveda Boulevard is designated as a Major Highway – Class II with a required right of way width of 104 feet (details of original street design in Bureau of Engineering ”D” plans, D-21701, is provided in Appendix D). Bike lanes are proposed for this section in the 2010 Bicycle Plan (LDCP 2010). BMPs proposed are intended to fit within the typical widths for the designation and the proposed bike lanes and should be coordinated with proposed plans for the area. Runoff from Sepulveda Boulevard should be treated in bioretention areas in accordance with LA Standard Plan S-481 on the east side of Sepulveda Boulevard. The depth of engineered soil layer, storage layer and ponding zone of the bioretention cells should be 2’, 2’-9”, and 2’-6” respectively. The west side of Sepulveda Blvd. will have a newly constructed protected bicycle lane, in which bioretention will be placed along the outside edge of the lane serving as protection, and permeable pavement will be the foundation of the bicycle lane. The depth of paving surface, and storage layer of the permeable pavement should be 1”, and 2’-9” respectively. Current Sepulveda Blvd. conditions are shown in Figure 19. Example BMP configurations are shown in Figure 20 and Figure 21.

Figure 19. Existing Sepulveda Boulevard conditions.

Figure 20. Conceptual rendering showing protected bike lane with permeable pavement and bioretention (Note: BMPs are not recommended in the median. Vegetation in the median is a component of the Great Streets Initiative referenced in Section 4.).

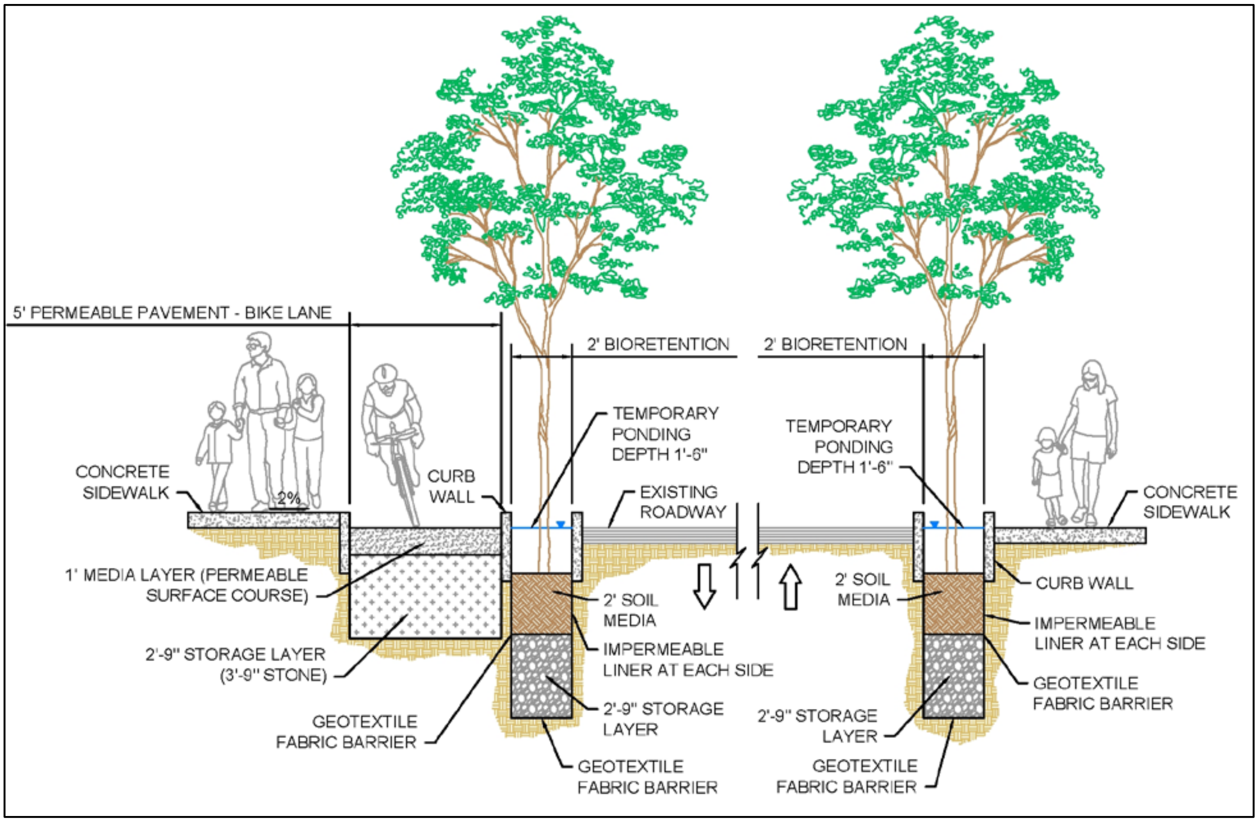

Figure 21. Expected cross section for Alternative 2.

The BMPs recommended in the Alternative 2 Pre Pumping should be designed to meet the following specifications and should comply with LA Standard Plan S-480 (Green Streets):

- Bioretention Areas
  - Ponding depth should be maintained at a minimum of 18 inches.
  - Infiltration rate in existing soils should be a minimum of 0.5 in/hr.
  - If the infiltration rate is less than 0.5 in/hr or if the site is located adjacent to a building foundation or in a liquefaction zone, underdrains and an engineered soil media should be installed. Bioretention soil media should have a minimum depth of 5 feet and should meet the following criteria:
    - Soil media consists of 85 percent washed course sand, 10 percent fines (range: 8–12 percent, and 5 percent organic matter. The expected infiltration rate should range from 0.57 to 1.98 in/hr.
    - The sand portion should consist of concrete sand (passing a one-quarter-inch sieve). Mortar sand (passing a one-eighth-inch sieve) is acceptable as long as it is thoroughly washed to remove the fines.
    - Fines should pass a # 270 (screen size) sieve.

    - Soil media must have an appropriate amount of organic material to support plant growth. Organic matter is considered an additive to help vegetation establish and contributes to sorption of pollutants but should generally be minimized (5 percent). Organic materials will oxidize over time, causing an increase in ponding that could adversely affect the performance of the bioretention area. Organic material should consist of aged bark fines, or similar organic material. Organic material should not consist of manure or animal compost. Newspaper mulch has been shown to be an acceptable additive.
    - pH should be between 6–8, cation exchange capacity (CEC) should be greater than 5 milliequivalent (meq)/100 g soil.
    - High levels of phosphorus in the media have been identified as the main cause of bioretention areas exporting nutrients. All bioretention media should be analyzed for background levels of nutrients. Total phosphorus should not exceed 15 ppm.
  - Bioretention areas should be lined on the sides with a 30 mil liner to protect the surrounding infrastructure.
  - PVC liners used for the lining of bioretention should meet the requirements of ASTM D-7176. The PVC liner should resist ultraviolet and shall be sufficiently flexible to cover and closely conform to 90 degree edges and corners of the filter bed excavation at ambient temperatures as low as 45 degrees Fahrenheit without application of heat. A suitable geotextile fabric shall be placed on the top and bottom of the membrane for puncture protection.
  - A minimum 5 feet of redial clearance between the BMP and any light pole or utility must be provided
  - A minimum of 48 inches wide sidewalk access must be included at each end of the BMPs from the sidewalk to the street curb.
  - All geotextile shall comply with the following:

Property	Test Reference	Media Barrier
Grab Strength, lbs (N), Min.	ASTM D-4632	90 (400)
Elongation, Minimum (at peak load) %, Max.	ASTM D-4632	50
Puncture Strength, lbs (N), Min.	ASTM D-3787	65 (290)
Permittivity, Sec., Min.	ASTM D-4491	2.5
Burst Strength, psi (kPa), Min.	ASTM D-3786	225 (1550)
Toughness, lbs (N), Min.	% Elongation x Grab Strength	5500 (24500)
Ultraviolet Resistance % Strength Retained @ 500 Weatherometer Hours	ASTM D-D4355	70
Apparent Opening Size, US Sieve # (mm)	ASTM D-4751	70 (0.210)
Flow Rate, Gal/min/ft^2 (L/min/m^2)	ASTM D-4491	175 (7130)
Trapezoid Tear, lbs (N)	ASTM D-4533	45 (200)

- Permeable Pavement
  - Bedding material should be a 1- to 2-inch layer of washed no. 8 or 9 stone. It must be completely free of fines.
  - The structural layer below the permeable pavement must have a porosity of 40 percent and should extend to a depth of 3.75 feet below the paver surface. A washed no. 57 stone at a depth of at least 6 inches is recommended as a choker course overlaying no. 2 stone.
  - Installation must have a slope of less than 0.5 percent unless internal check dams are incorporated.

- Permeable pavement should be lined on the sides with a 30 mil liner to protect the surrounding infrastructure. If geotechnical analyses suggest that infiltration should be restricted, the entire system should be lined and an underdrain installed.
- PVC liners used for the lining of permeable pavement should meet the requirements of ASTM D-7176. The PVC liner should resist ultraviolet and shall be sufficiently flexible to cover and closely conform to 90 degree edges and corners of the filter bed excavation at ambient temperatures as low as 45 degrees Fahrenheit without application of heat. A suitable geotextile fabric shall be placed on the top and bottom of the membrane for puncture protection.

5.2.1. Design Details and Drawing

A photo log, conceptual plans, and cross-sectional details are provided in Appendix A. Example product details along with a list of certified professionals qualified to install pervious concrete and concrete pavers is included in Appendix E.

6. Plant Selection

For the BMPs to function properly for stormwater treatment and blend into the landscape, vegetation selection is crucial. Appropriate vegetation will have the following characteristics:

1. Plant materials must be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 10 to 48 hours.
2. It is recommended that a minimum of three shrubs and three herbaceous groundcover species be incorporated to protect against facility failure from disease and insect infestations of a single species. To match current site landscaping, only one tree has been recommended.
3. Native plant species or hardy cultivars that are not invasive and do not require chemical inputs are recommended to be used to the maximum extent practicable.

A selection of recommended plant species, along with additional details including the recommended landscape position, size at maturity and light requirements, is provided in Table 7 based on the City of Los Angeles' Urban Forestry Division Street Tree Selection Guide (City of Los Angeles Urban Forestry Division 2011) and landscape architect recommendations. Existing trees at the site include Metrosideros tomentosa, Pinus canariensis, and Fraxinus uhdei.

Table 7. Recommended plant list

Trees		**Los Angeles native - LA** **California native - CA** **Nonnative– X**	**Landscape position:** 1 - Low[a], 2 - Mid[b],3 - High[c]	**Mature size** (height x width)	**Irrigation demands:** High - H ▪ Moderate - M Low - L ▪ Rainfall Only - N	**Light requirements** Sun - SU ▪ Shade - SH Part Shade - PS Sun or Shade - SS	**Season** Evergreen - E, Deciduous - D Semi-Evergreen – SE
***Cercisoccidentalis*[d]**	**Western redbud**	**LA**	**1**	**10-18' x 10-18'**	**M**	**SU, PS**	**D**
***Chilopsislinearis*[d]**	**Desert willow**	**LA**	**1**	**15-30' x 10-20'**	**L-M**	**SU**	**D**
Umbellulariacalifornica	California bay	LA	1	20-25' x 20-25'	L-H	SU, PS, SH	E
Shrubs							
Baccharispilularis 'Pigeon Point'	Dwarf coyote bush	LA	3	1-2' x 6'	L-M	SU	E
Rhamnuscalifornica 'Little Sur'	Dwarf California coffeeberry	LA	2	3-4' x 3'	N-M	SU, PS	E
Heteromelesarbutifolia	Toyon	LA	3	6-10' x 6-10'	M	SU, PS	E
***Baccharissalicifolia*[d]**	**Mulefat**	**LA**	**1**	**4-10'x8'**	**M-H**	**SU, PS, SH**	**SE**
***Rosa californica*[d]**	**California rose**	**LA**	**1**	**3-6' x 6'**	**M-H**	**SU, PS, SH**	**SE**
Grasses and grass-like plants							
***Elymusglaucus*[d]**	**Blue wild rye**	**LA**	**1**	**2-4' x 5'**	**L-M**	**SU, PS**	**SE**
***Muhlenbergiarigens*[d]**	**Deer grass**	**LA**	**1**	**2-4' x 3-4'**	**L**	**SU**	**E**
***Juncuspatens*[d]**	**California gray rush**	**CA**	**1**	**2' x 2'**	**L-H**	**SU, PS**	**E**

Notes

The Landscape position is the lowest area recommended for each species. Plants in areas 1 and 2 might also be appropriate for higher locations. When specifying plants, availability should be confirmed by local nurseries. Some species might need to be contract-grown, and it might be necessary for the contractor to contact the nursery well before planting because some species might not be available on short notice.

[a] Landscape Position 1 (Low): These areas experience seasonal flooding. Seasonal flooding for bioretention areas is typically 9 inches deep, for up to 72 hours (the design infiltration period for a bioretention area). If parts of the bioretention area are to be inundated for longer durations or greater depth, the designer should develop a plant palette with longer term flooding in mind. Several of the species listed as tolerant of seasonal flooding might be appropriate, but the acceptability of each species considered should be researched and evaluated case by case.

[b] Landscape Position 2 (Mid): These areas are low but are not expected to flood. However, they are likely to have saturated soils for extended periods.

[c] Landscape Position 3 (High): These areas are generally on well-drained slopes adjacent to stormwater BMPs. Soils typically dry out between storm events.

[d] **Bolded species** have been observed in the city and are known to be suitable for the recommended landscape position.

7. Green Infrastructure Operations and Maintenance

Maintenance of stormwater BMPs should be incorporated into existing routine maintenance activities. Permeable pavement should be swept during the existing monthly street sweeping schedule and City of LA Bureau of Street Services maintenance personnel should be trained to maintain stormwater BMPs located in the public right-of-way. Maintenance activities for the BMPs should be focused on the major system components, especially landscaped areas. Landscaped components should blend over time through plant and root growth, organic decomposition, and they should develop a natural soil horizon. The biological and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance.

Irrigation might be needed, especially during plant establishment or in periods of extended drought. Irrigation frequency will depend on the season and type of vegetation. Drought tolerant plants require less irrigation than other plants.

Table 8, Table 9, and Table 10 outline the required maintenance tasks, their associated frequency, and notes to expand on the requirements of each task based on recommendations from researchers in the green infrastructure field.

Table 8. Inspection and maintenance tasks for underground infiltration basins.

Task	Frequency	Maintenance Notes
Dry season inspection	One time per year	Inspect once during the dry season to ensure volume capacity. Clean if required.
Wet season inspection	Monthly during wet season	Monthly during the wet season to ensure volume capacity. Inspect and confirm level of silt and sediment.
Vault cleaning	Dry season – 1 time Wet season – 1 times	Dry season cleaning to happen just before the start of the wet season.
Valve maintenance	As needed	

Table 9. Bioretention operations and maintenance considerations.

Task	Frequency	Maintenance notes
Monitor infiltration and drainage	1 time/year	Inspect drainage time (12–24 hours). Might have to determine the infiltration rate (every 2–3 years). Turning over or replacing the media (top 2–3 inches) might be necessary to improve infiltration (at least 0.5 in/hr).
Pruning	1 time/year	Nutrients in runoff often cause bioretention vegetation to flourish.
Mulching	1 time/year	Recommend maintaining 1-inch to 3-inch uniform mulch layer.
Mulch removal	1 time/3–4 years	Biodegraded mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	1 time/2–3 days for first 1–2 months; sporadically after establishment	If drought conditions exist, watering after the initial year might be required.
Soil amendments	1 time initially	One-time spot soil amendments for first year vegetation.
Remove and replace dead plants	1 time/year	It is common for 10% of plants to die during first year. Survival rates tend to increase with time.
Inlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for sediment accumulation to ensure that flow into the retention area is as designed. Remove any accumulated sediment.
Outlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for erosion at the outlet and remove any accumulated mulch or sediment.
Miscellaneous upkeep	2 times/year	Tasks include trash collection, plant health, spot weeding, and removing mulch from the overflow device.

Table 10. Permeable pavement operations and maintenance considerations.

Task	Frequency	Maintenance notes
Impervious to pervious interface	Once after first rain of the season, then monthly during the rainy season	Check for sediment accumulation to ensure that flow onto the permeable pavement is not restricted. Remove any accumulated sediment. Stabilize any exposed soil.
Street sweeping	Weekly during routine mechanical sweeping and twice a year with vacuum sweeper (or as needed)	Portions of pavement should be swept with a vacuum street sweeper at least twice per year or as needed to maintain infiltration rates.
Replace void fill materials (applies to pervious pavers only)	1-2 times per year (and after any vacuum truck sweeping)	Fill materials will need to be replaced after each sweeping and as needed to keep interstitial bedding material even with the paver surface.
Miscellaneous upkeep	4 times per year or as needed for aesthetics	Tasks include trash collection, sweeping, and spot weeding. Ensure landscaping materials (soil, mulch, grass clippings, etc.) are not stockpiled on permeable pavement surfaces.

8.Cost Estimate

The estimated cost of the pump station upgrades are included in Table 11 and the costs of implementing each of the alternative described above are included in Table 12, Table 13, and Table 14. This cost estimate is a guide only and should be updated at the time of preliminary design to account for fluctuation in cost of material, labor, or components, or unforeseen contingencies.

Table 11. Pump plant upgrade costs.

Item No.	Description	Estimated Qty	Unit	Unit Cost	Total
1	Mobilization and Demobilization	1	LS	$145,000	$145,000
2	Demolition/Removal of Existing Pumps and Discharge Piping	1	LS	$30,000.00	$30,000
3	Furnish and Install 1,200 GPM Submersible Pump	1	EA	$60,000.00	$60,000
4	Furnish and Install 17,900 GPM Vertical Turbine Solids Handling Pump	2	EA	$300,000.00	$600,000
5	Furnish and Install 4-inch Outlet Piping	1	LS	$7,500.00	$7,500
6	Furnish and Install 30-inch Outlet Piping	1	LS	$15,000.00	$15,000
7	Replace Chain-Link Fencing Around Site	350	LF	$20.00	$7,000
8	Replace Damaged Bar Screens	1	LS	$10,000.00	$10,000
9	Upgrade Railing and Ladders	1	LS	$10,000.00	$10,000
10	Replace Damaged Louver in Motor Room	1	LS	$1,000.00	$1,000
11	Sand Blast and Paint the Interior and Exterior of the Building	1	LS	$30,000.00	$30,000
12	Replace the Ventilation System	1	LS	$30,000.00	$30,000
13	Upgrade the Interior and Exterior Lighting	1	LS	$10,000.00	$10,000
14	Furnish and Install 250 KW Natural Gas Generator, Tier 4F	1	LS	$400,000.00	$400,000
15	Furnish and Install MCC	1	LS	$175,000.00	$175,000
16	Furnish and Install SCADA/I&C	1	LS	$60,000.00	$60,000
Subtotal Cost					**$1,590,500**
17	Construction contingency (25% of subtotal)				$400,000
Total Cost					**$1,990,500**

Table 12. Alternative 1 scenario 1: Post-Pump Treatment 20 cfs Gravity Diversion cost estimate.

Item No	Description	Estimated Qty	Unit	Unit Cost	Total
	Preparation				
1	Temporary Construction Fence	1,916	LF	$2.50	$4,790
2	Silt Fence	1,916	LF	$3.00	$5,748
	Site Preparation				
3	Excavation and Removal	3,941	CY	$45.00	$177,332
	Structures				
4	Structural Layer (washed no 57 or no 2 stone)	281	CY	$50.00	$14,050
5	Utility Conflicts	1	LS	$10,000.00	$10,000
6	Connection to Infiltration Gallery	1	LS	$350.00	$350
7	Diversion Structure	1	EA	$8,000.00	$8,000
8	Force Main 30" DI	80	LF	$60.00	$4,800
	Underground Storage				
9	Fine Grading	7,600	SF	$0.72	$5,472
10	Underground Infiltration Basin	1,126	CY	$378.00	$425,590
11	Maintenance/Observation Access to the Underground Infiltration Basin	5		$5,000.00	$25,000
Construction Subtotal					**$681,130**
12	Bond (5% of subtotal)				$34,060
13	Mobilization (10% of subtotal)				$68,110
14	Construction contingency (20% of subtotal)				$136,230
Construction Total					**$919,530**
15	Design (40% of Construction Total)				$367,810
Total Cost					**$1,287,340**

Table 13. Alternative 1 scenario 2: Post-Pump Treatment 2.5 cfs Direct Pumping cost estimate.

Item No	Description	Estimated Qty	Unit	Unit Cost	Total
	Preparation				
1	Temporary Construction Fence	1,916	LF	$2.50	$4,790
2	Silt Fence	1,916	LF	$3.00	$5,748
	Site Preparation				
3	Excavation and Removal	1,689	CY	$45.00	$76,005
	Structures				
4	Structural Layer (washed no 57 or no 2 stone)	281	CY	$50.00	$14,050
5	Utility Conflicts	1	LS	$10,000.00	$10,000
6	Connection to Existing Wet-Well	1	LS	$350.00	$350
7	Force Main 4" DI	80	LF	$50.00	$4,000
	Underground Storage				
8	Fine Grading	7,600	SF	$0.72	$5,472
9	Underground Infiltration Basin	1,126	CY	$378.00	$425,590
10	Maintenance/Observation Access to the Underground Infiltration Basin	5		$5,000.00	$25,000
Construction Subtotal					**$571,010**
11	Bond (5% of subtotal)				$28,550
12	Mobilization (10% of subtotal)				$57,100
13	Construction contingency (20% of subtotal)				$114,200
Construction Total					**$770,860**
14	Design (40% of Construction Total)				$308,340
Total Cost					**$1,079,200**

Table 14. Alternative 2: Pre-Pump Green Infrastructure Treatment cost estimate.

Item No	Description	Estimated Qty	Unit	Unit Cost	Total
	Preparation				
1	Traffic Control	40	Day	$1,000.00	$40,000
2	Temporary Construction Fence	4,824	LF	$2.50	$12,060
3	Silt Fence	4,824	LF	$3.00	$14,472
	Site Preparation				
4	Curb and Gutter Removal	2,400	LF	$3.30	$7,920
5	Saw Cut Existing Asphalt	1,200	LF	$5.12	$6,144
6	Asphalt Removal	8,400	SF	$3.36	$28,224
7	Sidewalk Removal	2,400	SF	$2.01	$4,824
8	Excavation and Removal	2,182	CY	$45.00	$98,190
	Structures				
9	Curb and Gutter	2,400	LF	$22.00	$52,800
10	Permeable Pavement	8,400	SF	$12.00	$100,800
11	Structural Layer (washed no 57 or no 2 stone)	907	CY	$50.00	$45,370
12	Concrete Transition Strip	1,200	LF	$4.00	$4,800
13	Utility Conflicts	1	LS	$10,000.00	$10,000
	Bioretention				
14	Fine Grading	5,000	SF	$0.72	$3,600
15	Drainage Stone (washed no 57 stone)	367	CY	$50.00	$18,334
16	Hydraulic Restriction Layer (30 mil liner)	6,216	LF	$0.60	$3,730
17	Soil Media Barrier (washed sand)	30.86	CY	$40.00	$1,234
18	Soil Media Barrier (choking stone, washed no 8)	30.86	CY	$45.00	$1,389
19	Mortared Cobble Energy Dissipater	95	SF	$2.25	$214
20	Curb Opening with Grate	19	LS	$350.00	$6,650
	Landscaping				
21	Soil Media	370	CY	$45.00	$16,667
22	Vegetation	5,000	SF	$4.00	$20,000
23	Mulch	46	CY	$55.00	$2,546
Construction Subtotal					**$499,970**
24	Bond (5% of subtotal)				$25,000
25	Mobilization (10% of subtotal)				$50,000
26	Construction contingency (20% of subtotal)				$99,990
Construction Total					**$674,960**
27	Design (40% of Construction Total)				$269,980
Total Cost					**$944,940**

9. Additional Considerations

9.1. Monitoring Plan

Performance monitoring of stormwater BMPs is an important component of a BMP implementation program. Monitoring provides the BMP's designer a mechanism to validate certain design assumptions and to quantify compliance with pollutant-removal performance objectives. Specific monitoring objectives should be considered early in the design process to ensure that BMPs are adequately configured for monitoring. Detailed monitoring guidance is provided by the EPA (USEPA 2012). The instrumentation and monitoring configuration will vary from site to site, but a monitoring approach using an inlet/outlet sample location setup is recommended for this site.

9.1.1. Monitoring Hydrology

An inlet/outlet sampling setup is suggested as the most effective monitoring approach to quantify flow and volume in stormwater BMPs. The runoff source and type of BMP will dictate the configuration of inflow monitoring. A weir or flume (Figure 22) is typically installed at the inlet of a BMP. Outflow can be monitored using similar techniques as inflow by installing a weir or ADV at the point of overflow/outfall (Figure 23). Outlet samples can also be collected from systems configured with underdrains utilizing specially designed v-notch weirs such as the one shown in Figure 24. Figure 25 shows an example of potential monitoring points.

Figure 22. Inlet curb cut with an H-flume.

Figure 23. Outlet of a roadside bioretention equipped with a V-notch weir for flow monitoring.

Figure 24. Typical weir for monitoring flow in an underdrain.

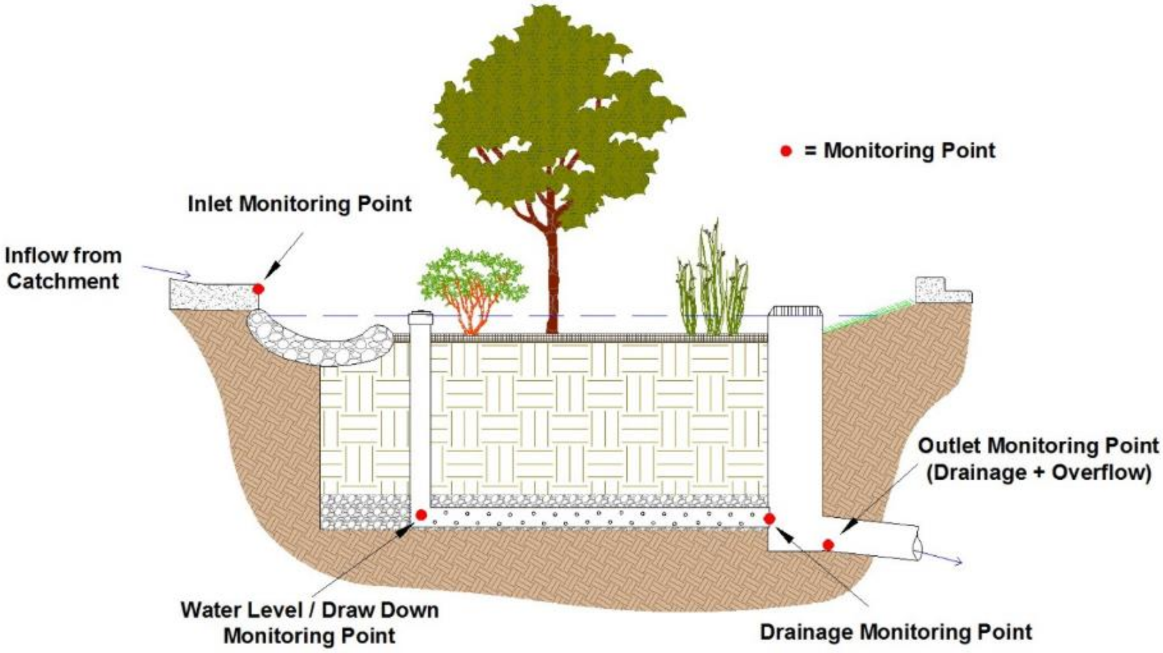

Figure 25. Typical monitoring points.

In addition to monitoring inflow and outflow, rainfall should be recorded on-site. Rainfall data can also be used to estimate inflow to BMPs that receive runoff only by sheet flow or direct rainfall (e.g., permeable pavement or green roofs). The type of rain gauge depends on monitoring goals and frequency of site visits. An automatic recording rain gauge (e.g., tipping bucket rain gauge), used to measure rainfall intensity and depth, is often paired with a manual rain gauge for data validation (Figure 26). For more advanced monitoring, weather stations can be installed to simultaneously monitor relative humidity, air temperature, solar radiation, and wind speed; these parameters can be used to estimate evapotranspiration.

Water level (and drawdown rate) is another useful hydrologic parameter. Depending on project goals, perforated wells or piezometers can be installed to measure infiltration rate and drainage. Care should be taken when installing wells to ensure that runoff cannot enter the well at the surface and *short circuit* directly to subsurface layers; short circuiting can result in the discharge of untreated runoff that has bypassed the intended treatment mechanisms. It might be useful to pair soil moisture sensors with water level loggers in instances where highly detailed monitoring performance data are required (such as for calibration and validation of models).

Figure 26. Example of manual (left) and tipping bucket (right) rain gauges.

9.1.2. Monitoring Water Quality

Although hydrologic monitoring can occur as a standalone practice, water quality data must be paired with flow data to calculate meaningful results. Flow-weighted automatic sampling is the recommended method for collecting samples that are representative of the runoff event and can be used to calculate pollutant loads (total mass of pollutants entering and leaving the system). Simply measuring the reduction in pollutant concentrations (mass per unit volume of water) from inlet to outlet can provide misleading results because it does not account for load reductions associated with infiltration, evapotranspiration, and storage.

Influent water quality samples are typically collected just upstream of the inlet monitoring device (e.g., weir box, flume) just before the runoff enters the BMP. The downstream sampler should be at the outlet control device just before the overflow enters the existing storm drain infrastructure. A strainer is usually installed at collecting end of the sampler tubing to prevent large debris and solids from entering and clogging the sampler. Automatic samplers should be programmed to collect single-event, composite samples according to the expected range of storm flows. Depending on the power requirements, a solar panel or backup power supply might be needed.

In addition to collecting composite samples, some water quality constituents can be monitored in real-time. Some examples include dissolved oxygen, turbidity, conductivity, and temperature.

9.1.3. Sample Collection and Handling

Quality assurance and quality control protocols for sample collection are necessary to ensure that samples are representative and reliable. The entire sample collection and delivery procedure should be well documented, including chain of custody (list of personnel handling water quality samples) and notes regarding site condition, time of sampling, and rainfall depth in the manual rain gauge. Holding times for water quality samples vary by constituent, but all samples should be collected, placed on ice, and delivered to the laboratory as soon as possible (typically 6 to 24 hours) after a rainfall event. Some water quality constituents require special treatment upon collection, such as acidification, to preserve the sample for delivery. Appropriate health and safety protocols should always be followed when on-site, including using personal protective equipment such as safety vests, nitrile gloves, and goggles.

9.2. Public Education and Outreach

The green infrastructure BMPs will provide learning opportunities for community residents who frequent the area. A demonstration project will provide an example of how BMPs can be implemented in existing infrastructure and will serve as a consistent reminder of their impact on stormwater quality. When the project is completed, educational signage describing the BMPs and indicating the BMPs role in maintaining healthy water quality should remain on-site.

9.3. Future Retrofit Opportunities

The 12.7 acre drainage area of SWS 685149 was the focus of these wet weather treatment conceptual designs because of the required upgrade of Pump Plant 622. If more extensive, watershed-wide retrofits will be planned for future implementation, optimization analysis should consider the entire 505-acre drainage area in order to generate a cost effective solution for controlling the quality of runoff draining to the R4-LAR-Sepulveda storm drain system. During EWMP formulation, BMP opportunities throughout the entire R4-LAR-Sepulveda subwatershed drainage area were identified. These results can be used to guide future stormwater retrofit projects in the area.

10. References

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Appendix A - Fact Sheets

Best Management Practice Conceptual Designs for Upper Los Angeles River

CONCEPTUAL PLAN–EXHIBIT A.1

SITE: Pumping Plant No. 622

Site Location			
Landowner	City of Los Angeles	Latitude	34°12'54.60"N
Date of Field Visit	05/02/2015	Longitude	118°27'57.85"W
Field Visit Personnel	SD, LT, JW	Street Address	15266 Cabrito Rd Van Nuys, CA 91406
Major Watershed	LAR Sepulveda		

Existing Site Description: The conceptual design centers around the existing Pump Plant 622 near the intersection of Sepulveda Boulevard and Cabrito Road. The pump plant is intended to provide flood protection to an area roughly bounded by the 405 freeway to the west, Pacoima Wash to the east, Rayen Street to the north, and the Van Nuys Metrolink is immediately south of the pump station. Storm water flows from underground storm drain pipes in Sepulveda Blvd. are pumped up to a box culvert storm drain that flows to the southeast.

Watershed Characteristics	
Drainage Area, acres	29.6
Hydrologic Soil Group	A/B
Total Impervious, %	90
Design Storm Event, in	85TH

Retrofit Characteristics		
Proposed Retrofit	Green Street	
BMP footprint, ft^2	Biretention Permeable Pavement	5000 8400
Ponding Depth, ft	Biretention Permeable Pavement	1.5 0.01
Media Depth, ft	Biretention Permeable Pavement	2 1

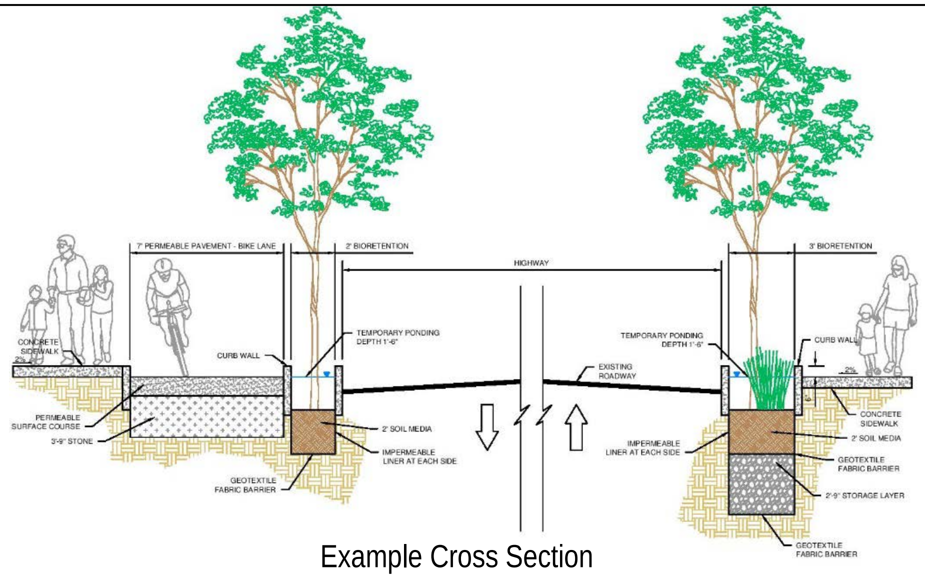
Proposed Retrofit Description: The proposed retrofit would involve installation of curb cuts to convey runoff to bioretention areas in the right-of-way along Sepulveda Blvd. to provide stormwater treatment and traffic calming benefits. A protected bike lane will increase safety for bicyclists and pedestrians while protecting permeable pavement in the bike lane from vehicular traffic. Treating the 85th percentile storm will reduce the amount of time that the main pumps have to operate by approximately 70%.

Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, Esri, HERE, DeLorme, TomTom, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Current Street View (Photo 1a)

Rendered Street Improvements (Photo 1b)

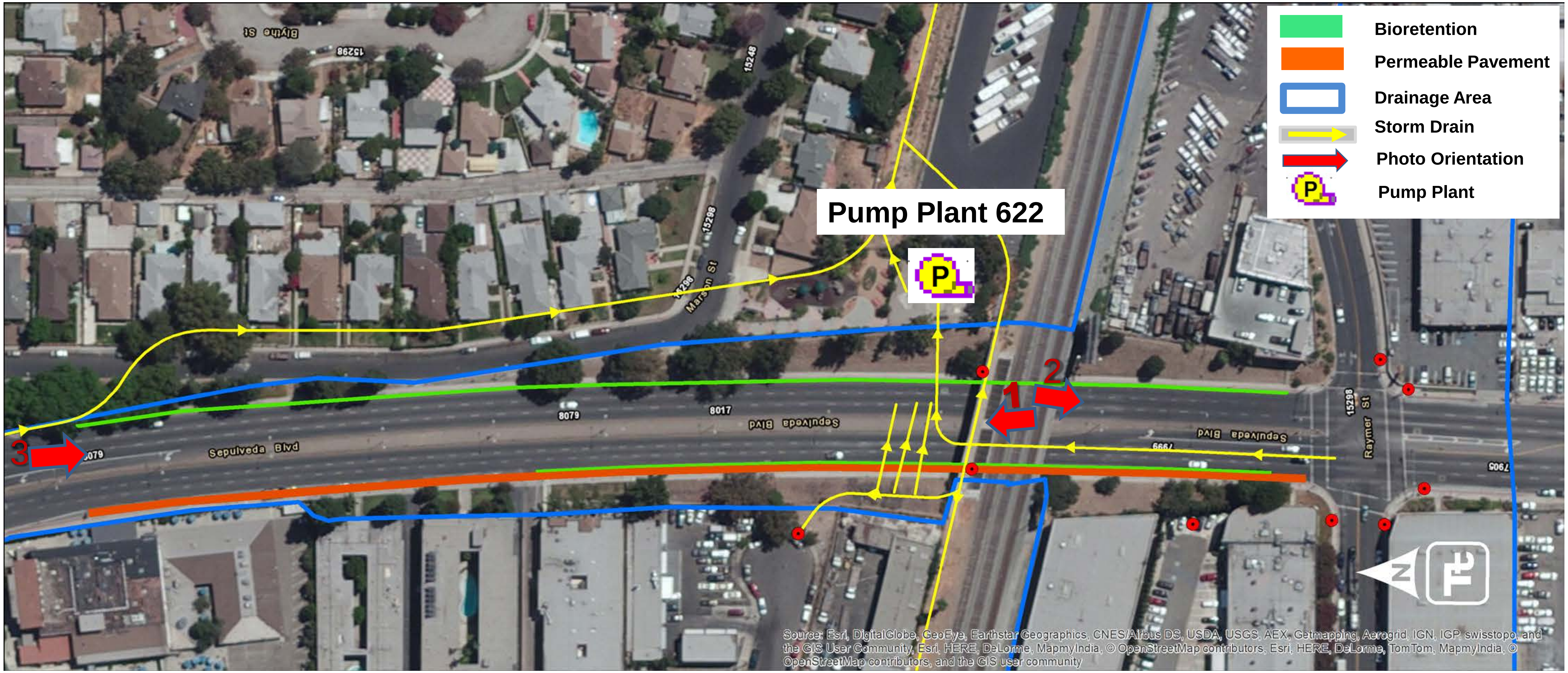


Example Cross Section

Best Management Practice Conceptual Designs for Upper Los Angeles River

CONCEPTUAL PLAN–EXHIBIT A.2

SITE: Pumping Plant No. 622

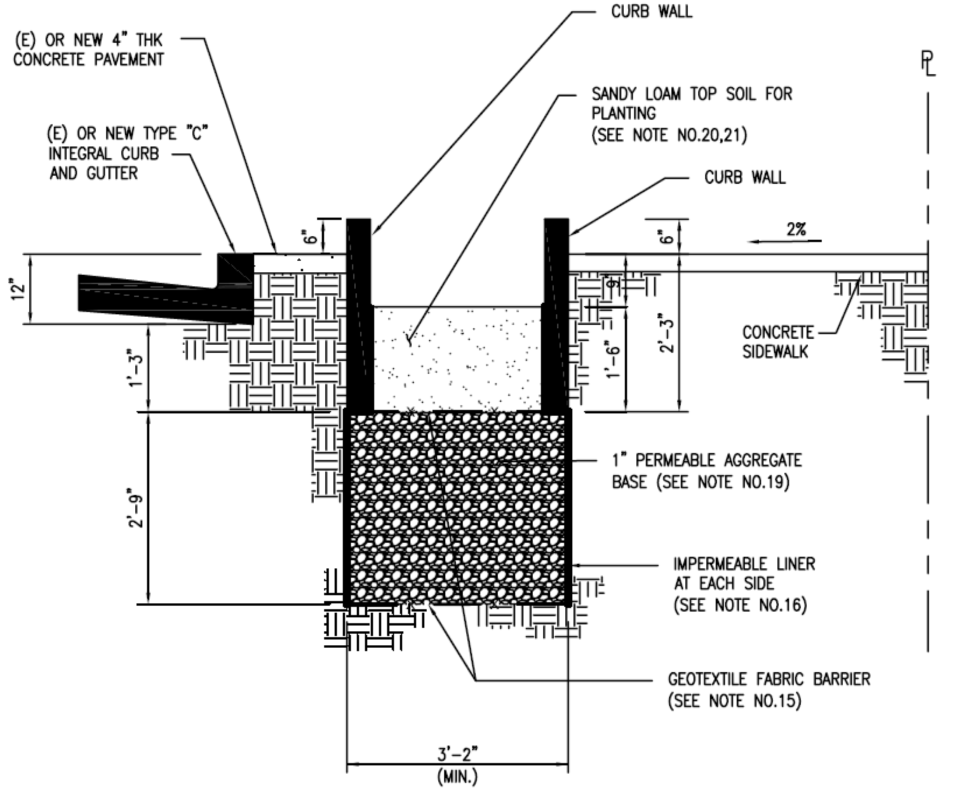


Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, Esri, HERE, DeLorme, TomTom, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Best Management Practice Conceptual Designs for Upper Los Angeles River

CONCEPTUAL PLAN–EXHIBIT A.3

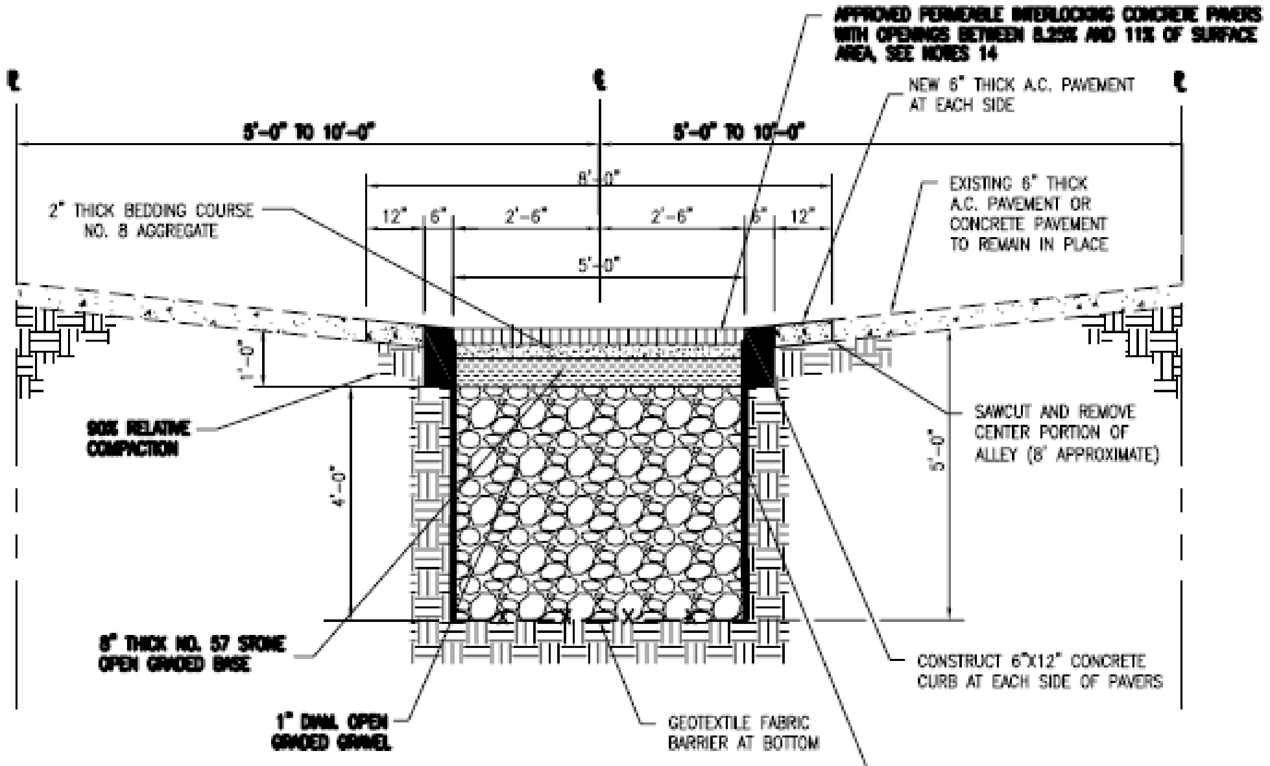
SITE: Pumping Plant No. 622



SECTION B–B

TYPICAL SWALE SECTION

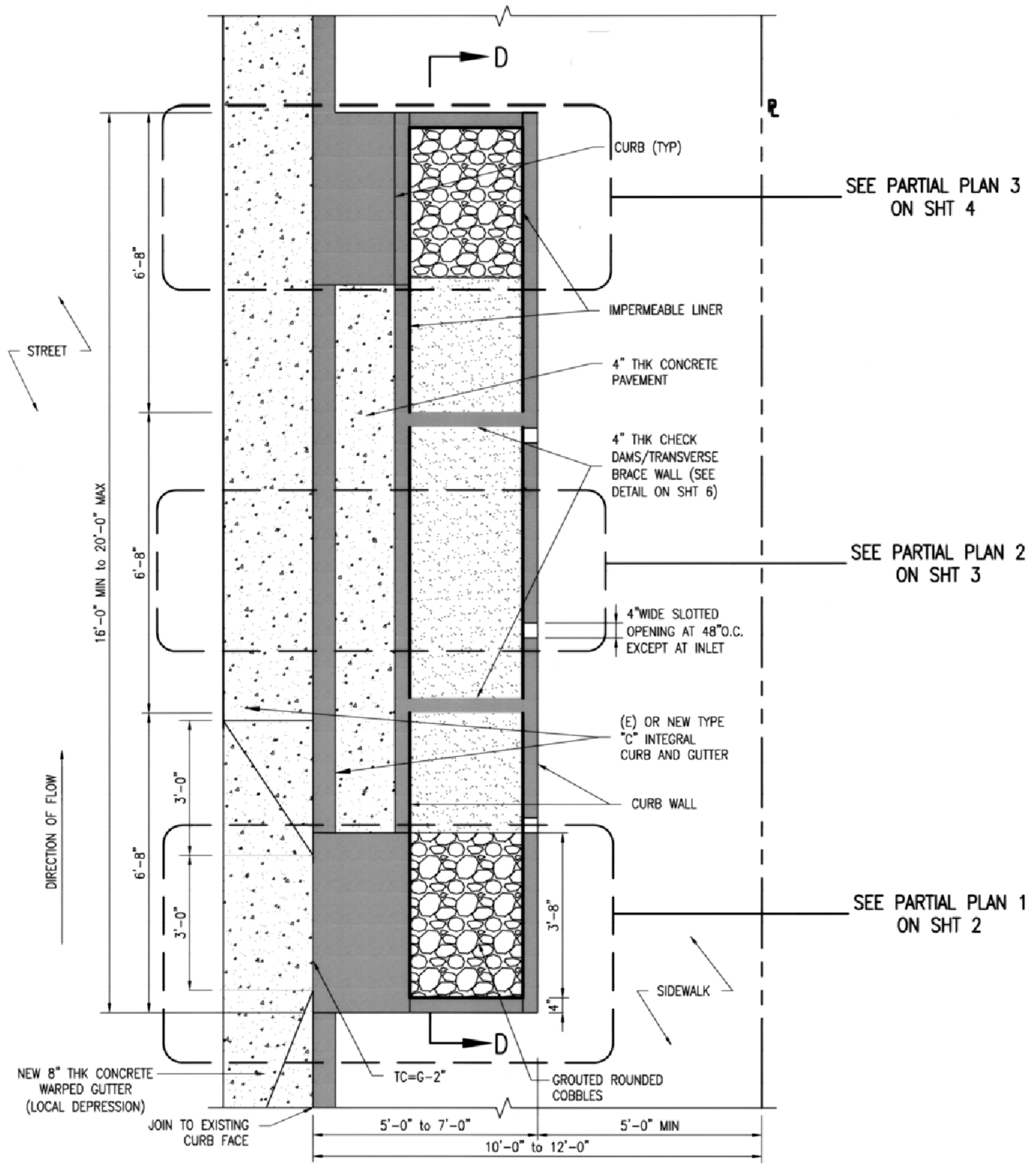
STANDARD PLAN NO. S–481–0 SHEET 3 OF 8 SHEETS



SECTION A–A

EXISTING ALLEY

STANDARD PLAN NO. S–485–0 SHEET 2 OF 3 SHEETS



PLAN

BUREAU OF ENGINEERING
DEPARTMENT OF PUBLIC WORKS
CITY OF LOS ANGELES

PARKWAY SWALE IN MAJOR/SECONDARY HIGHWAYS

STANDARD PLAN
S–481–0

PREPARED
ALICE GONG, CE49107
BUREAU OF SANITATION
ENRIQUE C. ZALDIVAR, P.E., DIRECTOR

CHECKED
PATRICK LEE, CE42448
BUREAU OF ENGINEERING

SUBMITTED
6/28/10
JEONG PARK, S.E. DATE
ENGINEER OF DESIGN
BUREAU OF ENGINEERING

6/29/10
KEN REDD, P.E. DATE
ACTING DEPUTY CITY ENGINEER

APPROVED
Gary Lee Moore 6-29-10
GARY LEE MOORE, P.E. DATE
CITY ENGINEER

GARY LEE MOORE
No. C-49446
Exp. 9/30/10

SUPERSEDES

REFERENCES
S–410
S–480
S–484

VAULT INDEX NUMBER:

SHEET 1 OF 8 SHEETS

CITY OF LOS ANGELES
SANITATION
DEPARTMENT OF PUBLIC WORKS

Appendix B - Hydrocalcs

Peak Flow Hydrologic Analysis

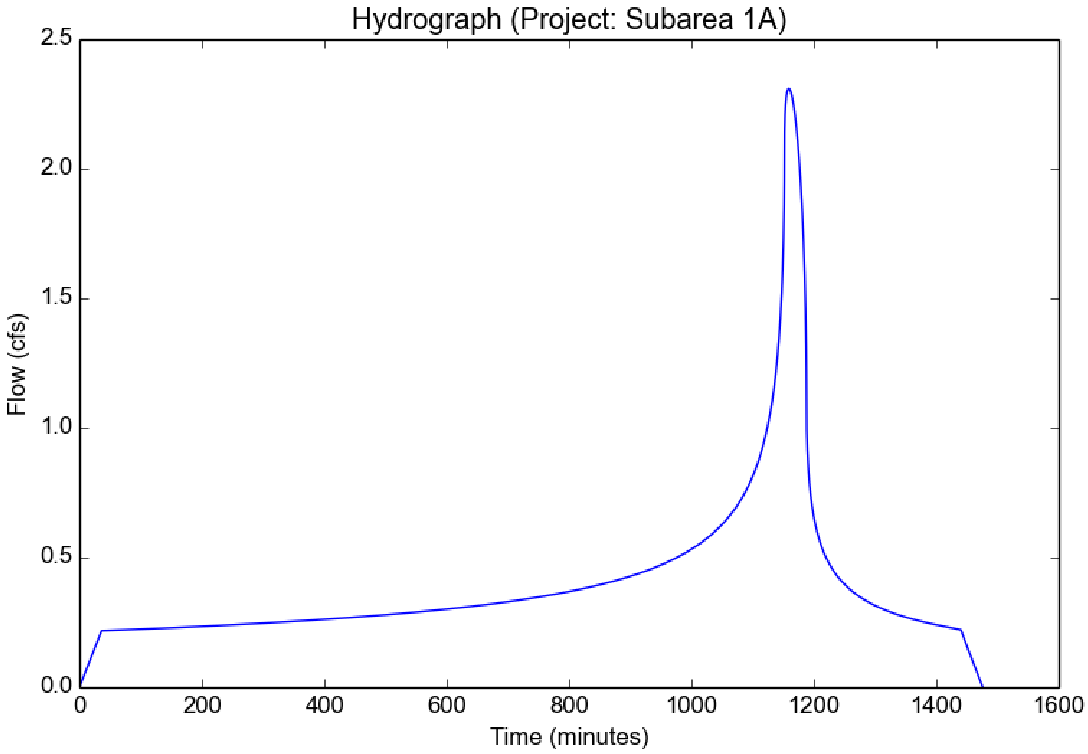
File location: W:/Projects/City of Los Angeles/2015 Conceptual Design (TOS 31)/Modeling/HydroCalc/Project - Pump_622_85th.pdf
Version: HydroCalc 0.3.0-beta

Input Parameters

Project Name	Project
Subarea ID	Subarea 1A
Area (ac)	12.7
Flow Path Length (ft)	1000.0
Flow Path Slope (vft/hft)	0.02
85th Percentile Rainfall Depth (in)	0.94
Percent Impervious	0.9
Soil Type	16
Design Storm Frequency	85th percentile storm
Fire Factor	0.71
LID	True

Output Results

Modeled (85th percentile storm) Rainfall Depth (in)	0.94
Peak Intensity (in/hr)	0.2218
Undeveloped Runoff Coefficient (Cu)	0.1
Developed Runoff Coefficient (Cd)	0.82
Time of Concentration (min)	36.0
Clear Peak Flow Rate (cfs)	2.3094
Burned Peak Flow Rate (cfs)	2.3852
24-Hr Clear Runoff Volume (ac-ft)	0.809
24-Hr Clear Runoff Volume (cu-ft)	35241.5609



Peak Flow Hydrologic Analysis

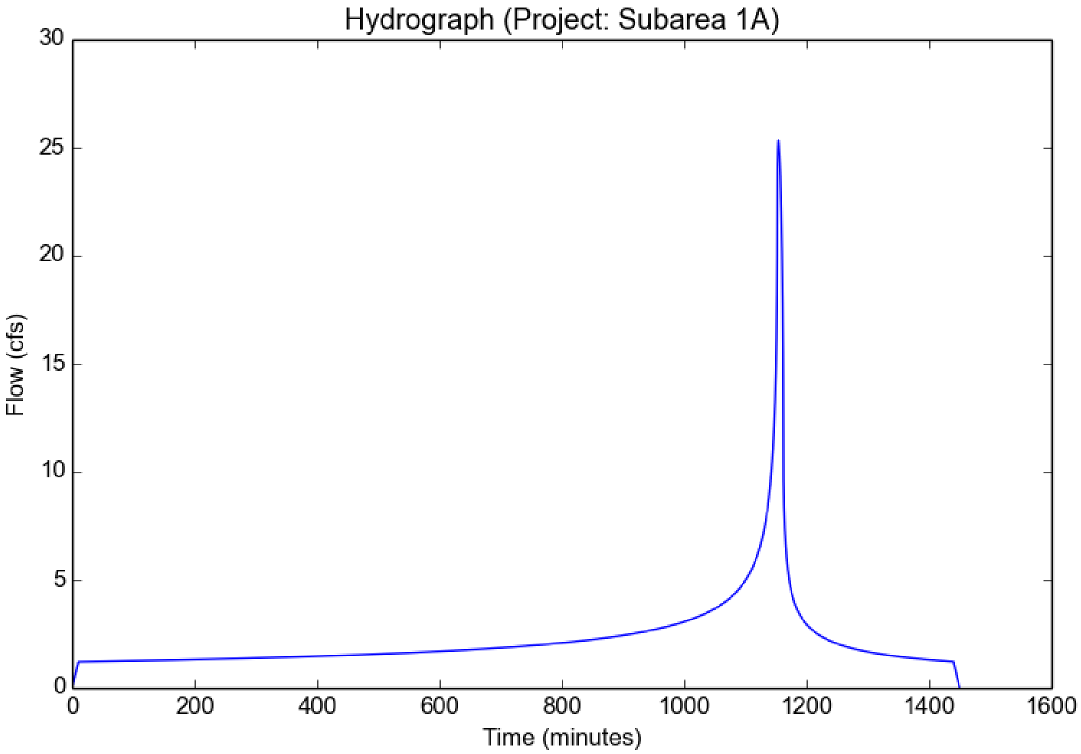
File location: W:/Projects/City of Los Angeles/2015 Conceptual Design (TOS 31)/Modeling/HydroCalc/Project - Pump_622_10Yr.pdf
Version: HydroCalc 0.3.0-beta

Input Parameters

Project Name	Project
Subarea ID	Subarea 1A
Area (ac)	12.7
Flow Path Length (ft)	1000.0
Flow Path Slope (vft/hft)	0.02
50-yr Rainfall Depth (in)	7.3
Percent Impervious	0.9
Soil Type	16
Design Storm Frequency	10-yr
Fire Factor	0.71
LID	False

Output Results

Modeled (10-yr) Rainfall Depth (in)	5.2122
Peak Intensity (in/hr)	2.2451
Undeveloped Runoff Coefficient (Cu)	0.7835
Developed Runoff Coefficient (Cd)	0.8884
Time of Concentration (min)	10.0
Clear Peak Flow Rate (cfs)	25.3296
Burned Peak Flow Rate (cfs)	26.1809
24-Hr Clear Runoff Volume (ac-ft)	4.5316
24-Hr Clear Runoff Volume (cu-ft)	197396.8282



Peak Flow Hydrologic Analysis

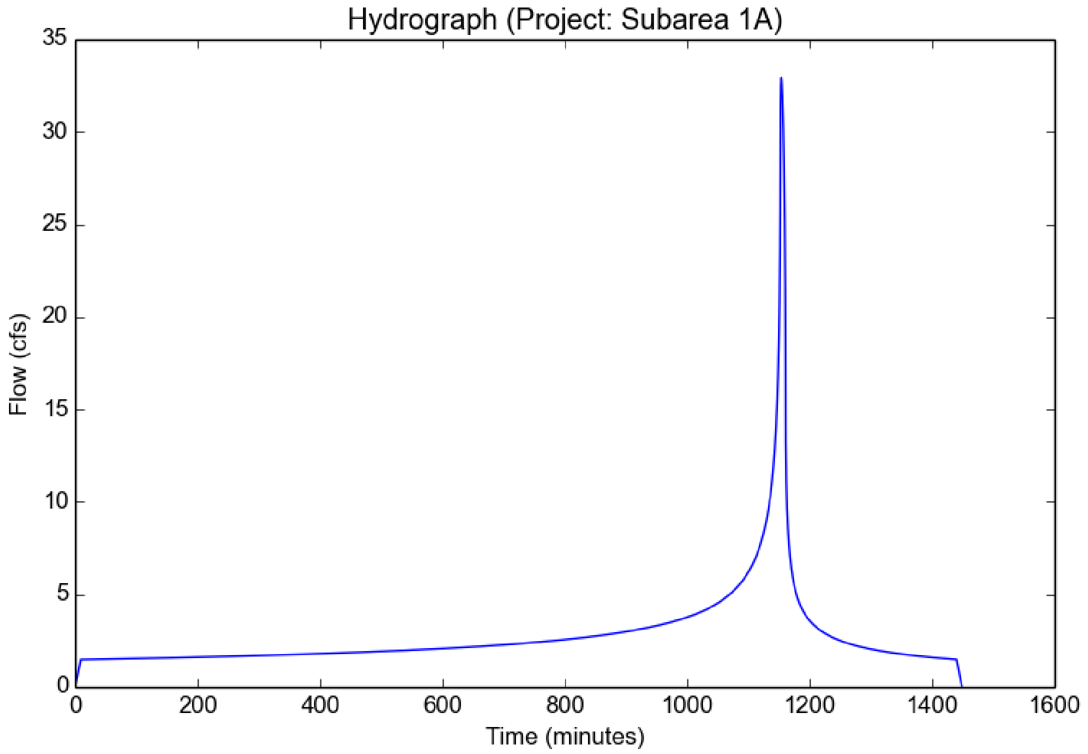
File location: W:/Projects/City of Los Angeles/2015 Conceptual Design (TOS 31)/Modeling/HydroCalc/Project - Pump_622_25Yr.pdf
Version: HydroCalc 0.3.0-beta

Input Parameters

Project Name	Project
Subarea ID	Subarea 1A
Area (ac)	12.7
Flow Path Length (ft)	1000.0
Flow Path Slope (vft/hft)	0.02
50-yr Rainfall Depth (in)	7.3
Percent Impervious	0.9
Soil Type	16
Design Storm Frequency	25-yr
Fire Factor	0.71
LID	False

Output Results

Modeled (25-yr) Rainfall Depth (in)	6.4094
Peak Intensity (in/hr)	2.901
Undeveloped Runoff Coefficient (Cu)	0.8417
Developed Runoff Coefficient (Cd)	0.8942
Time of Concentration (min)	9.0
Clear Peak Flow Rate (cfs)	32.9434
Burned Peak Flow Rate (cfs)	34.0304
24-Hr Clear Runoff Volume (ac-ft)	5.5879
24-Hr Clear Runoff Volume (cu-ft)	243408.3593



Peak Flow Hydrologic Analysis

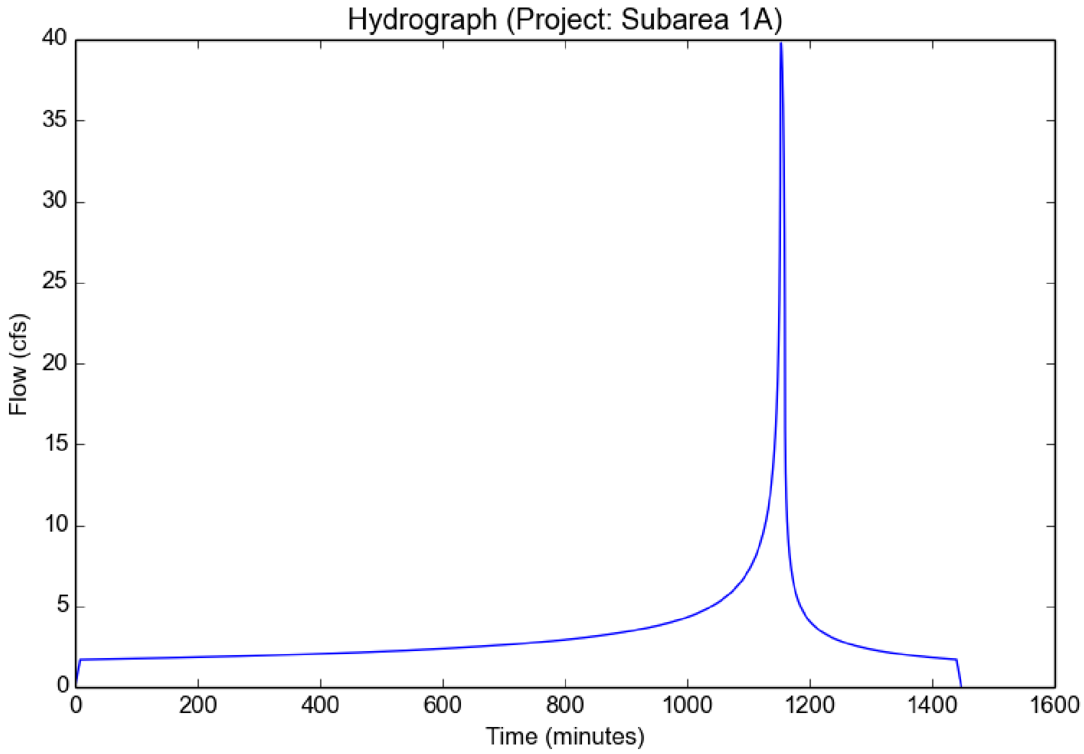
File location: W:/Projects/City of Los Angeles/2015 Conceptual Design (TOS 31)/Modeling/HydroCalc/Project - Pump_622_50Yr.pdf
Version: HydroCalc 0.3.0-beta

Input Parameters

Project Name	Project
Subarea ID	Subarea 1A
Area (ac)	12.7
Flow Path Length (ft)	1000.0
Flow Path Slope (vft/hft)	0.02
50-yr Rainfall Depth (in)	7.3
Percent Impervious	0.9
Soil Type	16
Design Storm Frequency	50-yr
Fire Factor	0.71
LID	False

Output Results

Modeled (50-yr) Rainfall Depth (in)	7.3
Peak Intensity (in/hr)	3.4921
Undeveloped Runoff Coefficient (Cu)	0.8746
Developed Runoff Coefficient (Cd)	0.8975
Time of Concentration (min)	8.0
Clear Peak Flow Rate (cfs)	39.8024
Burned Peak Flow Rate (cfs)	41.1071
24-Hr Clear Runoff Volume (ac-ft)	6.3775
24-Hr Clear Runoff Volume (cu-ft)	277805.1634



Appendix C – Pump Calculations

CITY OF LOS ANGELES
Plant No. 622 Storm Water PS

System Curve Calculations

Objective: Determine the system curve for the Plant #622 (Sepulveda) Storm Water PS

Givens:
1. The original pump design point is 15,550 gpm @ 32 TDH
2. Minor losses at the pump station are based on the As-Built plans.
3. The required design flow is 17,900 gpm @ 36 TDH

Assumptions:
1. The Hazen-Williams C-factors are assumed to be as follows:
   Aged Ductile Iron Pipe = 100
2. Minor losses are neglected within the pipeline except at the pump station.
3. The minor losses are taken from "Pumping Station Design" pgs. 898-900
4. The pump suction grade line is based on the water levels in the Plant #622 wet well
   LWL = 750 HWL = 760.25
5. The pump discharge is pumping to the summit manhole.
   Elev = 785.83

Step 1 ***Calculate Pipe Friction Losses***

Hazen-Williams Equation: $h_L=10.44*L(ft)*Q^{1.85}(gpm)/C^{1.85}*D^{4.87}(inches)$

Pipe Dia (in)	**Length (L.F.)**	**Material**	**C Factor (Assumed)**
30	17	DIP	100

Step 2 ***Calculate Minor Losses***

Minor Losses Equation: $h_M=Kv^2/2g$

Pipe Dia (in)	**Fitting**	**K Values**	**Quantity**	**K Total**
30	Ent. Loss	0.05	1	0.05
Total K Value for 16-inch Pipe				**0.05**

Step 2 *Minor Losses (Continued)*

Pipe Dia (in)	Fitting	K Values	Quantity	K Total
30	45-Bend	0.2	2	0.4
30	Exit	1	1	1
Total K Value for 12-inch Pipe				**1.4**

Step 3 *Determine Static Lift*

$H_{(static)}$ = Summit MH -Elev (Wet Well)

Maximum Static Lift	
Summit MH	785.83
Low Water Level	750
$H_{(static-max)}$=	35.83

Minimum Static Lift	
Summit MH	785.83
High Water Level	760.25
$H_{(static-min)}$=	25.58

CITY OF LOS ANGELES
Plant No. 622 Storm Water PS

System Curve Calculations

Step 4 ***Determine System Curve***

Q (gpm)	Friction H_L (ft)	Minor H_L (ft)	Max TDH (ft)	Min TDH (ft)	Avg TDH (ft)	Velocity in FM (ft/sec)
0	0.0	0.0	35.8	25.6	30.7	0.00
800	0.0	0.0	35.8	25.6	30.7	0.36
1600	0.0	0.0	35.8	25.6	30.7	0.73
2400	0.0	0.0	35.9	25.6	30.7	1.09
3200	0.0	0.0	35.9	25.6	30.8	1.45
4000	0.0	0.1	35.9	25.7	30.8	1.82
4800	0.0	0.1	36.0	25.7	30.8	2.18
5600	0.0	0.1	36.0	25.7	30.9	2.54
6400	0.0	0.2	36.0	25.8	30.9	2.91
7200	0.0	0.2	36.1	25.9	31.0	3.27
8000	0.0	0.3	36.2	25.9	31.0	3.63
8800	0.0	0.4	36.2	26.0	31.1	4.00
9600	0.1	0.4	36.3	26.1	31.2	4.36
10400	0.1	0.5	36.4	26.1	31.3	4.72
11200	0.1	0.6	36.5	26.2	31.4	5.09
12000	0.1	0.7	36.6	26.3	31.5	5.45
12800	0.1	0.8	36.7	26.4	31.6	5.81
13600	0.1	0.9	36.8	26.5	31.7	6.18
14400	0.1	1.0	36.9	26.7	31.8	6.54
15200	0.1	1.1	37.0	26.8	31.9	6.90
16000	0.1	1.2	37.2	26.9	32.0	7.27
16800	0.1	1.3	37.3	27.0	32.2	7.63
17600	0.2	1.4	37.4	27.2	32.3	7.99
18400	0.2	1.6	37.6	27.3	32.5	8.36
19200	0.2	1.7	37.7	27.5	32.6	8.72
20000	0.2	1.9	37.9	27.6	32.8	9.08
20800	0.2	2.0	38.1	27.8	32.9	9.45
21600	0.2	2.2	38.2	28.0	33.1	9.81
22400	0.3	2.3	38.4	28.2	33.3	10.17
23200	0.3	2.5	38.6	28.3	33.5	10.54
24000	0.3	2.7	38.8	28.5	33.7	10.90
24800	0.3	2.9	39.0	28.7	33.9	11.26
25600	0.3	3.0	39.2	28.9	34.1	11.63
26400	0.3	3.2	39.4	29.2	34.3	11.99
27200	0.4	3.4	39.6	29.4	34.5	12.35
28000	0.4	3.6	39.9	29.6	34.7	12.72
28800	0.4	3.9	40.1	29.8	35.0	13.08

CITY OF LOS ANGELES
Plant No. 622 Storm Water PS

System Curve Calculations

Step 5 ***New Pump Curve***

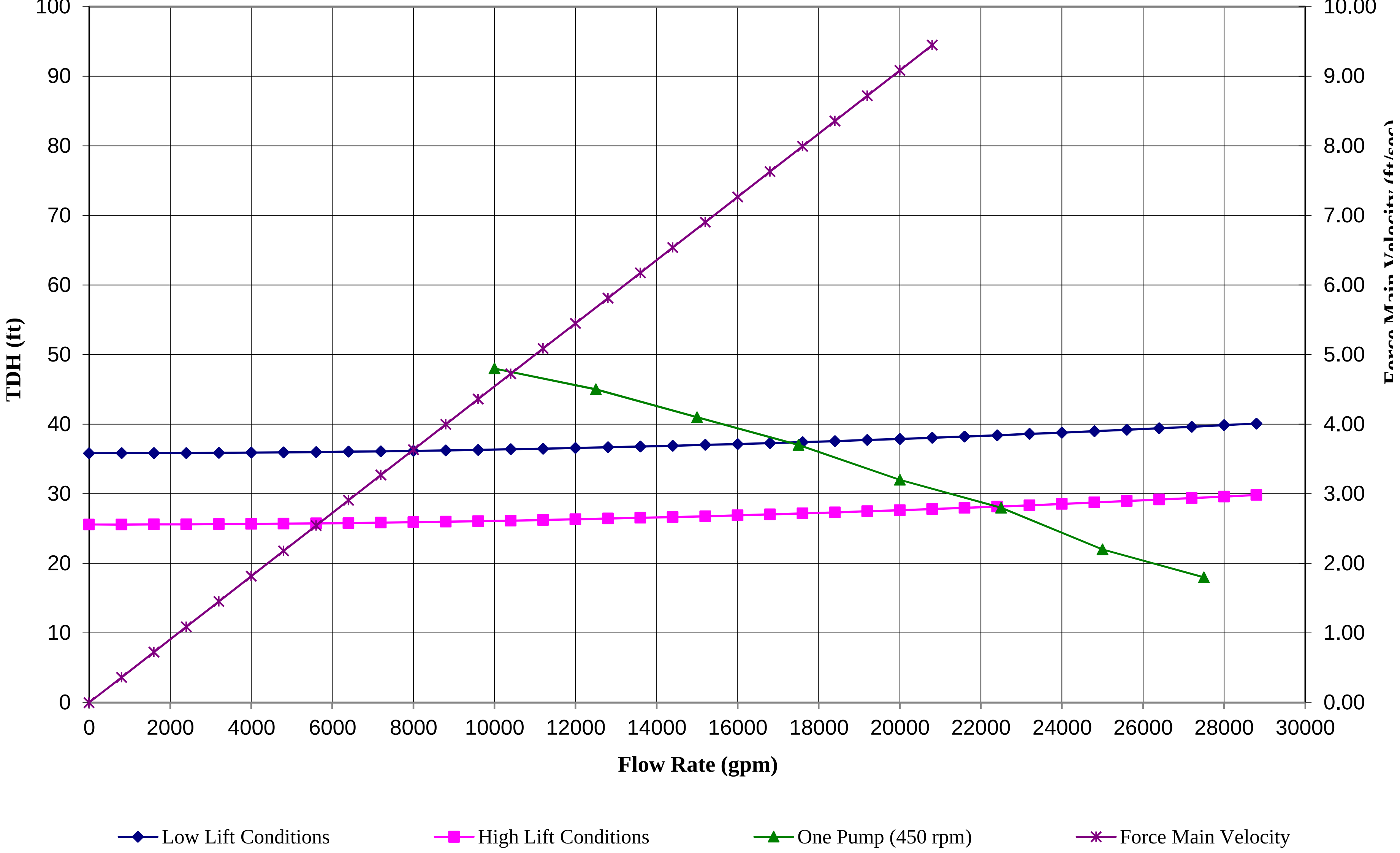
Fairbanks-Morse

Vertical Turbine Solids Handling

450 RPM - 200 HP - 29.75 in Impeller

Q (gpm)	**TDH (ft)**
10000	48
12500	45
15000	41
17500	37
20000	32
22500	28
25000	22
27500	18

CITY OF LOS ANGELES
Plant No. 622 Storm Water PS
System Curve
Fairbanks-Morse 30" VTSH



CITY OF LOS ANGELES
Plant No. 622 Storm Water PS

System Curve Calculations

Objective: Determine the system curve for the Plant #622 (Sepulveda) maintenance pump

Givens:

1. The original pump design point is 500 gpm @ 43 TDH
2. Minor losses at the pump station are based on the As-Built plans.
3. The maintenance pump will be used to drain the last 4' of water in the wet well.
4. The new design point shall match the existing.

Assumptions:

1. The Hazen-Williams C-factors are assumed to be as follows:
   Aged Ductile Iron Pipe = 100
2. Minor losses are neglected within the pipeline except at the pump station.
3. The minor losses are taken from "Pumping Station Design" pgs. 898-900
4. The pump suction grade line is based on the water levels in the Plant #622 wet well
   LWL = 744 HWL = 750.5
5. The pump discharge is pumping to the summit manhole.
   Elev = 787.2

Step 1 *Calculate Pipe Friction Losses*

Hazen-Williams Equation: h_L=10.44*L(ft)*$Q^{1.85}$(gpm)/$C^{1.85}$*$D^{4.87}$(inches)

Pipe Dia (in)	Length (L.F.)	Material	C Factor (Assumed)
4	55	DIP	100

Step 2 *Calculate Minor Losses*

Minor Losses Equation: h_M=Kv^2/2g

Pipe Dia (in)	Fitting	K Values	Quantity	K Total
4	Ent. Loss	0.05	1	0.05
Total K Value for 4-inch pipe				**0.05**

CITY OF LOS ANGELES
Plant No. 622 Storm Water PS

System Curve Calculations

Step 2 ***Minor Losses (Continued)***

Pipe Dia (in)	Fitting	K Values	Quantity	K Total
4	Exit Loss	1	1	1
4	45-bend	0.2	1	0.2
4	90-bend	0.8	1	0.8
Total K Value for 4-inch Pipe				**2**

Step 3 ***Determine Static Lift***

$H_{(static)}$ = Summit MH -Elev (Wet Well)

Maximum Static Lift	
Summit MH	787.2
Low Water Level	744
$H_{(static-max)}$=	43.2

Minimum Static Lift	
Summit MH	787.2
High Water Level	750.5
$H_{(static-min)}$=	36.7

CITY OF LOS ANGELES
Plant No. 622 Storm Water PS

System Curve Calculations

Step 4 ***Determine System Curve***

Q (gpm)	Friction H_L (ft)	Minor H_L (ft)	Max TDH (ft)	Min TDH (ft)	Avg TDH (ft)	Velocity in FM (ft/sec)
0	0.0	0.0	43.2	36.7	40.0	0.00
25	0.1	0.0	43.3	36.8	40.0	0.64
50	0.2	0.1	43.4	36.9	40.2	1.28
75	0.4	0.1	43.7	37.2	40.5	1.92
100	0.7	0.2	44.1	37.6	40.8	2.55
125	1.0	0.3	44.5	38.0	41.3	3.19
150	1.4	0.5	45.1	38.6	41.8	3.83
175	1.9	0.6	45.7	39.2	42.5	4.47
200	2.4	0.8	46.5	40.0	43.2	5.11
225	3.0	1.1	47.3	40.8	44.0	5.75
250	3.7	1.3	48.2	41.7	44.9	6.39
275	4.4	1.6	49.1	42.6	45.9	7.03
300	5.1	1.9	50.2	43.7	46.9	7.66
325	5.9	2.2	51.3	44.8	48.1	8.30
350	6.8	2.5	52.6	46.1	49.3	8.94
375	7.7	2.9	53.9	47.4	50.6	9.58
400	8.7	3.3	55.3	48.8	52.0	10.22
425	9.8	3.8	56.7	50.2	53.5	10.86
450	10.9	4.2	58.3	51.8	55.0	11.50
475	12.0	4.7	59.9	53.4	56.6	12.13
500	13.2	5.2	61.6	55.1	58.3	12.77
525	14.4	5.7	63.4	56.9	60.1	13.41
550	15.7	6.3	65.2	58.7	62.0	14.05
575	17.1	6.9	67.1	60.6	63.9	14.69
600	18.5	7.5	69.2	62.7	65.9	15.33
625	19.9	8.1	71.2	64.7	68.0	15.97
650	21.4	8.8	73.4	66.9	70.2	16.60
675	23.0	9.5	75.6	69.1	72.4	17.24
700	24.6	10.2	78.0	71.5	74.7	17.88
725	26.2	10.9	80.3	73.8	77.1	18.52
750	27.9	11.7	82.8	76.3	79.6	19.16

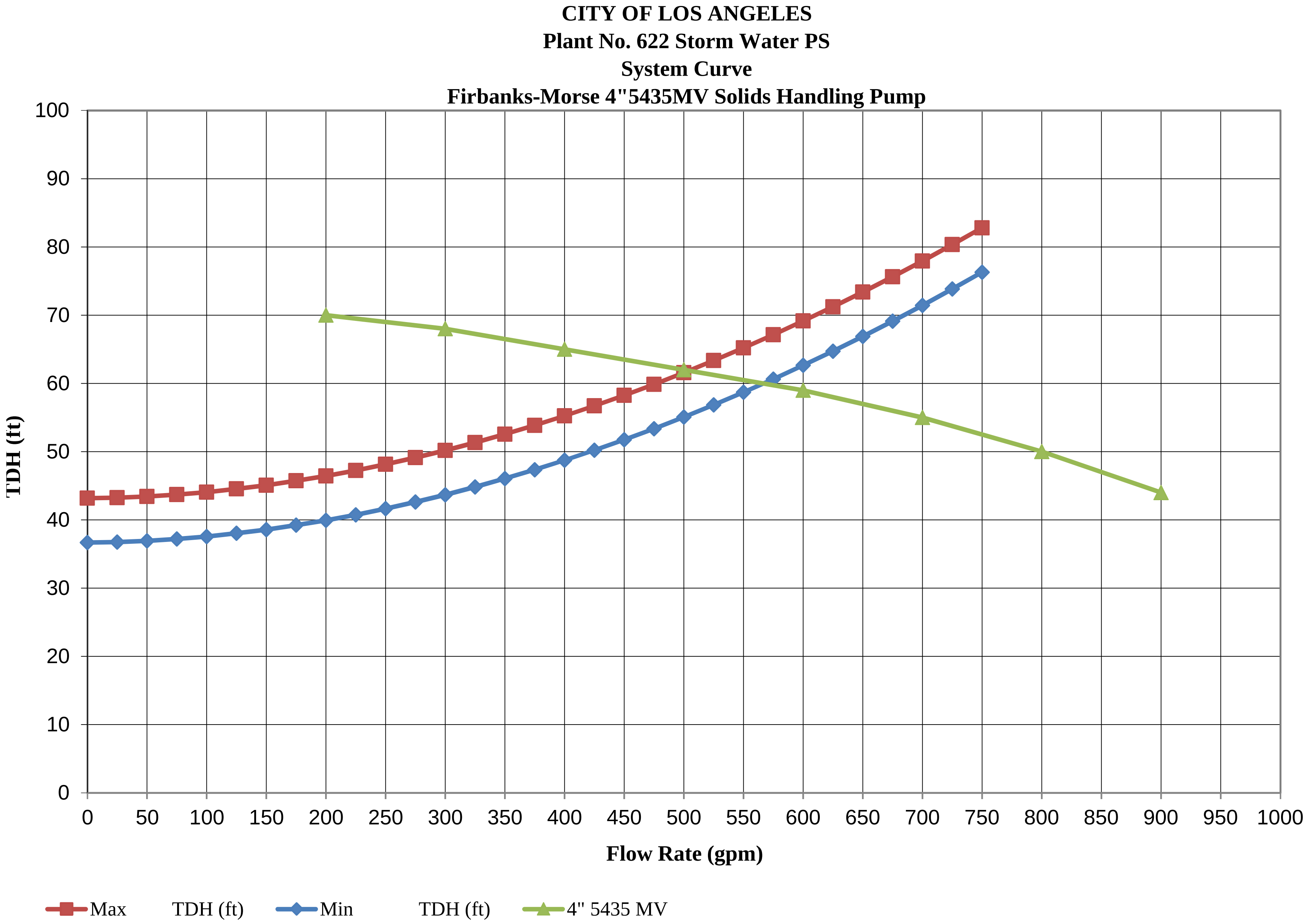
CITY OF LOS ANGELES
Plant No. 622 Storm Water PS

System Curve Calculations

Step 5 ***New Pump Curve***

Fairbanks
4" 5435 MV
10hp - 115 rpm

Q (gpm)	TDH (ft)	Q (gpm)
200	70	
300	68	
400	65	
500	62	
600	59	
700	55	
800	50	
900	44	



CITY OF LOS ANGELES
Plant No. 622 Storm Water PS
System Curve
Firbanks-Morse 4"5435MV Solids Handling Pump

CITY OF LOS ANGELES
Plant No. 622 Storm Water PS

System Curve Calculations

Objective: Determine the system curve for the Plant #622 (Sepulveda) maintenance pump

Givens:

1. The original pump design point is 500 gpm @ 43 Static Head
2. Minor losses at the pump station are based on the As-Built plans.
3. The maintenance pump will be used to drain the last 4' of water in the wet well.
4. The new design point be 1200 gpm (2.5 cfs) @ 59 TDH

Assumptions:

1. The Hazen-Williams C-factors are assumed to be as follows:
   Aged Ductile Iron Pipe = 100
2. Minor losses are neglected within the pipeline except at the pump station.
3. The minor losses are taken from "Pumping Station Design" pgs. 898-900
4. The pump suction grade line is based on the water levels in the Plant #622 wet well
   LWL = 744 HWL = 750.5
5. The pump discharge is pumping to the summit manhole.
   Elev = 787.2

Step 1 *Calculate Pipe Friction Losses*

Hazen-Williams Equation: h_L=10.44*L(ft)*$Q^{1.85}$(gpm)/$C^{1.85}$*$D^{4.87}$(inches)

Pipe Dia (in)	Length (L.F.)	Material	C Factor (Assumed)
6	55	DIP	100

Step 2 *Calculate Minor Losses*

Minor Losses Equation: $h_M=Kv^2/2g$

Pipe Dia (in)	Fitting	K Values	Quantity	K Total
6	Ent. Loss	0.05	1	0.05
Total K Value for 4-inch pipe				**0.05**

Step 2 ***Minor Losses (Continued)***

Pipe Dia (in)	**Fitting**	**K Values**	**Quantity**	**K Total**
6	Exit Loss	1	1	1
6	45-bend	0.2	1	0.2
6	90-bend	0.8	1	0.8
Total K Value for 4-inch Pipe				**2**

Step 3 ***Determine Static Lift***

$H_{(static)}$ = Summit MH -Elev (Wet Well)

Maximum Static Lift	
Summit MH	787.2
Low Water Level	744
$H_{(static\text{-}max)}$=	43.2

Minimum Static Lift	
Summit MH	787.2
High Water Level	750.5
$H_{(static\text{-}min)}$=	36.7

CITY OF LOS ANGELES
Plant No. 622 Storm Water PS

System Curve Calculations

Step 4 ***Determine System Curve***

Q (gpm)	Friction H_L (ft)	Minor H_L (ft)	Max TDH (ft)	Min TDH (ft)	Avg TDH (ft)	Velocity in FM (ft/sec)
0	0.0	0.0	43.2	36.7	40.0	0.00
50	0.0	0.0	43.2	36.7	40.0	0.57
100	0.1	0.0	43.3	36.8	40.1	1.14
150	0.2	0.1	43.5	37.0	40.2	1.70
200	0.3	0.2	43.7	37.2	40.5	2.27
250	0.5	0.3	44.0	37.5	40.7	2.84
300	0.7	0.4	44.3	37.8	41.0	3.41
350	0.9	0.5	44.6	38.1	41.4	3.97
400	1.2	0.7	45.1	38.6	41.8	4.54
450	1.5	0.8	45.5	39.0	42.3	5.11
500	1.8	1.0	46.1	39.6	42.8	5.68
550	2.2	1.2	46.6	40.1	43.4	6.24
600	2.6	1.5	47.2	40.7	44.0	6.81
650	3.0	1.7	47.9	41.4	44.7	7.38
700	3.4	2.0	48.6	42.1	45.4	7.95
750	3.9	2.3	49.4	42.9	46.1	8.52
800	4.4	2.6	50.2	43.7	46.9	9.08
850	4.9	3.0	51.1	44.6	47.8	9.65
900	5.4	3.3	52.0	45.5	48.7	10.22
950	6.0	3.7	52.9	46.4	49.7	10.79
1000	6.6	4.1	53.9	47.4	50.7	11.35
1050	7.2	4.5	54.9	48.4	51.7	11.92
1100	7.9	5.0	56.0	49.5	52.8	12.49
1150	8.5	5.4	57.2	50.7	53.9	13.06
1200	9.2	5.9	58.4	51.9	55.1	13.62
1250	10.0	6.4	59.6	53.1	56.3	14.19
1300	10.7	6.9	60.9	54.4	57.6	14.76
1350	11.5	7.5	62.2	55.7	58.9	15.33
1400	12.3	8.0	63.5	57.0	60.3	15.90
1450	13.1	8.6	64.9	58.4	61.7	16.46
1500	14.0	9.2	66.4	59.9	63.2	17.03

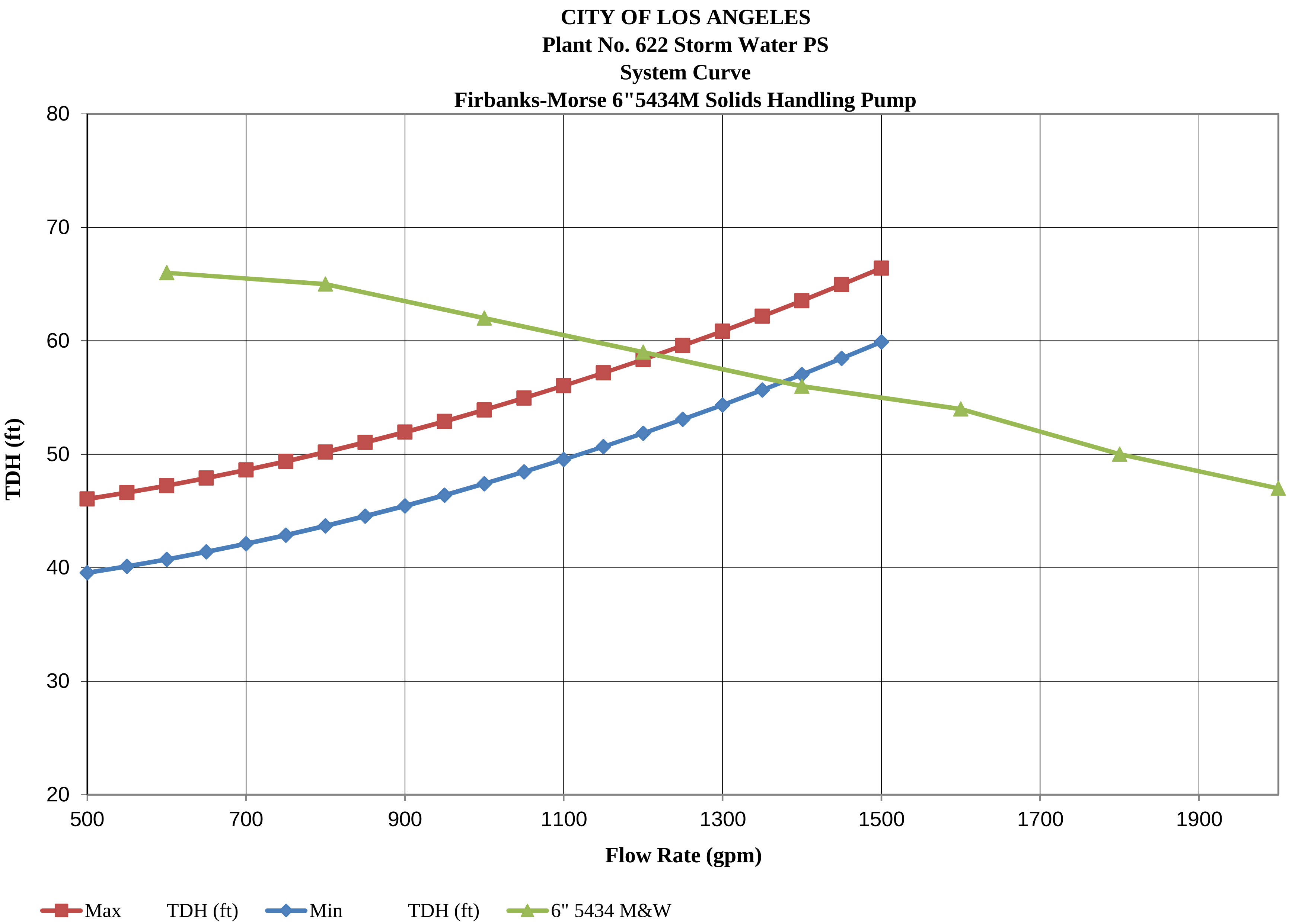
CITY OF LOS ANGELES
Plant No. 622 Storm Water PS

System Curve Calculations

Step 5 ***New Pump Curve***

Fairbanks
6" 5434 M&W
25hp - 115 rpm

Q (gpm)	TDH (ft)	Q (gpm)
600	66	
800	65	
1000	62	
1200	59	
1400	56	
1600	54	
1800	50	
2000	47	



CITY OF LOS ANGELES
Plant No. 622 Storm Water PS
System Curve
Firbanks-Morse 6"5434M Solids Handling Pump

Pump Data Sheet - Fairbanks Morse Pump, 60 Hz

Company:
Name:
Date: 4/1/2015

Pump:

Size: 6"5434M&W (BH)

Type: 5430-SOLIDS HANDLING
Synch speed: 900 rpm
Speed: 880 rpm
Dia: 15.9375 in

Curve: 340608BH
Impeller: TAJC5BH

Specific Speeds:
Ns: 1918
Nss: 7044

Dimensions:
Suction: 6 in
Discharge: 6 in

Pump Limits:

Temperature: 104 °F
Pressure: 75 psi g
Sphere size: 3 in
Power: ---
Eye area: ---

Search Criteria:

Flow: 1200 US gpm
Head: 59 ft

Fluid:

Water
SG: 1
Viscosity: 1.105 cP
NPSHa: ---
Temperature: 60 °F
Vapor pressure: 0.2563 psi a
Atm pressure: 14.7 psi a

Motor:

Consult Fairbanks Morse Pump, 60 Hz to select a motor for this pump.

---- Data Point ----

Flow:	1200 US gpm
Head:	59.6 ft
Eff:	76%
Power:	23.6 hp
NPSHr:	6.18 ft

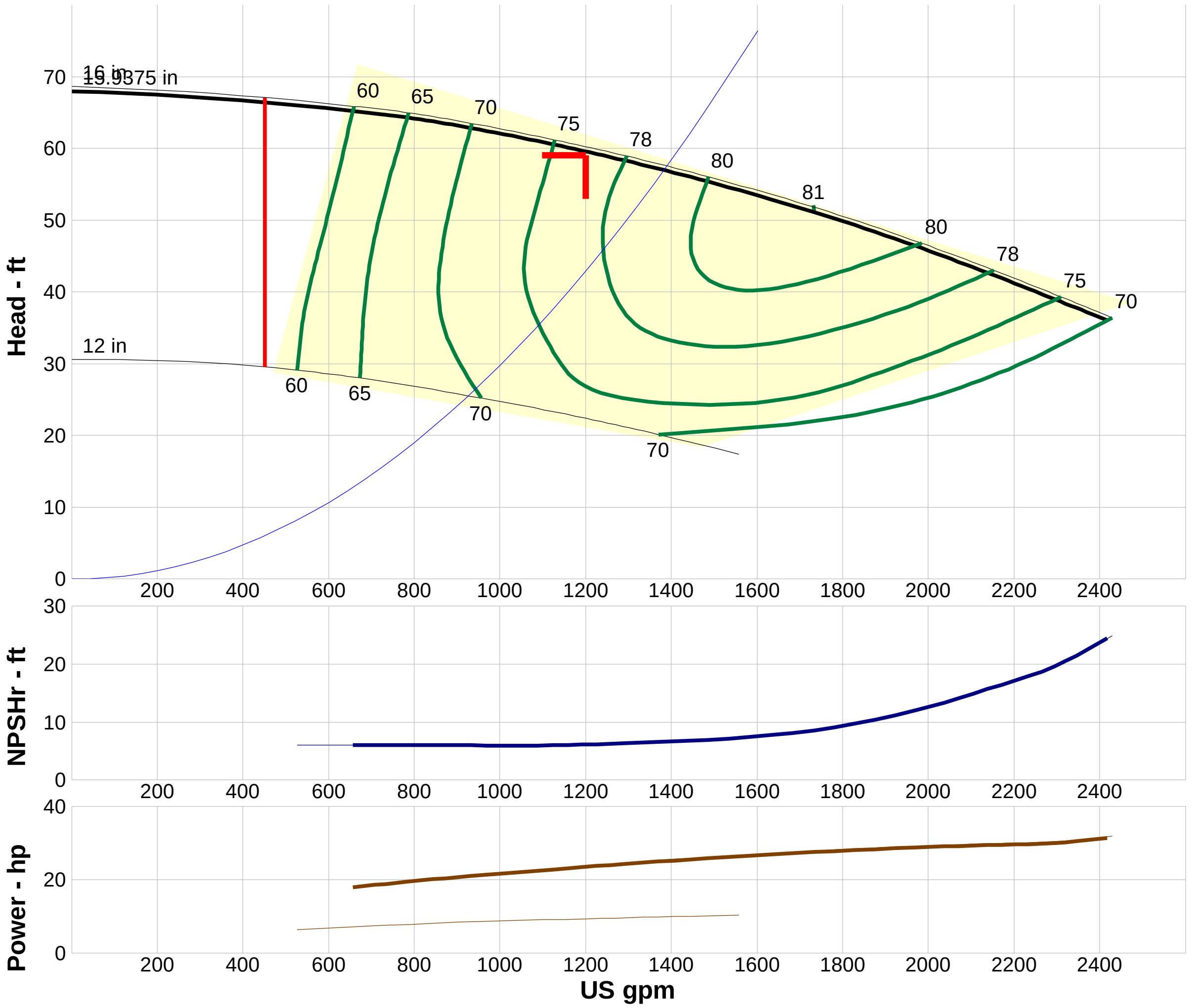
---- Design Curve ----

Shutoff head:	68 ft
Shutoff dP:	29.4 psi
Min flow:	450 US gpm

BEP: 81% @ 1733 US gpm
NOL power:
31.4 hp @ 2415 US gpm

-- Max Curve --

Max power:
31.9 hp @ 2428 US gpm



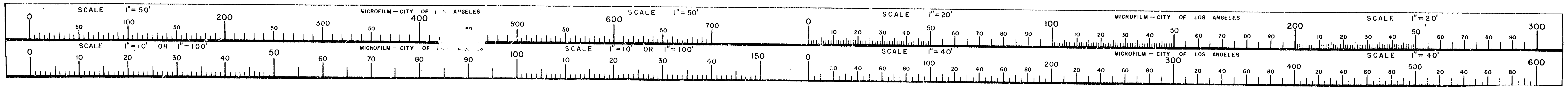
Curve efficiencies are typical. For guaranteed values, contact Fairbanks Morse or your local distributor. Las eficiencias en curvas son típicas. Para valores garantizados contacte a Fairbanks Morse o a su distribuidor local.

Performance Evaluation:

Flow US gpm	Speed rpm	Head ft	Efficiency %	Power hp	NPSHr ft
1440	880	56.1	80	25.6	6.82
1200	880	59.6	76	23.6	6.18
960	880	62.5	71	21.4	6
720	880	64.8	63	18.8	6
480	880	66	53	15.8	6

Selected from catalog: Fairbanks Morse Submersible.60 Vers: 3

Appendix D – BOE “D” Plans



INDEX TO PLANS

PLAN NO.	SHEET NO.	
D-21700		**RAILROAD AND STORM DRAIN BRIDGE**
	1	INDEX TO PLANS
	2	KEY MAP
	3	GENERAL PLAN, DESIGN DATA, GENERAL NOTES
	4	FOUNDATION PLAN
	5	PIER PLAN
	6	WEST ABUTMENT
	7	EAST ABUTMENT
	8	BEARING PAD AND SHEAR KEY DETAILS
	9	SOUTH WINGWALL
	10	NORTH WINGWALL
	11	DECK PLAN
	12	DECK DETAILS
	13	MISCELLANEOUS DETAILS
	14	MISCELLANEOUS DETAILS
	15	RAILING DETAILS
	16 - 17	PLAN OF EXISTING UTILITIES AND SUBSTRUCTURES
	18 - 20	PLAN OF RELOCATED UTILITIES AND SUBSTRUCTURES
	21	LOG OF TEST BORINGS
	22 - 23	SHOOFLY AND TEAM TRACKS
	24	MAINLINE AND TEAM TRACKS
	25	TRACK SUBGRADE CROSS-SECTIONS
D-21689		**PUMP PLANT – STRUCTURAL, CIVIL, MECHANICAL AND ELECTRICAL**
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	2	GENERAL PLAN
	3	ROOF PLAN AND BEAM DETAILS
	4	MOTOR ROOM PLAN AND BEAM DETAILS
	5	BAR SCREEN ROOM AND BEAM DETAILS
	6	STORAGE ROOM PLAN AND SECTIONS
	7	SECTIONS AND WALL BEAM AND STRUT DETAILS
	8	STAIRWELL DETAILS AND SECTIONS
	9	SECTIONS
	10	MISCELLANEOUS DETAILS
	11	ARCHITECTURAL DETAILS
	12	JUNCTION STRUCTURE
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	16	VENTILATION SYSTEM
	17	HATCH COVER DETAILS
	18	PIPE SUPPORTS AND MISCELLANEOUS DETAILS
	19	SILENCER AND MISCELLANEOUS DETAILS
	20	BAR SCREEN AND ELECTRODE WELL DETAILS
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	22	PLANS AND PROFILES OF FORCE MAIN AND DISCHARGE PIPE
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	3-4	PLAN AND PROFILE OF SEWERS IN SEPULVEDA BLVD.
	5	PLAN AND PROFILE OF SEWERS IN LANGDON AVE.; NOBLE AVE. AND BURNET AVE.

PLAN NO.	SHEET NO.	
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	3	KEY MAP AND GENERAL NOTES
	4	RESURFACING PLAN AND TYPICAL DETAILS
	5 - 21	STORM DRAIN PLAN AND PROFILE
	22	CROSS SECTIONS OF GRADED CHANNEL
	23	SUB-DRAINS
	24	CROSS SECTIONS OF GRADED DITCH OVER STORM DRAIN
	25	LOG OF SOIL BORINGS
	26	LOG OF SOIL BORINGS
	27-30	STRUCTURAL DETAILS
P-25813		**STREET PLANS**
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	2	TYPICAL SECTIONS AND STREET INDEX
	3	KEY MAP AND NOTICE TO CONTRACTORS
	4 - 5	PROFILE: SEPULVEDA BLVD. FROM LANARK ST. TO STAGG ST.
	6	PLAN: SEPULVEDA BLVD. AND ROSCOE BLVD. INTERSECTION
	7 - 12	PLAN: SEPULVEDA BLVD., 169 FT S/O ROSCOE BLVD. TO STAGG ST.
	13 - 14	PLAN AND PROFILE: SEPULVEDA BLVD. (FRONTAGE ROAD) AND CABRITO RD.
	15 - 16	PLAN AND PROFILE: LANARK ST.
	17	PLAN AND PROFILE: LANGDON AVE. AND PLAN: OLD RAYMER ST.
	18 - 19	PLAN AND PROFILE: RAYMER ST.
P-25814		**STREET PLANS**
	1	INDEX TO PLANS
	2	STREET INDEX AND GRADING PLAN
	3	DETOUR SIGNING PLAN
	4 - 8	DETOUR ROAD
	9	PLANS: ROSCOE BLVD. INTERSECTION WITH BURNET AVE. AND NOBLE AVE.
	10	PLANS: MARSON AVE. INTERSECTION WITH BURNET AVE. AND NOBLE AVE.
	11	PLANS: ROSCOE BLVD. INTERSECTION WITH LANGDON AVE., COLUMBUS AVE. AND ORION AVE.
	12	STAIRWAY DETAILS
	13 - 15	DEMOLITION AND REMOVAL PLAN
	16 - 17	SEPULVEDA BLVD. CROSS-SECTIONS
	18	SEPULVEDA BLVD. AND RAYMER ST. CROSS-SECTIONS
	19	PLAN AND PROFILE: ROSCOE BLVD. W/O ORION AVE.
D-21703		**STREET LIGHTING AND TRAFFIC**
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	2	NOTICE TO CONTRACTORS AND DETOUR LIGHTING
	3 - 5	FINAL STREET LIGHTING
	6	RAYMER ST. AND SEPULVEDA BLVD. TRAFFIC SIGNAL
	7	LANARK ST., SEPULVEDA BLVD. & SEPULVEDA PL. TRAFFIC SIGNAL
	8	RAYMER ST. & SEPULVEDA BLVD. DETOUR RD.
	9	NOBLE AVE. & ROSCOE BLVD.
	10	ROSCOE BLVD. & SEPULVEDA BLVD.

PLAN NO.	SHEET NO.	
D-21702		**EROSION CONTROL**
	1	INDEX TO PLANS
	2 - 3	IRRIGATION PLANS
	4	EROSION CONTROL DETAILS

SEPULVEDA BOULEVARD
GRADE SEPARATION
AT
RAYMER STREET
AND
THE SOUTHERN PACIFIC COMPANY'S
COAST LINE TRACKS

CITY OF LOS ANGELES
LYALL A. PARDEE CITY ENGINEER

DATUM NOTE

U. S. G. S. DATUM EFFECTIVE JULY 1, 1925 ORDINANCE NO. 52222 DEDUCT 5.775 FEET TO ADJUST TO DATUM PLANE IN USE PRIOR TO SAID DATE

REFERENCES

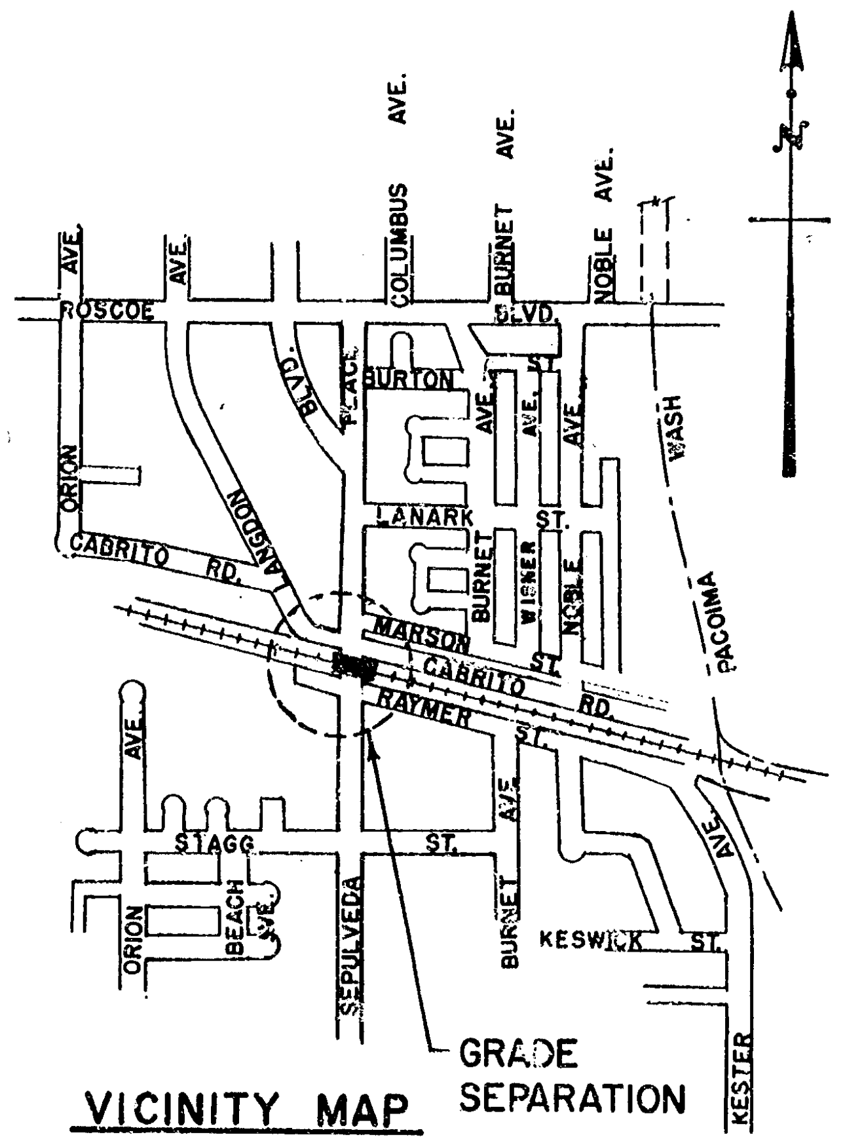
FIELD BOOK NO. 40053, 25716, 26066, 22407, 40042
DATE OF SURVEY April-67, Nov-64, April-62, July 67, May-67
DISTRICT MAP NO. 7497, 7498, 7519, 7520, 7581, 7582
ASSESSMENT MAP NO. ______ DIV. 597, 598, 749, 750, 791, 792, 793
DRAINAGE MAP NO. 398
SUPERSEDES PROFILE NO. ______

NOTICE TO CONTRACTORS

THIS IMPROVEMENT ALSO INCLUDES WORK CALLED FOR ON THE FOLLOWING SPECIAL PLANS AND PROFILES

STREET IMP. PROFILES P-25813 P-25814
SEWER PLANS D-21688
STORM DRAIN PLANS ______
STRUCTURAL PLANS D-21689 D-21700
ORNAMENTAL LIGHTING PLANS D-21703
EXISTING MANHOLES (TOTALS) STORM DRAIN 0 SEWER ______

SPECIFICATIONS: ALL WORK DETAILED ON THESE PLANS TO BE PERFORMED UNDER CONTRACT SHALL, EXCEPT AS OTHERWISE STATED OR PROVIDED FOR HEREON, BE CONSTRUCTED IN ACCORDANCE WITH "STANDARD SPECIFICATIONS FOR PUBLIC WORKS CONSTRUCTION, 1967 EDITION" AND THE SPECIAL SPECIFICATIONS.



VICINITY MAP
Not to Scale

BENCH MARKS			
F.B.	Pg.	Elev.	Description
25716	59	786.775	Standard Survey Mon. ℄ Int. Sepulveda Blvd. & Cabrito Rd.(W) 1960 adj.
25716	41	800.175	Standard Trav. Mon. 8-J-21 on ℄ Int. Sepulveda Blvd. & Roscoe Blvd. 1960 adj.
24701	28	781.085	Spk. ℄ Sepulveda Blvd. in ret. to curb of center island 30' S/O ℄ Stagg St. 1960 adj.
27831	42	781.730	Spk. West Curb Kester Ave. 3' S/O B.C.R. S.W. Corner Raymer St. 1960 adj.
27831	42	788.695	U.S.C. & G.S.-B.M. Disk "K-1135" on top of S. Diversion Gate Wall - 200'± N/O ℄ Raymer St. 1960 adj.
25716	41	792.375	Spk. N. Curb Lanark St. 5' E/O B.C.R. to Sepulveda Place 1960 adj.

SEPULVEDA BOULEVARD GRADE SEPARATION AT RAYMER STREET AND THE SOUTHERN PACIFIC COMPANY'S COAST LINE TRACKS BETWEEN ROSCOE BOULEVARD AND STAGG STREET AND BETWEEN ORION AVENUE AND KESTER AVENUE – W.O. 71257

1958 STORM DRAIN BOND ISSUE

LOS ANGELES COUNTY
FLOOD CONTROL DISTRICT

~~LOS~~ ANGELES
PROJECT NO. 651
LINES A, B, C, & D

RECOMMENDED BY C. F. Cahilly
DIVISION ENGINEER (DESIGN)
APPROVAL RECOMMENDED BY W. Ransom
ASST CHIEF DEPUTY ENGINEER
7-5-68
APPROVED BY Walter J Wood
ACB CHIEF ENGINEER

REVISIONS			APPROVALS		
DATE	DESCRIPTION	BY	DIVISION ENGINEER	CITY ENGINEER	DATE
7/68	Rev. Sh. Nos 6, 27 & 28.	GF		Lyall A. Pardee	7/9/68

APPROVALS		
DIVISION OR DEPT.	ENGINEER	DATE
STREET OPENING		
STREET AND FREEWAY		
SANITARY SEWERS	Mark F. Riffe	2/14/68
STORM DRAIN	J. R. Cole	3/5/68
BRIDGE DESIGN		3/6/68
STREET LIGHTS JK	F. M. Apodaca	2/9/68
WATER DEPARTMENT		
TRAFFIC DEPT.		

SUBMITTED January 30 1968
BY L. D. Parker
DIVISION OR DISTRICT ENGINEER
Donald Thompson
CHIEF DEPUTY ENGINEER (DESIGN)
APPROVED Mar. 6, 1968
Lyall A. Pardee
CITY ENGINEER

SHEET NO. 1 OF 30 SHEETS
D-21701

DATE - JULY '68 L.A.C.F.C.D DWG. NO. 275-681-D3.1

DESIGN	CHECKED
DETAILS	CHECKED
QUANTITIES	ARCHITECTURE
SUPERVISED	REVIEWED

WORK ACCEPTED & COMPLETED DATE ORDER No
BD OF PUBLIC WORKS 7-9-71 78867
CONSTRUCTION CHANGES RECORDED 3-71 BY H.S.D.

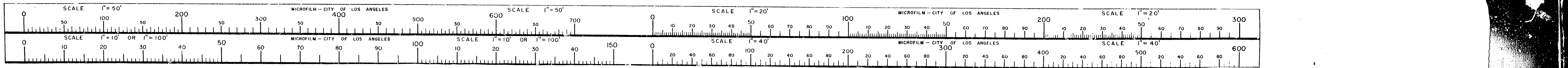
DIETZGEN 187H DURAVEL

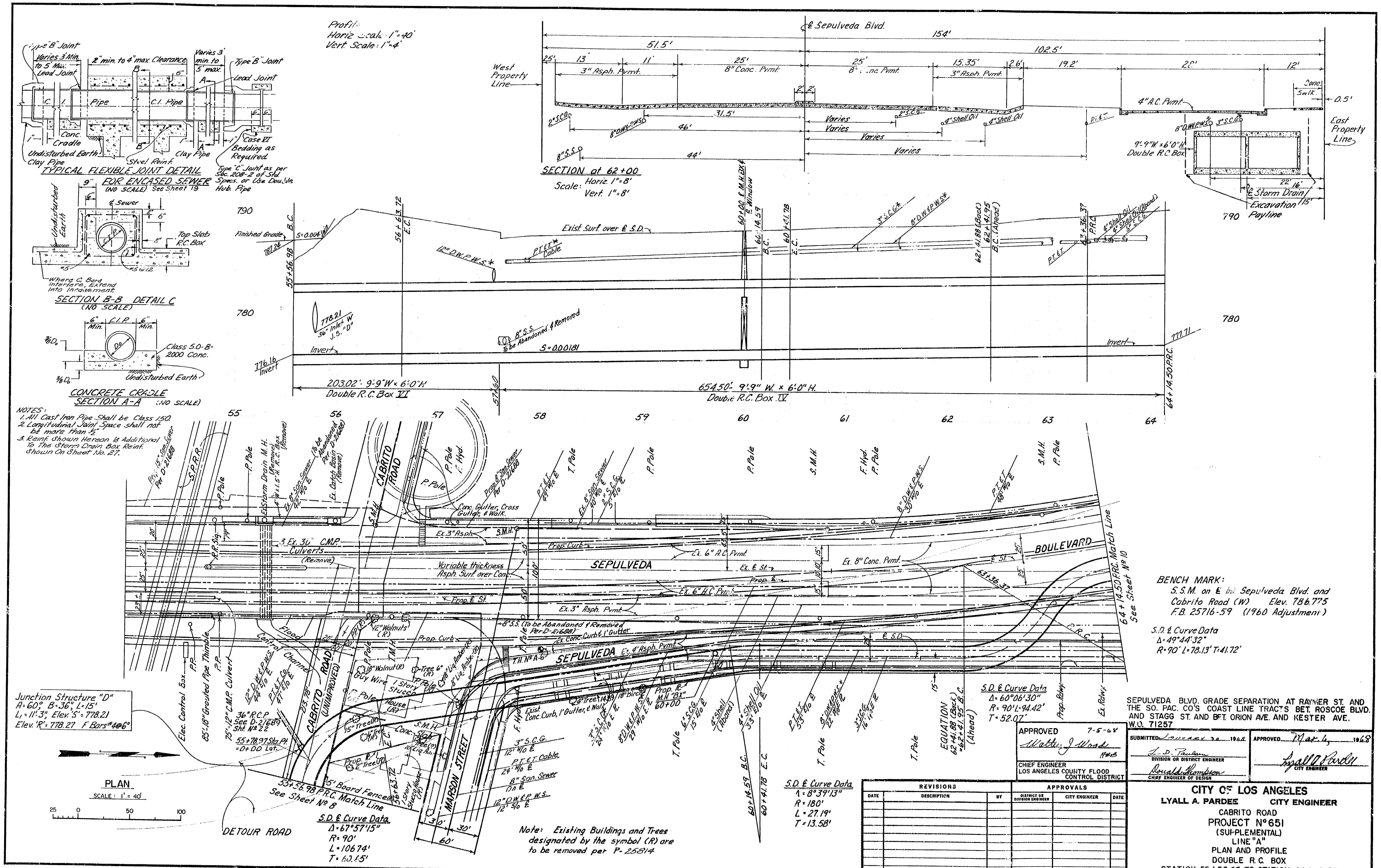
D-21701

D-21701

D-21701

CERTIFICATE
I hereby certify that this is a true and accurate copy of the official city record described there, made in accordance with Section 434 of the Charter of the City of Los Angeles, and Section 34090.5 of the Government Code.
Date 8 - 13 -
REX E. LAYTON, City Clerk
By





NOTES:
1. All Cast Iron Pipe Shall be Class 150.
2. Longitudinal Joint Space Shall not be more than ½".
3. Reinf. Shown Hereon Is Additional To The Storm Drain Box Reinf. Shown On Sheet No. 27.

BENCH MARK:
S.S.M. on ℄ in Sepulveda Blvd. and Cabrito Road (W) Elev. 786.775
F.B. 25716-59 (1960 Adjustment)

Note: Existing Buildings and Trees designated by the symbol (R) are to be removed per P-25814

SEPULVEDA BLVD. GRADE SEPARATION AT RAYMER ST. AND THE SO. PAC. CO'S COAST LINE TRACTS BET. ROSCOE BLVD. AND STAGG ST. AND BET. ORION AVE. AND KESTER AVE.
W.O. 71257

APPROVED 7-5-68
Walter J Wood
RBB
CHIEF ENGINEER
LOS ANGELES COUNTY FLOOD CONTROL DISTRICT

SUBMITTED January 30 1968
L. D. Paulsen
DIVISION OR DISTRICT ENGINEER
Donald Thompson
CHIEF ENGINEER OF DESIGN

APPROVED Mar. 4 1968
Lyall A Pardee
CITY ENGINEER

REVISIONS			APPROVALS		
DATE	DESCRIPTION	BY	DISTRICT OR DIVISION ENGINEER	CITY ENGINEER	DATE

CITY OF LOS ANGELES
LYALL A. PARDEE CITY ENGINEER
CABRITO ROAD
PROJECT N°651
(SUPPLEMENTAL)
LINE "A"
PLAN AND PROFILE
DOUBLE R.C. BOX
STATION 55+56.98 TO STATION 64+14.50

SHEET NO. 9 OF 30 SHEETS D-21701

DATE-JULY'68 L.A.C.F.C.D. DWG. NO. 275-651-03.9

K+E IMPERIAL FORM S-346-2LA LA 3714

D-21701

CERTIFICATE
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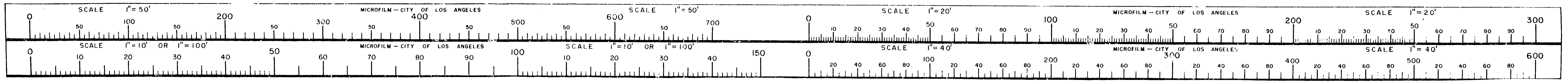
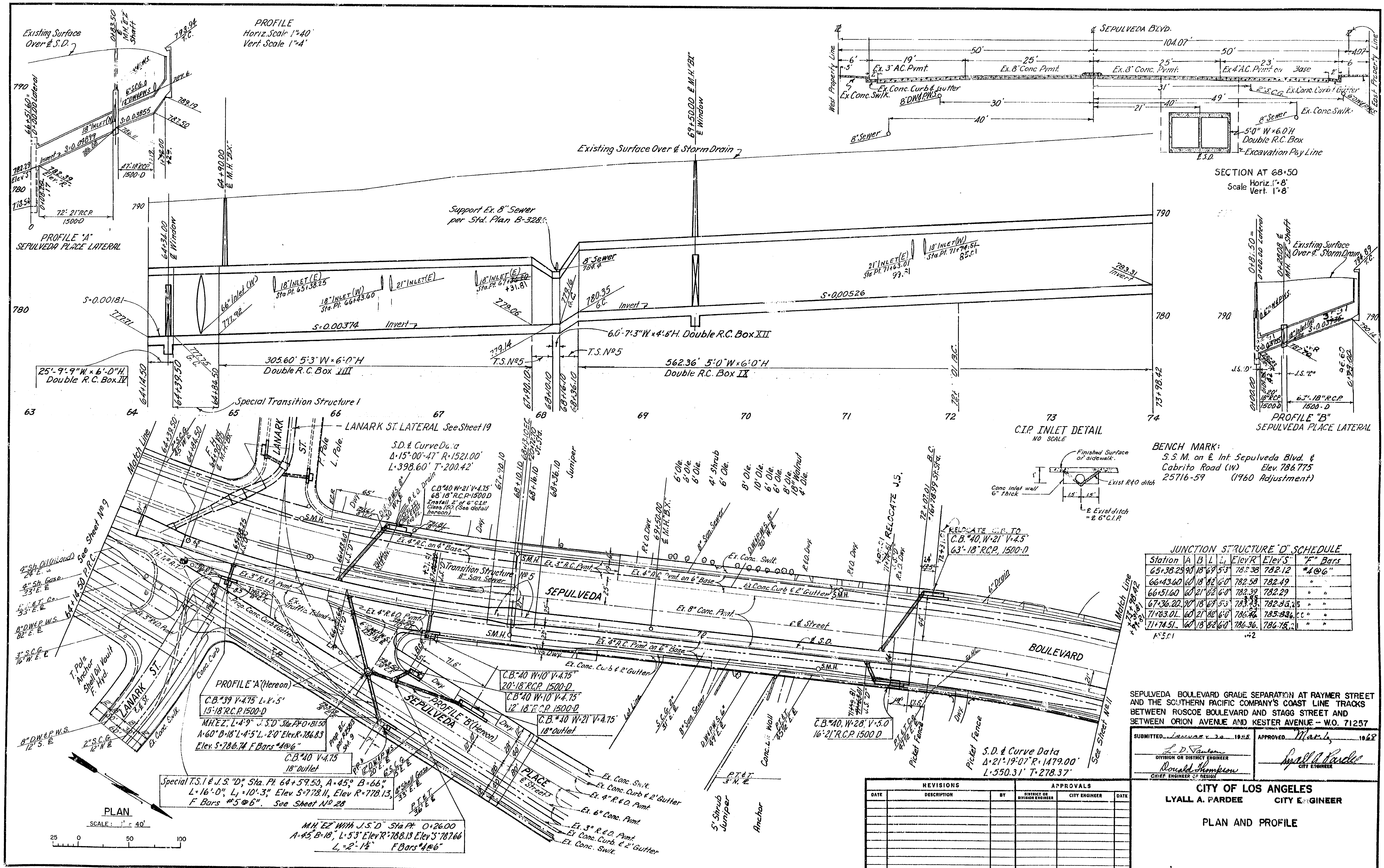
Date 8 - 13 -
REX E. LAYTON, City Clerk
By





JUNCTION STRUCTURE "D" SCHEDULE

Station	A	B	L	L1	Elev "R"	Elev "S"	"F" Bars
65+38.25	90°	18"	6'9"	5'3"	782.38	782.12	#4@6"
66+43.60	60°	18"	8'2"	6'0"	782.58	782.49	"
66+51.60	60°	21"	8'2"	6'0"	782.39	782.29	" "
67+36.20	90°	18"	6'9"	5'3"	783.43	782.85	" "
71+63.0L	60°	21"	8'2"	6'0"	786.46	785.836	" "
71+74.51	60°	18"	8'2"	6'0"	786.36	786.75	" "

SEPULVEDA BOULEVARD GRADE SEPARATION AT RAYMER STREET
AND THE SOUTHERN PACIFIC COMPANY'S COAST LINE TRACKS
BETWEEN ROSCOE BOULEVARD AND STAGG STREET AND
BETWEEN ORION AVENUE AND KESTER AVENUE – W.O. 71257

SUBMITTED January 30 1958
L. D. Paulson
DIVISION OR DISTRICT ENGINEER
Donald Thompson
CHIEF ENGINEER OF DESIGN

APPROVED Mar. 6, 1968
Lyall A. Pardee
CITY ENGINEER

REVISIONS			APPROVALS		
DATE	DESCRIPTION	BY	DISTRICT OR DIVISION ENGINEER	CITY ENGINEER	DATE

CITY OF LOS ANGELES

LYALL A. PARDEE CITY ENGINEER

PLAN AND PROFILE

SHEET NO. 10 OF 30 SHEETS

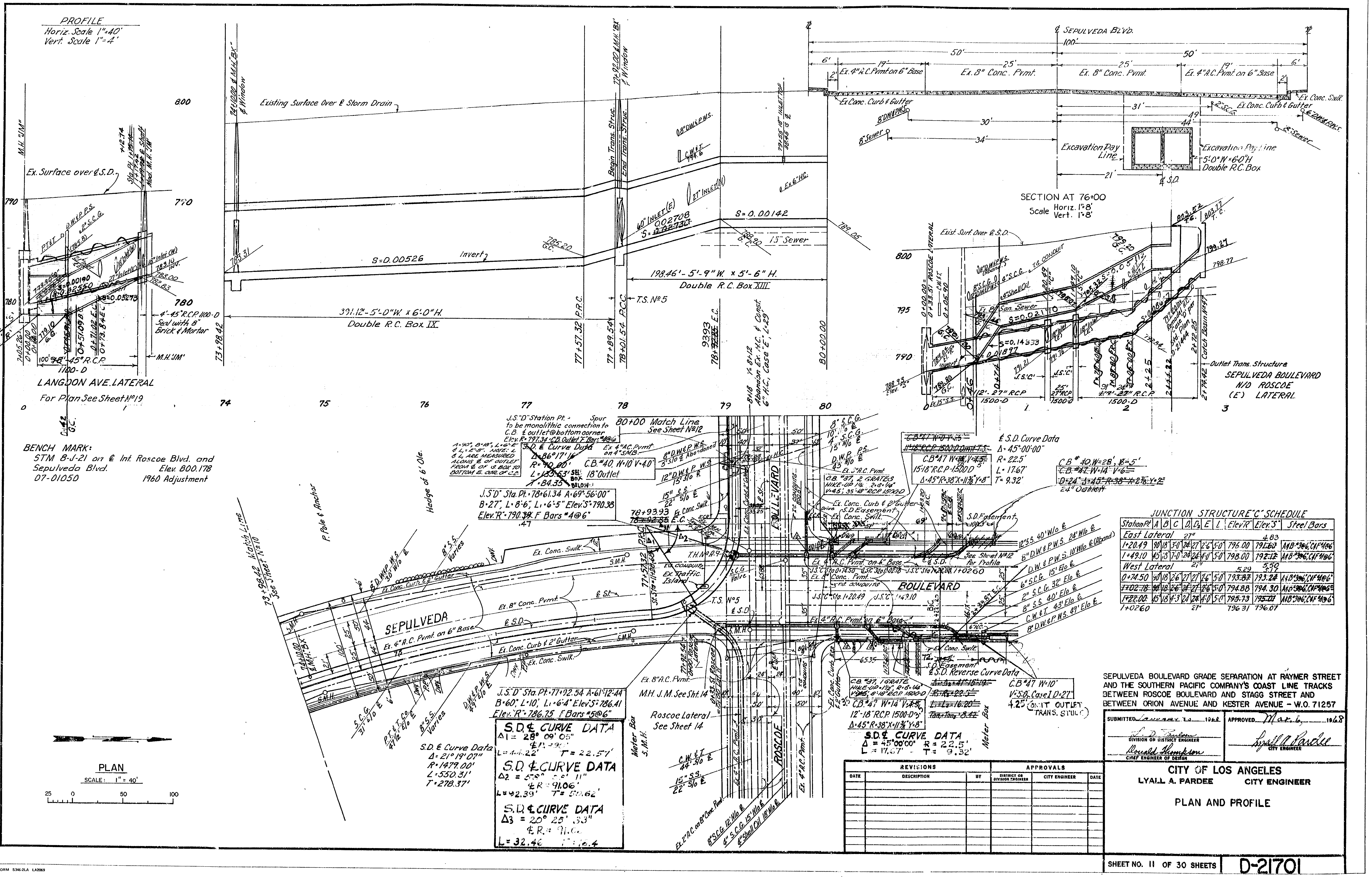
D-21701

D-21701

CERTIFICATE

I hereby certify that this is a true and accurate copy of the official record described there, made in accordance with Section of the Charter of the City of Los Angeles, and Section .5 of the Government Code

Date 13- LAYTON, City Clerk
By



JUNCTION STRUCTURE "C" SCHEDULE

Station Pt.	A	B	C	D1	D2	E	L	Elev "R"	Elev. "S"	Steel Bars
East Lateral				27"					4.83	
1+20.49	90°	18"	3'-0"	~~24~~	27"	2'-6"	5'-0"	796.00	~~791.60~~	A&B-#3@6", C&F #4@6"
1+49.10	45°	18"	7'-0"	24	24	4'-0"	5'-0"	798.00	~~792.17~~	A&B-#3@6", C&F #4@6"
West Lateral					27"			5.29	5.50 5.17	
0+74.50	90°	18"	2'-6"	27"	27"	2'-6"	5'-0"	~~793.87~~	~~793.24~~	A&B #3@6", C&F #4@6"
~~1+02.18~~	~~90°~~	~~18"~~	~~2'-6"~~	~~24~~	~~27"~~	~~2'-6"~~	~~5'-0"~~	~~794.88~~	~~794.30~~	~~A&B #3@6", C&F #4@6"~~
~~1+22.00~~	45°	18"	4'-3"	24	~~24~~	4'-0"	5'-0"	~~795.73~~	~~795.01~~	A&B #3@6", C&F #4@6"
1+0260					27"			796.31	796.07	

SEPULVEDA BOULEVARD GRADE SEPARATION AT RAYMER STREET AND THE SOUTHERN PACIFIC COMPANY'S COAST LINE TRACKS BETWEEN ROSCOE BOULEVARD AND STAGG STREET AND BETWEEN ORION AVENUE AND KESTER AVENUE - W.O. 71257

SUBMITTED January 30 1968
L. D. Paulson
DIVISION OR DISTRICT ENGINEER
Donald Thompson
CHIEF ENGINEER OF DESIGN

APPROVED Mar. 6 1968
Lyall A. Pardee
CITY ENGINEER

REVISIONS			APPROVALS		
DATE	DESCRIPTION	BY	DISTRICT OR DIVISION ENGINEER	CITY ENGINEER	DATE

CITY OF LOS ANGELES
LYALL A. PARDEE CITY ENGINEER

PLAN AND PROFILE

SHEET NO. 11 OF 30 SHEETS
D-21701

D-21701

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Date 8 - 13 -
REX E. ON, City Clerk
By

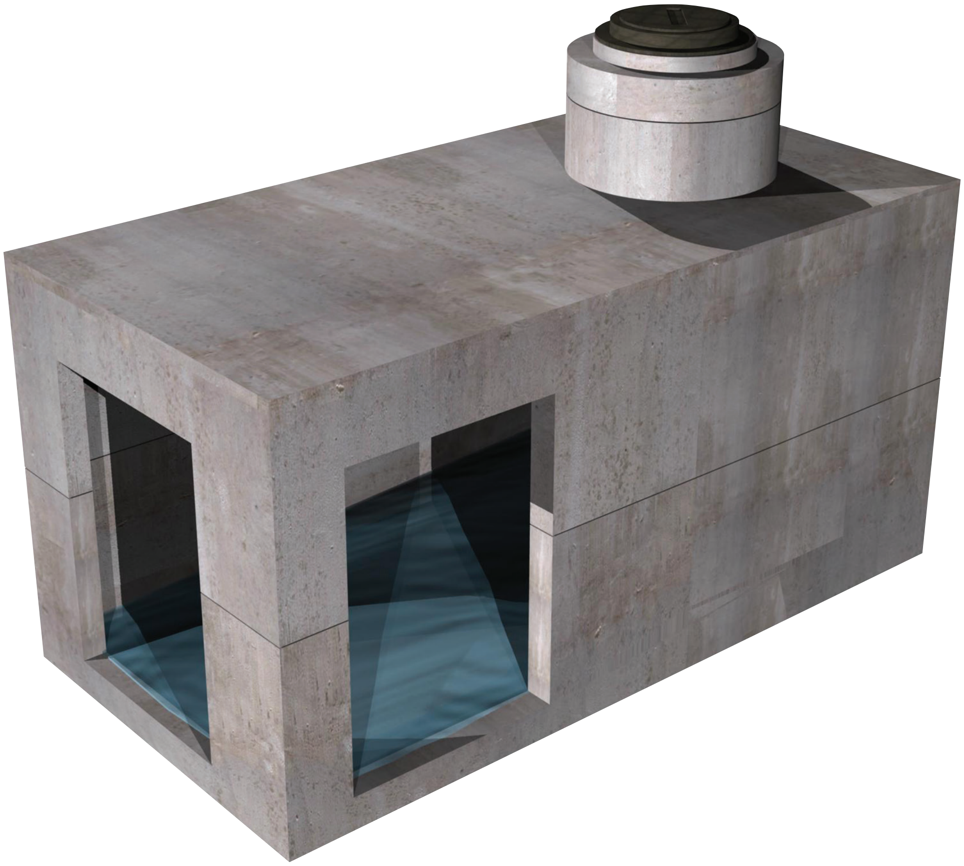
Appendix E – Product Information

STORM CAPTURE

Detention / Infiltration

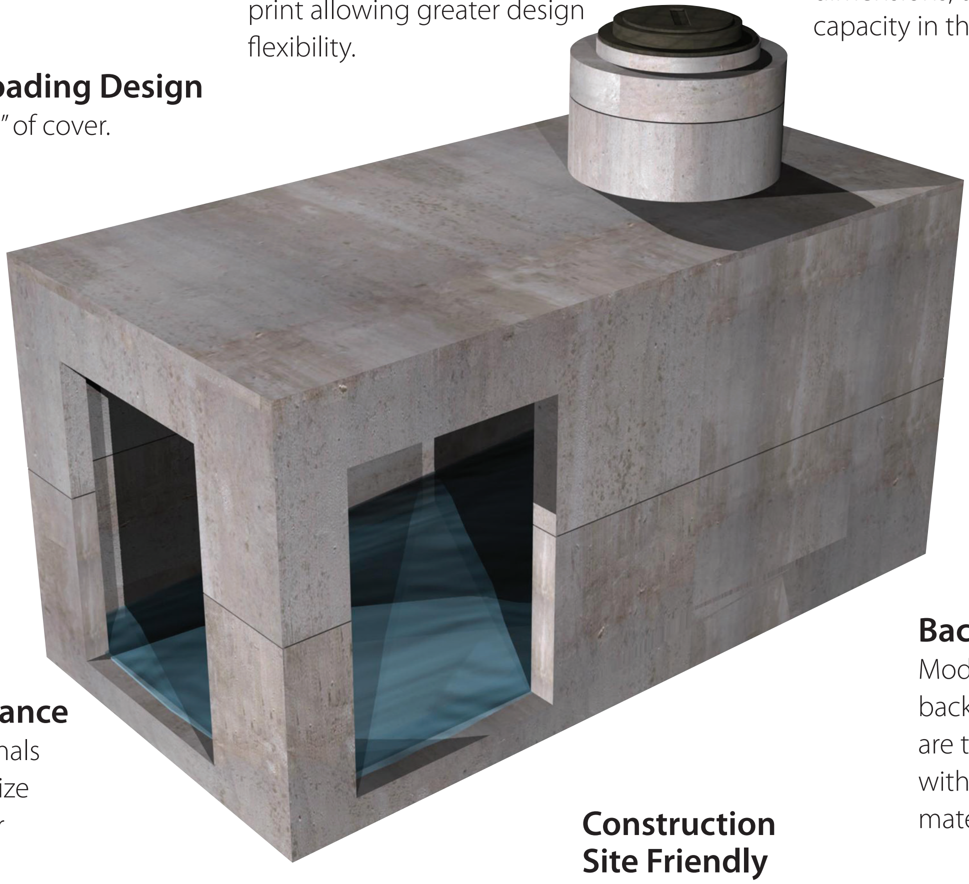
TOTAL STORMWATER MANAGEMENT SYSTEM

From Oldcastle Stormwater Solutions Comes Storm Capture, A Modular Stormwater Management System for Infiltration, Detention, Retention, and Treatment.



Oldcastle
Stormwater Solutions™

Storm Capture Module



Description
7′ x 15′ with a 14′ maximum/adjustable height inside dimensions, the largest capacity in the industry.

Large Storage Capacity
results in smaller system footprint allowing greater design flexibility.

Traffic Loading Design
with only 6″ of cover.

Easy to Install
modules for fast installation.

Flexible Heights
Available in heights from 2′ to 14′ to best-fit site needs.

Backfill
Modules do not rely on backfill for storage, and are typically backfilled with existing site materials.

Design Assistance
Let our professionals help you customize an application for your needs.

Construction Site Friendly
Contractor does not have to give up any of the site once the Storm Capture system is installed.

Treatment Train
Available with treatment train capability, pretreatment, post treatment, or both.


Same day staging and installation of StormCapture project.


StormCapture Project using Linkslab design.


StormCapture modules are designed for HS20 traffic loading.

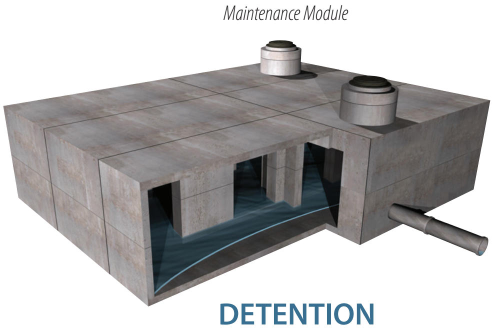

StormCapture infiltration system.

Storm Capture Benefits

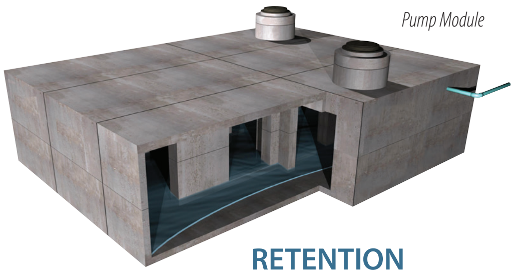
- **Fast service** - Quick and easy project help by our national engineering team with layouts and specifications to meet each project's requirements.
- **Cost savings** - Highly competitive installed and life-cycle costs.
- **Manufactured** to the rigid standards of the Oldcastle quality control program at Oldcastle facilities around the country.
- **Codes** - Designed to the latest codes for HS-20-44 (full truck load plus impact).
- **Sustainability** - The system is maintainable for long-term sustainability.
- **LID** - Ideal for Low Impact Development (LID).
- **LEED** - Manufactured locally with recycled material for potential LEED credits. *LEED 2009 for New Construction & Major Renovation, US Green Building Council: Sustainable Sites (5.1, 5.2, 6.1, 6.2), Materials & Resources (4.1, 4.2, 5.1, 5.2), Water Efficiency (1.1, 1,2, 3.1, 3.2)*

Applications

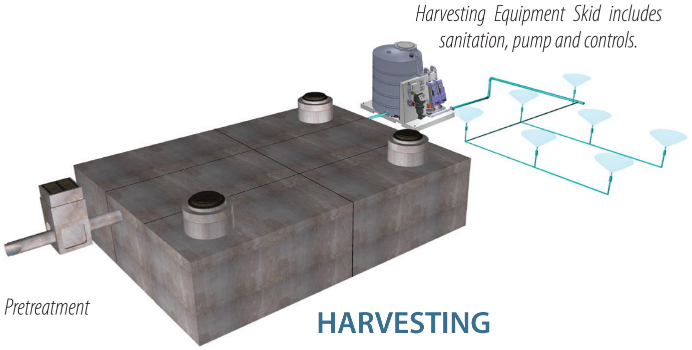
Storm Capture has many solutions for detention, retention, treatment, and harvesting that involve a combination of many parts designed to solve your stormwater management needs. Let us show you how we can design and customize a solution for you.



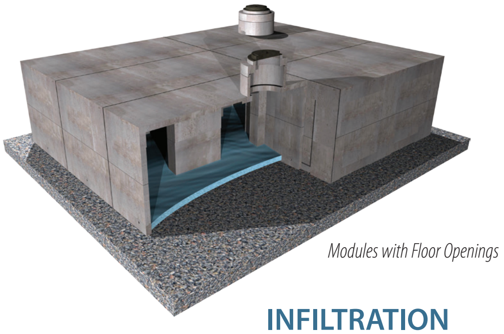
DETENTION



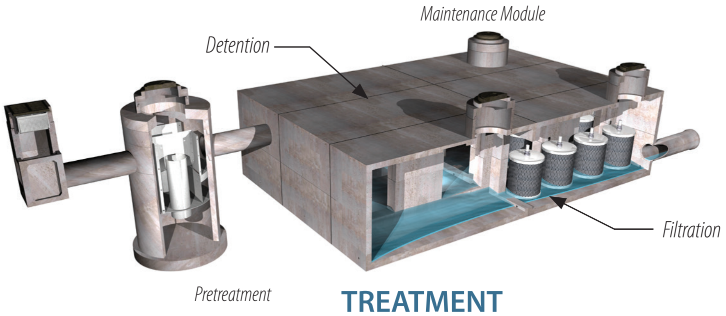
RETENTION



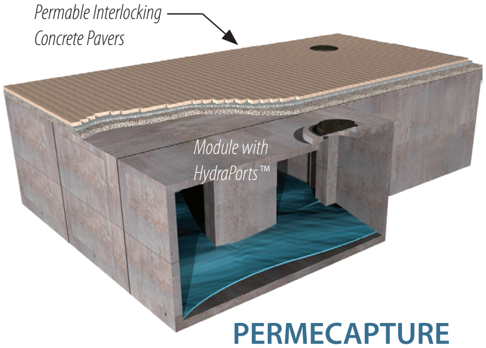
HARVESTING



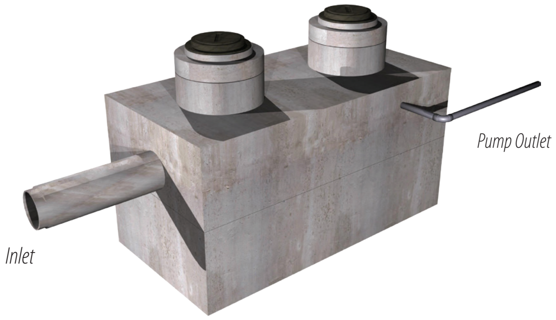
INFILTRATION



TREATMENT



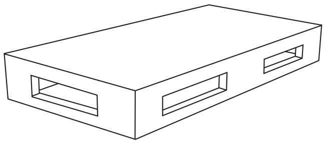
PERMECAPTURE



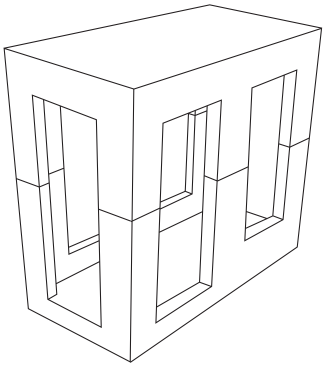
CISTERNS

INSTALLED IN ONE DAY

Module Sizes



SC1 – one piece modules can be used for applications from 2' to 7' tall. These are appropriate for cisterns, infiltration, detention, and retention systems. SC1 modules are typically installed on a minimal compacted gravel base, dependent on specific project requirements.



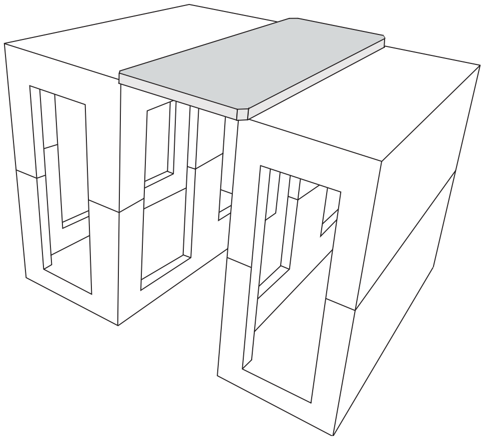
SC2 – two piece modules can be used for applications from 7' all the way up to 14' tall for maximum storage capacity in the smallest footprint. These are appropriate for cisterns, infiltration, detention, and retention systems. SC2 modules are typically installed on a compacted native subgrade.

Module Capacity

Size (ft.)	Capacity (ft^3.)
7x15x2	226
7x15x3	343
7x15x4	460
7x15x5	577
7x15x6	690
7x15x7	807
7x15x8	910

Size (ft.)	Capacity (ft^3.)
7x15x9	1027
7x15x10	1144
7x15x11	1257
7x15x12	1374
7x15x13*	1491
7x15x14*	1608

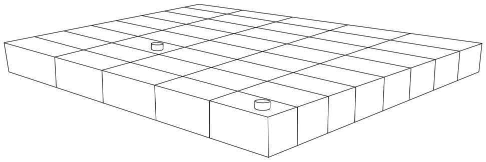
* Special design considerations required and limited availability
All dimensions are inside dimensions

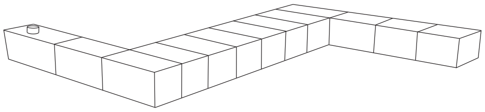


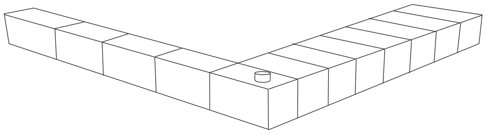
Link Slab – for large storage assemblies, the unique link slab design allows significant reduction in the quantity of modules and associated costs, while providing the maximum in storage capacity.

Endless Configurations

Contact us today to start designing your system!







Oldcastle
Stormwater Solutions™

(800) 579-8819

www.oldcastlestormwater.com
www.stormcapture.com

KRISTAR

Humes
Water Solutions

Strength. Performance. Passion.

StormTrap® system Installation guide

SingleTrap™ model

STORMTRAP®
PRECAST CONCRETE MODULAR STORM WATER DETENTION

Contents

The StormTrap® system **1**
Design and installation standards 1
Specifications **2**
Module details 2
  Masses and dimensions 2
Handling and installation **3**
Safety 3
Pre-delivery 3
  Equipment requirements 3
  Site preparation 4
Delivery 5
Lifting 5
Module installation 6
Contact information **9**

The StormTrap® system

The StormTrap® system is a purpose-built stormwater detention and infiltration solution which provides a fully trafficable, below ground on-site detention system (OSD).

The system takes a unique design approach by connecting individual precast concrete modules into a single layer configuration that meets each project's requirements. This delivers a simple and flexible design solution without compromising above ground land use.

The growing popularity of the StormTrap® system is not only driven by its unique design and performance benefits, but by the significant installation economies it can provide. The modular design of the system means large detention volumes are delivered with the installation of each module. And because installers are able to use traditional construction processes, the installation can be completed in minimal time. Generally, it is expected that an individual StormTrap® module can be set in position in less than 10 minutes.

The StormTrap® system is available in two configurations to provide conventional detention, high early discharge or infiltration to ground water. The SingleTrap™ system and DoubleTrap™ system provide design solutions to meet volume requirements. This guide refers to the installation of the SingleTrap™ system.

The SingleTrap™ system is either founded on a strip footing to create a large infiltrative surface area, or founded on a conventional concrete slab for use as either a traditional detention basin or a basin with high early discharge.

The installation of the StormTrap® system is very simple:

1. Establish a suitable foundation.
2. Place modules row-by-row.
3. Apply StormWrap™ mastic tape across the top of the module joins.
4. Backfill.

There are a number of time-lapse videos available from humeswatersolutions.com.au which demonstrate the construction sequence and methodologies undertaken during the installation of a StormTrap® system. The library of videos includes a variety of project sizes and configurations.

As the system is made from precast concrete it is extremely strong and trafficable to AS 5100 traffic loadings (light duty designs are also available). Once the system has been installed there is no requirement for any further structural work in the trafficable pavement. The system will not deflect during construction loading, which allows rapid backfilling, and it won't suffer creep, as can be experienced with some lightweight systems.

Design and installation standards

The StormTrap® system is designed and installed in accordance with the requirements of the following Australian standards:

- AS 3600-2001 – Concrete Structures Code
- AS 5100-2004 – Bridge Design Code
- AS 5100.2-2004 – Bridge Design – Design Loads
- AS 1597.2-1996 – Precast Reinforced Concrete Box Culverts - Large Culverts
- AS/NZS 1170.1-2002 – Structural Design Actions – Part 1: Permanent, Imposed and other Actions.

Specifications

Module details

There are a number of different StormTrap® modules available and their use and placement will depend on design requirements and site layout (refer to Figure 1).

While the length and width of the modules remains constant, the height, and subsequently the mass, will vary according to the leg height for the system. The leg height varies from 600 mm to 1,500 mm, and is adjustable at 25 mm increments within this range.

Some modules will contain openings to allow for stormwater pipes or culverts and maintenance access points. Inlets and outlets may be placed at varying inverts and positions around the perimeter of the structure.

Depending on the overall size, each StormTrap® system will generally be designed with either 600 mm or 1,050 mm diameter openings for access through the roof at either end of the system. However, access openings may be in any location to fit in with specific site requirements. Designs can be modified to accommodate 900 mm x 900 mm grates.

Masses and dimensions

SingleTrap™ modules have a maximum internal leg height of 1,500 mm. The maximum mass of each module is shown in Table 1.

Table 1 – Masses and dimensions (1,500 mm height)

Module type	Mass (kg)	Length x width (mm)
I	6,730	4,000 x 2,350
II	4,320	2,000 x 2,350
III	7,660	4,000 x 2,350
IV	4,810	2,000 x 2,350
V	4,810	2,000 x 2,350
VI	8,590	4,000 x 2,350
VII	5,280	2,000 x 2,350
Light duty I	4,400	4,000 x 2,350

Figure 1 – A sample layout of a SingleTrap™ system

V	III	III	IV
II	I	I	II
II	I	I	II
IV	III	III	V

Standard type I

Standard type II

Standard type III

Standard type IV

Standard type V

Standard type VI

Standard type VII

Light duty type I

Handling and installation

Safety

Safety is a priority for Humes. It is important for all parties to observe safety requirements and regulations during transportation, handling, storage and installation, including wearing appropriate personal safety protection equipment.

It is the responsibility of the main contractor or installation contractor to produce a Safe work method statement; we recommend that this statement complies with both the National Code of Practice for Precast Tilt-up and Concrete Elements in Building Construction, and local and state codes (where they exist). Personnel should follow any safety advice provided by the main contractor/installation contractor.

The precast concrete component should only be lifted using the appropriate lifting clutches which are fitted into the designated lift points via the cast-in anchors. All lifting equipment must be certified to lift the specific mass and approved for lifting heavy components. The mass of the StormTrap® modules will vary depending on its geometry; weights will be clearly marked on the precast units and in the relevant project drawings.

All lifting and placement must proceed with caution and strictly in accordance with all relevant occupational health and safety standards. Bumping or impact of modules can cause damage and should be avoided.

The advice in this publication is of a general nature only. Where any doubt exists as to the safety of a particular lift or installation procedure, seek the guidance of a professional engineer or contact Humes for advice.

Pre-delivery

To ensure the safe and efficient installation of the StormTrap® system it is important to undertake sufficient planning prior to its arrival on site.

Equipment requirements

The following list of equipment is required for a safe and efficient installation:

- tape measure
- a can of marking spray
- chalk line/masonry string
- pinch/crowbar
- stanley knife
- two ladders
- broom
- level
- four chains
- four five-tonne Swiftlift® clutches
- Swiftlift® clutches for manhole covers or risers
- swivel for chains
- 20 mm spacers or gap gauge (available from Humes)
- safety harness for working at height
- StormMastic™ sealant
- StormWrap™ mastic tape.

Left:
Gap gauge

Site preparation

Before the StormTrap® system is installed, the concrete foundation must be poured (refer to the approval drawings supplied by Humes). The foundation details will depend on whether the system is required to provide stormwater detention or infiltration (refer to Figure 2 and Table 2 for an example).

Once the foundation is cured mark the outside edges of the system on the slab (as per the layout dimensions of the approval drawings).

Figure 2 – Example of a foundation plan

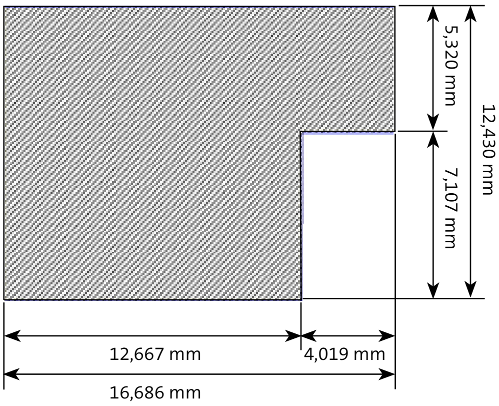
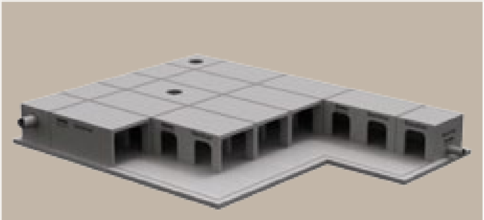
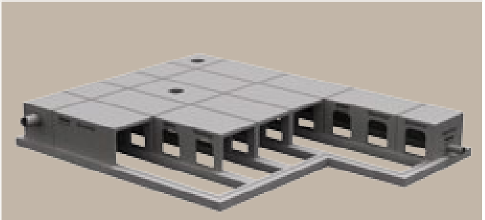
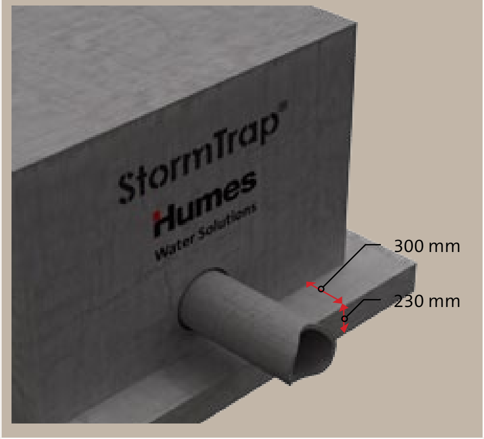
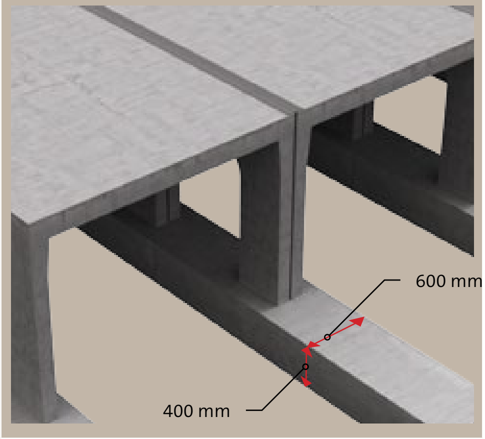


Table 2 – Foundation details

System type	Detention	Infiltration
		
Foundation	Continuous concrete slab	Strip footing
Dimensions	Slab is 230 mm thick* and extends 300 mm past outer edge of the system.  	Slab 'strips' are 400 mm thick and 600 mm wide running underneath the line of StormTrap® feet. 
Recommended cure period	7 days	7 days

Note:
*Slab design is based on in-situ material having a bearing capacity of 150 KPa; this may differ according to engineer's specifications.

Delivery

Prior to deliveries commencing, a pre-installation site meeting will occur with the contractor to finalise shipping plans including the sequencing of deliveries and the order of unloading and installing each of the modules.

The shipping plan will help to alleviate the double-handling of modules; save time and effort, make more efficient use of the crane, and reduce site congestion. The shipping plan will be provided to both the specifying engineer and contractor for sign off prior to commencing the delivery of modules to site (refer to Figure 3).

The StormTrap® modules will be delivered to site either on a semi-trailer or B-double depending on site access and the number of modules to be delivered. Each truck will typically contain 3-6 modules depending on the particular module type and mass. The first truck will typically take about 45 minutes to unload, the second truck about 30-45 minutes, and then each subsequent truck about 20-30 minutes.

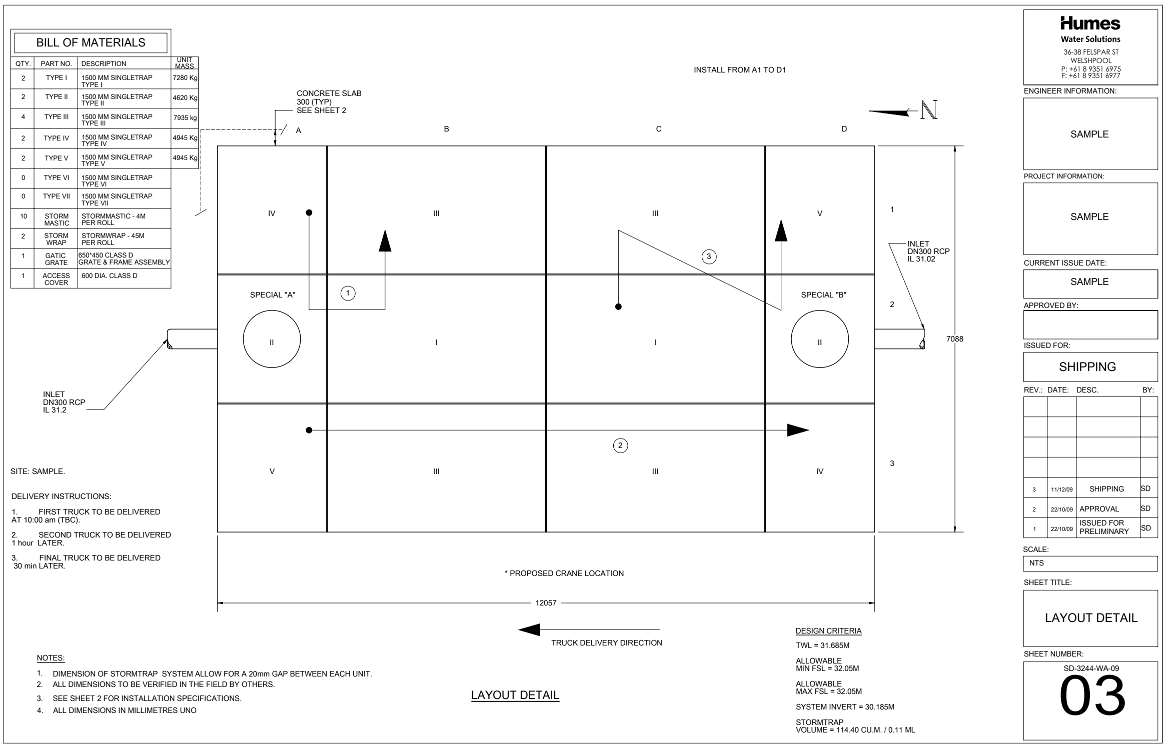
Lifting

All the precast units are supplied with cast-in lifting anchors to enable safe handling. To prevent stress and possible concrete cracking, all units must be handled using the cast-in lifting anchors and associated lifting clutches (lifting clutches can be obtained from the crane contractor or Humes). Installers should use tagged lifting equipment only. It is the installation contractor's responsibility to ensure the lifting clutches are available on site. The lifting points of anchors are clearly shown on the Humes drawings.

Wherever possible, all modular components should be lifted from the delivery truck and set directly onto the prepared substructure. Each module will take approximately 5-10 minutes to unload and set into position.

If for some reason temporary storage of the modules is required on site, they should be placed carefully on level, even ground, free of rocks and uniformly supported across the entire leg surface by using timbers. Modules should not be stacked on top of each other.

Figure 3 – Example of a shipping plan



BILL OF MATERIALS

QTY.	PART NO.	DESCRIPTION	UNIT MASS
2	TYPE I	1500 MM SINGLETRAP TYPE I	7280 Kg
2	TYPE II	1500 MM SINGLETRAP TYPE II	4620 Kg
4	TYPE III	1500 MM SINGLETRAP TYPE III	7935 kg
2	TYPE IV	1500 MM SINGLETRAP TYPE IV	4945 Kg
2	TYPE V	1500 MM SINGLETRAP TYPE V	4945 Kg
0	TYPE VI	1500 MM SINGLETRAP TYPE VI	
0	TYPE VII	1500 MM SINGLETRAP TYPE VII	
10	STORM MASTIC	STORMMASTIC - 4M PER ROLL	
2	STORM WRAP	STORMWRAP - 45M PER ROLL	
1	GATIC GRATE	650*450 CLASS D GRATE & FRAME ASSEMBLY	
1	ACCESS COVER	600 DIA. CLASS D	

SITE: SAMPLE.

DELIVERY INSTRUCTIONS:

1. FIRST TRUCK TO BE DELIVERED AT 10:00 am (TBC).
2. SECOND TRUCK TO BE DELIVERED 1 hour LATER.
3. FINAL TRUCK TO BE DELIVERED 30 min LATER.

NOTES:

1. DIMENSION OF STORMTRAP SYSTEM ALLOW FOR A 20mm GAP BETWEEN EACH UNIT.
2. ALL DIMENSIONS TO BE VERIFIED IN THE FIELD BY OTHERS.
3. SEE SHEET 2 FOR INSTALLATION SPECIFICATIONS.
4. ALL DIMENSIONS IN MILLIMETRES UNO

LAYOUT DETAIL

DESIGN CRITERIA

TWL = 31.685M

ALLOWABLE MIN FSL = 32.05M

ALLOWABLE MAX FSL = 32.05M

SYSTEM INVERT = 30.185M

STORMTRAP VOLUME = 114.40 CU.M. / 0.11 ML

Humes
Water Solutions
36-38 FELSPAR ST
WELSHPOOL
P: +61 8 9351 6975
F: +61 8 9351 6977

ENGINEER INFORMATION: SAMPLE

PROJECT INFORMATION: SAMPLE

CURRENT ISSUE DATE: SAMPLE

APPROVED BY:

ISSUED FOR: SHIPPING

REV.:	DATE:	DESC.	BY:
3	11/12/09	SHIPPING	SD
2	22/10/09	APPROVAL	SD
1	22/10/09	ISSUED FOR PRELIMINARY	SD

SCALE: NTS

SHEET TITLE: LAYOUT DETAIL

SHEET NUMBER: SD-3244-WA-09 03

Module installation

Top:
Step one

Middle:
Step two

Bottom:
Step three

A representative of Humes Water Solutions will be present on site at the commencement of the installation (as required) to provide support to the contractor and observe deliveries and installation.

The StormTrap® system is typically installed as follows:

1. Sweep the concrete slab/footings clean of dirt and debris.

2. Lay a bead of StormMastic™ sealant on the slab approximately 60 mm inside the perimeter line marking.

3. Secure the first module with four Swiftlift® anchors. Take care not to strike the modules together when you are unloading and lowering them. Be aware of pinch hazard at all times and don't walk or work under suspended loads.

4. When lowering the first module into position, pause 50 mm above the concrete slab, then gradually lower it into position once it is aligned with the perimeter markings. Ensure the unit is square and the bottom of the module is on the foundation before you remove the lifters.

Top:
Step four

Middle:
Step five

Bottom:
Step six

5. Align the next module with the edge markings and position it adjacent to, but no more than 20 mm from the first block (check with a gap gauge). Use a pinch or crowbar to assist with the finer adjustment of the modules.

6. Continue to install the modules row-by-row, in the order shown on the shipping plan.

Top:
Step seven

Bottom:
Step eight

7. Once two rows of modules have been laid and checked, apply StormWrap™ tape across the joins.

8. When four rows of modules have been laid, checked and sealed, backfilling can then occur (refer per note F. on page 2 of the approval drawings).

Note: During the installation check the overall dimensions of the system to make sure creep is not occurring. Adjust the laying gap when necessary to recover any discrepancies.

Contact information

National sales 1300 361 601
humeswatersolutions.com.au
info@humeswatersolutions.com.au

Head Office

18 Little Cribb St
Milton 4064 QLD
Ph: (07) 3364 2800
Fax: (07) 3364 2963

Queensland

Brisbane/Gold Coast
Ph: (07) 3866 7100
Fax: (07) 3866 7101

Bundaberg
Ph: (07) 4152 2644
Fax: (07) 4152 5847

Rockhampton
Ph: (07) 4924 7900
Fax: (07) 4924 7901

Sunshine Coast
Ph: (07) 5472 9700
Fax: (07) 5472 9711

Toowoomba
Ph: (07) 4694 1420
Fax: (07) 4634 3874

Townsville
Ph: (07) 4758 6000
Fax: (07) 4758 6001

New South Wales

Canberra
Ph: (02) 6285 5309
Fax: (02) 6285 5334

Grafton
Ph: (02) 6644 7666
Fax: (02) 6644 7313

Kempsey
Ph: (02) 6562 6755
Fax: (02) 6562 4235

Lismore
Ph: (02) 6621 3684
Fax: (02) 6622 1342

Newcastle
Ph: (02) 4032 6800
Fax: (02) 4032 6822

Sydney
Ph: (02) 9832 5555
Fax: (02) 9625 5200

Tamworth
Ph: (02) 6763 7300
Fax: (02) 6763 7301

Victoria

Echuca
Ph: (03) 5480 2371
Fax: (03) 5482 3090

Melbourne
Ph: (03) 9360 3888
Fax: (03) 9360 3887

Tasmania

Invermay
Ph: (03) 6335 6300
Fax: (03) 6335 6330

South Australia

Adelaide
Ph: (08) 8168 4544
Fax: (08) 8168 4549

Western Australia

Gnangara
Ph: (08) 9302 8000
Fax: (08) 9309 1625

Perth
Ph: (08) 9351 6999
Fax: (08) 9351 6977

Northern Territory

Darwin
Ph: (08) 8984 1600
Fax: (08) 8984 1614

Humes

Water Solutions

National sales 1300 361 601

humeswatersolutions.com.au

info@humeswatersolutions.com.au

A Division on Holcim Australia

TechBrief
DECEMBER 2012 | FHWA-HIF-13-006

Pervious Concrete

This TechBrief presents an overview of pervious concrete and its use in pavement applications. General information on the composition of pervious concrete is provided, along with a summary of its benefits, limitations, and typical properties and characteristics. Important considerations in mix proportioning, hydrological design, structural design, construction, and maintenance are also described.

Introduction

Pervious concrete, sometimes referred to as no-fines, gap-graded, permeable, or enhanced porosity concrete, is an innovative approach to controlling, managing, and treating stormwater runoff. When used in pavement applications, pervious concrete can effectively capture and store stormwater runoff, thereby allowing the runoff to percolate into the ground and recharge groundwater supplies.

Pervious concrete contains little or no fine aggregate (sand) and carefully controlled amounts of water and cementitious materials. The paste coats and binds the aggregate particles together to create a system of highly permeable, interconnected voids that promote the rapid drainage of water (Tennis et al. 2004; ACI 2010). Typically, between 15 and 25 percent voids are achieved in the hardened concrete, and flow rates for water through the pervious concrete are generally in the range of 2 to 18 gal/min/ft^2 (81 to 730 L/min/m^2), or 192 to 1,724 inch/hr (488 to 4,379 cm/hr) (ACI 2010). Figure 1 shows a typical cross section of a pervious concrete pavement.

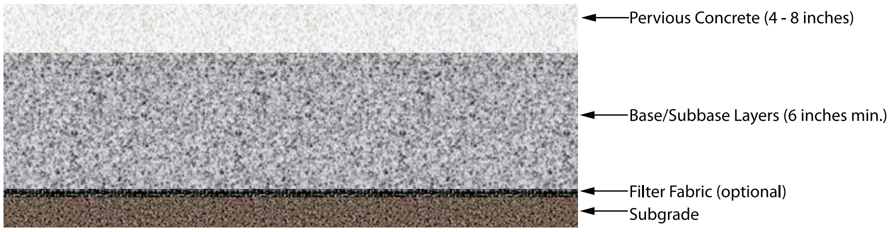


FIGURE 1. Typical pervious concrete pavement cross section (adapted from EPA 2010).

ACPT

THE ADVANCED CONCRETE PAVEMENT TECHNOLOGY (ACPT) Products Program is an integrated, national effort to improve the long-term performance and cost-effectiveness of the Nation's concrete highways. Managed by the Federal Highway Administration through partnerships with State highway agencies, industry, and academia, the goals of the ACPT Products Program are to reduce congestion, improve safety, lower costs, improve performance, and foster innovation.

The ACPT Products Program identifies, refines, and delivers for implementation available technologies from all sources that can enhance the design, construction, repair, and rehabilitation of concrete highway pavements. The ACPT Marketing Plan enables technology transfer, deployment, and delivery activities to ensure that agencies, academia, and industry partners can derive maximum benefit from promising ACPT products in the quest for long-lasting concrete pavements that provide a safe, smooth, and quiet ride.

www.fhwa.dot.gov/pavement/concrete

U.S. Department of Transportation
Federal Highway Administration

Benefits and Limitations

Table 1 summarizes some of the major benefits and limitations associated with pervious concrete. As described above, perhaps the most significant benefit provided by pervious concrete is in its use as a stormwater management tool. Stormwater runoff in developed areas (often the result of or exacerbated by the presence of conventional impervious pavement) has the potential to pollute surface and groundwater supplies, as well as contribute to flooding and erosion (Leming et al. 2007).

Pervious concrete can be used to reduce stormwater runoff, reduce contaminants in waterways, and renew groundwater supplies. With high levels of permeability, pervious concrete can effectively capture the "first flush" of rainfall (that part of the runoff with a higher contaminant concentration) and allow it to percolate into the ground where it is filtered and "treated" through soil chemistry and biology (Tennis et al. 2004; ACI 2010).

Other major benefits provided by pervious concrete include reduction in heat island effects (water percolating through the pavement can exert a cooling effect through evaporation, and convective airflow can also contribute to cooling (Cambridge 2005)), reductions in standing water on pavements (and associated hydroplaning and splash/spray potential), and reduced tire–pavement noise emissions (due to its open structure that helps absorb noise at the tire–pavement interface) (ACI 2010). In addition, pervious concrete can contribute toward credits in the LEED® (Leadership in Energy and Environmental Design) rating system for sustainable building construction (Ashley 2008).

Along with its many benefits, there are some limitations associated with the use of pervious concrete. First and foremost, pervious concrete has typically been used on lower trafficked roadways, although there are a number of installations on higher volume facilities, and research is being conducted on the structural behavior of pervious concrete slabs (see, for example, Suleiman et al. 2011; Vancura et al. 2011). In addition, pervious concrete exhibits material characteristics (primarily lower paste contents and higher void contents) and produces hardened properties (notably density and strength) that are significantly different from conventional concrete; as a result, the current established methods of quality control/quality assurance (e.g., slump, strength, air content) are in many

TABLE 1. Summary of Pervious Concrete Benefits and Limitations (Tennis et al. 2004; ACI 2010)

Benefits/Advantages	Limitations/Disadvantages
• Effective management of stormwater runoff, which may reduce the need for curbs and the number and sizes of storm sewers. • Reduced contamination in waterways. • Recharging of groundwater supplies. • More efficient land use by eliminating need for retention ponds and swales. • Reduced heat island effect (due to evaporative cooling effect of water and convective airflow). • Elimination of surface ponding of water and hydroplaning potential. • Reduced noise emissions caused by tire–pavement interaction. • Earned LEED® credits.	• Limited use in heavy vehicle traffic areas. • Specialized construction practices. • Extended curing time. • Sensitivity to water content and control in fresh concrete. • Lack of standardized test methods. • Special attention and care in design of some soil types such as expansive soils and frost-susceptible ones. • Special attention possibly required with high groundwater.

cases not applicable (ACI 2010). Moreover, a number of special practices, described later, are required for the construction of pervious concrete pavements. And, while there have been concerns about the use of pervious concrete in areas of the country subjected to severe freeze–thaw cycles, available field performance data from a number of projects indicate no signs of freeze–thaw damage (Delatte et al. 2007; ACI 2010).

Applications

Pervious concrete has been used in pavement applications ranging from driveways and parking lots to residential streets, alleys, and other low-volume roads (Tennis et al. 2004). Within these applications, pervious concrete has been used as the surface course, as a drainable base course (often in conjunction with edge drains to provide subsurface drainage), or as a drainable shoulder (to help provide lateral drainage to a pavement and prevent pumping). The focus in recent years has been on its use as a surface course as a means of providing stormwater management.

Typical Properties and Characteristics

As noted previously, many of the properties of pervious concrete are different from those of conventional concrete. These properties are primarily a function of the porosity (air void content) of the pervious concrete, which in turn depends on the cementitious content, the water-to-cementitious materials (w/cm) content, the compaction level, and the aggregate gradation and quality (ACI 2010). Table 2 summarizes some of the typical material properties associated with pervious concrete. These properties and characteristics must be considered during the structural design and pavement construction.

The cost of pervious concrete may be 15 to 25 percent higher than conventional concrete, but cost can vary significantly depending on the region, the type of application, the size of the project, and the inclusion of admixtures.

TABLE 2. Typical Pervious Concrete Properties (Tennis et al. 2004; Obla 2007)

Property	Common Value / Range
Plastic Concrete	
Slump	N/A
Unit weight	70% of conventional concrete
Working time	1 hour
Hardened Concrete	
In-place density	100 to 125 lb/ft^3
Compressive strength	500 to 4,000 lbf/in^2 (typ. 2,500 lbf/in^2)
Flexural strength	150 to 550 lbf/in^2
Permeability	2 to 18 gal/ft^2/min (384 to 3,456 ft/day)

1 in = 25.4 mm; 1 lb/ft^3 = 16 kg/m^3; 1 lbf/in^2 = 6.89 kPa; 1 gal/ft^2/min = 40.8 L/m^2/min

Mixture Proportioning

Like conventional concrete, pervious concrete is a mixture of cementitious materials, water, coarse aggregate, and possibly admixtures, but it contains little or no fines; however, note that a small amount of fine aggregate, typically 5 to 7 percent, is required for freeze–thaw durability (Schaefer et al. 2006; Kevern et al. 2008). Table 3 shows the typical range of materials proportions that have been used in pervious concrete. Commentary on the components of a pervious concrete is provided below (Tennis et al. 2004; Delatte et al. 2007; ACI 2010):

Cementitious materials. As with conventional concrete mixtures, conventional portland cements or blended cements are used as the primary binder in pervious concrete, although supplementary cementitious materials may also be used.

Coarse aggregate. Coarse aggregate is kept to a narrow gradation, with the most common gradings of coarse aggregate used in pervious concrete meeting the requirements of ASTM C33/C33M—aggregate sizes of 7, 8, 67, and 89. Coarse aggregate size 89 (top size 0.375 inch (9.5 mm)) has been used extensively for parking lot and pedestrian applications. Rounded and crushed aggregates, both normal and lightweight, have been used to make pervious concrete.

Water. The control of water is important in the development of pervious concrete mixtures, and the selection of an appropriate w/cm value is important for obtaining desired strength and void structure in the concrete. A high w/cm can result in the cement paste flowing off of aggregate and filling the void structure, whereas a low w/cm can result in mixing and placement difficulties and reduced durability. Commonly, w/cm values between 0.27 and 0.34 are used.

Admixtures. As with conventional concrete, chemical admixtures can be used in pervious concrete to obtain or enhance specific properties of the mixture. In particular, set retarders and hydration stabilizers are commonly used to help control the rapid setting associated with many pervious concrete mixtures. Air-entraining admixtures are required in freeze–thaw environments although no current method exists to quantify the amount of entrained air in the fresh paste. Air entrainment can be determined on hardened samples according to ASTM C457.

TABLE 3. Typical Pervious Concrete Materials Proportions (ACI 2010)

Mix Constituent or Design Parameter	Range
Coarse aggregate	2,000 to 2,500 lb/yd³
Cementitious materials	450 to 700 lb/yd³
Water-to-cementitious ratio	0.27 to 0.34
Aggregate-to-cementitious ratio (by mass)	4 to 4.5:1

1 lb/yd³ = 0.59 kg/m³

Mix proportioning for pervious concrete is based on striking a balance between voids, strength, paste content, and workability (ACI 2010). As such, the development of trial batches is essential to determining effective mix proportions using locally available materials. Detailed information on mix proportioning is available from ACI (2010).

Some limited work has been done investigating the freeze–thaw characteristics of pervious concrete and mix design for cold weather climates (NRMCA 2004; Schaefer et al. 2006). The freeze–thaw resistance of pervious concrete appears to be dependent on the saturation level of the voids; consequently a drainable base layer with a minimum thickness of 6 inches (150 mm) is recommended to help keep the pervious concrete layer from becoming saturated. Furthermore, as previously noted, the freeze–thaw resistance of pervious concrete has been shown to improve when sand is included in the pervious concrete mixture (Schaefer et al. 2006; Kevern et al. 2008).

Design of Pervious Pavements

Two primary considerations enter into the determination of the thickness of pervious concrete pavements: 1) hydrologic design to meet environmental requirements and 2) structural design to withstand the anticipated traffic loading applications (Leming et al. 2007; ACI 2010). These design considerations are briefly described below.

Hydrologic Design

In evaluating the hydrologic design capabilities of a pervious pavement, the approach is to determine whether the characteristics of the pervious concrete pavement system are sufficient to infiltrate, store, and release the expected inflow of water (which

includes direct rainfall and may also include excess runoff from adjacent impervious surfaces). As such, information required in a hydrologic analysis includes the precipitation intensity levels, the thickness and permeability characteristics of the pervious concrete pavement, cross slopes and geometrics, and permeability properties and characteristics of the underlying base, subbase, and subgrade materials.

Many hydrological design methods exist that can be used when designing pervious concrete pavement systems, including the Natural Resources Conservation Service Curve Number Method and the Rational Method (Leming et al. 2007). In essence, the hydrologic design of pervious concrete pavements should consider two possible conditions to ensure that excess surface runoff does not occur (Leming et al. 2007):

1. Low permeability of the pervious concrete material that is inadequate to capture the "first flush" of a rainfall event.
2. Inadequate retention provided in the pervious concrete structure (slab and subbase).

Often, the thickness of a pervious concrete pavement is first determined based on structural requirements and then analyzed to determine its suitability to meet the hydrologic needs of the project site. If the thickness is found to be insufficient, adjustments can be made to the thickness of the pervious pavement or the underlying base course. Details on hydrologic design are beyond the scope of this document but are available in the literature (Leming et al. 2007; Wanielista et al. 2007; Rodden et al. 2011).

Structural Pavement Design

Pervious concrete pavements can be designed using virtually any standard concrete pavement procedure (e.g., American Association of State Highway and Transportation Officials, Portland Cement Association, StreetPave) (Delatte 2007). The American Concrete Pavement Association has recently developed a comprehensive program, PerviousPave, that can be used to develop both structural and hydrological designs for pervious pavements (Rodden et al. 2011). Regardless of the procedure used, there are critical factors to consider in the design of pervious concrete pavements (ACI 2010):

Subgrade and subbase. In the design of pervious pavements, foundation support is typically characterized by a composite modulus of subgrade reaction, which should account for the effects of both the subgrade and the subbase. An open-graded subbase is commonly used beneath pervious concrete pavements not only to provide an avenue for vertical drainage of water to the subgrade, but also to provide storage capabilities. Special subgrade conditions (such as frost susceptibility or expansive soils) may require direct treatment.

Concrete flexural strength. The flexural strength of concrete is an important input in concrete pavement structural design. However, testing to determine the flexural strength of pervious concrete may be subject to high variability; therefore, it is common to measure compressive strengths and to use empirical relationships to estimate flexural strengths for use in design (Tennis et al. 2004).

Traffic loading applications. The anticipated traffic to be carried by a pervious pavement is commonly characterized in terms of equivalent 18,000-lb (80 kN) single-axle load repetitions, which many procedures compute directly based on assumed truck-traffic distributions. Most pervious concrete pavements are used in low-truck-traffic applications.

Currently there are no thickness standards for pervious concrete pavements, but many pervious pavements for parking lots are constructed 6 inches (150 mm) thick, whereas pervious pavements for low-volume streets have been

constructed between 6 and 12 inches (150 and 300 mm) thick (ACI 2010).

Construction Considerations

Because of its unique material characteristics, pervious concrete has a number of special construction requirements. Key aspects of pervious concrete construction include the following (Tennis et al. 2004; ACI 2010):

Placement and consolidation. Most pervious concrete is placed using fixed-form construction. For smaller projects, a hand-held straightedge or vibrating screed may be acceptable for placement, whereas for larger projects an A-frame, low-frequency, vibrating screed may be used. A few projects have used laser screeds and concrete slipform equipment. Consolidation is generally accomplished by rolling the concrete with a steel roller. Overall, the low water content and porous nature of pervious concrete require that delivery and placement be completed as quickly as possible.

Finishing. Pervious concrete pavements are not finished in the same manner as conventional pavements. In essence, the final surface finish is achieved as part of the consolidation process, which leaves an open surface. Normal concrete finishing procedures, such as with bull floats and trowels, should not be performed.

Jointing. Jointing is commonly done on pervious concrete to control random crack development. These joints are commonly formed (using a specially designed compacting roller-jointer) to a depth between one-fourth and one-third of the slab thickness.

Curing and protection. After the concrete has been jointed, it is important that the concrete be effectively cured; this is commonly achieved through the placement of thick (typically 6 mil (0.15mm)) plastic sheeting over all exposed surfaces. The plastic sheeting should be applied no later than 20 minutes following discharge of the concrete, and should remain in place for at least 7 days (longer times may be required under cold weather placement conditions or if supplementary cementitious materials are used in the mix). Liquid membrane curing compounds are not commonly used because they prevent surface moisture loss and do nothing to prevent evaporation from within the pervious concrete (Kevern et al. 2009).

Inspection and testing. The American Concrete Institute has prepared a summary of recommended inspection and testing activities that should be performed during construction of pervious concrete pavements (ACI 2010), as well as a specification for pervious concrete construction (ACI 2008). Acceptance testing for pervious concrete is typically limited to density (ASTM C1688) and thickness (ASTM C42). Test methods specific to pervious concrete are listed below:

- ASTM C1688, *Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete.*
- ASTM C1701, *Standard Test Method for Infiltration Rate of In Place Pervious Concrete.*
- ASTM C1747, *Standard Test Method for Determining Potential Resistance to Degradation of Pervious Concrete by Impact and Abrasion.*
- ASTM C1754, *Standard Test Method for Density and Void Content of Hardened Pervious Concrete.*

In recognition of the special construction requirements of pervious concrete, the National Ready Mixed Concrete Association has developed a program designed to educate, train, and certify contractors in pervious concrete placement (see http://nrmca.org/Education/Certifications/Pervious_Contractor.htm).

Maintenance

Over time, sand, dirt, vegetation, and other debris can collect in pervious concrete's voids and reduce its porosity, which can negatively affect

the functionality of the system. Thus, periodic maintenance may be needed to remove surface debris and restore infiltration capacity. Two common maintenance methods are pressure washing and power vacuuming (ACI 2010).

Performance

The performance of pervious concrete pavements may be assessed in a number of ways, including monitoring changes in the permeability/porosity of the system (which would indicate clogging of the void structure), the presence of distress (both structural and surficial), and resistance to freeze–thaw damage. Unfortunately, there are limited long-term performance data on pervious concrete, but generally performance is considered satisfactory. For example, a study in Florida indicated that pervious concrete pavements that were 10 to 15 years old were operating in a satisfactory manner without significant amounts of clogging (Wanielista et al. 2007). In another study, field inspections of 22 projects located in freeze areas were conducted, with reported good performance and no visual signs of freeze–thaw damage (although all projects were less than 4 years old at the time of inspection) (Delatte et al. 2007).

Where the performance of pervious concrete pavements has not been satisfactory, poor performance is often attributed to contractor inexperience, higher compaction of soil than specified, and improper site design (ACI 2010).

Summary and Future Needs

The use of pervious concrete has increased significantly in the last several years, perhaps largely because it is considered an environmentally friendly, sustainable product. The use of pervious concrete provides a number of benefits, most notably in the effective management of stormwater runoff. Other significant benefits include reducing contaminants in waterways, recharging groundwater supplies, reducing heat island effects, and reducing pavement–tire noise emissions.

Still, there are a number of areas that need additional developmental work to improve or enhance the capabilities of pervious concrete pavements. One area is the continued monitoring of the performance of pervious concrete so that long-term performance trends can be documented; this will also help in evaluating the suitability of pervious concrete for other applications, such as overlays. Tied in with this is the assessment of the suitability of current structural design approaches to provide competent designs, particularly regarding the fatigue behavior of pervious concrete. Finally, a third area is in the testing and evaluation of pervious concrete, as current test methods for conventional concrete are not generally applicable to pervious concrete.

References

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Contact—For more information, contact the following:

Federal Highway Administration (FHWA)
Office of Pavement Technology
Sam Tyson, P.E.—sam.tyson@dot.gov

ACPT Implementation Team
Shiraz Tayabji, Ph.D., P.E., Fugro Consultants, Inc.—
stayabji@aol.com

Research—This TechBrief was developed by Kurt D. Smith, P.E., and James Krstulovich (Applied Pavement Technology, Inc.), as part of FHWA's ACPT product implementation activity. The TechBrief is based on research cited within the document. The ACPT Implementation Team acknowledges Dr. John Kevern of the University of Missouri–Kansas City for his technical review of this document.

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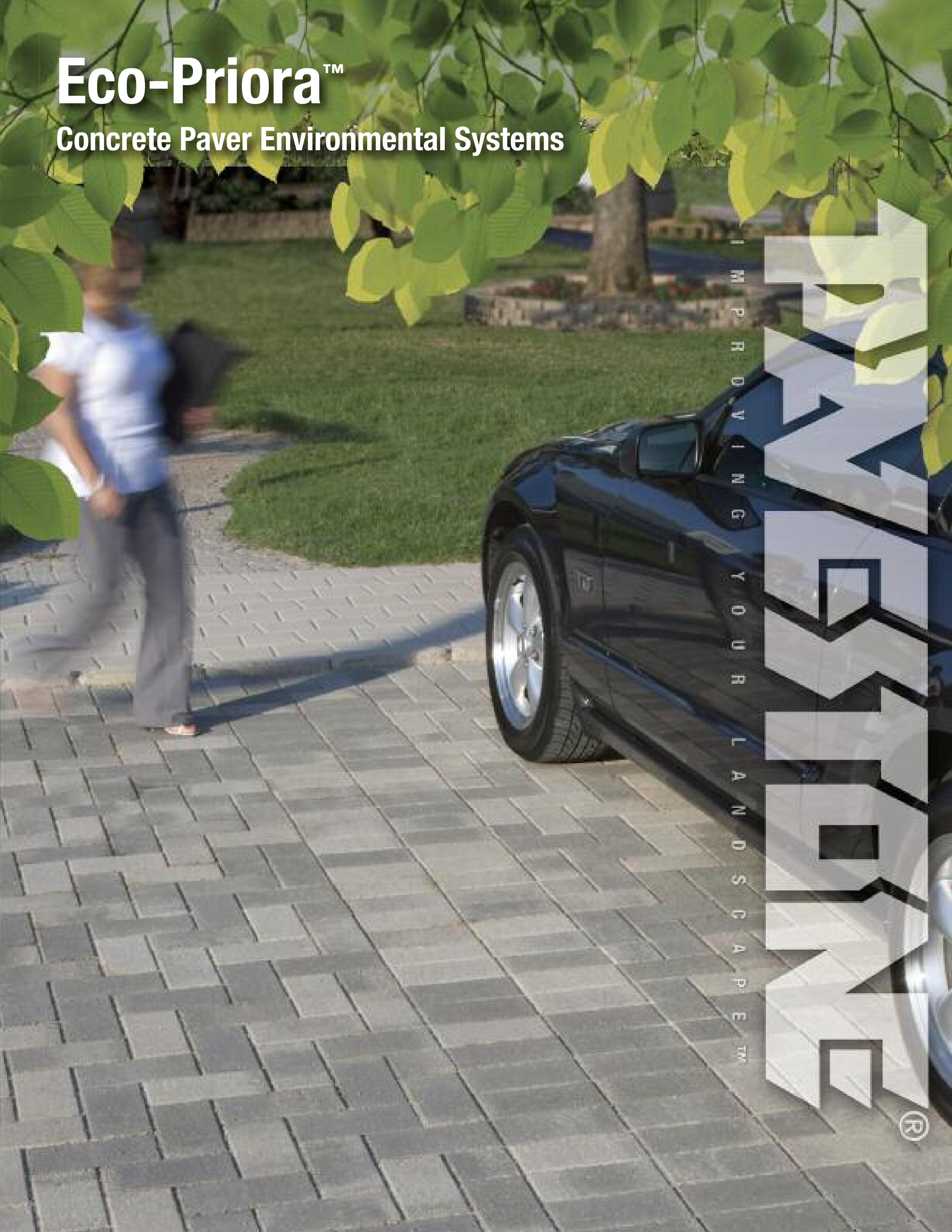
Key Words—concrete pavement construction, design, drainage, LEED® credit, maintenance, pavement design, pavement construction, permeability, pervious concrete, porous concrete, stormwater, sustainability

DECEMBER 2012 **FHWA-HIF-13-006**

Eco-Priora™

Concrete Paver Environmental Systems



UNILOCK®

IMPROVING YOUR LANDSCAPE™

Eco-Priora™

Pavestone Eco-Priora™ is the sustainable solution for permeable pavements. Eco-Priora™ is produced in a 120mm x 240mm rectangular module that is 80mm in thickness with a patented interlocking joint and a micro-chamfered top edge profile. This ingenuity is singular to the Pavestone Eco-Priora™ product and insures optimum pavement performance unequaled in the permeable paver industry. The unique Eco-Priora™ joint profile allows surface water to infiltrate into the pavement and its sub-layers. With initial permeability average flow rates of over 100 inches per hour, the Eco-Priora™ product, even with a clogging factor, will still meet the majority of current storm water management plans (SWMP). The structural interlocking capability is achieved by the paving unit having interlocking joints with a minimum of two vertically aligned horizontal interlocking spacer bars on each of its sides. These spacer bars interlock throughout the depth of the block and nest adjacently with neighboring paving units. This interlocking function resists lateral and vertical displacement when the unit is exposed to load. The dynamics of pavement stress are better distributed providing a structurally superior permeable paving system.

The micro-chamfered top edge profile produces a horizontal edge to edge dimension that is nominally 7mm including installation gapping. This small joint complies dimensionally with current ADA requirements for walking surfaces with spaces no greater than 1/2 inch. This narrow jointed surface diminishes vibration for wheelchairs and shopping carts when compared to all other permeable paving products. Eco-Priora™ can assist in meeting current EPA storm water regulations and LEED certification. The Eco-Priora™ product best achieves the balance of aesthetic segmental paving and the function of permeable pavement.

APPLICATIONS

Parking Lots • Driveways • Patios • Entrance Areas • Sidewalks
Terraces Garden Pathways • Pool Decks • Pedestrian Malls • Roof Gardens • Streets

COMPOSITION AND MANUFACTURE

Eco-Priora™ is available in one size. Height = 80mm. Eco-Priora™ is made from a "no slump" concrete mix made under extreme pressure and high frequency vibrations. Eco-Priora™ has a compressive strength greater than 8000 psi, a water absorption maximum of 5% and will meet or exceed ASTM C-936. Note: Requires modifying the ASTM C 140 - Paver Annex A4 - "The test specimen shall be 60 ± 3 mm thick and, if necessary, cut to a specimen size having a Height/Thickness (width) [H/T] aspect ratio of 0.6 ± 0.1

INSTALLATION

1. Excavate unsuitable, unstable or unconsolidated subgrade material. Compact the area, which has been cleared as per the engineer's of record (EOR) requirements. Backfill and level with open graded aggregates as per the EOR's structural and hydraulic design.
2. Place bedding course of hard and angular material conforming to the grading requirements of ASTM No. 8 or No. 9 to a uniform minimum depth of 1 1/2" -2". (38mm) screeded to the grade and profile required.
3. Install Eco-Priora™ with joints approximately 1/4". (7mm).
4. Where required, cut pave stones with an approved cutting device to fit accurately, neatly and without damaged edges.
5. Tamp pave stones with a plate compactor, uniformly level, true to grade and free of movement.
6. Spread a thin layer of hard angular material conforming to the grading requirements of ASTM No. 8 or No. 9 aggregate over entire paving area.
7. Make one more pass with plate compactor to nest the aggregate and fill joints to the top.
8. Sweep and remove surplus joint material.

Complete installation & specification details are available by contacting your Pavestone Sales Representative.

Note: ✔ Permeable pavements require both civil and hydraulic engineering. All final pavements design shall be approved by a licensed engineer familiar with local site conditions, building codes and storm water management plans.

PRODUCT INFORMATION

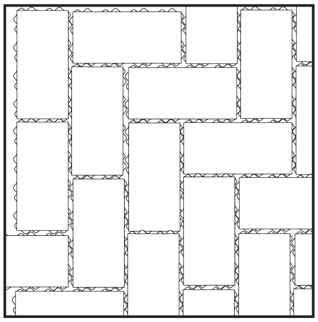
Eco-Priora™ is available in one size. Height = 80mm

ECO-PRIORA™
(120mm x 240mm)

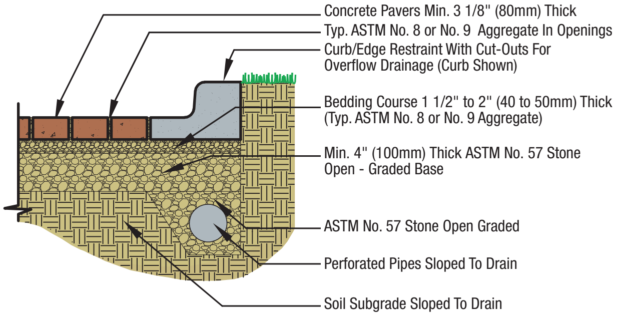
Eco-Priora™

Dimensions:	4 3/4" W x 9 7/16" L x 3 1/8" H
Wt./Stone:	11.5 lbs.
Stones/Pallet:	280
Approx. Wt./Pallet:	3,255 lbs.
Sq. Ft./Pallet:	88
Product Number:	699

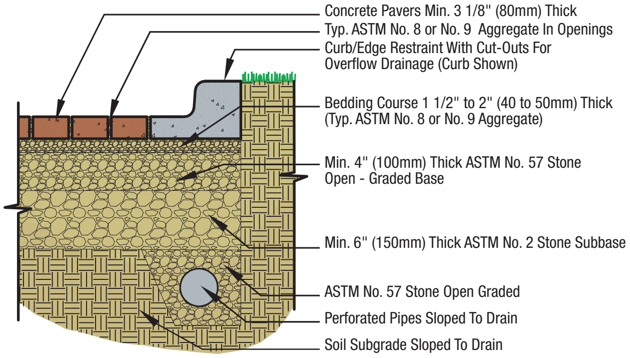
INSTALLATION
PATTERN

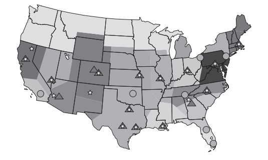


PERMEABLE PAVERS TREATMENT



PERMEABLE PAVERS TREATMENT AND DETENTION





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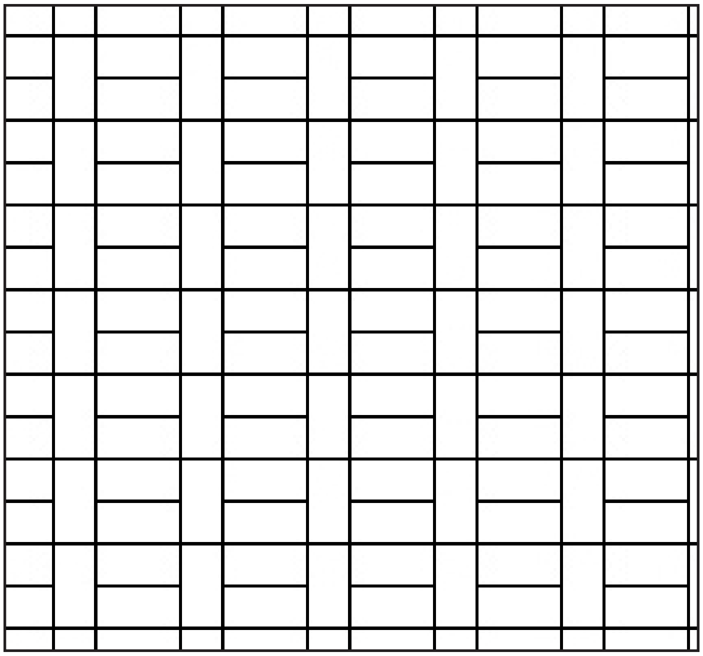
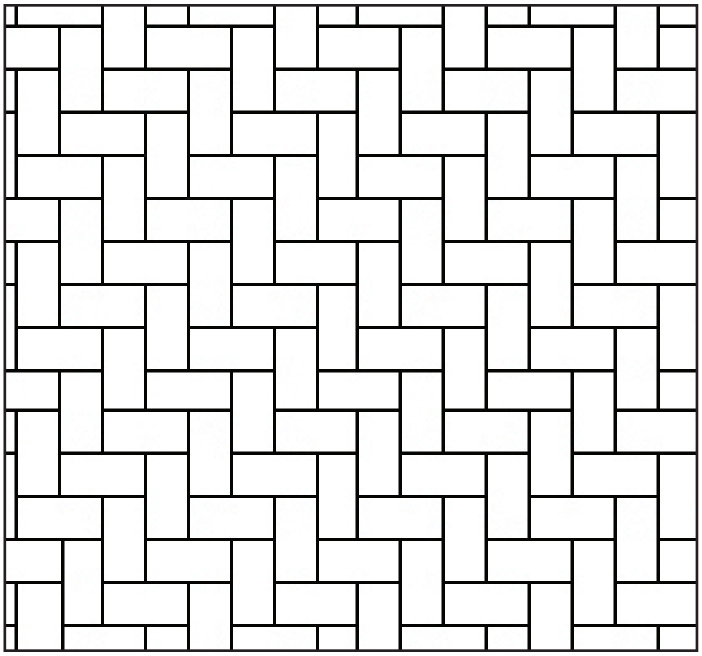
Member of ASLA and NCMA   ICPI Charter Member   World Wide Pavers

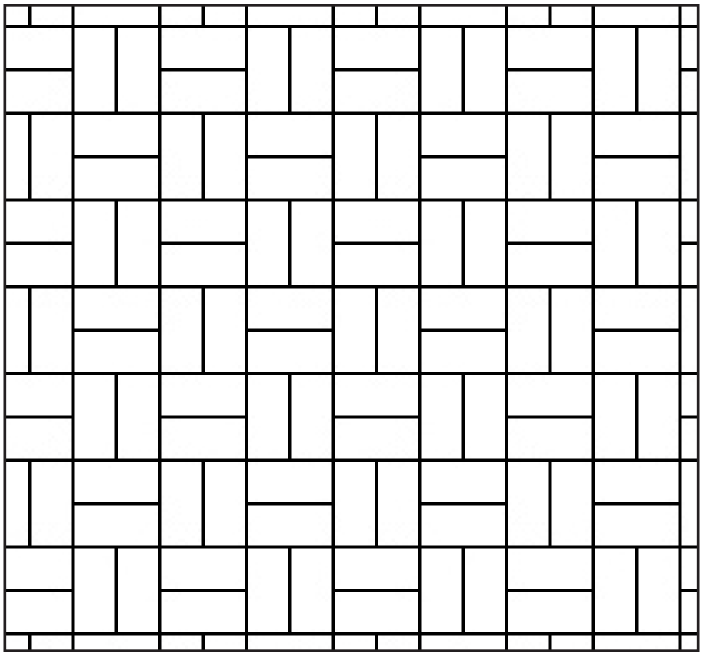
Eco-Priora™ 699 Installation Patterns



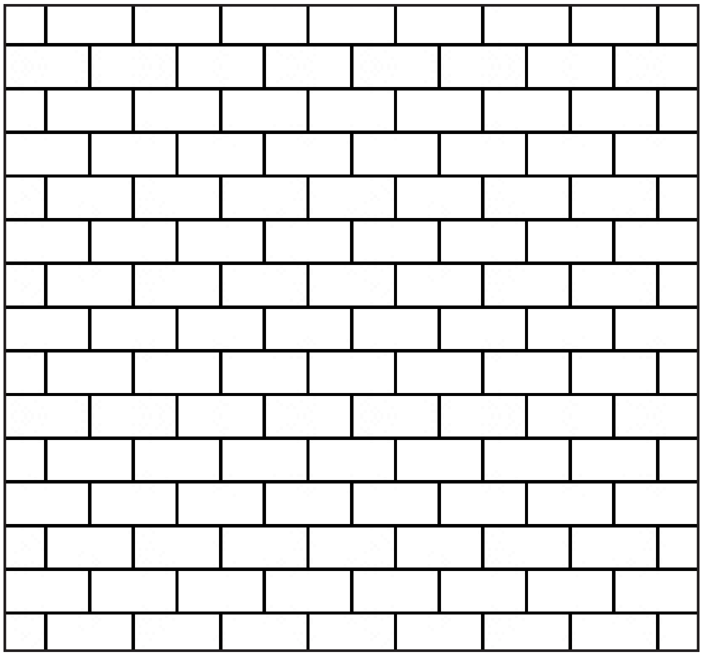
BASKETWEAVE (1)



HERRINGBONE (2)



PARQUET (5)

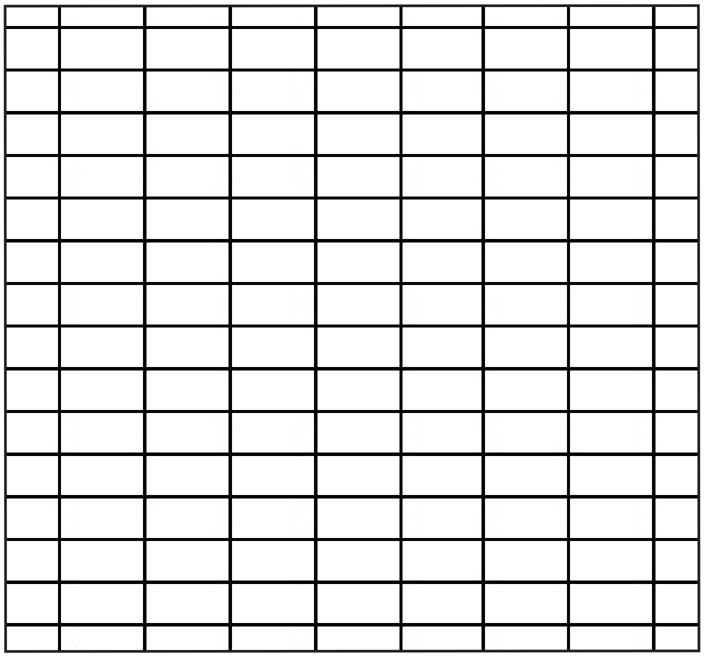


RUNNER BOND (7)

PAVESTONE®

CREATING BEAUTIFUL LANDSCAPES℠

Eco-Priora™ 699 Installation Patterns



STACK (8)

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Belgard Environmental Product

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AquaLine™ L-stone Multi-Cobble

Environmental Collection

Beauty, functionality and quality are hallmarks of the Belgard® Commercial AquaLine™ paver series, while the innovative design features of L-shape make it the perfect pavement choice for plazas, sidewalks, parking lots, alleys and small roadways. It is available in a variety of nationally offered colors, finishes and surface textures, including Texturgard™ - an ultra-durable wearing course that virtually eliminates the appearance of aging.

ADA COMPLIANT ♿ *HEAVY VEHICULAR—100MM* *VEHICULAR—80MM* *MECHANICAL INSTALLATION*

Designed to provide an aesthetically pleasing large format permeable surface that is pedestrian friendly and functional for vehicular traffic. AquaLine combines structural joints and infiltrating voids to optimize system performance. Easier to install due to the additional interlock provided by the L-shape. It is the result of years of research on existing permeable paver products.

Benefits of AquaLine™ L-stone Multi-Cobble

STRENGTH

Manufactured to exceed the minimum standards specified in ASTM C936. Test results from an independent third party are available upon request.

ECOLOGICAL SOLUTIONS

Engineered to infiltrate up to 140 inches per hour which greatly exceeds even the heaviest storms. Where water quality improvements are required, select aggregates can be used in the voids to optimize contaminant removal.

ECONOMICAL

Permeable Pavement Systems serve as both the driving surface and stormwater management system, eliminating the need for traditional infrastructure, allowing more property to be used for revenue generation. Pavers have also been proven to last in excess of 50 years, greatly benefitting life cycle costs.

LOW MAINTENANCE

Maintenance is similar to what is commonly required for other pavement surfaces. If voids become plugged, aggregate and debris can be vacuum extracted and new aggregate material inserted, restoring the original infiltration rate.

AFFORDABILITY

Packaged for mechanical installation, resulting in a cost effective installed price.

COMFORT

ADA compliant walking surface that is high-heel and pedestrian friendly. Causes low-vibration for strollers, bikes, shopping carts and wheelchairs.

LEED POINTS

Can contribute to credits for stormwater quality and quantity, recycled materials, heat island effect, and innovation in design, among others.

AquaLine™ L-stone Multi-Cobble

Size: 12" x 12" x 3 1/8" (or 12" x 12" x 4")

Colors: 9 national colors, local custom colors available upon request

Finishes: Smooth, Shot Blast, Ground Face

Processes: Colorgard, Texturgard

Chamfer: 2mm

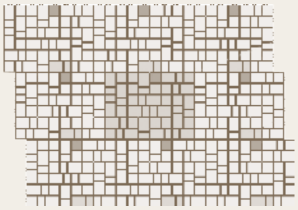
Spacers: Dual positive-interlocking integrated bars

Joint/Void: Maximum 8 mm non-structural voids

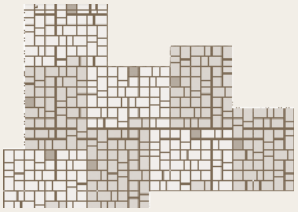
Appearance: Random 3 size cobble

BELGARD AQUALINE™ L-SHAPE	
Dimensions	12" x 12" x 80mm
sold by	sf
sf/plt	96
lbs/plt	3380
layers/plt	8
lf/plt	96*
units/plt	128
sf/layer	12
sf/unit	0.75
lf/unit	0.75
lbs/unit	26.4

*Linear feet measured when used as 12" soldier course installed in pairs (see front photo).



Stitched Pattern



Non-Stitched Pattern

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Belgard Environmental Product

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Eco Dublin™
Environmental Collection

Beauty, functionality and quality are hallmarks of the Belgard® Commercial brand, and our Environmental Collection of permeable pavers is no exception. Belgard permeable pavers combine the best of Belgard with innovative stormwater management for a superior product line that provides sustainable solutions and aesthetically appealing designs.

ADA COMPLIANT ♿ *LT. VEHICULAR—80MM* *MECHANICAL INSTALLATION*

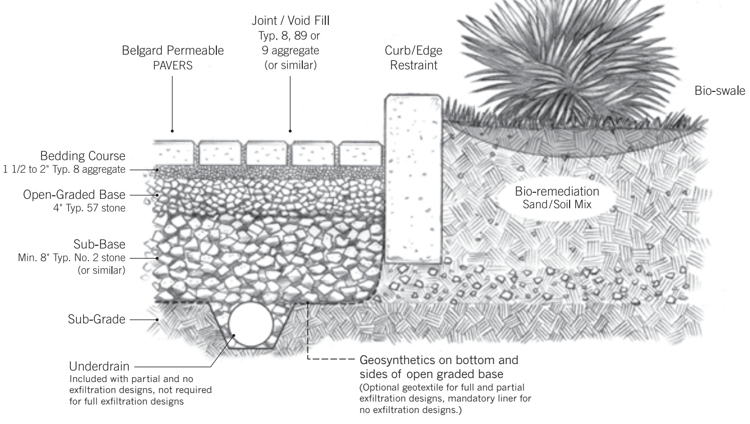
Eco Dublin™

Smart-looking style meets smart science. The classic look of cut stone and contemporary materials technology combine in Eco Dublin™, the latest addition to Belgard's Environmental Series of permeable pavers.

Benefits of Belgard® Permeable Paving Stone Systems

- On the US Environmental Protection Agency's (EPA) menu for structural Low Impact Development (LID) BMPs
- Can contribute toward several LEED NC-2009 points
- Reduces stormwater runoff by up to 100%
- Can be used to achieve total maximum daily load (TMDL) limits for a range of pollutants
- Certified SRI colors reduce heat island effect
- Can reduce or eliminate the need for traditional drainage and detention requirements, saving space and money
- Can be designed to accommodate all native soil types
- 50-year design life based on proven field performance

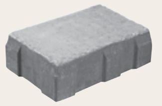
SAMPLE PICP SYSTEM CROSS SECTION



The availability of specific aggregate will often vary from region to region. In cases where it becomes necessary to substitute a similar size, your project engineer should always be consulted.

3 7/16″ x 6 7/8″ x 3 1/8″
(87.78mm x 174.57mm x 80mm)

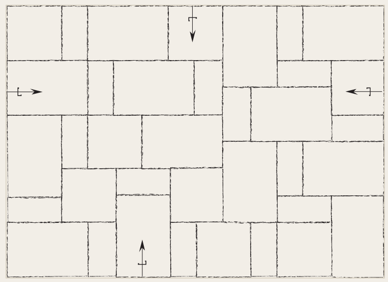
6 7/8″ x 6 7/8″ x 3 1/8″
(174.57mm x 174.57mm x 80mm)



Large Rectangle
6 7/8″ x 10 1/4″ x 3 1/8″
(174.57mm x 261.35mm x 80mm)

Shapes

(All three shapes come in each bundle.)



Mechanical Installation Laying Pattern

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Belgard Environmental Product

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Aqua Roc™
Environmental Collection

Beauty, functionality and quality are hallmarks of the Belgard® Commercial brand, and our Environmental Collection of permeable pavers is no exception. Belgard permeable pavers combine the best of Belgard with innovative stormwater management for a superior product line that provides sustainable solutions and aesthetically appealing designs.

ADA COMPLIANT ♿ *VEHICULAR—80MM* *LT. VEHICULAR—80MM* *MECHANICAL INSTALLATION*

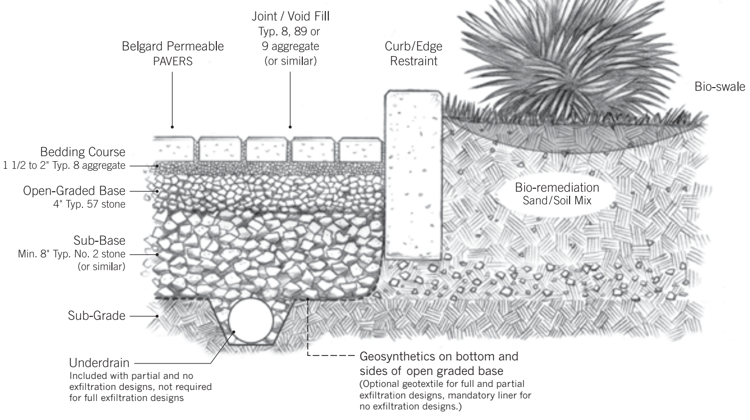
Aqua Roc™

Aqua Roc is a versatile paver featuring not only the environmentally-friendly benefits of a permeable paver, but also high visual appeal, low maintenance, and proven durability. Aqua Roc's versatile pattern range allows for flexible design options, making it an excellent choice for vehicular use.

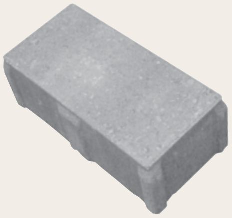
Benefits of Belgard® Permeable Paving Stone Systems

- On the US Environmental Protection Agency's (EPA) menu for structural Low Impact Development (LID) BMPs
- Can contribute toward several LEED NC-2009 points
- Reduces stormwater runoff by up to 100%
- Can be used to achieve total maximum daily load (TMDL) limits for a range of pollutants
- Certified SRI colors reduce heat island effect
- Can reduce or eliminate the need for traditional drainage and detention requirements, saving space and money
- Can be designed to accommodate all native soil types
- 50-year design life based on proven field performance

SAMPLE PICP SYSTEM CROSS SECTION

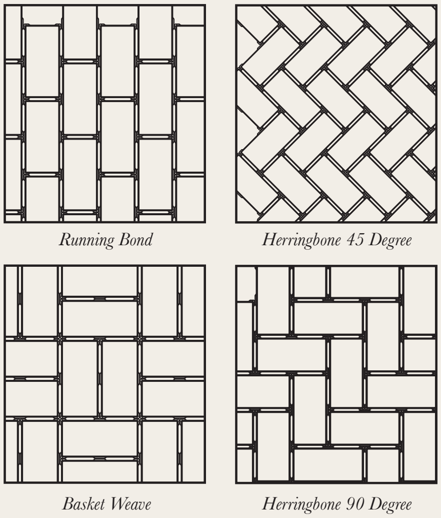


The availability of specific aggregate will often vary from region to region. In cases where it becomes necessary to substitute a similar size, your project engineer should always be consulted.



Shape

4 1/2" x 9" x 3 1/8"
(114.3mm x 228.6mm x 80mm)



Laying Patterns

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Interlocking Concrete Pavement Institute Certified Installer	City	State
California Outdoor Living	Anaheim	CA
Marina Landscape, Inc.	Anaheim	CA
VERSAI Design and Development, Pavers Division	Beverly Hills	CA
Pacific Coast Pavers	Brea	CA
Peterson Brothers Construction	Brea	CA
AJ's Landscaping	Brentwood	CA
Paver Decor Masonry, Inc.	Calimesa	CA
System Pavers - San Diego	Carlsbad	CA
OLVERA MASONRY INC.	Carpinteria	CA
Landmark Site Contractors	Corona	CA
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Castlelite Block, LLC	Dixon	CA
Paver Plus, Inc.	Downey	CA
Paving Stone of San Diego, Inc.	El Cajon	CA
Coyote Construction - Pavers	Escondido	CA
Claddagh Paving	Fallbrook	CA
Aloha Pavers, Inc.	Huntington Beach	CA
I.M. Masonry Construction, Inc.	Lancaster	CA
Precision Contractors, Inc.	Lancaster	CA
Earth Shelter Developers	Lodi	CA
Go Pavers	Los Angeles	CA
Stowe Contracting, Inc.	Marina	CA
Stowe General Construction	Modesto	CA
Sierra Madre Landscape	Monrovia	CA
Systems Paving - Dallas	Newport Beach	CA
System Pavers - Novato	Novato	CA
Haney Landscape Inc.	Ojai	CA
System Pavers - Inland Impire	Ontario	CA
Alan Smith Pools	Orange	CA
Farley Interlocking Paving	Palm Desert	CA
Sunshine Landscape	Palm Desert	CA
DMA Construction	Paso Robles	CA
Edsons Pavers, Inc.	Perris	CA
Viking Pavers Inc.	Point Richmond	CA
System Pavers - Sacramento	Rancho Cordova	CA
McEntire Landscaping, Inc.	Redding	CA
INSTALL IT DIRECT	San Diego	CA
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Black Diamond Paver Stone and Landscape, Inc	San Jose	CA
European Paving Designs, Inc.	San Jose	CA
JCMS Landscaping	Santee	CA
Prime Gardens, Inc.	Sherman Oaks	CA
Alford's English Gardens INC	Signal Hill	CA
JFK Pavestone, Inc.	Simi Valley	CA

Tahoe Outdoor Living DBA Tahoe Paving Stones	South Lake Tahoe	CA
Pacific Pavingstone, Inc.	Sun Valley	CA
Weiland & Associates, Inc.	Swall Meadows	CA
System Pavers - Northern California	Union City	CA
System Pavers - Northern California	Union City	CA
Scarlett's Landscape, Inc.	Ventura	CA
System Pavers - Ventura	Ventura	CA
Southwest Specialties of California, Inc.	Walnut	CA
Southwest Specialties of California, Inc.	Walnut	CA

PERVIOUS

First Name	Intial	Last Name	Suffix	Company	City	State	ZIP	Cert Type	Expiration Date
Anthonie		Smith		T.B. Penick	San Diego	CA	92128	Pervious Concrete Craftsman	6/3/2016
Bill		Beeson		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Craftsman	2/5/2019
Danny		Stewart		T.B. Penick	San Diego	CA	92128	Pervious Concrete Craftsman	6/3/2016
David		Liguori		Bay Area Pervious Concrete	San Carlos	CA	94070	Pervious Concrete Craftsman	11/14/2019
Dennis	M.	Collins		Enviro-Crete, Inc.	Orangevale	CA	95662	Pervious Concrete Craftsman	10/1/2017
Guy		Collignon		Enviro-Crete, Inc.	Orangevale	CA	95662	Pervious Concrete Craftsman	6/13/2016
Steven	J.	Carrera		S 7 J Carrera Construction, Inc.	Watsonville	CA	95076	Pervious Concrete Craftsman	2/24/2016
Wayne		Jenness		T.B. Penick	San Diego	CA	92120	Pervious Concrete Craftsman	6/3/2016

First Name	Intial	Last Name	Suffix	Company	City	State	ZIP	Cert Type	Expiration Date
Alejandro		Ruiz Villalobos		Robert A. Bothman	Salinas	CA		Pervious Concrete Installer	10/26/2017
Alexander		Renteria		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
Arturo		Rosas		Beeson Masonry	Lake Hughes	CA	93532	Pervious Concrete Installer	8/6/2019
Daniel		Rodriguez Avalos		Robert A. Bothman, Inc.	Salinas	CA		Pervious Concrete Installer	10/26/2017
Edward		Ramirez		GPF Concrete	Perris	CA	92574	Pervious Concrete Installer	1/16/2017
Hector		Vela Villagrana		Robert A. Bothman Inc.	Antioch	CA	94509	Pervious Concrete Installer	10/26/2017
Humberto		Tovalin		T.B. Penick	San Diego	CA	92128	Pervious Concrete Installer	6/3/2016
Isaias		Ruiz		Melo Concrete Construction	Gilroy	CA		Pervious Concrete Installer	10/26/2017
Jaime		Sanitillan		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
Jaime		Villegas		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
James		Lamping		T.B. Penick	San Diego	CA	92128	Pervious Concrete Installer	6/3/2016
Joey		Lankford		Beeson Masonry	Lake Hughes	CA	93532	Pervious Concrete Installer	8/6/2019
Jose		Ceron		Bay Area Pervious Concrete	San Carlos	CA	94070	Pervious Concrete Installer	11/8/2015
Juan		Munoz		Galvan's Place and Finish	Perris	CA	92574	Pervious Concrete Installer	1/16/2017
Luis		Castellanos		Robet A. Bothman Inc.	San Jose	CA		Pervious Concrete Installer	10/26/2017
Mario		Ortiz		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
Michael		Orosz		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
Mike		Beczak		T.B. Penick	San Diego	CA	92128	Pervious Concrete	6/3/2016

First Name	Intial	Last Name	Suffix	Company	City	State	ZIP	Cert Type	Expiration Date
								Installer	
Piedad		Menchara Solorio		Robert A. Bothman Inc.	Salinas	CA	93905	Pervious Concrete Installer	10/26/2017
Ricardo	R.	Galvan		Galvan's Place and Finish	Perris	CA	92571	Pervious Concrete Installer	1/16/2017
Robert		Estrada		Bay Area Pervious Concrete	San Carlos	CA	95040	Pervious Concrete Installer	5/4/2017
Ron		Parietti			Pilot Hill	CA	95664	Pervious Concrete Installer	6/30/2015
Salvador		Rosas		Robert A. Bothman Inc.	San Jose	CA	95116	Pervious Concrete Installer	10/26/2017
Sergio		Grageda		Bay Area Pervious Concrete	San Carlos	CA	94070	Pervious Concrete Installer	11/8/2015
Victor		Santana		Robert A. Bothman Inc.	Salinas	CA	93906	Pervious Concrete Installer	10/26/2017

Appendix F – Soil Report

815310002
CITY OF LOS ANGELES
BUREAU OF STANDARDS

140— 3305

LOG OF TEST HOLE NO. 2 **DRILLED:** 8-26-87

DRILL RIG: CME-75 using 8" diameter auger

LOCATION: 195' S/o SCF Burton St. & 21' W/o ℄ Sepulveda Place

ELEVATION: **BY:** McElroy

VERTICAL SCALE: 1"=5'

	HYD. PRESS.	BLOW COUNT	DRY DENS.	FIELD MOIST.	SAMPLES	FIELD DESCRIPTION	UNIFIED SOIL CLASSIF.
2" 0						2" of sand and gravel base materials overlying brown fine to medium-grained poorly graded sand with a trace of clay fines. Slightly damp and fairly loose. Color changed to light tan at 8 ft. and below.	SP
5		8	107	6.5	■		
10						Brown clayey sand. Slightly damp and firm.	SC
10½		6	108	9.0	■		
13						Brownish tan fine to medium-grained poorly graded sand with some clay fines. Some small subrounded grounded gravel at 13 ft.	SP
15						NO WATER L.E.L. Readings at 5' and 10' were zero	

MPLES
REPRESENT.
SHELBY
SPLIT SPOON
PISTON

NO. 403 E

140- 3701

LOG OF TEST HOLE NO. 1 **DRILLED:** 3-8-91

CITY OF LOS ANGELES
BUREAU OF STANDARDS

904700001 ✓

DRILL RIG: CME-75 USING 6" DIAMETER AUGER

LOCATION: 3' E/o ECF Oxford Ave. & 35' N/o ¢ Melrose Ave. (In parkway by sidewalk)

ELEVATION: 302.0 Feet

BY: Redlin

VERTICAL SCALE: 1" = 5'

Depth In Feet	Hyd. Press.	Blow Count.	Dry Dens.	Field Moist.	Samples	FIELD DESCRIPTION	UNIFIED SOIL CLASSIF.
0							
1	350		89	28.0	S	Dark brown, silt. Moist and firm. Color changed to light tan at 2½ ft. with an increase in silt content.	ML
3	650		104	26.0	S		
6						NO WATER	

LOG OF TEST HOLE NO. 2 **DRILLED:** 3-8-91

904700002

DRILL RIG: CME-75 USING 6" DIAMETER AUGER

LOCATION: 3' N/o SCF Melrose Ave. & 30' E/o ¢ Oxford Ave.

ELEVATION: 300.0 Feet

BY: Redlin

VERTICAL SCALE: 1" = 5'

Depth In Feet	Hyd. Press.	Blow Count.	Dry Dens.	Field Moist.	Samples	FIELD DESCRIPTION	UNIFIED SOIL CLASSIF.
9½" 0							
1	400		101	20.5	S	9½" AC pavement in poor condition with some settlement overlying light greenish brown silty sand/clayey sand. Moist and firm.	SM-SC
3	400		85	22.0	S		
6						NO WATER	

Samples

☒ Represent
S Shelby
■ Split Spoon
P Piston
☐

S1530001
CITY OF LOS ANGELES
BUREAU OF STANDARDS

140— 3305

LOG OF TEST HOLE NO. 1 DRILLED: 8-26-87

DRILL RIG: CME-75 using 8" diameter auger

LOCATION: 7' S/o ℄ Alley S/o Burton St. & 58' E/o ECF Sepulveda Place

ELEVATION: BY: McElroy

VERTICAL SCALE: 1" = 5'

DEPTH IN FEET	HYD. PRESS.	BLOW COUNT	DRY DENS.	FIELD MOIST.	SAMPLES	FIELD DESCRIPTION	UNIFIED SOIL CLASSIF.
4½" 0						4½" AC pavement (fair condition) overlying brown lean clay with some very fine-grained sand. Damp and firm	CL
5		5	102	9.0	■		
10							
12		7	109	8.5	■		
13						Light tan to brown clayey sand. Dry and firm. Clay decreasing with depth and progressing toward poorly graded sand at 17 ft.	SC to SP
15							
17						NO WATER L.E.L. Readings at 5' and 12' were zero	

AMPLES
R REPRESENT.
S SHELBY
■ SPLIT SPOON
P PISTON

NO. 403

Appendix 4.D.3

Upgrades to Pump Plants and Associated Stormwater Treatment Opportunities in the City of Los Angeles Upper Los Angeles River Watershed

Implementation Strategy for Pump Plant 647

Upgrades to Pump Plants and Associated Stormwater Treatment Opportunities in the City of Los Angeles Santa Monica Bay Watershed

Implementation Strategy for Pump Plant 647

Jointly prepared by:

Tetra Tech
3475 East Foothill Boulevard
Pasadena, CA 91107

Black & Veatch Corporation
800 Wilshire Blvd, #600
Los Angeles, CA 90017

City of Los Angeles
LA Sanitation
Watershed Protection Division
1149 S Broadway, 10th Floor
Los Angeles, CA 90015-2213

June 11, 2015

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1. Introduction

Multiple pollutants currently impair the beneficial uses of the Los Angeles beaches along the Pacific Ocean. To address these impairments, the City of Los Angeles (City) must comply with the water quality requirements presented in the Municipal Separate Storm Sewer System (MS4) Permit) and State-mandated total maximum daily loads (TMDLs). Recently prepared Drafts for the Enhanced Watershed Management Programs (EWMPs) prescribe collaborative and adaptive strategies for the City to attain compliance with these requirements; however, the scale of implementation is extraordinary.

The draft EWMPs currently forecast implementation of over 4,600 acre-feet of green infrastructure and regional control measures by the City (totaling $6 billion in capital cost) in the Upper Los Angeles River (ULAR) and Ballona Creek EWMP areas. At this scale, cost-effective implementation will be challenging in many locations, particularly when the suitable opportunities for stormwater treatment are *not* located near runoff and pollutant sources. One solution is to divert runoff to the highest efficiency opportunities using existing infrastructure.

EWMP Requirement:
Implement >4,600 acre-feet of BMPs in the Ballona Creek basin before 2021

There are multiple aging pump plants located strategically throughout the City of Los Angeles – each intended to alleviate or prevent flooding in low lying areas where gravity flow is not feasible (Figure 1). If upgrades to these pumps can be leveraged to provide water quality benefits (Figure 2), the advantages are two-fold:

1. ***Creating* High-Efficiency Treatment Opportunities:** The efficiency (pollutant reduction per dollar) is maximized by routing runoff to areas with high treatment potential and maximizing the treated drainage area using existing infrastructure.
2. **Improving Resilience:** Control measures sited upstream from pumps can reduce pump cycle frequency, energy use, and maintenance burden by intercepting and retaining runoff volume from small storm events.

This conceptual design describes recommended upgrades to the aging infrastructure at Pump Plant 647 along with integrating multi-benefit stormwater treatment strategies into the plant upgrades. A cost-effective solution that addresses Permit water quality requirements in tandem with flood control functions will be recommended. These solutions would also provide multiple other benefits for residents and businesses in the area, and promote a greener, healthier, and more sustainable urban landscape. The concepts will justify incorporating water quality components into future infrastructure upgrades, and will have wider implications when considering leveraging existing infrastructure to support integrated water planning (OneWater) in the Los Angeles region.

TYPICAL EXISTING CONDITIONS

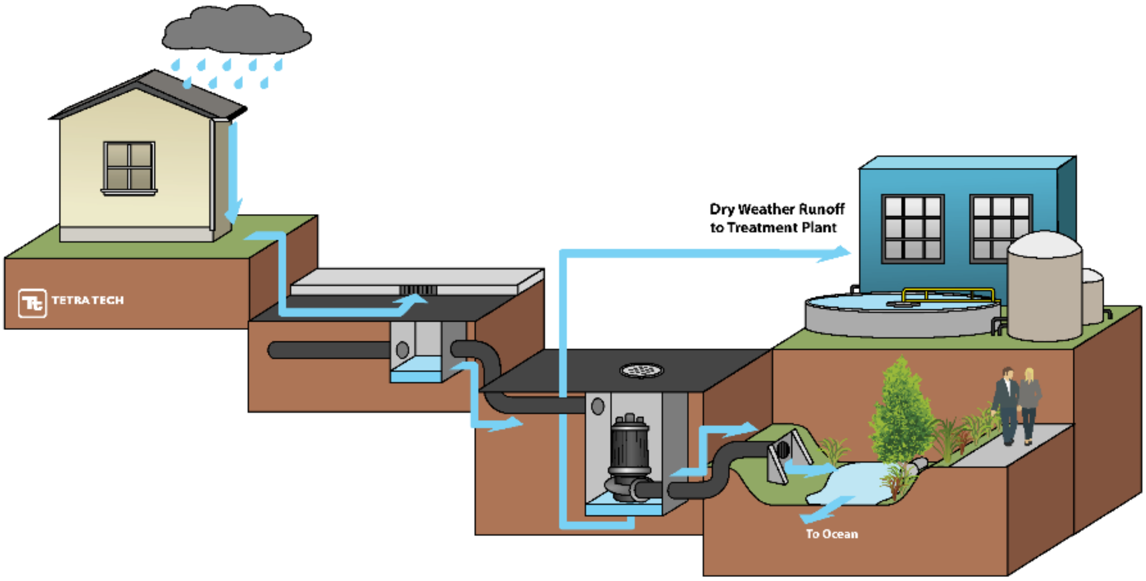

Figure 1. Conceptual diagram illustrating a typical infrastructure design. Pumps in low-lying areas use energy to convey runoff directly to the receiving water without treatment. In some instances, dry weather flows are diverted to the sanitary sewer for treatment.

POTENTIAL SYNERGY: LEVERAGING INFRASTRUCTURE UPGRADES

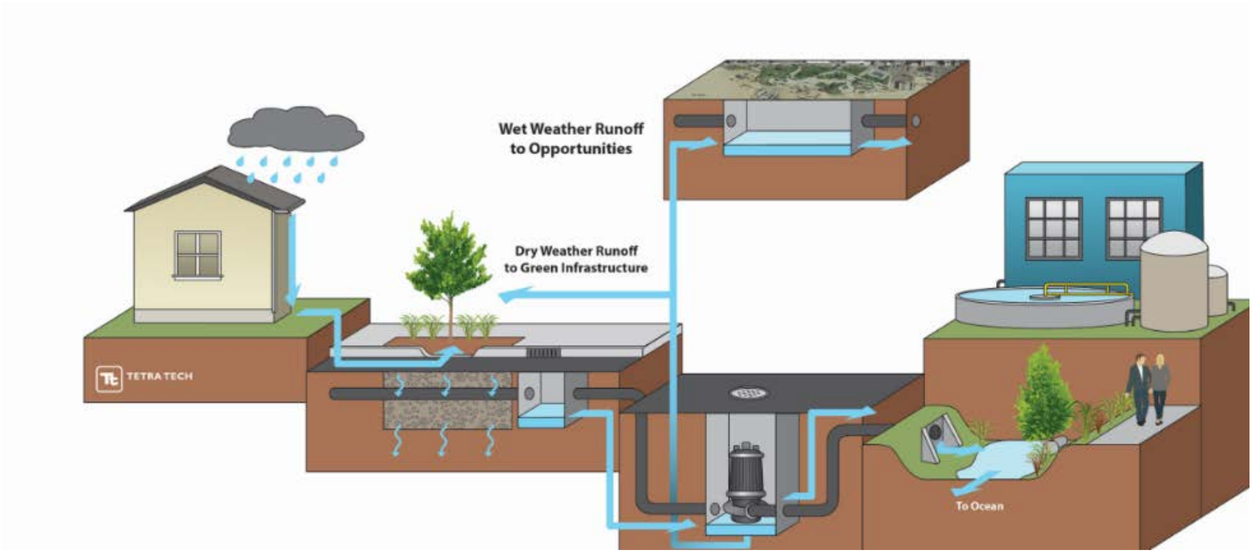

Figure 2. Conceptual diagram illustrating the potential benefits of integrating water quality design into future upgrades. Integrating water quality and flood control can lead to cost-effective treatment by taking advantage of existing facilities to move runoff to BMP opportunities. Upstream control measures can also reduce the burden on pumps by intercepting runoff near the source.

2. Background

This conceptual design focuses on the rehabilitation and green infrastructure modification of Pump Plant 647. Key background information, such as regulatory context and a description of the project site is provided in the following paragraphs.

2.1. Stormwater Regulations and Work to Date

Santa Monica Bay is on the *Clean Water Act 303(d) List of Water Quality Limited Waterbodies* for bacteria, DDT (tissue and sediment), PCBs (tissue and sediment), debris/plastic pellets, sediment toxicity, and lead. To address these impairments, the State has developed TMDLs for bacteria, PCB/DDT, and trash, which contain compliance schedules for the City to reduce impacts from stormwater discharges. The Santa Monica Bay Beaches Bacteria TMDL has a wet-weather compliance date of 2021. Moreover, compliance of these TMDLs would also address the pollutant reduction requirements of the 2012 MS4 (MS4) Permit (Order No. R4-2012-0175; NPDES Permit No. CAS004001). The stormwater project described herein would be a key component of the bacteria Load Reduction Strategies for TMDL compliance of the Santa Monica Bay Beaches Bacteria TMDL, and would address many other stormwater pollutants from the targeted subwatershed during wet weather events.

2.2. Project Location and Site Description

The targeted drainage area, mainly located in subwatershed SWS 1173, is bordered by Pacific Avenue to the west, Venice Boulevard to the east, Electric Avenue to the north, and Mildred Avenue to the south, shown in Figure 3. SWS 1173 is serviced by approximately 79 catch basins that drain to a network of both city and county storm drains that discharge to the Pacific Ocean (Figure 3 and Table 1). At the southern end of Main Street, Pump Plant 647 receives stormwater runoff from an approximately 128-acre subwatershed.

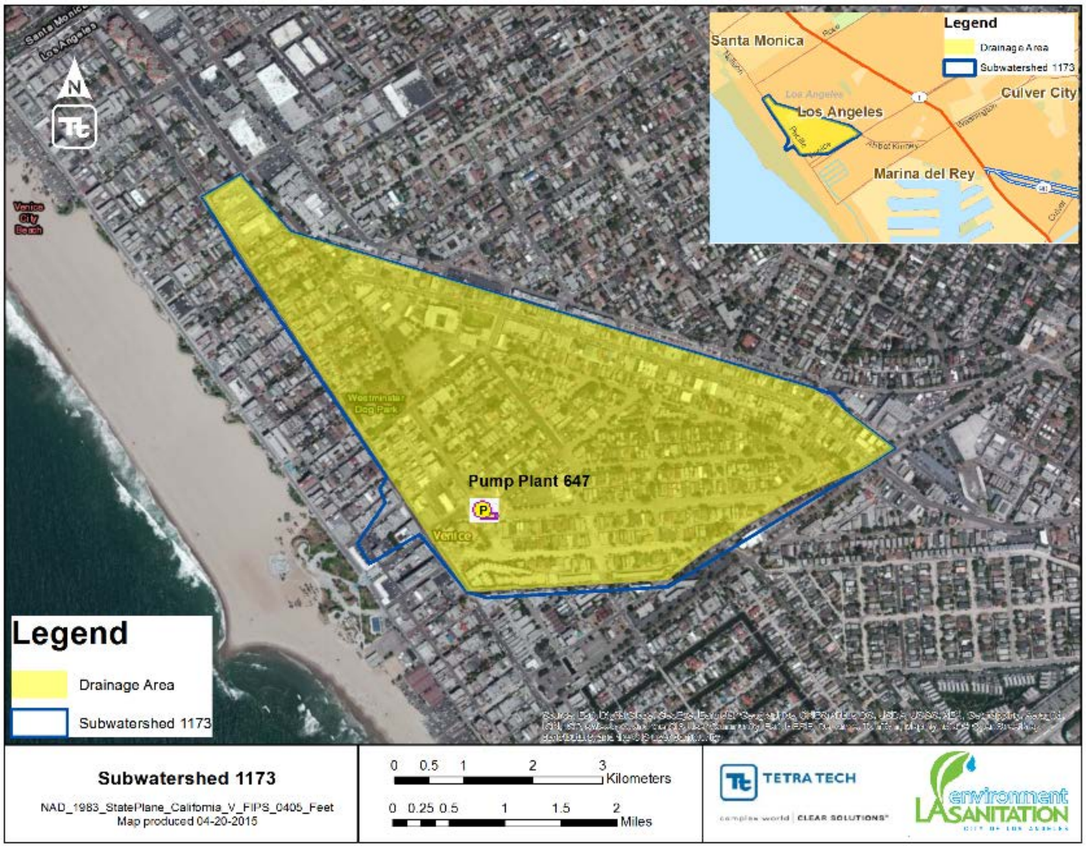

Figure 3. Subwatershed 1173.

Table 1. Site summary

Site attribute	Value
Watershed	Santa Monica Bay
Subwatershed	SWS 1173
Total Pump Plant Drainage Area	127.7 acres

3. Proposed Pump Plant Upgrades

Pump Plant 647 is intended to provide flood protection to an area roughly bounded by Electric Avenue, Venice Boulevard, Mildred Avenue, and Pacific Avenue in the Venice area of the City. It does so by lifting storm water flows from underground storm drain pipes in Grand Avenue, Windward Avenue, and Main Street up to a surge box/outlet arch-culvert storm drain that flows to the west. This outlet arch culvert eventually ties into a 66-inch diameter Los Angeles County storm drain and Santa Monica Bay. The current configuration of the pump plant piping is shown in Figure 4.

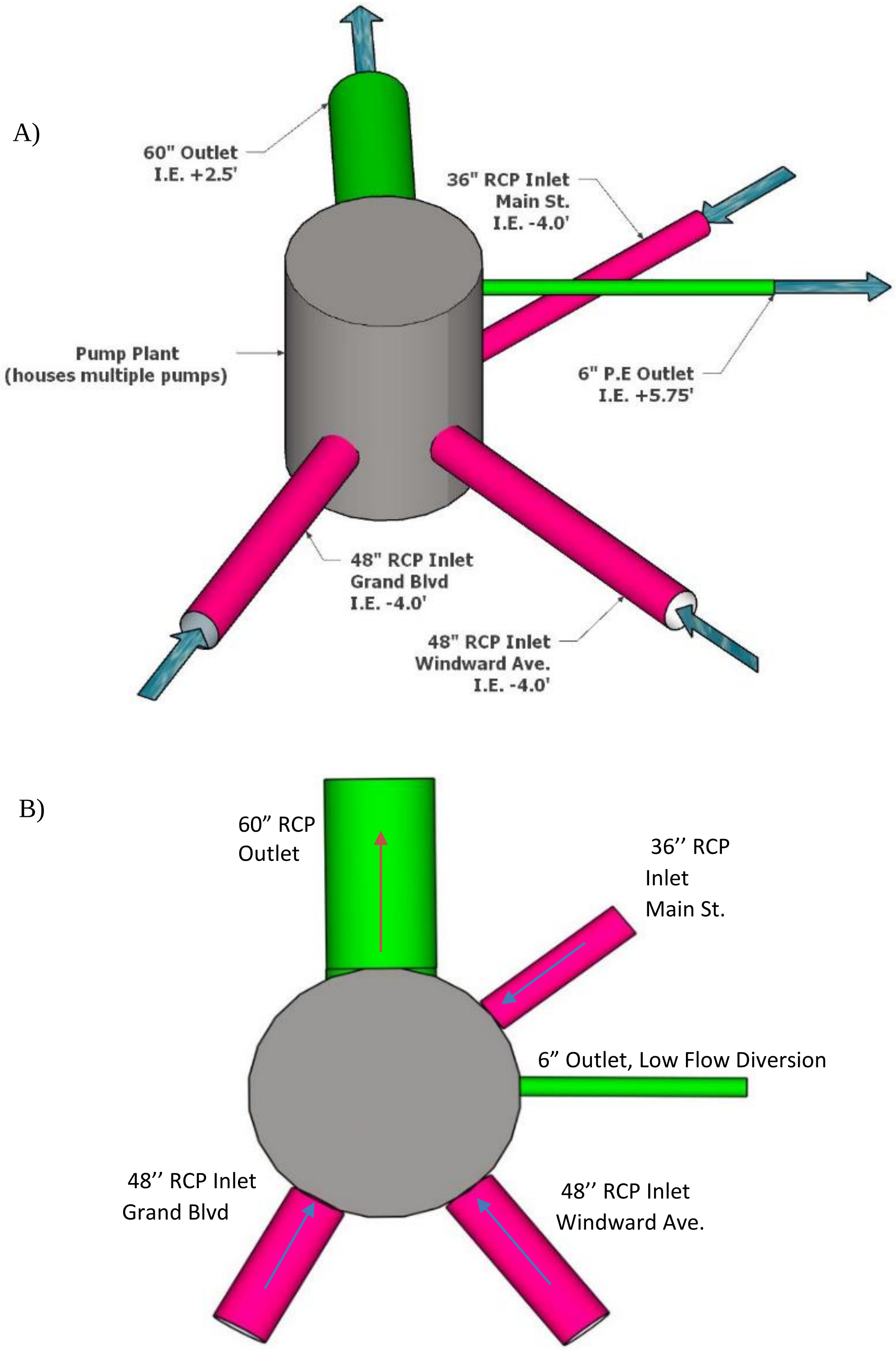

Figure 4. A) Isometric Configuration of Pump Plant 647. B) Plan Configuration of Pump Plant 647.

Note: Green indicates outlet pipes and pink indicates inlet pipes.The characteristics of the Pump Plant 647 are summarized in the following sections. This information was obtained through a review of the as-built plans, a site visit to the plant, and other information obtained from LA Sanitation.

3.1. General Description of Pump Plant No. 647

The following is a summary of field observation made during site visit conducted with Leila Talebi, Tim Joyce from Tetra Tech, and Robert Mcquay from LABOS of 03/05/2015.

- Street address: 1600 Main Street, Venice, CA.
- Plant is located in the middle of a traffic circle where Windward Avenue, Main Street, and Grand Avenue cross.
- Constructed in 1927.
- Underground, single level, 50-foot inside diameter reinforced concrete structure with a wet well, drywell, and surge chamber.
- Steel stairs provide access to the interior of the dry well section of the pump plant from the ground surface.
- Miscellaneous metal items are damaged or not to current standard including railings, platforms, and ladders.
- The 10-ton gantry-crane has a damaged chain and a “DO NOT OPERATE” tag.
- Lighting is original and inadequate for many maintenance operations.
- The plant includes five service pumps, a draw-down pump, and three low-flow diversion pumps in the wet-well. The service pumps appear to be original to 1927 and exhibit rust and leaking oil and grease.
- The plant’s wet well storage is approximately 80,000 gallons.
- Inlet pipes are as follows:
    - 48” ID RCP from Grand Avenue with an invert elevation of -5.0.
    - 36” ID RCP from Main Street with and invert elevation of -4.0.
    - 48” ID RCP from Windward Avenue with an invert elevation of -5.0.
- The dry-well pumps discharge to a surge chamber with an invert elevation of +2.36.
- The wet-well low flow diversion pumps discharge to a 54” ID RCP sanitary sewer located under Main Street with an invert elevation of -10.2.
- A backup generator is not located on-site. A 125 KW Onan trailer mounted portable backup generator is located at Pump Plant 646.
- Based on discussions with maintenance staff, flooding of the area occasionally occurs. It is unclear to City staff if the flooding is caused by storm drain/plant capacity, clogging of the Los Angeles County outlet pipe with sand, or both.

3.2. Existing Pumps and Proposed Upgrades

This section describes the existing and proposed pump types and capacities for Pump Plant 647.

3.2.1. Existing Duty Pumps

Based upon information provided by operations staff, the five duty pumps located in the dry-well are Fairbanks Morse horizontal turbine pumps with a total pumping capacity of 45,000 gpm (100 cfs) with a total design head (TDH) of 50’. Based upon our preliminary analysis, it does not appear that the TDH should be that high of a value, but detailed existing pump information is not available.

A 4” Fairbanks Morse draw-down pump is also in place. According to Staff, the purpose of this pump was to drain the water from the wet well from below the low water elevation of the duty pumps. According to Staff, this pump is not operational but this function has been replaced by the Low Flow Diversion (LFD) pumps.

Per the City of Los Angeles Storm Drain Design Manual, sump areas like this are to be sized for the 50-year storm. The 50-year storm for this this area was calculated to be approximately 163 cfs in Appendix B. The pump capacity of Plant 647 is 100 cfs, approximately 40% less than the 50-year storm and has no redundancy. Pump stations are usually designed for 100% redundancy.

3.2.2. Existing Low Flow Diversion Pumps

Based upon information provided by operations staff, the LFD consists of three submersible ABS pumps. The purpose of these pumps is to divert low-flows to the sanitary sewer. This pump plant experiences a high amount of dry-weather flows, approximately 13,000 gallons per day.

3.2.3. Proposed Duty Pumps

Due to the age, condition, and flow capacity, the duty pumps should be replaced and upgraded to meet the 50-year storm of 163 cfs and provide redundancy for the plant in the event of a single pump failure. Because of the flow requirements and available space within the existing plant, three dry-pit submersible pumps (2 duty and 1 standby) are considered for this application.

The preliminary pumps selected for this application are three Flygt model Flygt CT 3800/905 solids handling pump with 350 HP motors. To reduce the power load demand on motor start-up, solid state soft starters should be considered for the motor control center. Since the proposed pumps are considerably larger than the existing pumps, the interaction of the new pumps with the existing infrastructure, including the wet well and the outlet surge box, should be studied in greater detail during the design phase. The pump system curve for these pumps is included in Appendix C.

3.2.4. Proposed Low Flow Diversion Pumps

The existing LFD pumps seem to be acceptable and may remain in place if a connection to the sanitary sewer is desired. However, these pumps are not large enough to divert the 85th percentile flow of 12 cfs (as discussed in Section 4) to the BMP. To convey the 85th percentile flow to the BMP, the preliminary pump selected is a Flygt model CP 3306/605 submersible pump with 70 HP motor. To reduce the power load demand on motor start-up, solid state soft starters should be considered for the motor control center. Two pumps will be provided to provide 100% redundancy and to maintain operation during a pump failure maintenance operations. The force main between the BMP pumps and the BMP was preliminarily sized as a 16-inch ductile iron pipe with a length of 1,300 feet. The pump system curve for the BMP pumps is included in Appendix C.

3.2.5. Pump System Summary

The existing and proposed pump system for Pump Plant 647 is summarized in Table 2.

Table 2. Existing and proposed pump system components.

Existing Conditions				
Pump	Pump Type	Pump Capacity (gpm)	TDH (feet)	Motor Size (HP)
Duty Pump #1	NON-OPERABLE Fairbanks Morse – 8" Horizontal Pump	N/A	N/A	N/A
Duty Pump #2	Fairbanks Morse – 14" Horizontal Pump	6,000	50	30
Duty Pump #s 3, 4, and 5	Fairbanks Morse – 20" Horizontal Pump	14,000 (each)	50	75
Draw-down Pump	NON-OPERABLE 4" pump	N/A	N/A	N/A
LFD Pump #s 1 and 2	ABS Submersible	250	N/A	4.7
LFD Pump # 3	ABS Submersible	460	N/A	7.5
Proposed Conditions				
Duty Pump #s 1, 2, and Standby Pump 3	Flygt CT 3800/905	36,600 (each)	18	350
BMP Pump #s 1 and 2	Flygt CP 3306/605	5,400 (each)	45	70

3.3. Structural Integrity

Based upon our cursory visual examination of the pump plant by our structural engineer, David Kuang, on March 5, 2015, which was limited to those portions that were exposed to view (top of roof slab, pump plant dry well interior, and limited areas of the pump plant wet well interior), the structure appeared to generally be in fair to good condition. There are minor concrete spalls and areas of wear in various locations on top of the roof slab (see Figure 5), as well as light to moderate surficial corrosion of the hatch covers. Inside the dry well, moderate corrosion of the underside of the hatch covers was observed, as well as a few minor concrete spalls at the concrete curbs upon which the hatch covers sit. There is a long crack in the bottom of the roof slab that runs perpendicular to the wet well/dry well divider wall (cutoff wall) with minor water stains along its length, indicating a through-crack with some leakage from above (see Figure 6 and Figure 7). The crack extends over the top of the electrical panels and may pose a hazard when water is coming through the crack (see Figure 6). There are water stains on the wall under one of the pipes connected to the surge chamber, indicating minor leakage at the pipe penetration through the wall (see Figure 7). The clearance between the bottom of the ships ladder and the guardrail is substandard and does not meet the CalOsha requirement for aisles of 24" minimum (see Figure 8). Taking photos through one of the wet well access hatches and observing the photos, there appears to be a slab repair that was done to the underside of the roof slab that may be showing signs of delaminating (see Figure 9). At the surge chamber, there is a spall at one of the support columns with exposed column reinforcement, as well as a horizontal crack in the surge chamber wall (see Figure 10).

No structural design data was found or shown on the as-built drawings, so the original design parameters are unknown.

Figure 5. Roof Slab Spall.

Figure 6. Roof Slab Crack (upper left) Over Electrical Panels.

Figure 7. Roof Slab Crack (top) and Water Stains Under Pipe Penetration (far right).

Figure 8. Aisle Between Ships Ladder and Guardrail is Substandard (middle) and Obstructed.

Figure 9. Wet Well Roof Slab Repair Showing Signs of Delamination (top right).

Figure 10. Surge Chamber Support Column Concrete Spall (bottom) and Wall Crack (middle).

3.3.1. Proposed Structural Upgrades

The overall condition of the structure appears to be satisfactory. The wet well should be drained and examined for additional concrete deterioration and concrete reinforcing corrosion. Concrete spalls and cracks should be repaired in order to protect the concrete reinforcement from further corrosion and to prevent further degradation of the concrete. Corrosion of the hatch covers should be monitored, and removal of the corrosion and coating of the covers should be considered. If a current Code analysis/evaluation of the structure is desired, including detailed structural analyses, a geotechnical investigation should be performed to determine design lateral earth pressures, and to determine if seismic earth pressure should be considered. Material properties such as concrete compressive strength and reinforcement yield stress can conservatively be assumed, or materials testing may be performed in order to obtain more accurate material strengths for analysis.

To provide access for construction and maintenance of the three replacement duty pumps, the roof slab over the dry well will need to be redesigned. The existing roof slab will be completely removed, the walls extended vertically about 5 feet, and a new roof slab constructed that will incorporate three pump access hatches, LFD and BMP pump hatches, and one hatch over the access stairs. Additionally, the existing roof support beam, columns, and gantry crane will be removed and not replaced.

Due to the proposed modifications noted below, additional minor structural modifications may be required to accommodate the new equipment.

3.4. Miscellaneous Upgrades

Based upon site observations and discussions with maintenance staff, the following miscellaneous repairs and upgrades should be considered:

- Upgrade the Motor Control Center.
- Upgrade the SCADA / Instrumentation and Control Equipment.
- Replace pump discharge piping and valves.
- Install level control through ultrasonic sensors (primary) with float backup.
- Upgrade railings and ladders.
- Replace damaged hatches.
- Sand blast and paint the interior of the building.
- Replace the ventilation system.
- Upgrade the interior lighting.
- New portable generator dedicated to the plant.
- Replace potable water piping and backflow.
- Implement recommendations from the Arc Flash Study (to be determined).

3.4.1. Conceptual Layout and Design

The concept elements of the Pump Plant are as follows:

- Replace and upgrade the duty pumps, sized to convey the 50-year storm and provide redundancy in the event of a single pump failure.
- Install 100% redundant submersible pumps in the wet well to convey the 85th percentile flow to the BMP.
- Perform miscellaneous upgrades.

3.4.2. Power Requirements

This section describes the power requirements needed to supply Pump Plant 647.

3.4.2.1. Electrical Supply

Per the 2000 Venice Pavillion Low Flow Diversion project as-built plans, the existing pump plant has 600A/480V electrical service. A preliminary review indicates that if the replacement pumps include a solid state soft starter the existing service will need to upgraded to a 1600A/480V services for the replacement pumps.

3.4.2.2. Backup Power Supply

The existing 125 KW backup generator is not of sufficient size to power the replacement pumps. As a replacement to this generator, a new 750 KW Tier 4 compliant portable diesel backup generator should be purchased and dedicated to Plant 647. Due to the exposed public nature of the site, the new generator should be stored at the nearest secure Bureau of Sanitation facility.

3.4.3. Operations and Maintenance

Operations and maintenance (O&M) procedures will be very similar to those currently conducted at Pump Plant 647. Major O&M items include monthly exercising of pumps and generator, as well as annual in-depth inspection, lubrication, and scheduled/worn-out part replacement.

3.5. Preliminary Opinion of Cost

Including a 25% contingency, the preliminary opinion of cost to complete the Pump Plant upgrades is approximately $5.5 million. A more detailed breakdown of costs is included in Section 8.

Due to the preliminary level of this study, this preliminary opinion of cost should be considered suitable for the early planning stage of the project. As the work becomes more defined in the subsequent project stages, it is expected that the opinion of cost will be revised.

3.6. Storm Drainage Network

Current dry weather flows at the pump plant are reported to be approximately 13,000 gallons per day. While continuous dry weather monitoring is not available for this watershed, monitoring was performed in the City of Los Angeles for a watershed of nearly the same size and similar land use (Tetra Tech 2015). This monitoring data was scaled to the watershed and was used as the basis to estimate the expected dry weather flow from the watershed. Dry weather flows for a watershed of this size and land use would be expected to be closer to 4,000 gallons per day. This analysis indicates that there is ground water intrusion into the storm drainage network. It is recommended that significant rehabilitation be performed on the storm drainage infrastructure in addition to the pump station. This could include cured in place pipe, slip lining, or completely replacing the pipe. At a minimum, a closed circuit TV inspection of the pipe system should be performed to determine the sources of this significant level the intrusion. The existing dry weather flows will have a substantial impact on the performance of the pumping plant and the frequency and duration that the pumps operate.

4. Green Infrastructure Alternative Analysis Evaluation for Wet Weather Treatment

Integrating green infrastructure improvements into the rehabilitation of Pump Plant 647 can enhance the overall performance of the system and expand the benefit of Pump Plant beyond its original function as a flood control mechanism. By linking the “gray infrastructure” (i.e. the physical pump plant) with the green infrastructure, multiple objectives can be achieved within a seamless system, reducing the overall cost to achieve each individual objective separately. In addition to the flood control function, this integration can help to achieve EWMP water quality improvement objectives while simultaneously providing the numerous advantages that green infrastructure brings to the City, such as an improvement to the community’s overall well-being, increased property values, enhanced aesthetics, and recreational opportunities.

According to the Santa Monica Bay EWMP, right-of-way along streets are the most extensive opportunity to implement BMPs on public land. In developed areas, curb and gutter in the road provide an opportunity to intercept both dry and wet weather runoff prior to entering the storm drain system and treat it within the extents of the public right-of-way. Green streets have been demonstrated to provide "complete streets" benefits in addition to stormwater management, including pedestrian safety and traffic calming, street tree canopy and heat island effect mitigation. The City of Los Angeles is planning to implement a Great Streets Initiative that seeks to enhance various areas of the City by making changes with temporary treatments such as plazas and parklets, and permanent changes to curbs, street lighting, and street trees (www.lamayor.org/greatstreets). The Great Streets Initiative is being implemented in aims of activating public spaces, providing economic revitalization, increasing public safety, and enhancing local culture. One setback for this area is narrow sidewalks, preventing the street from reaching its full potential. Because bicycle riding is permitted on sidewalks in the City of Los Angeles, a potential solution to narrow sidewalks would be to create a bicycle lane, decreasing sidewalk traffic In addition to the Great Streets initiative, the City of Los Angeles 2010 Bicycle Plan (LDCP 2010) proposes a bike lane for Riviera Ave. from Grand Blvd. to Mildred Ave., Windward Ave. from Park Row to Riviera Ave., Grand Blvd. from Main St. to Venice Blvd., Main St. from Santa Monica City Limits to Venice Blvd., Abbot Kinney Blvd. from Main St. to Washington Blvd. The plan notes that bicycle lanes along streets has been shown to have multiple economics, social, and environmental benefits such as, improvement to the businesses, increased number of riders, and enhanced safety. Utilizing permeable pavement in the bike lane can add an enhancement to water quality to the long list of benefits.

Localized flooding can result from insufficient capacity to drain a site and/or from excessive (and often unanticipated) offsite flows. Many causes of localized flooding can be remedied by repairing or replacing the existing infrastructure; however, it is often more practical to reduce the peak discharge and volume of runoff that are conveyed to the existing storm drainage network. As suggested in Alternative 2 below, retrofitting the study area with green infrastructure could provide a viable strategy to regulate runoff and alleviate localized flooding.

Implementing the green infrastructure concepts presented in the following sections provides an opportunity to integrate multiple initiatives currently proposed and in various stages of implementation across the City, the EWMP, Great Streets Initiative, and the 2010 Bicycle Plan. Combining all of these initiatives into one approach is a key component of the One Water plan approach.

Under existing conditions, stormwater runoff drains to the wet well via three main storm drains located under Windward Ave., Grand Blvd., and Main St. The runoff is then pumped out through five main pumps with total rate of 100 cfs into the existing City and County storm drains. In addition, three low diversion flow pumps are allocated to drain the wet well during periods of dry weather. Under proposed conditions, there are two alternatives for incorporating treatment for wet weather flow into the pump station upgrades that could be implemented in tandem or independently. Water from the pump plant could be diverted into an underground storage gallery (post-pump treatment) or stormwater flows could be treated before flowing into the pump plant (pre-pump treatment), using green infrastructure concepts suited for implementation in street parking lanes, protected bicycle lanes, and landscape areas, including permeable pavement and bioretention. Each alternative proposes incorporating treatment through green infrastructure in an attempt to improve the water quality of stormwater prior to discharge into the Pacific Ocean. Both alternatives incorporate diverting stormwater runoff from the street and the surrounding lands through a series of BMPs and allowing stormwater to either infiltrate or to retain the stormwater for beneficial uses.

Sufficient separation from the groundwater will need to be ensured through a geotechnical investigation. Literature, soil borings and as-builts show the existing groundwater table to be near mean seal level (Elevation 0) in this location (MWD 2007; LADWP 2011). Based on the literature review, alternative 2 assumes that sufficient separation is available and runoff will be permitted to infiltrate to the groundwater. However; for alternative 1 no infiltration is assumed.

Alternative 1 (“**Post-Pump Treatment**”): This alternative is designed to directly pump stormwater runoff into an underground storage gallery implemented underneath the park at the end of Market St. (Figure 11) designed to store the water for beneficial use. Stormwater runoff is routed from three catch basins draining from Windward Ave., Grand Blvd. and Main St., into a wet well in the pump plant. The proposed configuration of the pump plant is shown in Figure 12. The runoff produced by the 85th percentile/24 hour storm will be pumped out of the wet well and directly into the underground storage gallery, at a rate of approximately 11.5 cfs, To achieve this flow would require that the existing low flow diversion pump be upgraded to allow pumping of the peak flow rate for the 85th percentile storm design. A 6-inch outlet pipe would be connected to the existing sump pump and routed through the top of the existing pump outfall junction structure to divert the water to the proposed storage gallery. Treatment of the 85th-percentile runoff volume would constitute compliance with all water quality requirements for the tributary drainage area (based on current interpretation of the MS4 Permit, as discussed in the EWMPs). Utilizing the low flow diversion pump to pump runoff to the underground storage gallery not only can significantly improve water quality but also, could greatly reduce the need for the main pumps to turn on during small storm events and decrease the operation time considerably during larger storm events. This alternative includes two different scenarios that are intended to either use the captured water for irrigation purposes or temporarily store the water during the wet weather event and then send it back to the existing 54-inch sanitary sewer line.

Figure 11. Alternative 1 potential BMP location.

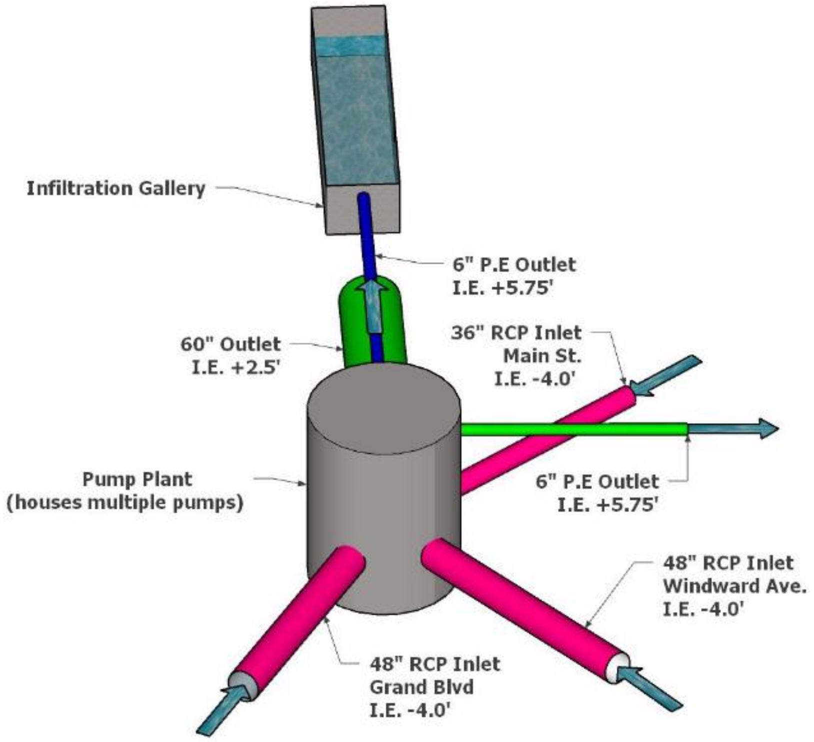

Figure 12. Direct Pumping System for Alternative 1

Alternative 1-Scenario 1: Under this Scenario, the wet weather runoff from the wet-well room would be pumped out at a constant rate of 11.5 cfs. A 6" outlet pipe would then divert the water from the existing low flow diversion pump to an underground storage gallery with an operable valve. The storage gallery will be sized so that it can store the runoff produced by the 85th percentile storm once the valve is closed. Once the storage system is full, excess flow will be gravity bypassed to the Pacific Ocean. This scenario proposes to utilize the stored runoff within the storage gallery for irrigation of the park at the end of Market St. in an attempt to reduce the demand on potable water or reclaimed water for irrigation. They irrigation demand at the park is estimated to average 10,525 gallons per day (ranging from 5,650 in December to 14,768 in July) Utilizing the water in the park, directly above where it is stored, will reduce the demand on potable water, eliminate the need for piping back to the sanitary system and reduces the strain on the treatment plant. There are two options for the park irrigation:

Option 1: Utilizing stored water for spray irrigation in the park.

Since the stored runoff within the storage gallery have variable pollutant concentrations, a treatment system should be used to treat the collected flow prior to spray irrigation in the park. The treatment system should treat the water to meet the guidelines in the Los Angeles County Department of Public Health (CDPH) document titled the *Guidelines for Harvesting Rainwater, Stormwater, & Urban Runoff for Outdoor Non-Potable Use* (2011).

Option 2: Utilizing stored water for the subsurface drip line

An alternative to the spray irrigation system is a subsurface drip line that would directly deposit water to the root systems of the plants. The subsurface irrigation system does not require the same level of water treatment as spray irrigation and can be used with minimal treatment.

Alternative 1-Scenario 2: In this scenario, the same as scenario 1, it is assumed that the wet weather flows would be pumped at a rate of 11.5 cfs once the low flow diversion pump has been upgraded from the wet-well and routed to the proposed underground storage gallery. The storage gallery is sized to fully capture the runoff produced by the 85th percentile storm. Once the storage system is full, excess flow will be gravity bypassed to the Pacific Ocean. Under this scenario, wet weather flows will be temporarily stored in the storage gallery. After the wet weather event, the stored runoff will be slowly drained, by gravity, back into the existing 54-inch sanitary sewer system and eventually, to the treatment plant. This scenario allows similar treatment as the current low flow or dry weather flows without overwhelming or exceeding the capacity of the treatment plant. Treating the wet weather runoff would allow that water to be available for use as reclaimed or reuse water.

During the dry season, the storm drain outlet that discharges into the ocean at the end of Market Street can be filled with sand partially blocking the outlet. Storing the water in the park also provides the benefit of allowing time for the outlet to be cleared reducing the strain on the pumps. Water stored in the underground storage gallery can also be pressurized and used to clear the outlet pipe.

Alternative 2, referred to as "**Pre-Pump Treatment**", is intended to treat the wet weather runoff from a 127.7-acre drainage area through permeable pavement and bioretention areas implemented within street parking lanes, protected bicycle lanes, and landscape areas of various streets (**Error! Reference source not found.** and Figure 14) prior to its arrival at the pump plant. To treat this runoff, bioretention areas could be implemented along landscape areas and alongside permeable pavement areas on various streets. Overflow from bioretention and additional runoff should be treated in permeable pavement implemented within street parking lanes or protected bicycle lanes.

Figure 13. Alternative 2 recommended areas near Pump Plant 647 for BMP implementation.

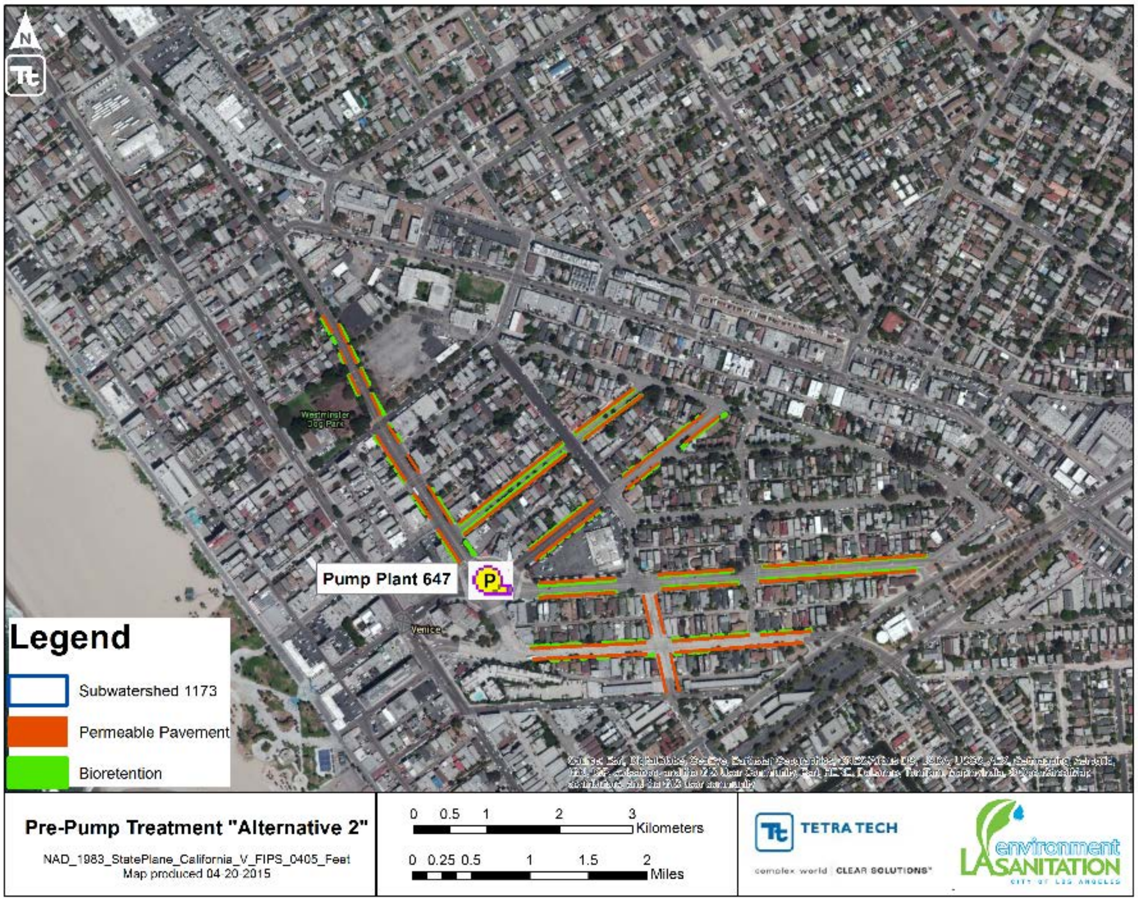

Figure 14. Alternative 2 recommended areas for SWS 1173 Drainage Area for BMP implementation.

Error! Reference source not found. presents a comparison of the configuration of each alternative. Details for the sizing and evaluation of each alternative is presented in Section 4.1.

Table 3. Comparison of Alternatives

BMP Type	Low Flow Diversion Rate (cfs)	Post-Pump Treatment			Pre-Pump Treatment		
		Area (ac)	Depth (ft)	Annual Volumetric Treatment (ft^3)	Area (ac)	Depth (ft)	Annual Volumetric Treatment (ft^3)
Underground Storage Gallery	11.5	1.6	4	2,067,686	N/A	N/A	N/A
Bioretention	N/A	N/A	N/A	N/A	0.37	4.75	2,555,678
Permeable Pavement		N/A	N/A	N/A	2.3	3.75	

4.1. BMP Sizing and Evaluation

The entire drainage area primarily encompasses multi-family residential and secondary roadway land uses, and contains approximately 75 percent impervious surface. Table 4 and Table 5 illustrate the predominant soil texture and the land use types within SWS 1173. The details of the two proposed alternatives are outlined below.

Table 4. SWS 1173 soils summary

Soil Series	Infiltration Rate (in/hr) (Source: USDA Soil Water Characteristics Program)	Hydrologic Soil Group (Source: LA Soils GIS Layer)	Percentage of Watershed
Sand	0.5-8	B	100%

Table 5. SWS 1173 distribution of land use types

Landuse type	Acres	Percent
Low Density Single Family Residential	2.2	1.7%
Multi-family Residential	43.4	34.0%
Commercial	16.6	13.0%
Institutional	8.16	6.4%
Industrial	1.49	1.2%
Transportation	3.39	2.7%
Secondary Roads	52.5	41.1%
Vacant Space	0.03	0.03%
Total	**127.7**	**100%**

4.1.1. Wet Weather Flow

Wet weather flow can vary significantly from storm to storm and from year to year. To analyze the proposed system and determine the potential inflow, a 20-year continuous simulation period from January 1, 1992 to December 31, 2011 was used. Hourly wet weather runoff time series for each contributing land use were obtained from the calibrated Watershed Management Modeling System (WMMS; Tetra Tech 2010a and Tetra Tech 2010b).

4.1.2. Existing Pollutant Loading Assessment

According to the Santa Monica Bay EWMP, bacteria is found to be the limiting pollutant, with a wet-weather compliance date of 2021 for the Santa Monica Bay Beaches Bacteria TMDL. Therefore for this study area, bacteria was used as the basis for removal comparison. The bacteria load entering the storm drain varies depending on the size of the storm and the number of dry days between storms. A 20-year continuous simulation period from January 1, 1992 to December 31, 2011 was used to analyze the bacteria removal and water quality improvement. The long-term time series for bacteria load across the watershed was obtained from the calibrated WMMS at an hourly time step (Tetra Tech 2010a and Tetra Tech 2010b). Other pollutants including copper, lead, nitrogen, phosphorous, and pathogens, long-term time series from the calibrated WMMS were used to analyze the comprehensive water quality benefits for the recommended alternative.

4.1.3. Geotechnical Literature Review

A geotechnical literature review was performed to identify potential geologic or subsurface issues that could affect BMP implementation or configuration. A soil report that was developed by Active Leak Testing, Inc. within the vicinity of pump plant 647 was used to determine the type of soils and suitability for infiltration at BMP sites. Based on the review of 9 soil boring logs, the site soils mostly consist of well graded sand (SW), poorly graded sand (SP), and silty sand (SM) up to the depth of 13 feet. Since sandy soil has high infiltration rate, it indicates that the site soils are suitable for infiltration. According to the soil boring at Main Street and Market Street, the first 10 feet of the silt soils consist of moist light brown silty sand (SM) following by brown silty clay/clayey silt (CL-ML) with sand content increasing with death in the next 3 feet. Groundwater was encountered at the depth of 13 feet and the rest of the site soil consist of light brown well-graded sand with some silt and grave (SW-SM) up to the depth of 30 feet. Soil borings from the area around the pump plant are include in Appendix F.

This review was limited to existing data and should be supplemented with a full, wet well examination, material strength determination, site-specific geotechnical and seismic investigation prior to preliminary designs. Infiltration rates and other subsurface conditions must be verified to ensure project success and public safety.

4.1.4. BMP Optimization and Performance

To optimize the size of the proposed BMPs, a range of possible BMPs sizes for both alternatives were modeled in the EPA's System for Urban Stormwater Treatment and Analysis Integration (SUSTAIN) using the 20-year, continuous simulation data to measure the overall impact on the water quality. SUSTAIN was developed by the EPA Office of Research and Development to facilitate selection and placement of BMPs and green infrastructure techniques at strategic locations in urban watersheds. It assists to develop, evaluate, and select optimal BMP combinations at various watershed scales on the basis of cost and effectiveness. In this study, the BMP's effectiveness was measured by its ability to remove total bacteria. Total bacteria was determined to be the limiting pollutant, indicating that if total bacteria is controlled, other pollutants would have similar or greater removal rates.

In addition, identifying appropriate numeric targets is necessary to evaluate and optimize performance of the stormwater facilities. One common hydrologic criterion for integrated water quality, flow reduction, and resources management is retention of the runoff volume generated by the 85th percentile storm event. At the study area, the 85th percentile storm event depth is 0.88 inch, according to the Los Angeles County isohyetal map. As a result, an additional analysis was performed to identify the size required to capture and treat the 85th percentile, 24-hour design storm event. The 20-year continuous time period (from 1992 to 2011) was then modeled through the identified BMP size to measure the overall, long-term expected water quality impacts. Two sets of analyses were performed for different solutions including Alternative 1"Post-Pump Treatment" and Alternative 2 "Pre-Pump Treatment".

Figure 15 shows the 85th percentile 24-hour hydrograph for the drainage area (127.7 acres), derived from the HydroCalc (Version 0.3.0 beta). The peak flow for the 85th percentile storm for the 127.7-acre study area was calculated to be 11.5 cfs, as illustrated in Figure 15.

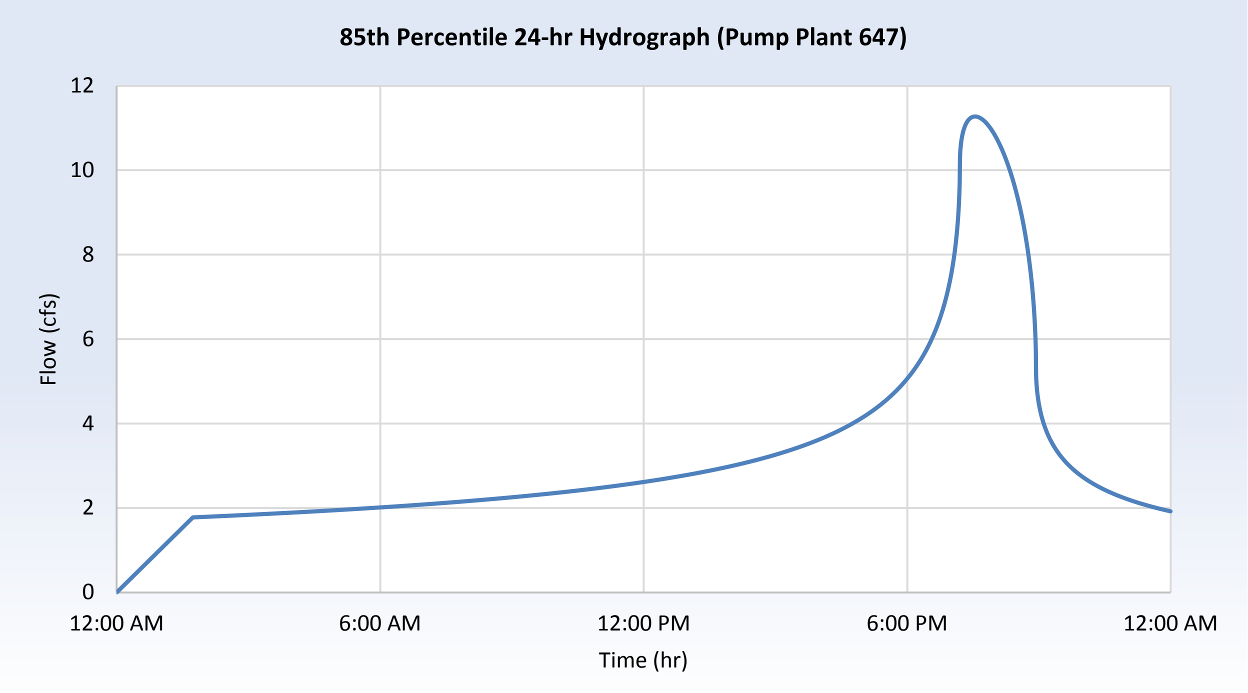

Figure 15. 85th Percentile 24-Hour Hydrograph for the 127.7- acre drainage area with 0.88 inch Rainfall Depth.

For alternative 1, both scenarios it is assumed that the main pumps cycle on when the wet well reaches a certain level. At that point, all of the volume in the wet well is pumped out at a rate of 165 cfs. This pumping scheme results in the pump cycling on and off multiple times throughout the duration of the storm event. Because of the configuration of the pump plant and the elevation of the outlet pipe, it is not feasible to divert even a portion of the 165 cfs flow to a BMP.

For alternative 1, in both scenarios a smaller sump pump would cycle to pump all of the flow entering the pump plant at a rate of 11.5 cfs or less. This pump would operate throughout the duration of the storm providing a consistent flow into the BMP. Diverting flow into a BMP capable of treating the volume of runoff produced by the 85th percentile storm with foot print of 1.6 acre and a capacity of approximately 6.5 acre-ft would provide a 50 percent reduction in bacteria (Figure 16) and a 46 percent reduction in volume (Figure 17).

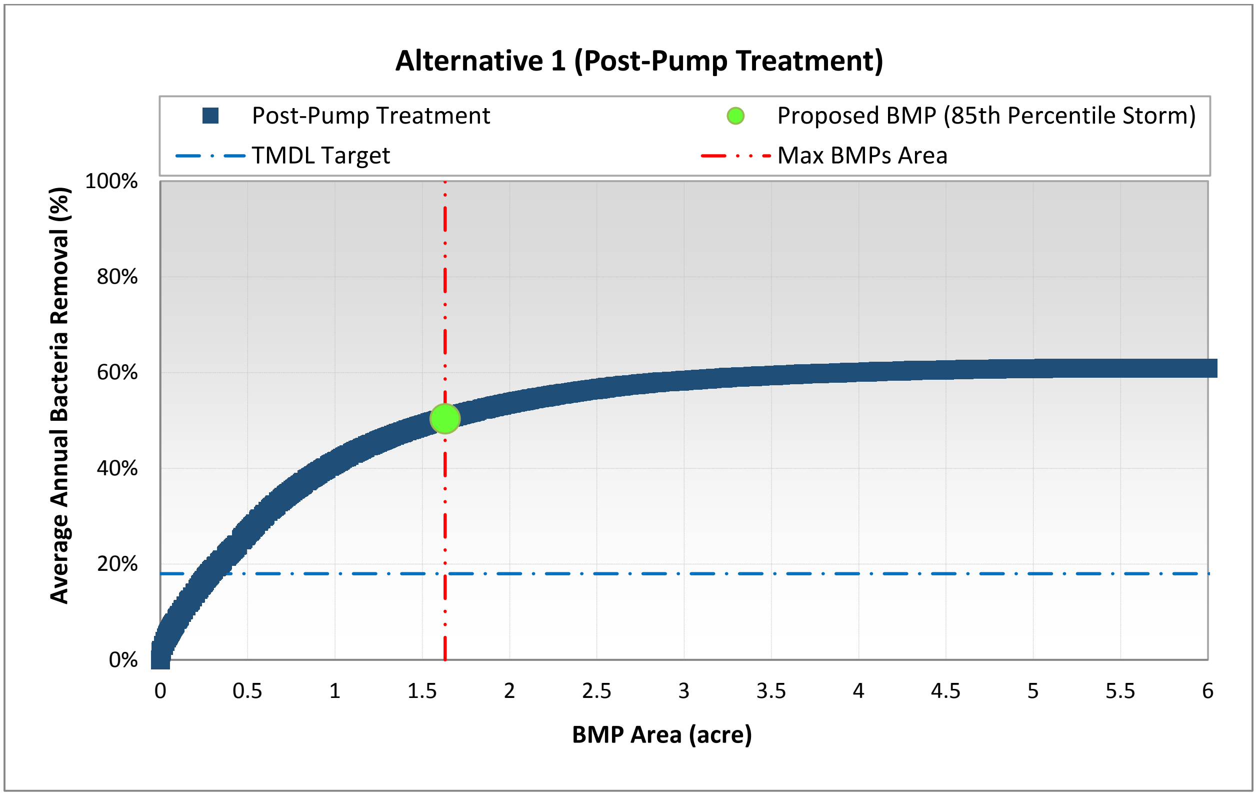

Figure 16. BMPs Capacity vs Average Annual Total Bacteria Reduction.

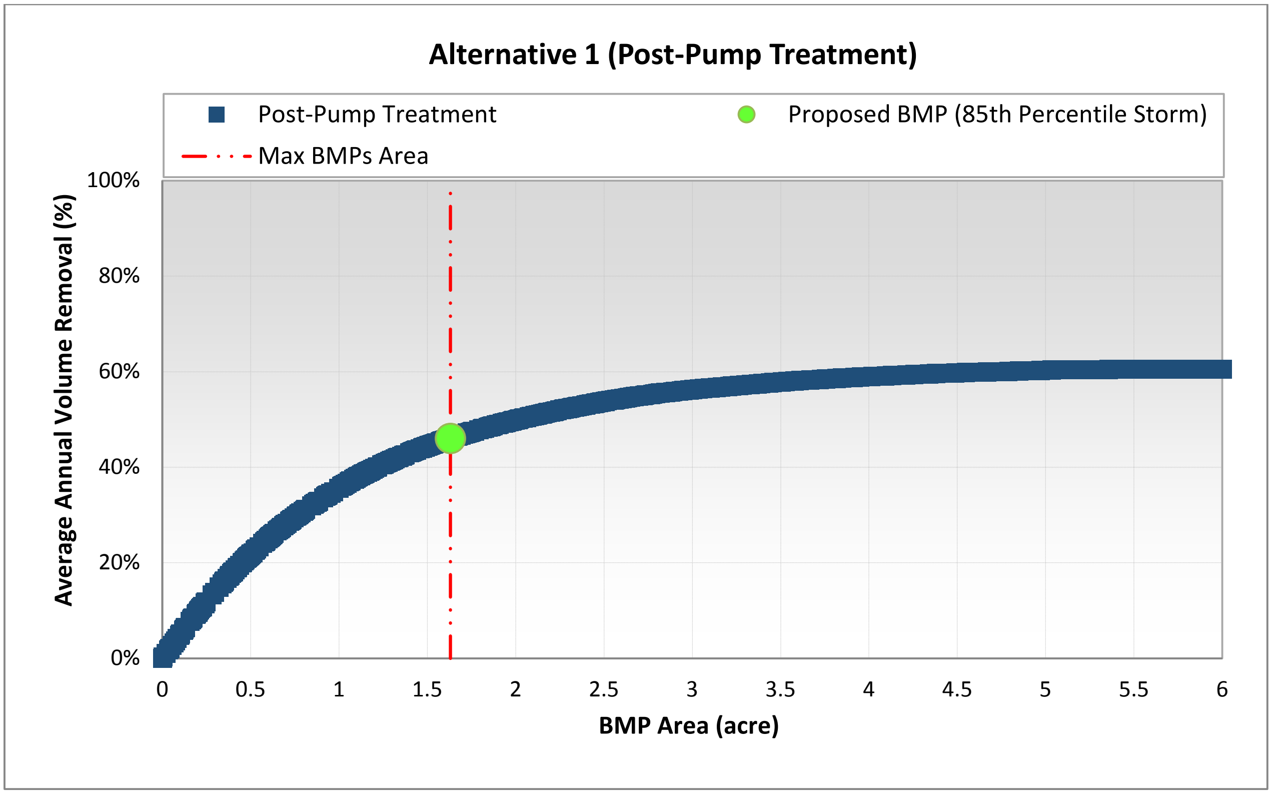

Figure 17. BMPs Capacity vs Average Annual Total Volume reduction.

For alternative 2 the BMPs opportunities would be implemented along several streets to treat wet weather runoff from a 127.7-acre drainage area before reaching the Pumping Plant. The 20-year continuous time period (from 1992 to 2011) is modeled to generate the cost-effectiveness curve and measure the overall, long-term expected water quality impacts (Figure 18 and Figure 19). The result of the analysis showed that the combination of permeable pavement and bioretention with the sizes of 100,800 and 16,000 square feet and retention volumes of 151,200 and 50,600 cubic feet respectively provide the capacity to treat the 85th percentile storm event. The respective BMPs sizes would result in 57 percent flow volume removal and 66 percent bacteria count reduction.

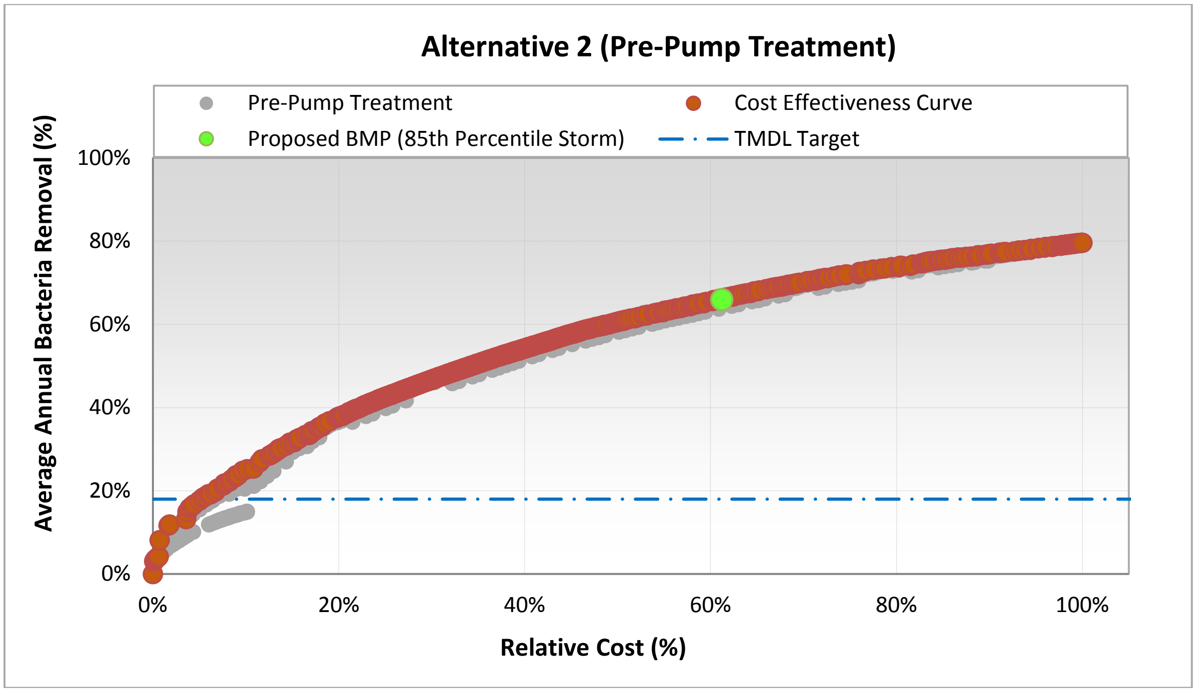

Figure 18. BMPs Capacity vs Average Annual Total Bacteria reduction.

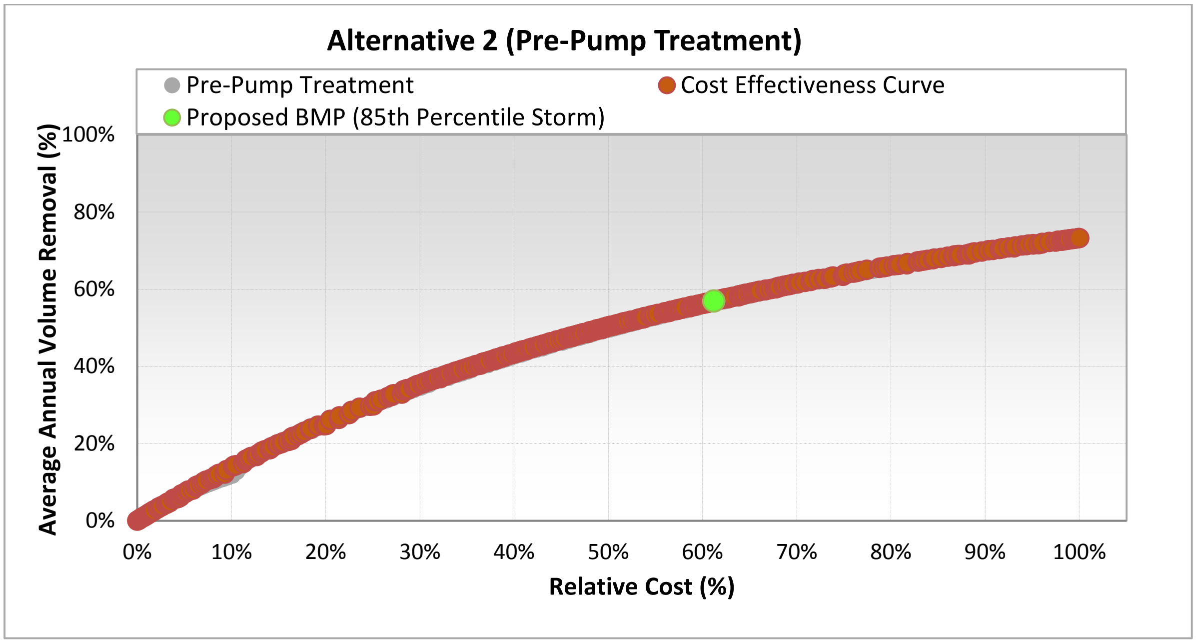

Figure 19. BMPs Capacity vs Average Annual Total Volume Reduction.

4.1.5. Irrigation Demand

As mentioned earlier, Alternative 1 proposes to utilize the stored runoff within the storage gallery for irrigation of the park at the end of Market St. The average daily irrigation demand for each month at the park is estimated using evapotranspiration data from California Irrigation Management Information System (CIMIS) station No.99. The calculated daily and monthly demands by each months are shown in Table 6.

Table 6. Average Daily Irrigation Demands for each month at the Park

Month	Daily Irrigation Demand, Gallons	Monthly Irrigation Demand, Gallons
January	6,123	189,808
February	7,332	205,286
March	9,723	301,413
April	12,763	382,875
May	13,507	418,719
June	14,229	426,865
July	14,768	457,821
August	14,637	453,748
September	11,703	351,105
October	8,935	276,974
November	6,734	202,028
December	5,650	175,145

Utilizing the water in the park, directly above where it is stored, will reduce the demand on potable water, eliminate the need for piping back to the sanitary system and reduces the strain on the treatment plant. The Rainwater Harvester 3.0 model was used to evaluate the relationship between the size of the underground storage gallery and potable water demand offset. The result of analysis indicates that the proposed storage gallery with a storage capacity of 6.5 acre-ft can not only fully capture the 85th percentile storm runoff, but could also offset the potable water demand by 90 percent (Figure 20).

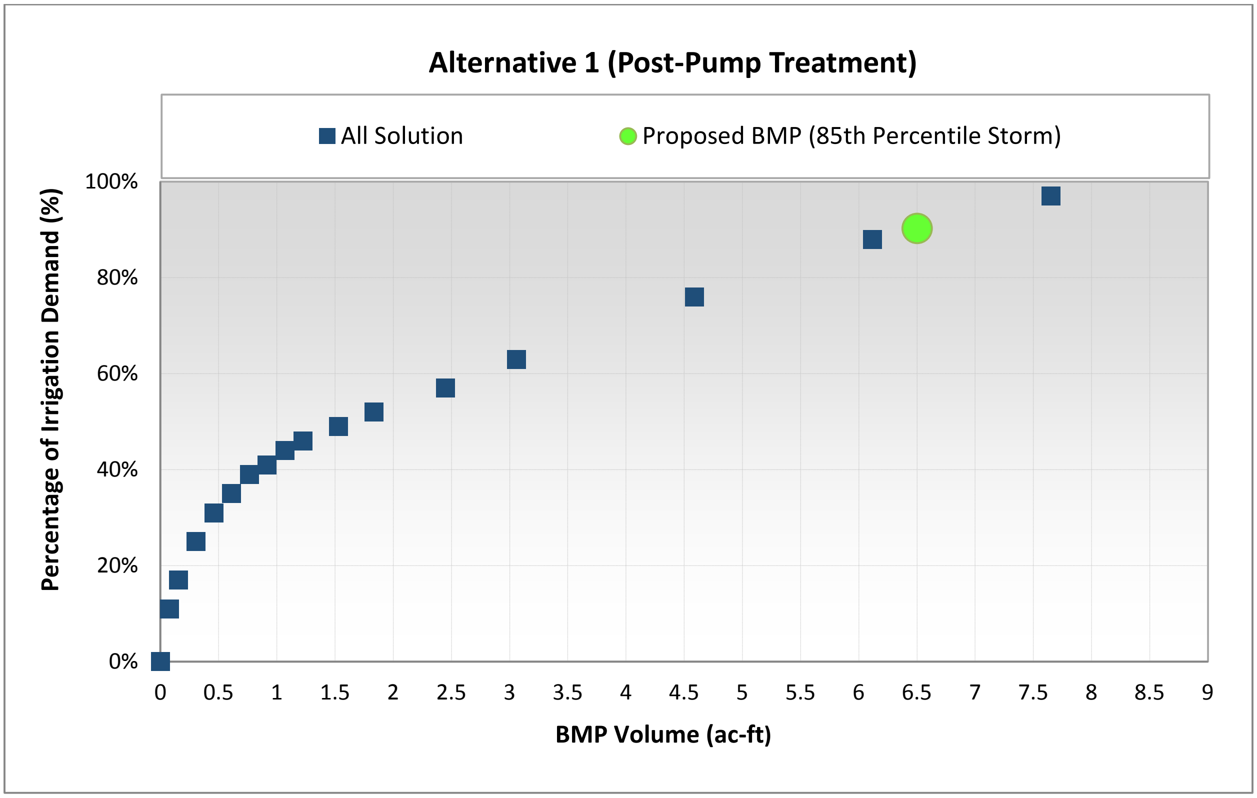

Figure 20. BMPs Capacity vs. Percentage of Irrigation Demand Reduction.

4.1.6. Treatment Alternative Comparison and Conclusions

Based on the comparison of the two alternatives presented in Table 7, Alternative-1 (11.5 cfs direct pumping) will provide the reasonable volume and associated pollutant load reduction. Alternative 1 will require a small upgrade to the current pump plant configuration to provide a larger low flow diversion pump. By using the low flow diversion pump to divert flows to the BMP, the main pumps will not have to operate as often.

Table 7. Average annual expected pollutant reductions and cost.

Constituent	Average annual loads	Average annual reduction					
		Post-Pump Treatment				Pre-Pump Treatment	
		Scenario 1		Scenario 2		Alternative 2	
	Pre-BMP	Reduction	Percentage	Reduction	Percentage	Reduction	Percentage
Volume, (ft^3)	4,491,365	2,067,686	46%	2,067,686	46%	2,555,678	57%
TSS, (lbs)	18006	7241.6	40%	7241.6	40%	11901.7	66%
TN,(lbs)	561	271.6	48%	271.6	48%	364.7	65%
TP, (lbs)	441	214.9	49%	214.9	49%	287.8	65%
Copper, (lbs)	7.3	2.9	40%	2.9	40%	4.8	66%
Lead, (lbs)	6.9	2.8	40%	2.8	40%	4.6	66%
Zinc, (lbs)	68.3	27.6	40%	27.6	40%	45.3	66%
Fecal counts	1.05E+13	5.29E+12	50%	5.29E+12	50%	6.95E+12	66%
Cost	N/A	$8,409,360		$7,546,850		$5,857,670	

Note: TSS = Total Suspended Solids; TN = Total Nitrogen; TP = Total Phosphorous

Implementing Alternative 1, scenario 1 will require installation of an irrigation system to utilize stored water for irrigation of the park. This scenario is more costly because of the treatment system and irrigation method required to be constructed. However, it reduces the demand on potable water or reclaimed water. Alternative 1, scenario 2 will only require construction of a small pipe to slowly drain out the storage gallery to the existing 54-inch storm drain under Main Street. Among all solutions, Alternative 2 is recommended since it requires no alteration to the current low flow diversion pump configuration. This alternative provides maximum resiliency for the main pumps. Treating the volume produced by the 85th percentile storm before the pump plant significantly reduces the amount of time that the main pumps have to operate by approximately 70%.

5. BMP Conceptual Layout, Design, and Performance Specifications

5.1. Post Pumping Alternative 1

The recommended BMP for alternative 1 (Scenario 1 and 2) is an underground storage gallery. A storage gallery is typically an empty storage vessel with either a manually operated valve or a permanently open outlet. If the storage gallery has an operable valve, the valve can be closed to store stormwater runoff for irrigation (Figure 21). Storage gallery can be designed as surface or subsurface units allowing for implementation around paved streets, parking lots, and buildings to provide initial stormwater detention and treatment of runoff. Such applications offer an ideal opportunity to minimize directly connected impervious areas in highly urbanized areas.

Figure 21. Subsurface Storage Gallery. (Source: www.oldcastlestormwater.com)

Typically, this system requires continual monitoring by the grounds crews, but provides greater flexibility in water storage and metering. If a storage gallery is provided with an operable valve and water is stored inside for long periods, the system openings must be covered to prevent mosquitoes from breeding. A storage gallery with a permanently open outlet can also passively regulate the outflow of stormwater runoff. If the system outlet is significantly smaller than the size of the inlet (e.g., ¼- to ½-inch diameter), runoff will build up inside of it during storms, and will empty out slowly after peak intensities subside. Since, no infiltration is allowed at the project site location, stored water will be either used for irrigation or sent to the existing sanitary sewer system. Observation ports and cleanouts should be included at the inlet of the storage gallery and along the length of the system to allow maintenance access and observation of any potential sediment accumulation.

There are multiple systems available designed to provide storage for underground systems. Two of them are StormCapture system developed by OldCastle (Figure 22), and the StormTrap system (Figure 23).

Source: www.oldcastlestormwater.com Source: www.oldcastlestormwater.com

Figure 22. StormCapture System.

Source: www.stormtrap.com Source: City of Los Angeles

Figure 23. Typicall StormTrap System.

Utilizing the low flow diversion pump to divert flow into the BMP will allow some flexibility in the configuration and depth of the BMP allowing the underground storage gallery to be close to the surface (approximately two feet below ground surface). This will provide approximately 5 feet of clearance from the groundwater table. Figure 24 shows the relative configuration of the diversion and underground storage gallery. Observation ports and cleanouts are recommended for the purpose of maintenance.

Figure 24. BMP configuration for Alternative 1.

5.2. Pre-Pumping Alternative 2

For alternative 2, the conceptual configuration of the BMPs providing the optimum level of treatment is intended to divert and treat water flowing from the street and surrounding parcels. The designation of each street in the area is shown in Table 8 (details of original street design in Bureau of Engineering ”D” plans, D-1182, D-1184, and D-1186, are provided in Appendix D). Bike lanes are proposed for this area in the 2010 Bicycle Plan (LDCP 2010). BMPs proposed are intended to fit within the typical widths for the designation and the proposed bike lanes and should be coordinated with proposed plans for the area. Runoff from various streets and surrounding parcels within the SWS 1173 drainage area should be treated with a combination of permeable pavement and bioretention areas in accordance with LA Standard Plan S-481 or S-484. The depth of engineered soil layer, storage layer and ponding zone of the bioretention cells should be 2’, 2’-9”, and 2’-6” respectively. The depth of paving surface, and storage layer of the permeable pavement should be also 1”, and 2’-9” respectively. These BMPs can be implemented in a variety of places, such as permeable pavement on protected bicycle lanes and street parking lanes and bioretention alongside permeable pavement areas or on landscape areas. Current conditions are shown in Figure 25.. Example BMP configurations are shown in Figure 26 and Figure 27. Treating the 85th percentile runoff volume by these BMPs would significantly reduce the amount of time that the main pumps have to operate by approximately 70%.

Table 8. Street Classification.

Street	Classification	Typical ROW Width
Main Street	Secondary Highway	90 feet
Windward Avenue	Collector Street	64 feet
Riviera Avenue	Local Street	60 feet
Grand Blvd	Local Street	60 feet
Venice Way	Secondary Highway	90 feet
Market Street	Local Street	60 feet

Figure 25. Existing Main Street conditions.

Figure 26. Conceptual rendering showing protected bike lane with permeable pavement and bioretention.

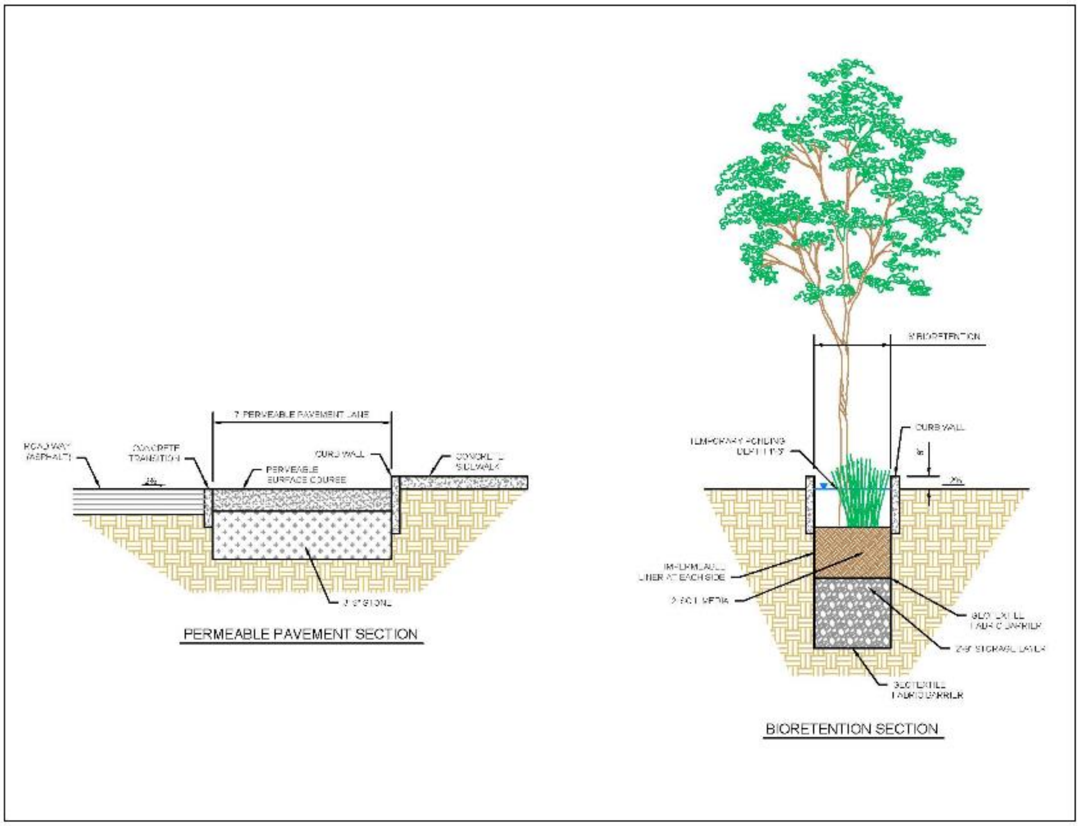

Figure 27. Expected cross section for Alternative 2.

The BMPs recommended in the Alternative 2 Pre Pumping should be designed to meet the following specifications and should comply with LA Standard Plan S-480 (Green Streets):

- Bioretention Areas
    - Ponding depth should be maintained at a minimum of 18 inches.

- Infiltration rate in existing soils should be a minimum of 0.5 in/hr.
- If the infiltration rate is less than 0.5 in/hr or if the site is located adjacent to a building foundation or in a liquefaction zone, underdrains and an engineered soil media should be installed. Bioretention soil media should have a minimum depth of 5 feet and should meet the following criteria:
  - Soil media consists of 85 percent washed course sand, 10 percent fines (range: 8–12 percent, and 5 percent organic matter.
  - The sand portion should consist of concrete sand (passing a one-quarter-inch sieve). Mortar sand (passing a one-eighth-inch sieve) is acceptable as long as it is thoroughly washed to remove the fines.
  - Fines should pass a # 270 (screen size) sieve.
  - Soil media must have an appropriate amount of organic material to support plant growth. Organic matter is considered an additive to help vegetation establish and contributes to sorption of pollutants but should generally be minimized (5 percent). Organic materials will oxidize over time, causing an increase in ponding that could adversely affect the performance of the bioretention area. Organic material should consist of aged bark fines, or similar organic material. Organic material should not consist of manure or animal compost. Newspaper mulch has been shown to be an acceptable additive.
  - pH should be between 6–8, cation exchange capacity (CEC) should be greater than 5 milliequivalent (meq)/100 g soil.
  - High levels of phosphorus in the media have been identified as the main cause of bioretention areas exporting nutrients. All bioretention media should be analyzed for background levels of nutrients. Total phosphorus should not exceed 15 ppm.
- Bioretention areas should be lined on the sides with a 30 mil liner to protect the surrounding infrastructure.
- PVC liners used for the lining of bioretention should meet the requirements of ASTM D-7176. The PVC liner should resist ultraviolet and shall be sufficiently flexible to cover and closely conform to 90 degree edges and corners of the filter bed excavation at ambient temperatures as low as 45 degrees Fahrenheit without application of heat. A suitable geotextile fabric shall be placed on the top and bottom of the membrane for puncture protection.
- All geotextile shall comply with the following:

Property	Test Reference	Media Barrier
Grab Strength, lbs (N), Min.	ASTM D-4632	90 (400)
Elongation, Minimum (at peak load) %, Max.	ASTM D-4632	50
Puncture Strength, lbs (N), Min.	ASTM D-3787	65 (290)
Permittivity, Sec., Min.	ASTM D-4491	2.5
Burst Strength, psi (kPa), Min.	ASTM D-3786	225 (1550)
Toughness, lbs (N), Min.	% Elongation x Grab Strength	5500 (24500)
Ultraviolet Resistance % Strength Retained @ 500 Weatherometer Hours	ASTM D-D4355	70
Apparent Opening Size, US Sieve # (mm)	ASTM D-4751	70 (0.210)
Flow Rate, Gal/min/ft^2 (L/min/m^2)	ASTM D-4491	175 (7130)
Trapezoid Tear, lbs (N)	ASTM D-4533	45 (200)

    - A minimum 5 feet of redial clearance between the BMP and any light pole or utility must be provided
    - A minimum of 48 inches wide sidewalk access must be approved at each end of the BMPs from the sidewalk to the street curb.
- Permeable Pavement
    - Bedding material should be a 1- to 2-inch layer of washed no. 8 or 9 stone. It must be completely free of fines.
    - The structural layer below the permeable pavement must have a porosity of 40 percent and should extend to a depth of 3.75 feet below the paver surface. A washed no. 57 stone at a depth of at least 6 inches is recommended as a choker course overlaying no. 2 stone.
    - Installation must have a slope of less than 0.5 percent unless internal check dams are incorporated.
    - Permeable pavement should be lined on the sides with a 30 mil liner to protect the surrounding infrastructure. If geotechnical analyses suggest that infiltration should be restricted, the entire system should be lined and an underdrain installed.
    - PVC liners used for the lining of permeable pavement should meet the requirements of ASTM D-7176. The PVC liner should resist ultraviolet and shall be sufficiently flexible to cover and closely conform to 90 degree edges and corners of the filter bed excavation at ambient temperatures as low as 45 degrees Fahrenheit without application of heat. A suitable geotextile fabric shall be placed on the top and bottom of the membrane for puncture protection.

5.2.1. Design Details and Drawing

A photo log, conceptual plans, and cross-sectional details are provided in Appendix A. Example product details along with a list of certified professionals qualified to install pervious concrete and concrete pavers is included in Appendix E.

6. Plant Selection

For the BMPs to function properly for stormwater treatment and blend into the landscape, vegetation selection is crucial. Appropriate vegetation will have the following characteristics:

1. Plant materials must be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 10 to 48 hours.
2. It is recommended that a minimum of three shrubs and three herbaceous groundcover species be incorporated to protect against facility failure from disease and insect infestations of a single species. To match current site landscaping, only one tree has been recommended.
3. Native plant species or hardy cultivars that are not invasive and do not require chemical inputs are recommended to be used to the maximum extent practicable.

A selection of recommended plant species, along with additional details including the recommended landscape position, size at maturity and light requirements, is provided in Table 9 based on the City of Los Angeles' Urban Forestry Division Street Tree Selection Guide (City of Los Angeles Urban Forestry Division 2011) and landscape architect recommendations.

Table 9. Recommended plant list.

Trees		**Los Angeles native - LA** California native - CA Nonnative– X	**Landscape position:** 1 - Low[a], 2 - Mid[b],3 - High[c]	**Mature size** (height x width)	**Irrigation demands:** High - H ▪ Moderate - M Low - L ▪ Rainfall Only - N	**Light requirements** Sun - SU ▪ Shade - SH Part Shade - PS Sun or Shade - SS	**Season** Evergreen - E, Deciduous - D Semi-Evergreen – SE
***Cercisoccidentalis*[d]**	**Western redbud**	**LA**	**1**	**10-18' x 10-18'**	**M**	**SU, PS**	**D**
***Chilopsislinearis*[d]**	**Desert willow**	**LA**	**1**	**15-30' x 10-20'**	**L-M**	**SU**	**D**
Umbellulariacalifornica	California bay	LA	1	20-25' x 20-25'	L-H	SU, PS, SH	E
Shrubs							
Baccharispilularis 'Pigeon Point'	Dwarf coyote bush	LA	3	1-2' x 6'	L-M	SU	E
Rhamnuscalifornica 'Little Sur'	Dwarf California coffeeberry	LA	2	3-4' x 3'	N-M	SU, PS	E
Heteromelesarbutifolia	Toyon	LA	3	6-10' x 6-10'	M	SU, PS	E
***Baccharissalicifolia*[d]**	**Mulefat**	**LA**	**1**	**4-10'x8'**	**M-H**	**SU, PS, SH**	**SE**
***Rosa californica*[d]**	**California rose**	**LA**	**1**	**3-6' x 6'**	**M-H**	**SU, PS, SH**	**SE**
Grasses and grass-like plants							
***Elymusglaucus*[d]**	**Blue wild rye**	**LA**	**1**	**2-4' x 5'**	**L-M**	**SU, PS**	**SE**
***Muhlenbergiarigens*[d]**	**Deer grass**	**LA**	**1**	**2-4' x 3-4'**	**L**	**SU**	**E**
***Juncuspatens*[d]**	**California gray rush**	**CA**	**1**	**2' x 2'**	**L-H**	**SU, PS**	**E**

Notes

The Landscape position is the lowest area recommended for each species. Plants in areas 1 and 2 might also be appropriate for higher locations. When specifying plants, availability should be confirmed by local nurseries. Some species might need to be contract-grown, and it might be necessary for the contractor to contact the nursery well before planting because some species might not be available on short notice.

[a] Landscape Position 1 (Low): These areas experience seasonal flooding. Seasonal flooding for bioretention areas is typically 9 inches deep, for up to 72 hours (the design infiltration period for a bioretention area). If parts of the bioretention area are to be inundated for longer durations or greater depth, the designer should develop a plant palette with longer term flooding in mind. Several of the species listed as tolerant of seasonal flooding might be appropriate, but the acceptability of each species considered should be researched and evaluated case by case.

[b] Landscape Position 2 (Mid): These areas are low but are not expected to flood. However, they are likely to have saturated soils for extended periods.

[c] Landscape Position 3 (High): These areas are generally on well-drained slopes adjacent to stormwater BMPs. Soils typically dry out between storm events.

[d] **Bolded species** have been observed in the city and are known to be suitable for the recommended landscape position.

7. Green Infrastructure Operations and Maintenance

Maintenance of stormwater BMPs should be incorporated into existing routine maintenance activities. Permeable pavement should be swept during the existing monthly street sweeping schedule and City of LA Bureau of Street Services maintenance personnel should be trained to maintain stormwater BMPs located in the public right-of-way. Maintenance activities for the BMPs should be focused on the major system components, especially landscaped areas. Landscaped components should blend over time through plant and root growth, organic decomposition, and they should develop a natural soil horizon. The biological and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance.

Irrigation might be needed, especially during plant establishment or in periods of extended drought. Irrigation frequency will depend on the season and type of vegetation. Drought tolerant plants require less irrigation than other plants.

Table 10, Table 11, and Table 12 outline the required maintenance tasks, their associated frequency, and notes to expand on the requirements of each task based on recommendations from researchers in the green infrastructure field.

Table 10. Inspection and maintenance tasks for underground storage galleries.

Task	Frequency	Maintenance Notes
Dry season inspection	One time per year	Inspect once during the dry season to ensure volume capacity. Clean if required.
Wet season inspection	Monthly during wet season	Monthly during the wet season to ensure volume capacity. Inspect and confirm level of silt and sediment.
Vault cleaning	Dry season – 1 time Wet season – 1 times	Dry season cleaning to happen just before the start of the wet season.
Valve maintenance	As needed	

Table 11. Bioretention operations and maintenance considerations.

Task	Frequency	Maintenance notes
Monitor infiltration and drainage	1 time/year	Inspect drainage time (12–24 hours). Might have to determine the infiltration rate (every 2–3 years). Turning over or replacing the media (top 2–3 inches) might be necessary to improve infiltration (at least 0.5 in/hr).
Pruning	1 time/year	Nutrients in runoff often cause bioretention vegetation to flourish.
Mulching	1 time/year	Recommend maintaining 1-inch to 3-inch uniform mulch layer.
Mulch removal	1 time/3–4 years	Biodegraded mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	1 time/2–3 days for first 1–2 months; sporadically after establishment	If drought conditions exist, watering after the initial year might be required.
Soil amendments	1 time initially	One-time spot soil amendments for first year vegetation.
Remove and replace dead plants	1 time/year	It is common for 10% of plants to die during first year. Survival rates tend to increase with time.
Inlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for sediment accumulation to ensure that flow into the retention area is as designed. Remove any accumulated sediment.
Outlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for erosion at the outlet and remove any accumulated mulch or sediment.
Miscellaneous upkeep	2 times/year	Tasks include trash collection, plant health, spot weeding, and removing mulch from the overflow device.

Table 12. Permeable pavement operations and maintenance considerations.

Task	Frequency	Maintenance notes
Impervious to pervious interface	Once after first rain of the season, then monthly during the rainy season	Check for sediment accumulation to ensure that flow onto the permeable pavement is not restricted. Remove any accumulated sediment. Stabilize any exposed soil.
Street sweeping	Weekly during routine mechanical sweeping and twice a year with vacuum sweeper (or as needed)	Portions of pavement should be swept with a vacuum street sweeper at least twice per year or as needed to maintain infiltration rates.
Replace void fill materials (applies to pervious pavers only)	1-2 times per year (and after any vacuum truck sweeping)	Fill materials will need to be replaced after each sweeping and as needed to keep interstitial bedding material even with the paver surface.
Miscellaneous upkeep	4 times per year or as needed for aesthetics	Tasks include trash collection, sweeping, and spot weeding. Ensure landscaping materials (soil, mulch, grass clippings, etc.) are not stockpiled on permeable pavement surfaces.

8. Cost Estimate

The estimated cost of the pump station upgrades are included in Table 13 and the costs of implementing each of the alternative described above are included in Table 14 through Table 16. This cost estimate is a guide only and should be updated at the time of preliminary design to account for fluctuation in cost of material, labor, or components, or unforeseen contingencies.

Table 13. Pump Plant Upgrade Costs.

Item No.	Description	Estimated Qty	Unit	Unit Cost	Total
1	Mobilization and Demobilization	1	LS	$365,000	$365,000
2	Demolition/Removal of Existing Pumps and Discharge Piping	1	LS	$30,000	$30,000
3	Furnish and Install 5,100 GPM Submersible Pump (For BMP)	2	EA	$60,000	$120,000
4	Furnish and Install 36,600 GPM Dry Pit Submersible Pump (For 50 year Storm)	3	EA	$450,000	$1,350,000
5	Furnish and Install 16-inch Discharge Piping to BMP	1300	LF	$250	$325,000
6	Furnish and Install 30-inch Discharge Piping to Surge Chamber	1	LS	$20,000	$20,000
7	Furnish and Install 30-inch Check Valve on Pump Discharge Piping	3	EA	$50,000	$150,000
8	Furnish and Install 40-inch Pump Suction Piping	1	LS	$20,000	$20,000
9	Furnish and Install 40-inch Plug Valves on Suction Piping	3	EA	$50,000	$150,000
10	Furnish and Install Level Control	1	LS	$10,000	$10,000
11	Replace Ventilation System	1	LS	$30,000	$30,000
12	Sandblast and Paint Interior Walls and Piping	1	LS	$50,000	$50,000
13	Structural Upgrades to Building	1	LS	$600,000	$600,000
14	New Portable Diesel Generator	1	LS	$800,000	$800,000
15	Upgrade the Interior Lighting	1	LS	$10,000	$10,000
16	Electrical Upgrades	1	LS	$250,000	$250,000
17	Furnish and Install SCADA/I&C	1	LS	$100,000	$100,000
18	Replace Potable Water System	1	LS	$5,000	$5,000
Subtotal Cost					**$4,385,000**
19	Construction contingency (25% of subtotal)				$1,100,000
Total Cost					**$5,500,000**

Table 14. Alternative 1 Scenario 1: Post-Pump Treatment 11.5 cfs Direct Pumping Cost Estimate.

Item No	Description		Unit	Unit Cost	Total
	Preparation				
1	Temporary Construction Fence	1,400	LF	$2.50	$3,500
2	Silt Fence	1,400	LF	$3.00	$4,200
	Site Preparation				
3	Excavation and Removal	15,778	CY	$45.00	$710,010
	Structures				
4	Structural Layer (washed no 57 or no 2 stone)	2,630	CY	$50.00	$131,500
5	Utility Conflicts	1	LS	$10,000	$10,000
6	Connection to Existing Wet-Well	1	LS	$350.00	$350
7	Force Main 16" DI	1,300	LF	$60.00	$78,000
	Underground Storage				
8	Fine Grading	71,002	SF	$0.72	$51,121
9	Underground Storage Gallery	10,519	CY	$378.00	$3,976,182
10	Maintenance/Observation Access to the Underground Infiltration Basin	9		$5,000.00	$45,000
11	Junction Structure	1		$8,000.00	$8,000
	Irrigation				
12	Stormwater lift station/wet well (200 gpm)	1	EA	$200,000	$200,000
13	Water treatment system (UV)	1	EA	$300,000	$300,000
14	Landscaping	71,002	SF	$2.00	$142,004
15	Electrical/control integration	1	EA	$3,000.00	$3,000
Construction Subtotal					**$5,662,870**
16	Bond (5% of subtotal)				$283,140
17	Mobilization (10% of subtotal)				$566,290
18	Construction contingency (20% of subtotal)				$1,132,570
Construction Total					**$7,644,870**
19	Design (10% of Construction Total)				$764,487
Total Cost					**$8,409,360**

Table 15. Alternative 1 Scenario 2: Post-Pump Treatment 11.5 cfs Direct Pumping Cost Estimate.

Item No	Description		Unit	Unit Cost	Total
	Preparation				
1	Temporary Construction Fence	1,400	LF	$2.50	$3,500
2	Silt Fence	1,400	LF	$3.00	$4,200
	Site Preparation				
3	Excavation and Removal	15,778	CY	$45.00	$710,010
	Structures				
4	Structural Layer (washed no 57 or no 2 stone)	2,630	CY	$50.00	$131,500
5	Utility Conflicts	1	LS	$10,000.00	$10,000
6	Connection to Existing Wet-Well	1	LS	$350.00	$350
1	Force Main 16" DI	1,300	LF	$60.00	$78,000
	Junction Structure	1		$8,000.00	$8,000
	System Control	1	EA	$4,188	$4,188
	Force Main 12" DI	1,000	LF	$60.00	$60,000
	Underground Storage				
8	Fine Grading	71,002	SF	$0.72	$51,121
9	Underground Storage Gallery	10,519	CY	$378.00	$3,976,182
10	Maintenance/Observation Access to the Underground Infiltration Basin	9		$5,000.00	$45,000
Construction Subtotal					**$5,082,050**
11	Bond (5% of subtotal)				$254,100
12	Mobilization (10% of subtotal)				$508,210
13	Construction contingency (20% of subtotal)				$1,016,410
Construction Total					**$6,860,770**
14	Design (10% of Construction Total)				$686,077
Total Cost					**$7,546,850**

Table 16. Alternative 2: Pre-Pump Green Infrastructure Treatment cost estimate.

Item No	Description	Estimated Qty	Unit	Unit Cost	Total
	Preparation				
1	Traffic Control	120	Day	$1,000.00	$120,000
2	Temporary Construction Fence	44,818	LF	$2.50	$112,045
3	Silt Fence	44,818	LF	$3.00	$134,454
	Site Preparation				
4	Curb and Gutter Removal	8,000	LF	$3.30	$26,400
5	Saw Cut Existing Asphalt	100,800	LF	$5.12	$73,728
6	Asphalt Removal	8,400	SF	$3.36	$338,688
7	Excavation and Removal	17,704	CY	$45.00	$796,680
	Structures				
8	Curb and Gutter	8,000	LF	$22.00	$176,000
9	Permeable Pavement	100,800	SF	$12.00	$1,209,600
10	Structural Layer (washed no 57 or no 2 stone)	10,888	CY	$50.00	$544,400
11	Concrete Transition Strip	14,400	LF	$4.00	$57,600
12	Utility Conflicts	1	LS	$80,000.00	$80,000
	Bioretention				
13	Fine Grading	16,000	SF	$0.72	$11,520
14	Drainage Stone (washed no 57 stone)	1,629	CY	$50.00	$81,450
15	Hydraulic Restriction Layer (30 mil liner)	32,008	LF	$0.60	$19,205
16	Soil Media Barrier (washed sand)	99	CY	$40.00	$3,960
17	Soil Media Barrier (choking stone, washed no 8)	99	CY	$45.00	$4,455
18	Mortared Cobble Energy Dissipater	400	SF	$2.25	$900
19	Curb Opening with Grate	80	LS	$350.00	$28,000
	Landscaping				
20	Soil Media	1,185	CY	$45.00	$53,325
21	Vegetation	16,000	SF	$4.00	$64,000
22	Mulch	148	CY	$55.00	$8,140
	Construction Subtotal				$3,944,550
23	Bond (5% of subtotal)				$197,230
24	Mobilization (10% of subtotal)				$394,460
25	Construction contingency (20% of subtotal)				$788,910
	Construction Total				$5,325,150
26	Design (10% of Construction Total)				$532,515
	Total Cost				**$5,857,670**

9. Additional Considerations

9.1. Monitoring Plan

Performance monitoring of stormwater BMPs is an important component of a BMP implementation program. Monitoring provides the BMP’s designer a mechanism to validate certain design assumptions and to quantify compliance with pollutant-removal performance objectives. Specific monitoring objectives should be considered early in the design process to ensure that BMPs are adequately configured for monitoring. Detailed monitoring guidance is provided by the EPA (USEPA 2012). The instrumentation and monitoring configuration will vary from site to site, but a monitoring approach using an inlet/outlet sample location setup is recommended for this site.

9.1.1. Monitoring Hydrology

An inlet/outlet sampling setup is suggested as the most effective monitoring approach to quantify flow and volume in stormwater BMPs. The runoff source and type of BMP will dictate the configuration of inflow monitoring. A weir or flume (Figure 28) is typically installed at the inlet of a BMP. Outflow can be monitored using similar techniques as inflow by installing a weir or ADV at the point of overflow/outfall (Figure 29). Outlet samples can also be collected from systems configured with underdrains utilizing specially designed v-notch weirs such as the one shown in Figure 30. Figure 31 shows an example of potential monitoring points.

Figure 28. Inlet curb cut with an H-flume.

Figure 29. Outlet of a roadside bioretention equipped with a V-notch weir for flow monitoring.

Figure 30. Typical weir for monitoring flow in an underdrain.

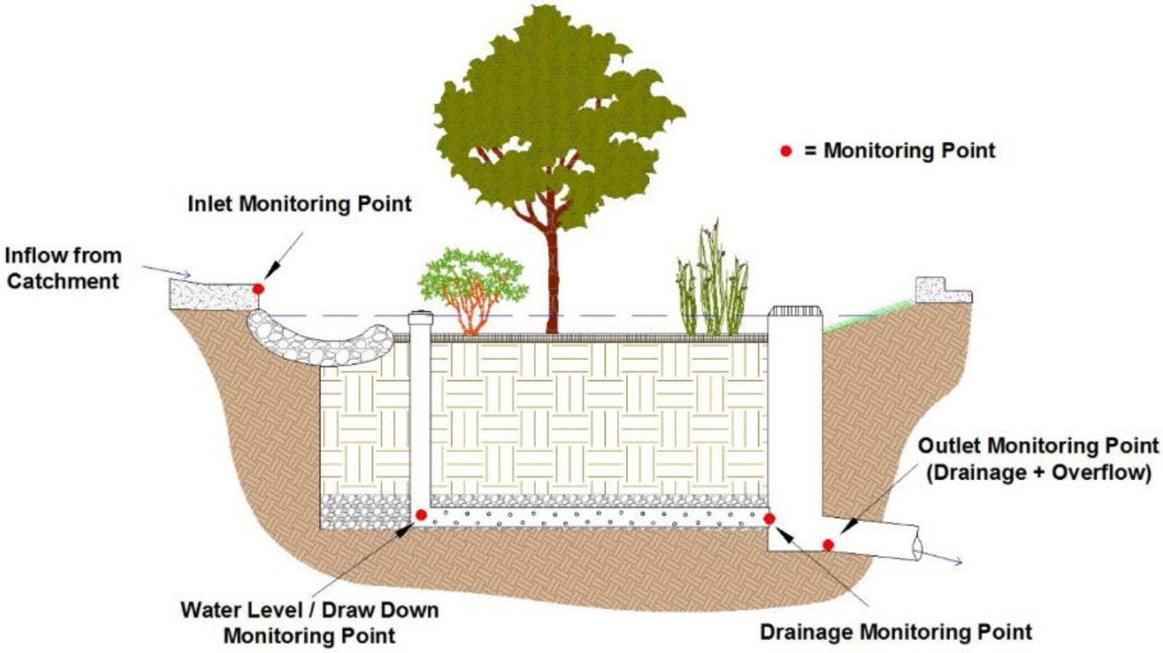

Figure 31. Typical monitoring points.

In addition to monitoring inflow and outflow, rainfall should be recorded on-site. Rainfall data can also be used to estimate inflow to BMPs that receive runoff only by sheet flow or direct rainfall (e.g., permeable pavement or green roofs). The type of rain gauge depends on monitoring goals and frequency of site visits. An automatic recording rain gauge (e.g., tipping bucket rain gauge), used to measure rainfall intensity and depth, is often paired with a manual rain gauge for data validation (Figure 32). For more advanced monitoring, weather stations can be installed to simultaneously monitor relative humidity, air temperature, solar radiation, and wind speed; these parameters can be used to estimate evapotranspiration.

Water level (and drawdown rate) is another useful hydrologic parameter. Depending on project goals, perforated wells or piezometers can be installed to measure infiltration rate and drainage. Care should be taken when installing wells to ensure that runoff cannot enter the well at the surface and *short circuit* directly to subsurface layers; short circuiting can result in the discharge of untreated runoff that has bypassed the intended treatment mechanisms. It might be useful to pair soil moisture sensors with water level loggers in instances where highly detailed monitoring performance data are required (such as for calibration and validation of models).

Figure 32. Example of manual (left) and tipping bucket (right) rain gauges.

9.1.2. Monitoring Water Quality

Although hydrologic monitoring can occur as a standalone practice, water quality data must be paired with flow data to calculate meaningful results. Flow-weighted automatic sampling is the recommended method for collecting samples that are representative of the runoff event and can be used to calculate pollutant loads (total mass of pollutants entering and leaving the system). Simply measuring the reduction in pollutant concentrations (mass per unit volume of water) from inlet to outlet can provide misleading results because it does not account for load reductions associated with infiltration, evapotranspiration, and storage.

Influent water quality samples are typically collected just upstream of the inlet monitoring device (e.g., weir box, flume) just before the runoff enters the BMP. The downstream sampler should be at the outlet control device just before the overflow enters the existing storm drain infrastructure. A strainer is usually installed at collecting end of the sampler tubing to prevent large debris and solids from entering and clogging the sampler. Automatic samplers should be programmed to collect single-event, composite samples according to the expected range of storm flows. Depending on the power requirements, a solar panel or backup power supply might be needed.

In addition to collecting composite samples, some water quality constituents can be monitored in real-time. Some examples include dissolved oxygen, turbidity, conductivity, and temperature.

9.1.3. Sample Collection and Handling

Quality assurance and quality control protocols for sample collection are necessary to ensure that samples are representative and reliable. The entire sample collection and delivery procedure should be well documented, including chain of custody (list of personnel handling water quality samples) and notes regarding site condition, time of sampling, and rainfall depth in the manual rain gauge. Holding times for water quality samples vary by constituent, but all samples should be collected, placed on ice, and delivered to the laboratory as soon as possible (typically 6 to 24 hours) after a rainfall event. Some water quality constituents require special treatment upon collection, such as acidification, to preserve the sample for delivery. Appropriate health and safety protocols should always be followed when on-site, including using personal protective equipment such as safety vests, nitrile gloves, and goggles.

9.2. Public Education and Outreach

The green infrastructure BMPs will provide learning opportunities for community residents who frequent the area. A demonstration project will provide an example of how BMPs can be implemented in existing infrastructure and will serve as a consistent reminder of their impact on stormwater quality. When the project is completed, educational signage describing the BMPs and indicating the BMPs role in maintaining healthy water quality should remain on-site.

9.3. Future Retrofit Opportunities

The 127.7 acre drainage area of SWS 1173 was the focus of these wet weather treatment conceptual designs because of the required upgrade of Pump Plant 647. These results can be used to guide future stormwater retrofit projects in the area.

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Appendix A - Fact Sheets

Best Management Practice Conceptual Designs for Upper Los Angeles River

CONCEPTUAL PLAN–Appendix A.1

SITE: Pumping Plant No. 647

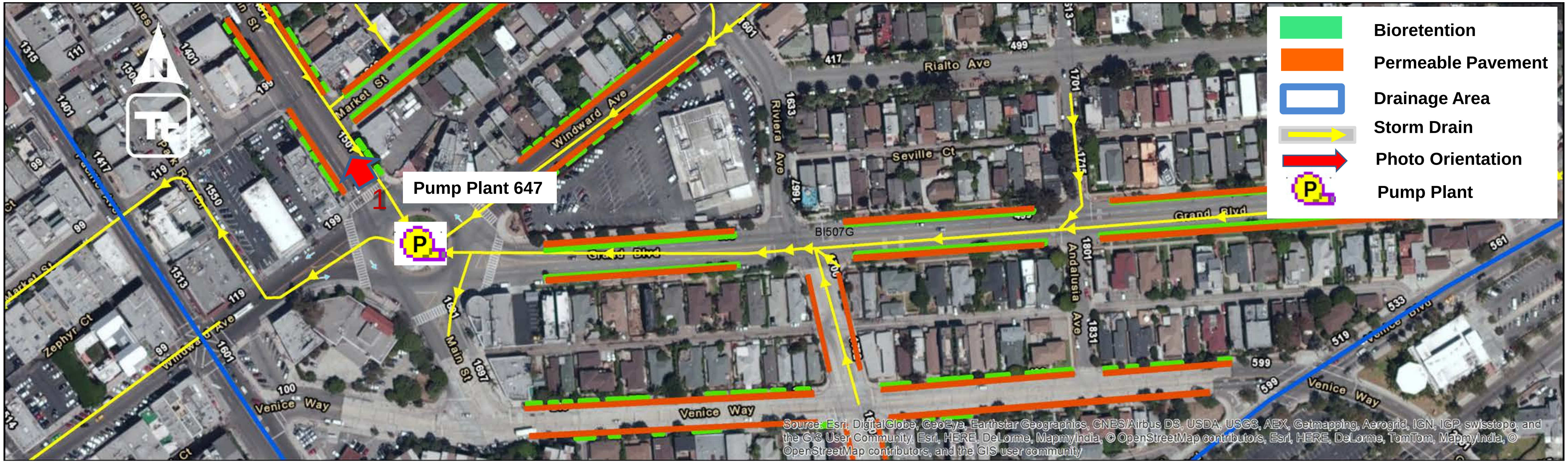
Site Location			
Landowner	City of Los Angeles	Latitude	33°59'16.72"N
Date of Field Visit	03/05/2015	Longitude	118°28'15.55"W
Field Visit Personnel	TJ, LT, RM	Street Address	1600 Main St Venice, CA 90291
Major Watershed	Santa Monica Bay		

Existing Site Description: The conceptual design centers around the existing Pump Plant 647 near the intersection of Main Street and Windward Avenue. The pump plant is intended to provide flood protection to an area roughly bounded by Electric Avenue, Venice Boulevard, Mildred Avenue, and Pacific Avenue in the Venice area of the City. Storm water flows from underground storm drain pipes in Grand Avenue, Windward Avenue, and Main Street are pumped up to a surge box/outlet arch-culvert storm drain that flows to the west.

Watershed Characteristics	
Drainage Area, acres	127.7
Hydrologic Soil Group	B
Total Impervious, %	75
Design Storm Event, in	85th

Retrofit Characteristics		
Proposed Retrofit		Green Street
BMP footprint, ft^2	Bioretention Permeable Pavement	100,800 16,000
Ponding Depth, ft	Bioretention Permeable Pavement	1.5 0.01
Media Depth, ft	Bioretention Permeable Pavement	3.75 4.75

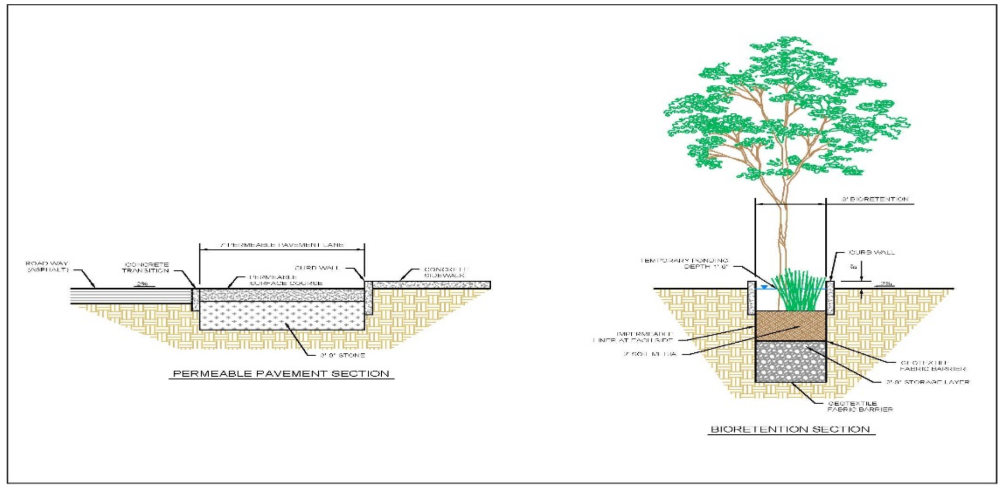
Proposed Retrofit Description: : The proposed retrofit would reduce flows to the pump plant by installing bioretention areas and permeable pavement in the right-of-way along multiple residential streets. Curb cuts could convey runoff to bioretention areas installed along the curb line to provide treatment. A protected bike lane will increase safety for bicyclists and pedestrians while protecting permeable pavement in the bike lane from vehicular traffic.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, Esri, HERE, DeLorme, TomTom, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Current Street View

Rendered Street Improvement



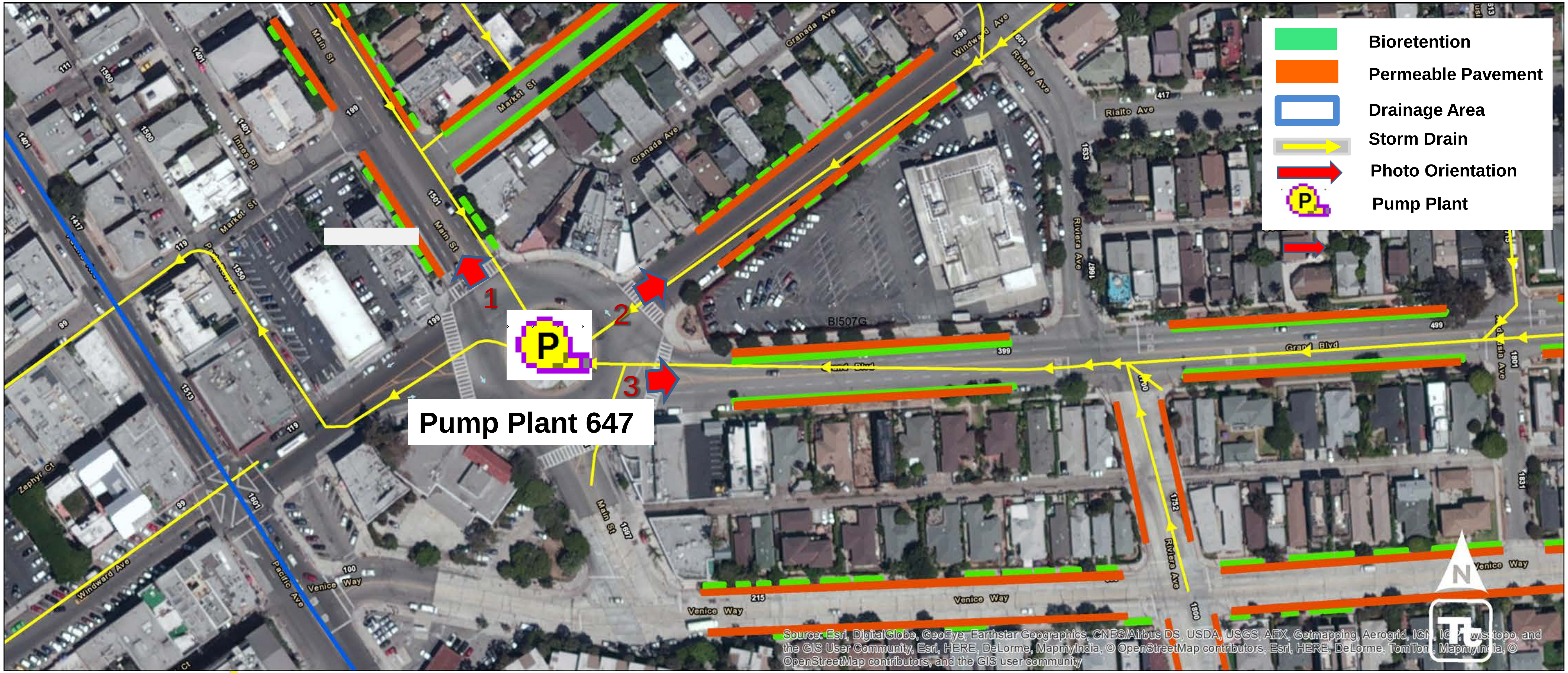
Example Cross Section

LASANITATION environment
CITY OF LOS ANGELES

Best Management Practice Conceptual Designs for Upper Los Angeles River

CONCEPTUAL PLAN–Appendix A.2

SITE: Pumping Plant No. 647



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, Esri, HERE, DeLorme, TomTom, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

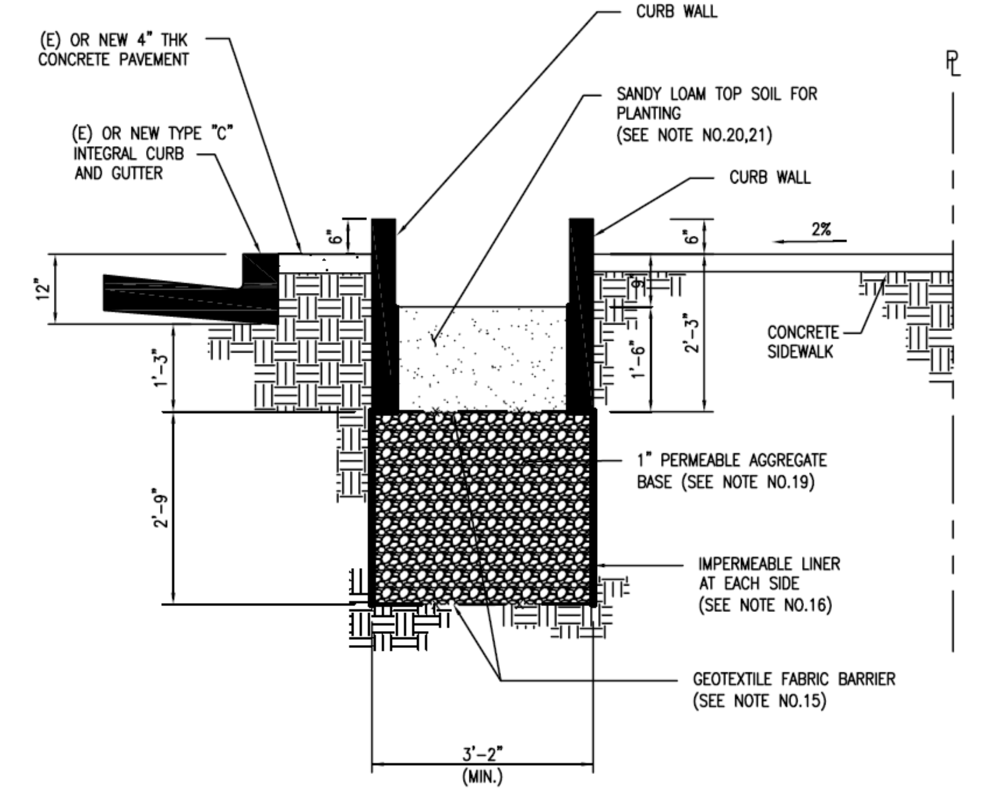
Best Management Practice Conceptual Designs for Upper Los Angeles River

CONCEPTUAL PLAN–Appendix A.3

SITE: Pumping Plant No. 647

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, A
the GIS User Community, Esri, HERE, DeLorme, TomTom, MapmyIndia, © OpenStreetMap con

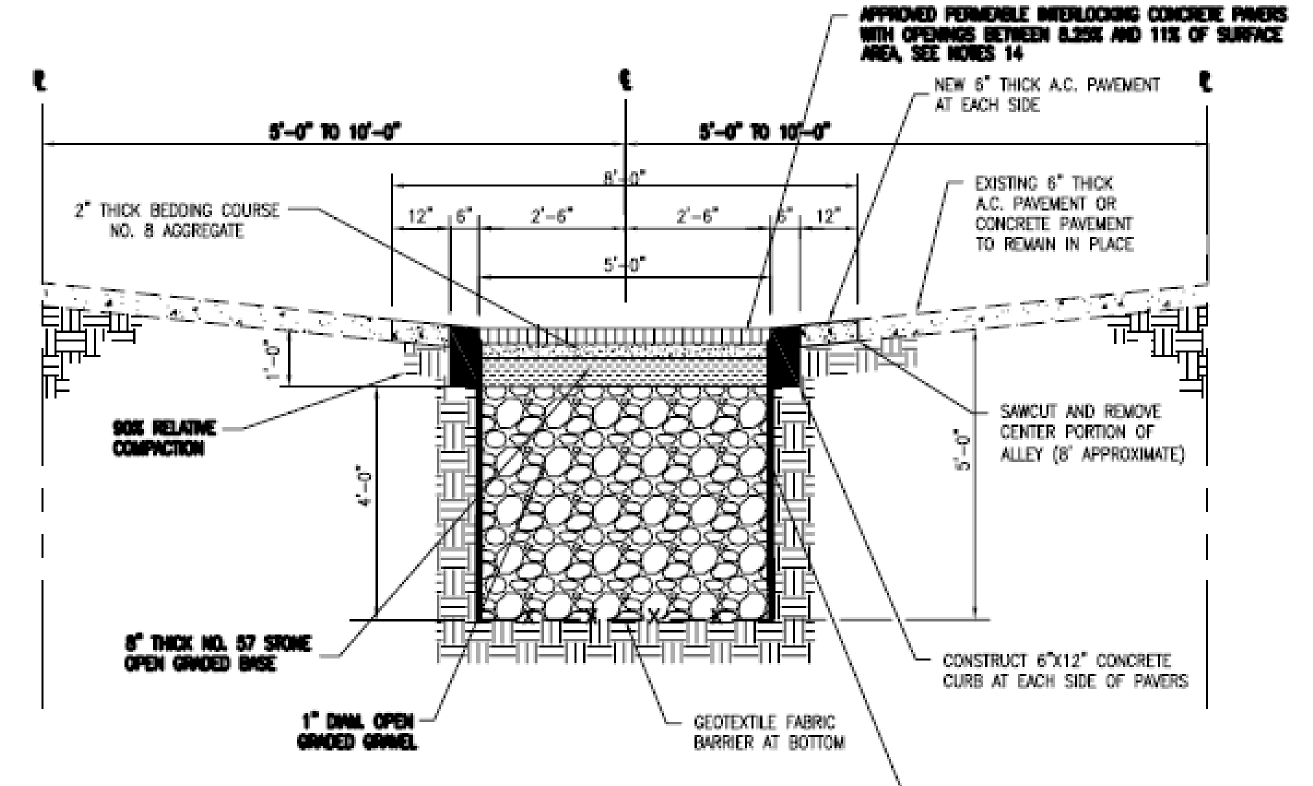
Best Management Practice Conceptual Designs for Upper Los Angeles River
CONCEPTUAL PLAN–Appendix A.4
SITE: Pumping Plant No. 647



SECTION B–B

TYPICAL SWALE SECTION

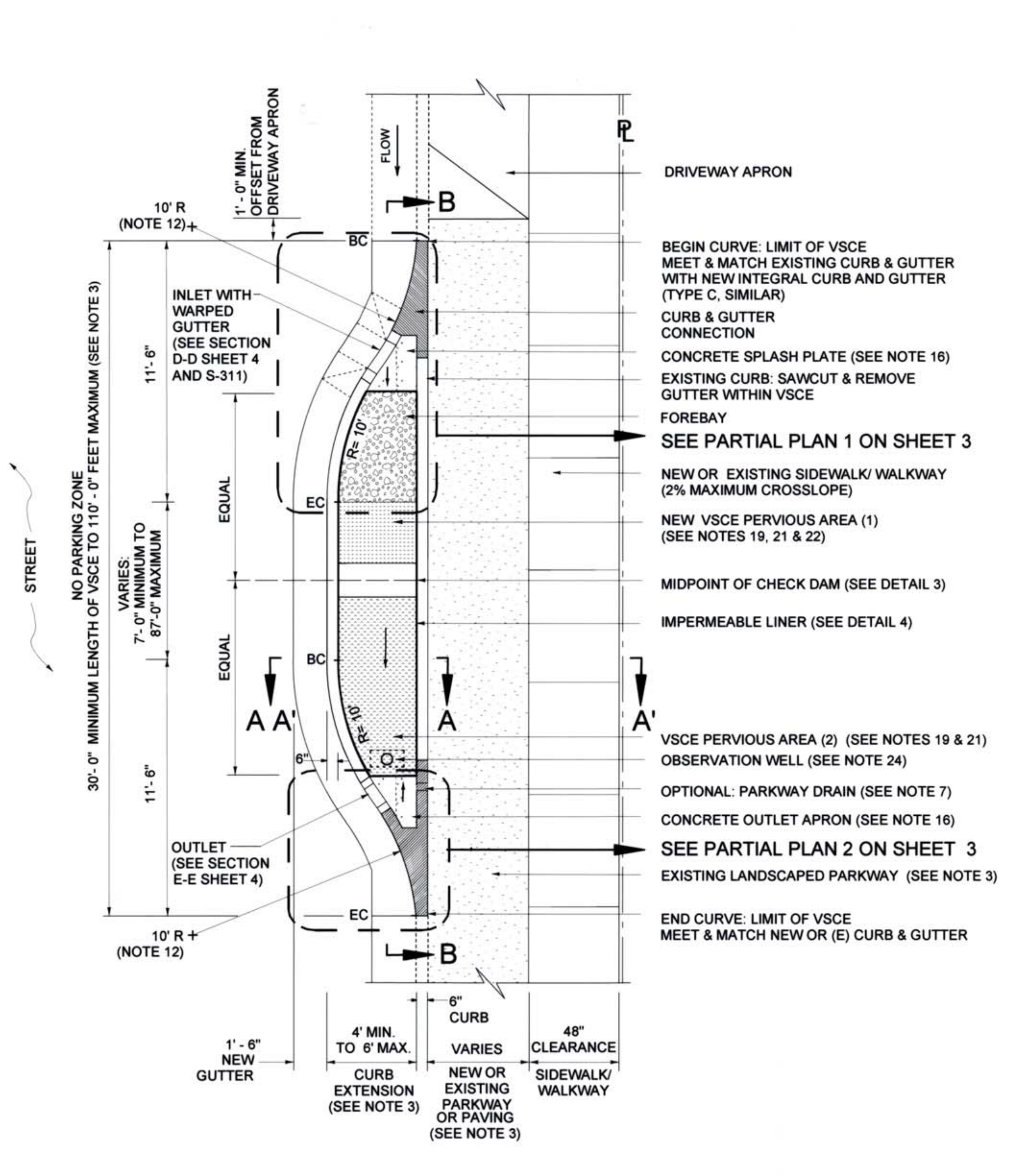
STANDARD PLAN NO.	S–481–0		SHEET 3 OF 8 SHEETS



SECTION A–A

EXISTING ALLEY

STANDARD PLAN NO.	S–485–0		SHEET 2 OF 3 SHEETS



PLAN

BUREAU OF ENGINEERING	DEPARTMENT OF PUBLIC WORKS		CITY OF LOS ANGELES	
VEGETATED STORMWATER CURB EXTENSION (VSCE)			STANDARD PLAN S–484–0	
PREPARED	SUBMITTED	APPROVED	SUPERSEDES	REFERENCES
DEBORAH DEETS, RLA 4839 BUREAU OF SANITATION ENRIQUE C. ZALDIVAR,P.E., DIRECTOR	6/28/10 JEONG PARK, S.E. DATE ENGINEER OF DESIGN BUREAU OF ENGINEERING	No. C-49446 Exp. 9/30/10		S–311 S–433 S–410 S–480 S–430 S–681
CHECKED PATRICK LEE, CE42448 BUREAU OF ENGINEERING	Kenneth R Redd 6/29/10 KEN REDD, P.E. DATE ACTING DEPUTY CITY ENGINEER	Gary Lee Moore 6-29-10 GARY LEE MOORE, P.E. DATE CITY ENGINEER	SHEET 1 OF 11 SHEETS	

CITY OF LOS ANGELES
SANITATION
DEPARTMENT OF PUBLIC WORKS

Appendix B - Hydrocalcs

Peak Flow Hydrologic Analysis

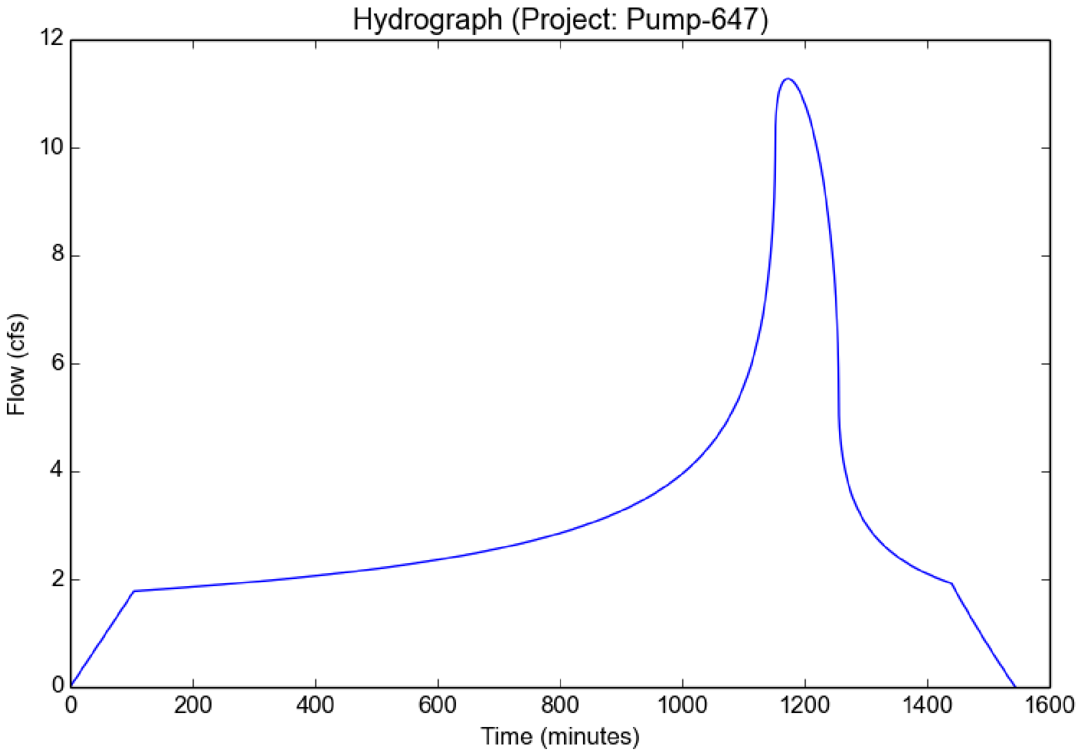
File location: W:/Projects/City of Los Angeles/2015 Conceptual Design (TOS 31)/Modeling/HydroCalc/Project - Pump-647-85th.pdf
Version: HydroCalc 0.3.1-beta

Input Parameters

Project Name	Project
Subarea ID	Pump-647
Area (ac)	127.7
Flow Path Length (ft)	3000.0
Flow Path Slope (vft/hft)	0.006
85th Percentile Rainfall Depth (in)	0.88
Percent Impervious	0.75
Soil Type	16
Design Storm Frequency	85th percentile storm
Fire Factor	0.71
LID	True

Output Results

Modeled (85th percentile storm) Rainfall Depth (in)	0.88
Peak Intensity (in/hr)	0.1261
Undeveloped Runoff Coefficient (Cu)	0.1
Developed Runoff Coefficient (Cd)	0.7
Time of Concentration (min)	104.0
Clear Peak Flow Rate (cfs)	11.2716
Burned Peak Flow Rate (cfs)	11.8333
24-Hr Clear Runoff Volume (ac-ft)	6.502
24-Hr Clear Runoff Volume (cu-ft)	283228.5742



Peak Flow Hydrologic Analysis

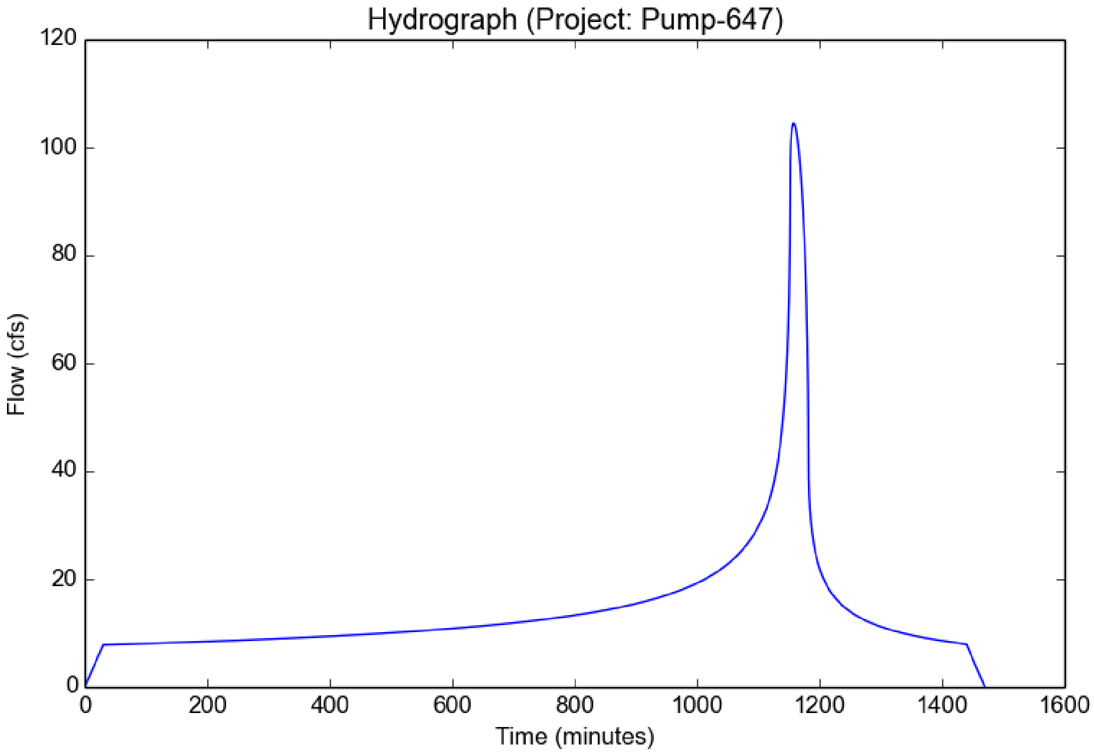
File location: W:/Projects/City of Los Angeles/2015 Conceptual Design (TOS 31)/Modeling/HydroCalc/Project - Pump-647-10yr.pdf
Version: HydroCalc 0.3.1-beta

Input Parameters

Project Name	Project
Subarea ID	Pump-647
Area (ac)	127.7
Flow Path Length (ft)	3000.0
Flow Path Slope (vft/hft)	0.006
50-yr Rainfall Depth (in)	5.5
Percent Impervious	0.75
Soil Type	16
Design Storm Frequency	10-yr
Fire Factor	0.71
LID	False

Output Results

Modeled (10-yr) Rainfall Depth (in)	3.927
Peak Intensity (in/hr)	1.0093
Undeveloped Runoff Coefficient (Cu)	0.5421
Developed Runoff Coefficient (Cd)	0.8105
Time of Concentration (min)	30.0
Clear Peak Flow Rate (cfs)	104.4712
Burned Peak Flow Rate (cfs)	110.0826
24-Hr Clear Runoff Volume (ac-ft)	29.5777
24-Hr Clear Runoff Volume (cu-ft)	1288406.3284



Peak Flow Hydrologic Analysis

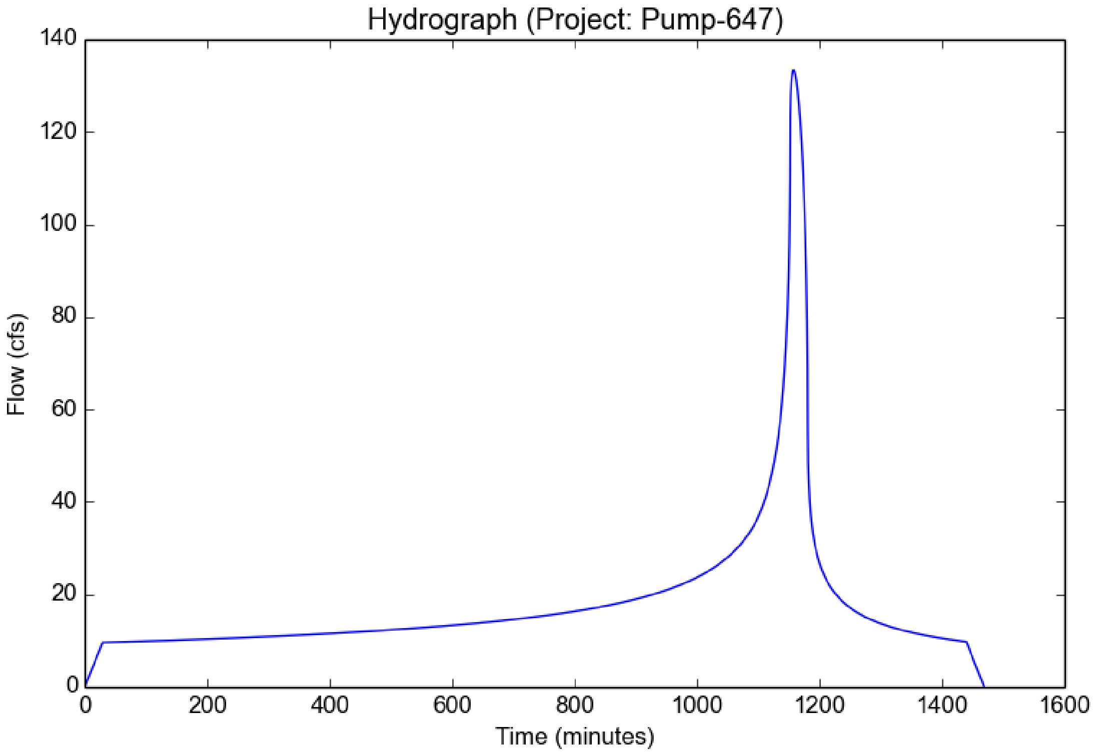
File location: W:/Projects/City of Los Angeles/2015 Conceptual Design (TOS 31)/Modeling/HydroCalc/Project - Pump-647-25yr.pdf
Version: HydroCalc 0.3.1-beta

Input Parameters

Project Name	Project
Subarea ID	Pump-647
Area (ac)	127.7
Flow Path Length (ft)	3000.0
Flow Path Slope (vft/hft)	0.006
50-yr Rainfall Depth (in)	5.5
Percent Impervious	0.75
Soil Type	16
Design Storm Frequency	25-yr
Fire Factor	0.71
LID	False

Output Results

Modeled (25-yr) Rainfall Depth (in)	4.829
Peak Intensity (in/hr)	1.2611
Undeveloped Runoff Coefficient (Cu)	0.6117
Developed Runoff Coefficient (Cd)	0.8279
Time of Concentration (min)	29.0
Clear Peak Flow Rate (cfs)	133.3328
Burned Peak Flow Rate (cfs)	139.9989
24-Hr Clear Runoff Volume (ac-ft)	36.5953
24-Hr Clear Runoff Volume (cu-ft)	1594090.0061



Peak Flow Hydrologic Analysis

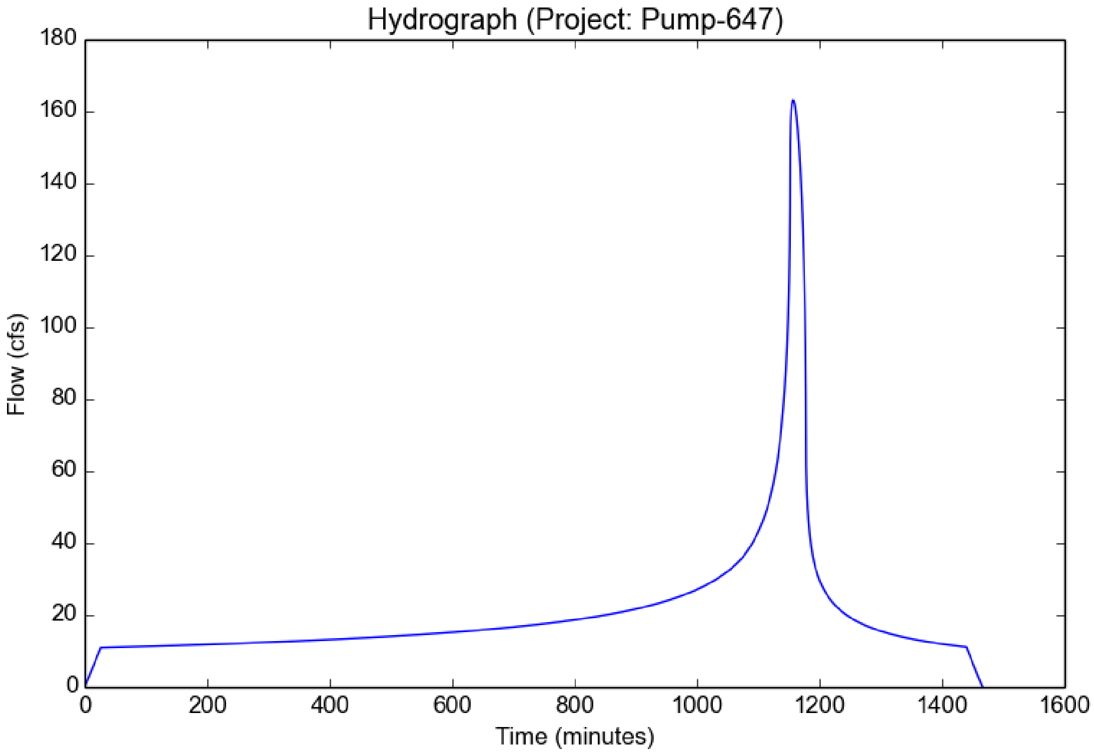
File location: W:/Projects/City of Los Angeles/2015 Conceptual Design (TOS 31)/Modeling/HydroCalc/Project - Pump-647-50yr.pdf
Version: HydroCalc 0.3.1-beta

Input Parameters

Project Name	Project
Subarea ID	Pump-647
Area (ac)	127.7
Flow Path Length (ft)	3000.0
Flow Path Slope (vft/hft)	0.006
50-yr Rainfall Depth (in)	5.5
Percent Impervious	0.75
Soil Type	16
Design Storm Frequency	50-yr
Fire Factor	0.71
LID	False

Output Results

Modeled (50-yr) Rainfall Depth (in)	5.5
Peak Intensity (in/hr)	1.512
Undeveloped Runoff Coefficient (Cu)	0.6797
Developed Runoff Coefficient (Cd)	0.8449
Time of Concentration (min)	26.0
Clear Peak Flow Rate (cfs)	163.1369
Burned Peak Flow Rate (cfs)	170.5978
24-Hr Clear Runoff Volume (ac-ft)	41.8838
24-Hr Clear Runoff Volume (cu-ft)	1824457.2622



Appendix C – Pump Calculations

CITY OF LOS ANGELES
Plant No. 647 Storm Water PS

System Curve Calculations

Objective: Determine the system curve for the Plant #647 (Venice) Storm Water PS BMP pun

Givens:
1. 85th Percentile flow is 11.3 CFS (5,072 gpm)
2. Assume 1300 lf of 16" pipe to BMP
3. Static Head is 20'

Assumptions:
1. The Hazen-Williams C-factors are assumed to be as follows:
   Aged Ductile Iron Pipe = 100
2. Minor losses are neglected within the pipeline and pump station
3. The pump suction grade line is based on the water levels in the Plant #647 wet well
   LWL = -3.06 HWL = 0.94
5. The pump discharge is pumping to the summit manhole.
   Elev = 15

Step 1 ***Calculate Pipe Friction Losses***

Hazen-Williams Equation: h_L=10.44*L(ft)*$Q^{1.85}$(gpm)/$C^{1.85}$*$D^{4.87}$(inches)

Pipe Dia (in)	Length (L.F.)	Material	C Factor (Assumed)
16	1300	DIP	100

Step 2 ***Calculate Minor Losses***

Minor Losses Equation: $h_M=Kv^2/2g$

Pipe Dia (in)	Fitting	K Values	Quantity	K Total
1	-	0	0	0
Minor losses have been neglected				**0**

CITY OF LOS ANGELES
Plant No. 647 Storm Water PS

System Curve Calculations

Step 2 ***Minor Losses (Continued)***

Pipe Dia (in)	Fitting	K Values	Quantity	K Total
1	-	0	0	0
1	-	0	0	0
Minor Losses have been neglected				**0**

Step 3 ***Determine Static Lift***

$H_{(static)}$ = Summit MH -Elev (Wet Well)

Maximum Static Lift		***Minimum Static Lift***	
Summit MH	15	Summit MH	15
Low Water Level	-3.06	High Water Level	0.94
$H_{(static-max)}$=	18.06	$H_{(static-min)}$=	14.06

CITY OF LOS ANGELES
Plant No. 647 Storm Water PS

System Curve Calculations

Step 4 ***Determine System Curve***

Q (gpm)	Friction H_L (ft)	Minor H_L (ft)	Max TDH (ft)	Min TDH (ft)	Avg TDH (ft)	Velocity in FM (ft/sec)
0	0.0	0.0	18.1	14.1	16.1	0.00
500	0.4	0.0	18.4	14.4	16.4	0.80
1000	1.3	0.0	19.4	15.4	17.4	1.60
1500	2.8	0.0	20.8	16.8	18.8	2.39
2000	4.7	0.0	22.8	18.8	20.8	3.19
2500	7.2	0.0	25.2	21.2	23.2	3.99
3000	10.0	0.0	28.1	24.1	26.1	4.79
3500	13.3	0.0	31.4	27.4	29.4	5.59
4000	17.1	0.0	35.1	31.1	33.1	6.39
4500	21.2	0.0	39.3	35.3	37.3	7.18
5000	25.8	0.0	43.9	39.9	41.9	7.98
5072	26.5	0.0	44.6	40.6	42.6	8.10
5500	30.8	0.0	48.8	44.8	46.8	8.78
6000	36.2	0.0	54.2	50.2	52.2	9.58

CITY OF LOS ANGELES
Plant No. 647 Storm Water PS

System Curve Calculations

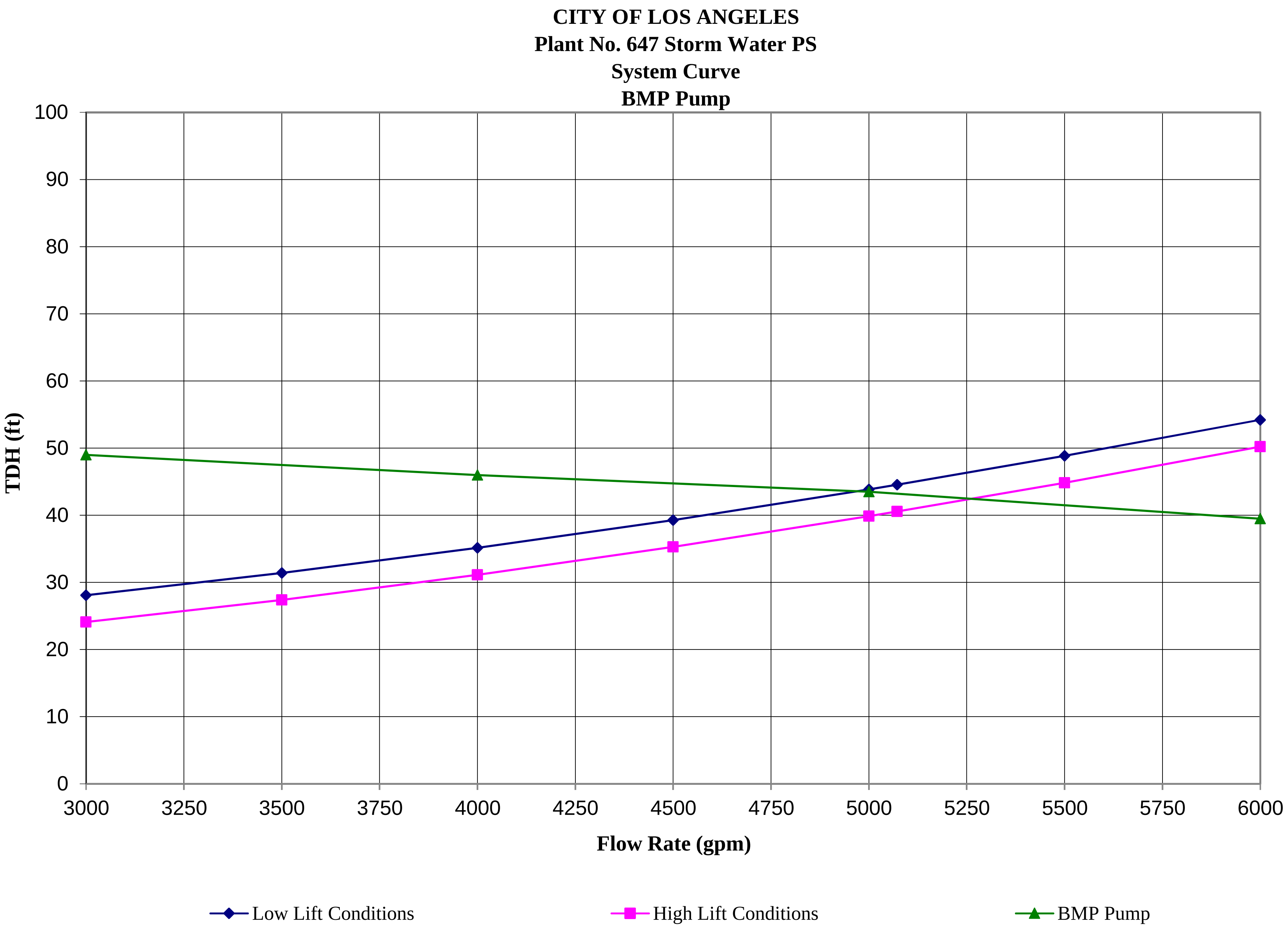
Step 5 ***New Pump Curve***

Flygt

NP 3400/736 3~1270

90 hp

Q (gpm)	TDH (ft)
1000	56
2000	53
3000	49
4000	46
5000	43.5
6000	39.5
7000	35


CITY OF LOS ANGELES
Plant No. 647 Storm Water PS
System Curve
BMP Pump
TDH (ft)
100
90
80
70
60
50
40
30
20
10
0
3000
3250
3500
3750
4000
4250
4500
4750
5000
5250
5500
5750
6000
Flow Rate (gpm)
Low Lift Conditions
High Lift Conditions
BMP Pump

CITY OF LOS ANGELES
Plant No. 647 Storm Water PS

System Curve Calculations

Objective: Determine the system curve for the Plant #647 (Venice) Storm Water PS 50 yr stor

Givens:

1. 50yr storm flow is 163.1 CFS = 73,204 gpm
2. Approximately 2500 LF to discharge point
3. High tide is at 6.67 ft

Assumptions:

1. The Hazen-Williams C-factors are assumed to be as follows:
   Aged Concrete Pipe = 100
2. Minor losses are neglected within the pipeline and pump station
3. The pump suction grade line is based on the water levels in the Plant #647 wet well
   LWL = -3.06 HWL = 0.94
5. The pump discharge is pumping to the summit manhole.
   Elev = 6.67

Step 1 *Calculate Pipe Friction Losses*

Hazen-Williams Equation: h_L=10.44*L(ft)*$Q^{1.85}$(gpm)/$C^{1.85}$*$D^{4.87}$(inches)

Pipe Dia (in)	Length (L.F.)	Material	C Factor (Assumed)
66	2500	Concrete	100

Step 2 *Calculate Minor Losses*

Minor Losses Equation: $h_M=Kv^2/2g$

Pipe Dia (in)	Fitting	K Values	Quantity	K Total
66	90 deg	0.25	3	0.75
66	Ent loss	0.8	1	0.8
Total assumed minor losses				**1.55**

CITY OF LOS ANGELES
Plant No. 647 Storm Water PS

System Curve Calculations

Step 2 ***Minor Losses (Continued)***

Pipe Dia (in)	Fitting	K Values	Quantity	K Total
1	-	0	0	0
1	-	0	0	0
None				**0**

Step 3 ***Determine Static Lift***

$H_{(static)}$ = Summit MH -Elev (Wet Well)

Maximum Static Lift		***Minimum Static Lift***	
Summit MH	6.67	Summit MH	6.67
Low Water Level	-3.06	High Water Level	0.94
$H_{(static-max)}$=	9.73	$H_{(static-min)}$=	5.73

CITY OF LOS ANGELES
Plant No. 647 Storm Water PS

System Curve Calculations

Step 4 ***Determine System Curve***

Q (gpm)	Friction H_L (ft)	Minor H_L (ft)	Max TDH (ft)	Min TDH (ft)	Avg TDH (ft)	Velocity in FM (ft/sec)
0	0.0	0.0	9.7	5.7	7.7	0.00
2500	0.0	0.0	9.7	5.7	7.7	0.23
5000	0.0	0.0	9.8	5.8	7.8	0.47
7500	0.1	0.0	9.8	5.8	7.8	0.70
10000	0.2	0.0	9.9	5.9	7.9	0.94
12500	0.3	0.0	10.0	6.0	8.0	1.17
15000	0.4	0.0	10.2	6.2	8.2	1.41
17500	0.5	0.1	10.3	6.3	8.3	1.64
20000	0.6	0.1	10.5	6.5	8.5	1.88
22500	0.8	0.1	10.6	6.6	8.6	2.11
25000	1.0	0.1	10.8	6.8	8.8	2.35
27500	1.2	0.2	11.1	7.1	9.1	2.58
30000	1.4	0.2	11.3	7.3	9.3	2.81
32500	1.6	0.2	11.5	7.5	9.5	3.05
35000	1.8	0.3	11.8	7.8	9.8	3.28
37500	2.1	0.3	12.1	8.1	10.1	3.52
40000	2.3	0.3	12.4	8.4	10.4	3.75
42500	2.6	0.4	12.7	8.7	10.7	3.99
45000	2.9	0.4	13.1	9.1	11.1	4.22
47500	3.2	0.5	13.4	9.4	11.4	4.46
50000	3.5	0.5	13.8	9.8	11.8	4.69
52500	3.9	0.6	14.2	10.2	12.2	4.93
55000	4.2	0.6	14.6	10.6	12.6	5.16
57500	4.6	0.7	15.0	11.0	13.0	5.40
60000	5.0	0.8	15.4	11.4	13.4	5.63
62500	5.3	0.8	15.9	11.9	13.9	5.86
65000	5.7	0.9	16.4	12.4	14.4	6.10
67500	6.2	1.0	16.9	12.9	14.9	6.33
70000	6.6	1.0	17.4	13.4	15.4	6.57
72500	7.0	1.1	17.9	13.9	15.9	6.80
73204	7.2	1.1	18.0	14.0	16.0	6.87
75000	7.5	1.2	18.4	14.4	16.4	7.04
77500	8.0	1.3	19.0	15.0	17.0	7.27
80000	8.4	1.4	19.5	15.5	17.5	7.51
82500	8.9	1.4	20.1	16.1	18.1	7.74
85000	9.4	1.5	20.7	16.7	18.7	7.98
87500	10.0	1.6	21.3	17.3	19.3	8.21

CITY OF LOS ANGELES
Plant No. 647 Storm Water PS

System Curve Calculations

Step 5 ***New Pump Curve***

Flygt
Dry Pit Submersible

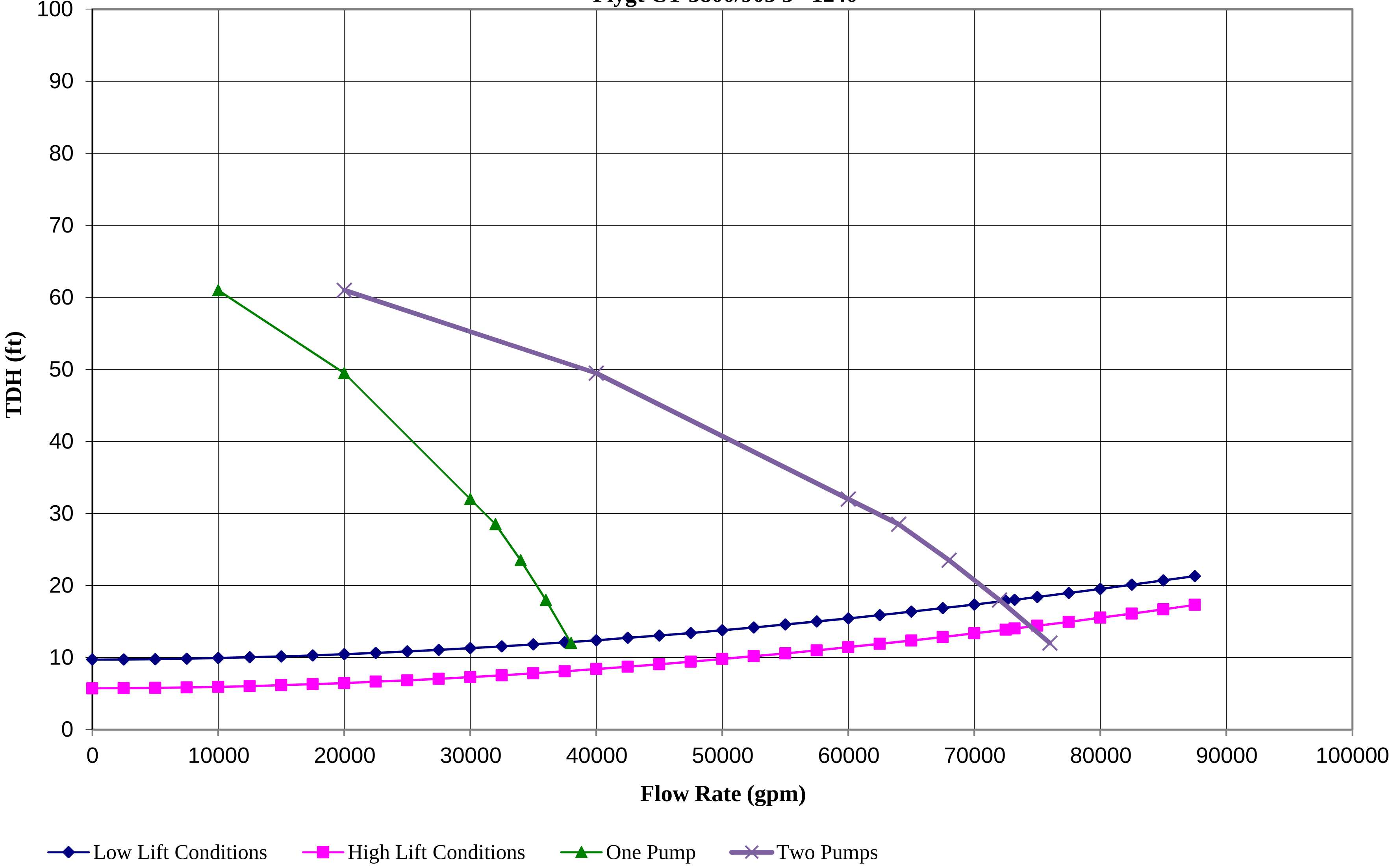
(1 Pump) CT 3800/985 3~1240

Q (gpm)	TDH (ft)
10000	61
20000	49.5

Flygt
Dry Pit Submersible

(2 Pumps) CT 3800/985 3~1240

Q (gpm)	TDH (ft)
20000	61
40000	49.5



CITY OF LOS ANGELES
Plant No. 647 Storm Water PS
System Curve
Flygt CT 3800/905 3~ 1240

Product specification

Receiver	**From**

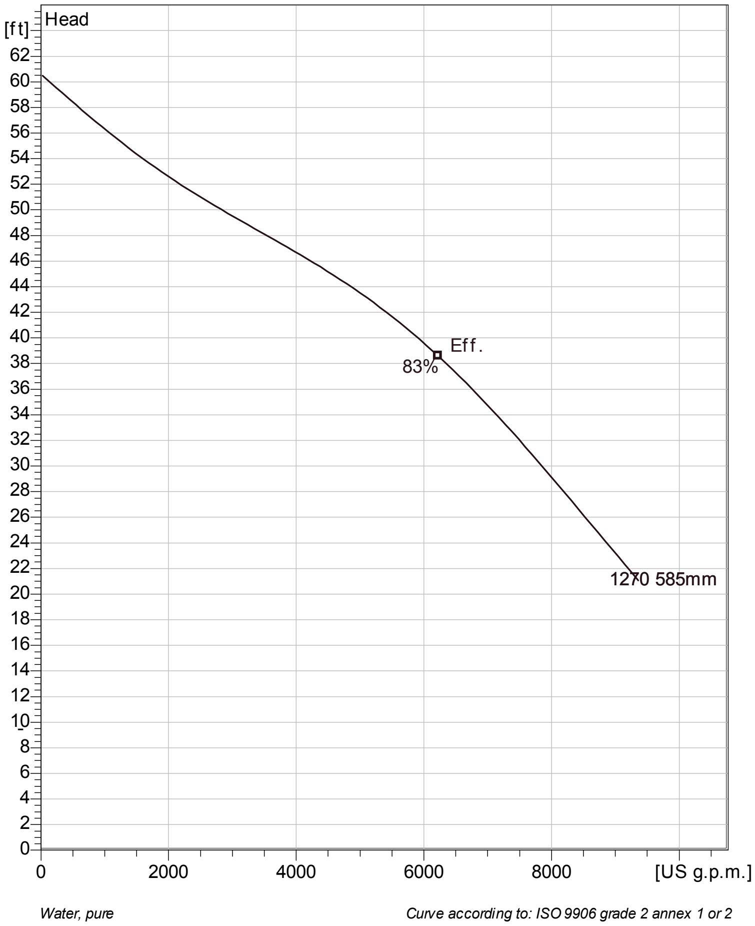
Quant.	**Item no.**	**Description**
2		**Block: 1** ***Patented self cleaning semi-open channel impeller, ideal for pumping in*** *waste water applications. Modular based design with high* *adaptation grade.* *DUTY POINT* *- Fluid:Water, pure* *- Flow:5072 US g.p.m* *- Head:44.6 ft* *- Fluid temperature:39.2 °F* *- Motor : 3~460V/60Hz* *- Rated power : 90 hp* *- Speed : 590 rpm* *- Total Moment of Inertia : 65.02 lb ft²* *- Degree of protection : --* *- Motor design : 3 PH STD W*
		Subtotal:

Total price excl. VAT	VAT in %	Total price incl. VAT
0.00 USD	1900	0.00 USD

Project	Project ID	Created by	Created on	Last update
TETRA TECH	**PLANT#647**	**Ricardo Guanio**	**2015-04-21**	**2015-04-21**

NP 3400/736 3~ 1270

Technical specification



Installation: P - Semi permanent, Wet

Note: Picture might not correspond to the current configuration.

General

Patented self cleaning semi-open channel impeller, ideal for pumping in waste water applications. Modular based design with high adaptation grade.

Impeller

Impeller material	Grey cast iron
Discharge Flange Diameter	15 3/4 inch
Suction Flange Diameter	500 mm
Impeller diameter	585 mm
Number of blades	3

Motor

Motor #	N0736.000 43-44-12VD-W 90hp
Stator variant	1
Frequency	60 Hz
Rated voltage	460 V
Number of poles	12
Phases	3~
Rated power	90 hp
Rated current	135 A
Starting current	475 A
Rated speed	585 rpm
Power factor	
1/1 Load	0.68
3/4 Load	0.62
1/2 Load	0.50
Efficiency	
1/1 Load	92.2 %
3/4 Load	92.5 %
1/2 Load	91.6 %

Configuration

Project	Project ID	Created by	Created on	Last update
TETRA TECH	**PLANT#647**	**Ricardo Guanio**	**2015-04-21**	**2015-04-21**

NP 3400/736 3~ 1270

Performance curve

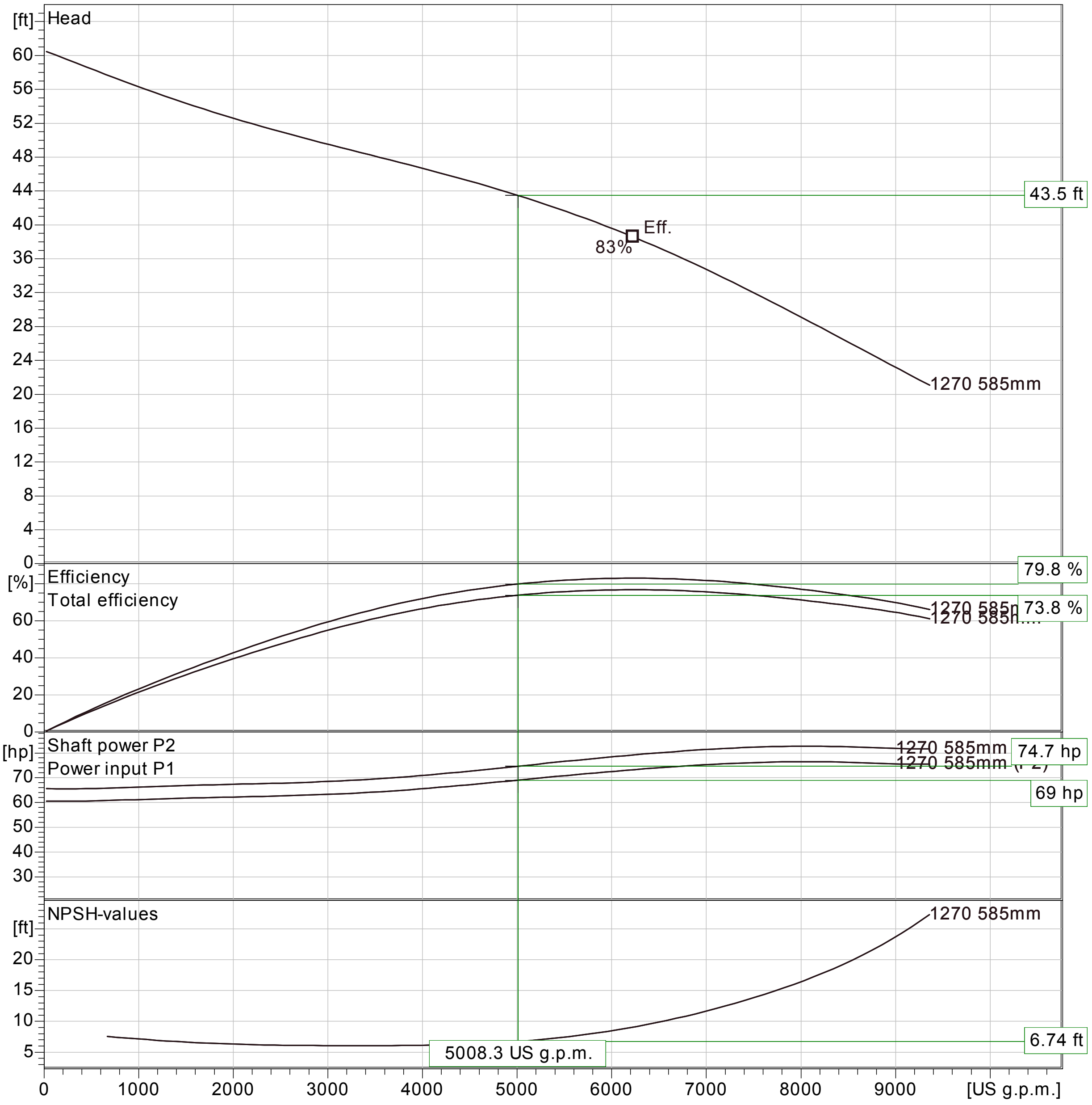
Pump

Discharge Flange Diameter	15 3/4 inch
Suction Flange Diameter	500 mm
Impeller diameter	$23^{1}/_{16}$"
Number of blades	3

Motor

Motor #	N0736.000 43-44-12VD-W 90hp
Stator variant	1
Frequency	60 Hz
Rated voltage	460 V
Number of poles	12
Phases	3~
Rated power	90 hp
Rated current	135 A
Starting current	475 A
Rated speed	585 rpm

Power factor	
1/1 Load	0.68
3/4 Load	0.62
1/2 Load	0.50
Efficiency	
1/1 Load	92.2 %
3/4 Load	92.5 %
1/2 Load	91.6 %



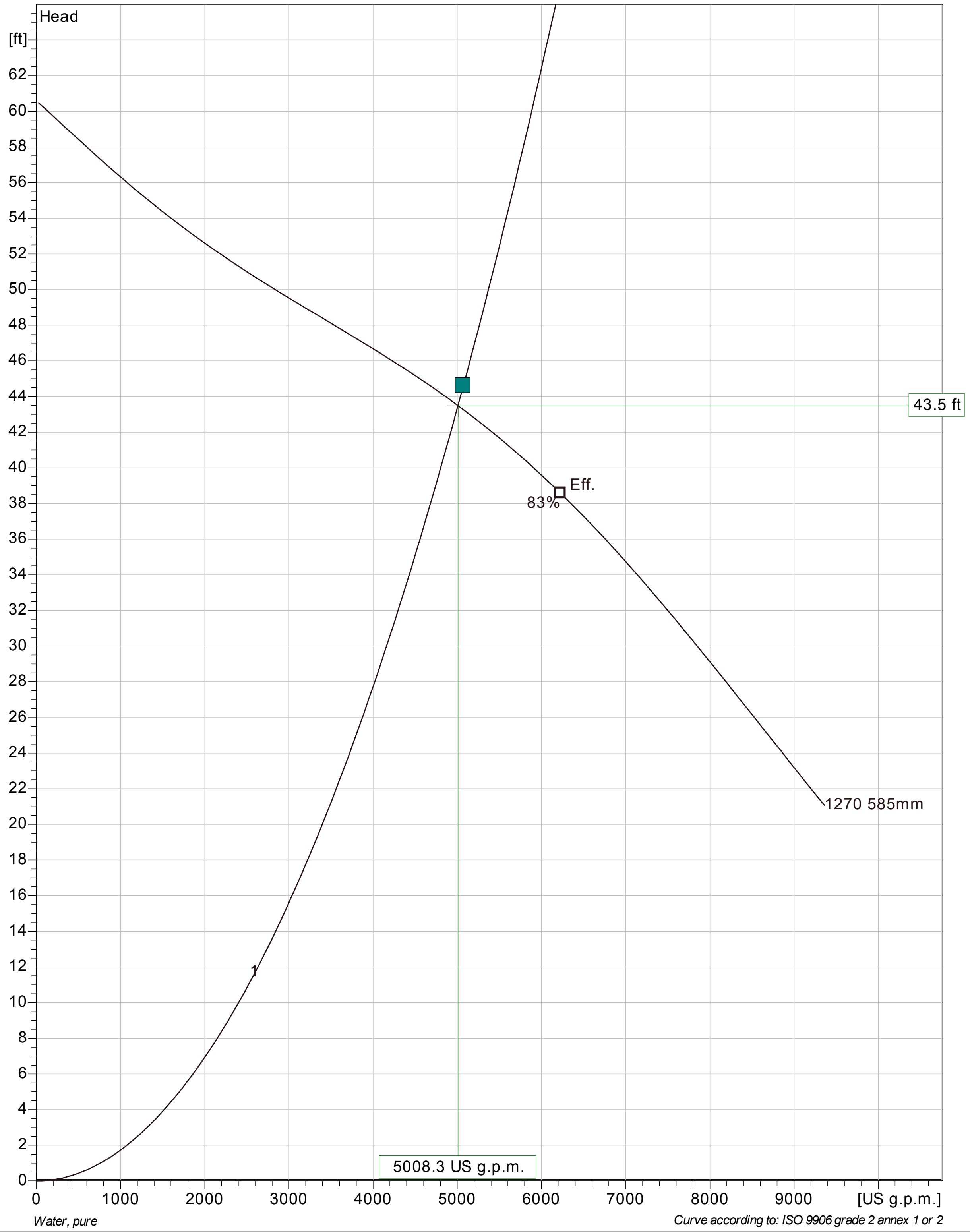
Water, pure

Curve according to: ISO 9906 grade 2 annex 1 or 2

Project	Project ID	Created by	Created on	Last update
TETRA TECH	**PLANT#647**	**Ricardo Guanio**	**2015-04-21**	**2015-04-21**

NP 3400/736 3~ 1270

Duty Analysis



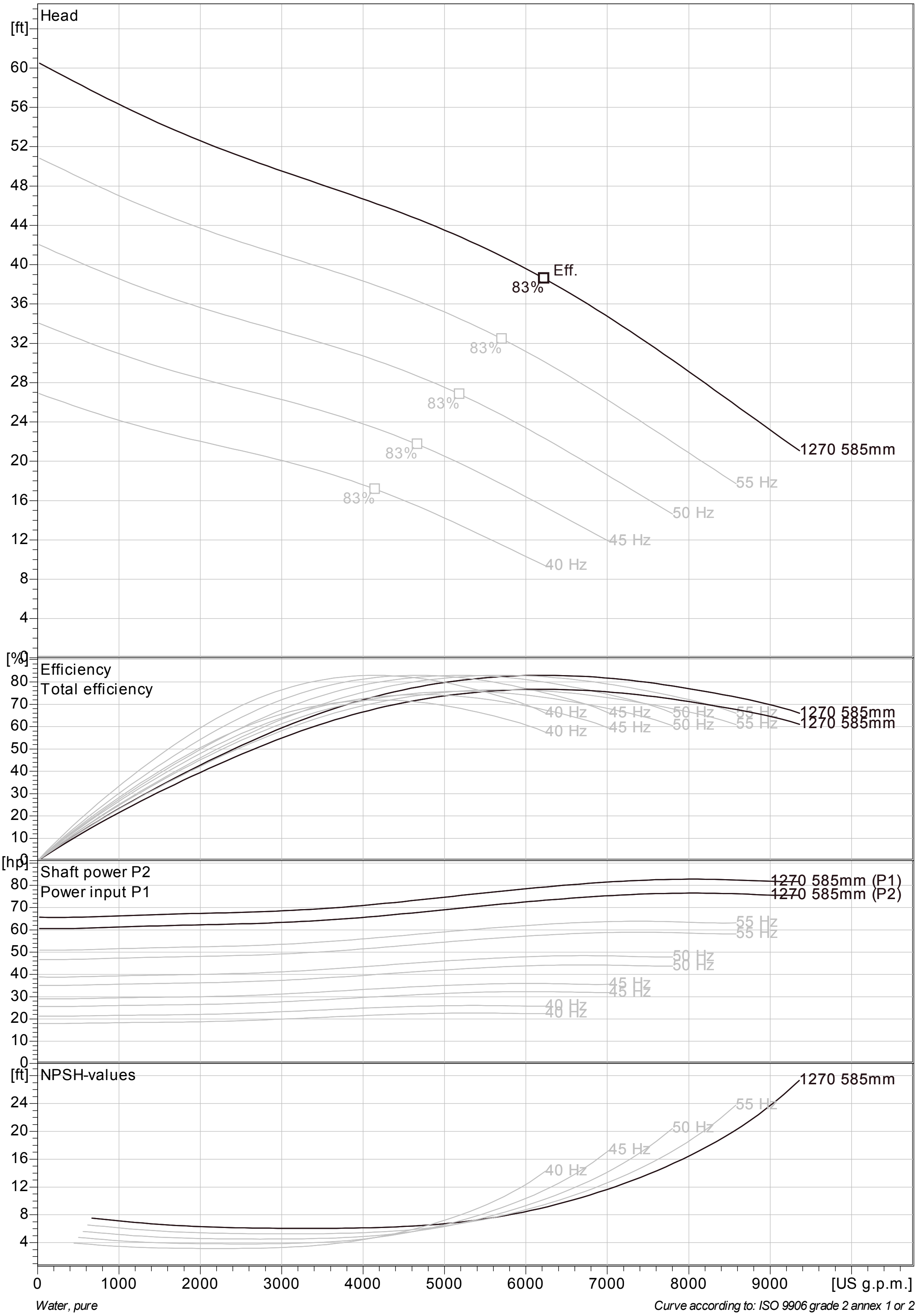
Water, pure

Curve according to: ISO 9906 grade 2 annex 1 or 2

	Individual pump			Total					
Pumps running /System	**Flow**	**Head**	**Shaft power**	**Flow**	**Head**	**Shaft power**	**Pump eff.**	**Specific energy**	**NPSHre**
1	5010 US g.p.m.	43.5 ft	69 hp	5010 US g.p.m.	43.5 ft	69 hp	79.8 %	185 kWh/US MG	6.74 ft

Project	Project ID	Created by	Created on	Last update
TETRA TECH	**PLANT#647**	**Ricardo Guanio**	**2015-04-21**	**2015-04-21**

NP 3400/736 3~ 1270
VFD Curve



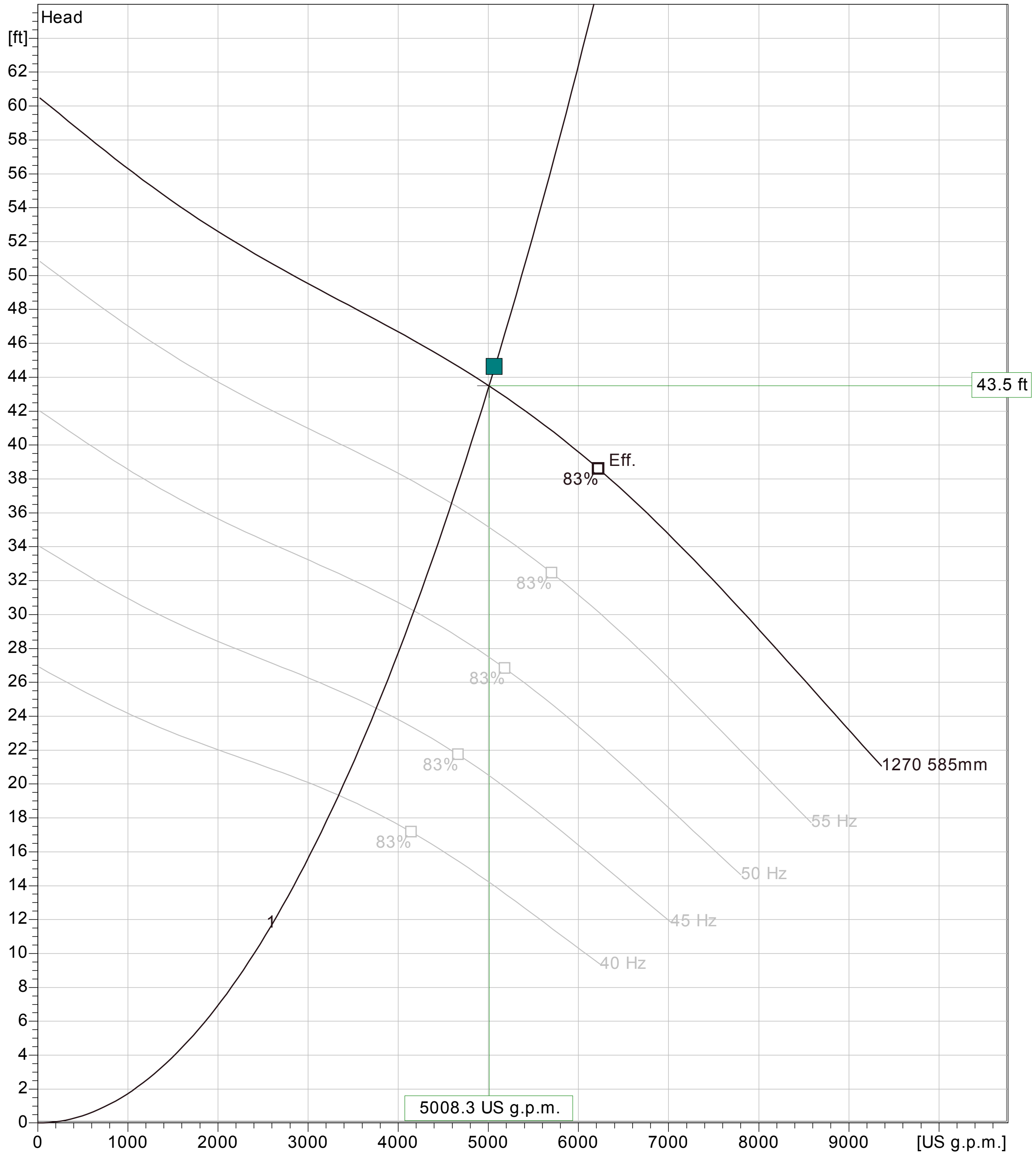
Water, pure

Curve according to: ISO 9906 grade 2 annex 1 or 2

Project	Project ID	Created by	Created on	Last update
TETRA TECH	**PLANT#647**	**Ricardo Guanio**	**2015-04-21**	**2015-04-21**

NP 3400/736 3~ 1270

VFD Analysis



Water, pure

Curve according to: ISO 9906 grade 2 annex 1 or 2

Pumps running /System	Individual pump Frequency	Flow	Head	Shaft power	Total Flow	Head	Shaft power	Hyd eff.	Specific energy	NPSHre
1	60 Hz	5010 US g.p.m.	43.5 ft	69 hp	5010 US g.p.m.	43.5 ft	69 hp	79.8 %	185 kWh/US MG	6.74 ft
1	55 Hz	4590 US g.p.m.	36.6 ft	53.2 hp	4590 US g.p.m.	36.6 ft	53.2 hp	79.8 %	156 kWh/US MG	5.87 ft
1	50 Hz	4170 US g.p.m.	30.2 ft	40 hp	4170 US g.p.m.	30.2 ft	40 hp	79.8 %	131 kWh/US MG	5.04 ft
1	45 Hz	3760 US g.p.m.	24.5 ft	29.1 hp	3760 US g.p.m.	24.5 ft	29.1 hp	79.8 %	108 kWh/US MG	4.25 ft
1	40 Hz	3340 US g.p.m.	19.3 ft	20.5 hp	3340 US g.p.m.	19.3 ft	20.5 hp	79.8 %	88.5 kWh/US MG	3.52 ft

Project	Project ID	Created by	Created on	Last update
TETRA TECH	**PLANT#647**	**Ricardo Guanio**	**2015-04-21**	**2015-04-21**

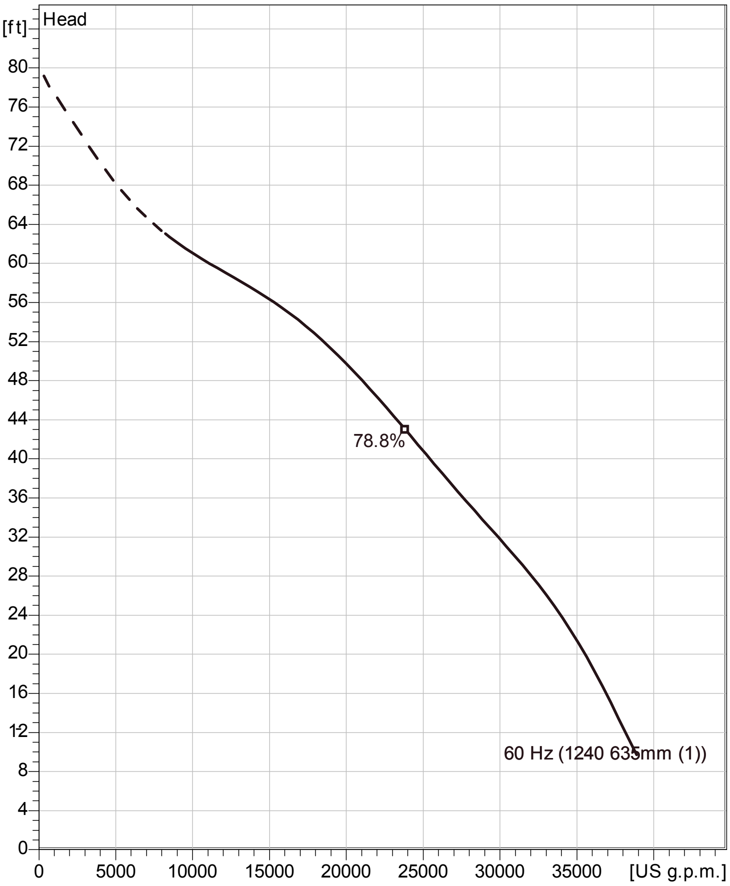
NP 3400/736 3~ 1270

Dimensional drawing

Project	Project ID	Created by	Created on	Last update
TETRA TECH	**PLANT#647**	**Ricardo Guanio**	**2015-04-21**	**2015-04-21**

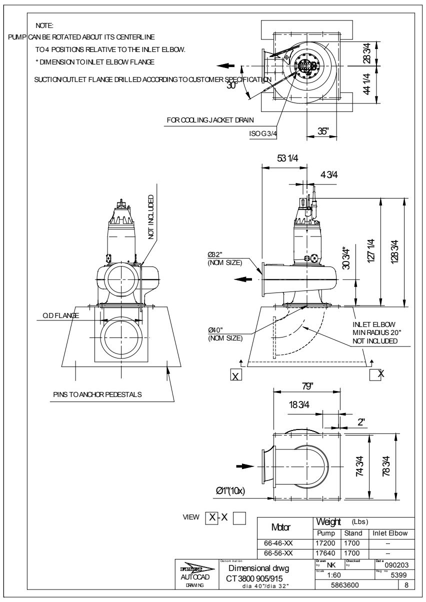
CT 3800/905 3~ 1240

Technical specification



Water, pure *Curve according to: ISO 9906 grade 2 annex 1 or 2*

Installation: **T - Vertical Permanent, Dry**



Motor	Weight (Lbs)		
	Pump	Stand	Inlet Elbow
66-46-XX	17200	1700	–
66-56-XX	17640	1700	–

Note: Picture might not correspond to the current configuration.

General

Shrouded single or multi-channel impeller pumps with large throughlets and single volute pump casing for liquids containing solids and fibres. Cast iron design with double sealing technology.

Impeller

Impeller material	Spherodial graphite cast iron
Discharge Flange Diameter	31 1/2 inch
Suction Flange Diameter	1000 mm
Impeller diameter	635 mm
Number of blades	4
Throughlet diameter	5 11/16 inch

Motor

Motor #	C0905.000 66-46-12AA-D 350hp
Stator variant	38
Frequency	60 Hz
Rated voltage	460 V
Number of poles	12
Phases	3~
Rated power	350 hp
Rated current	450 A
Starting current	1710 A
Rated speed	590 rpm
Power factor	
1/1 Load	0.78
3/4 Load	0.75
1/2 Load	0.67
Efficiency	
1/1 Load	93.5 %
3/4 Load	94.5 %
1/2 Load	94.5 %

Configuration

Project	Project ID	Created by	Created on	Last update
			2015-04-16	

xylem
Let's Solve Water

CT 3800/905 3~ 1240

Performance curve

FLYGT

Pump

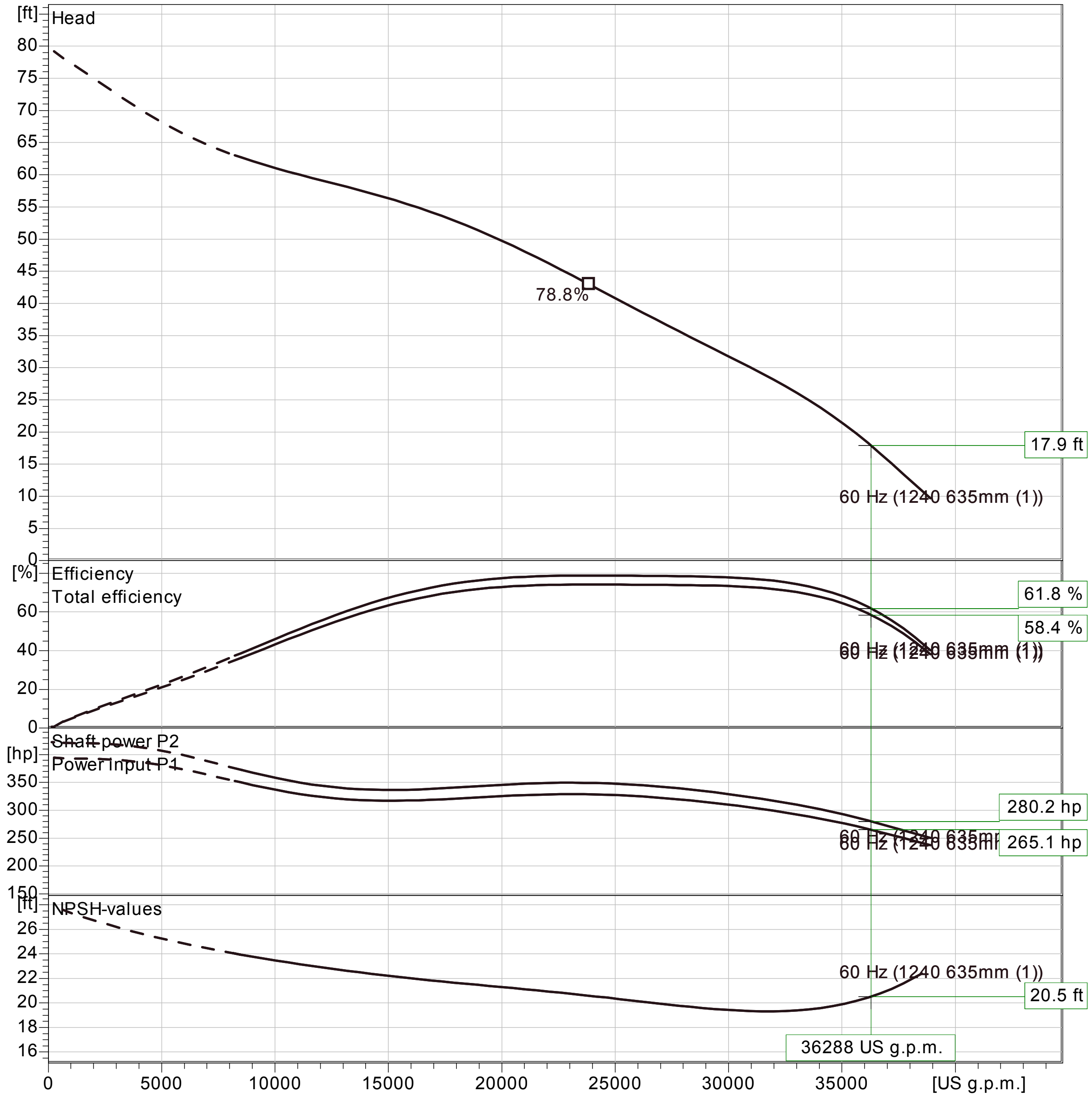
Discharge Flange Diameter	31 1/2 inch
Suction Flange Diameter	1000 mm
Impeller diameter	25"
Number of blades	4
Throughlet diameter	5 11/16 inch

Motor

Motor #	C0905.000 66-46-12AA-D 350hp
Stator variant	38
Frequency	60 Hz
Rated voltage	460 V
Number of poles	12
Phases	3~
Rated power	350 hp
Rated current	450 A
Starting current	1710 A
Rated speed	590 rpm

Power factor	
1/1 Load	0.78
3/4 Load	0.75
1/2 Load	0.67

Efficiency	
1/1 Load	93.5 %
3/4 Load	94.5 %
1/2 Load	94.5 %



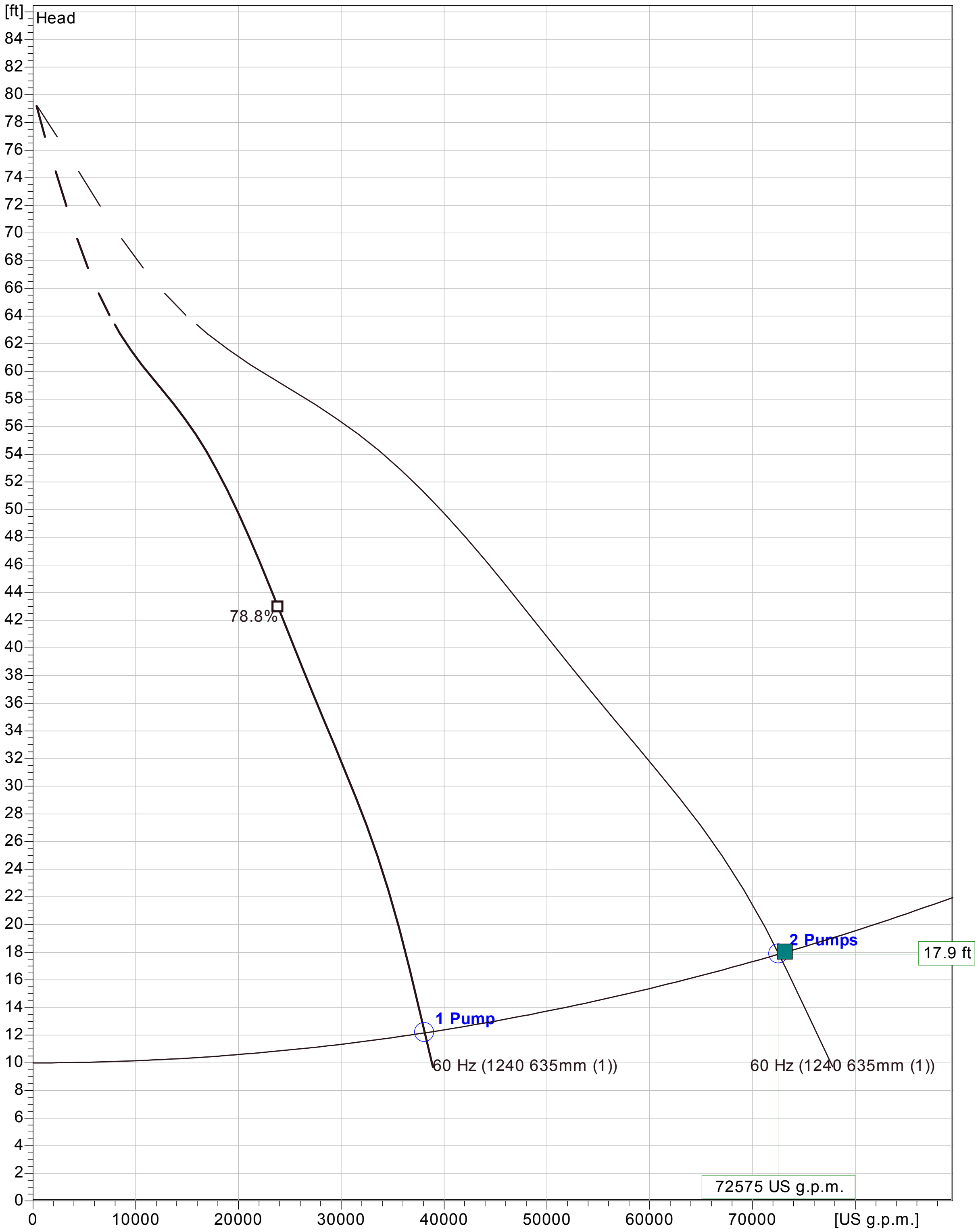
Water, pure

Curve according to: ISO 9906 grade 2 annex 1 or 2

Project	Project ID	Created by	Created on	Last update
			2015-04-16	

CT 3800/905 3~ 1240

Duty Analysis



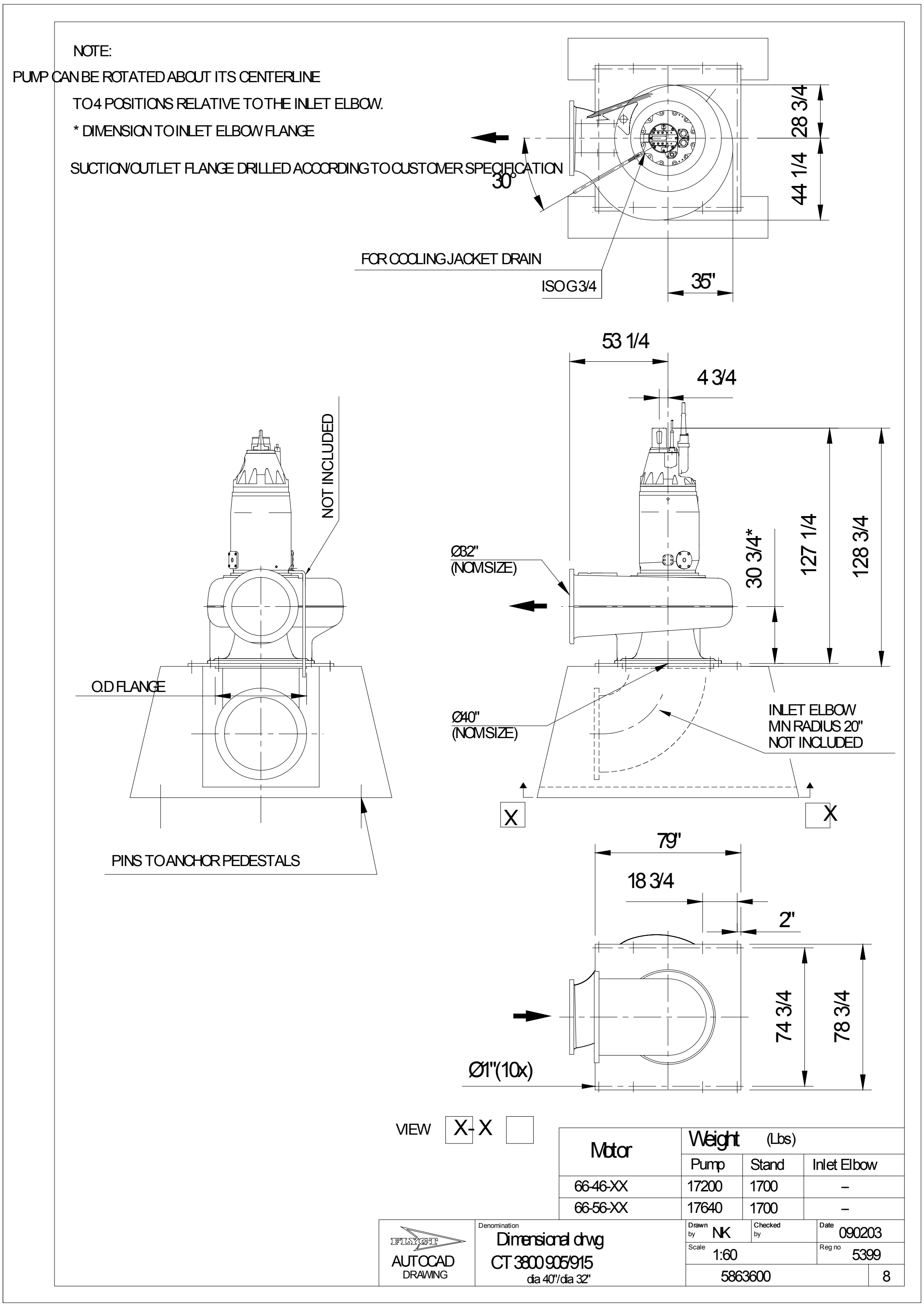
Water, pure

Curve according to: ISO 9906 grade 2 annex 1 or 2

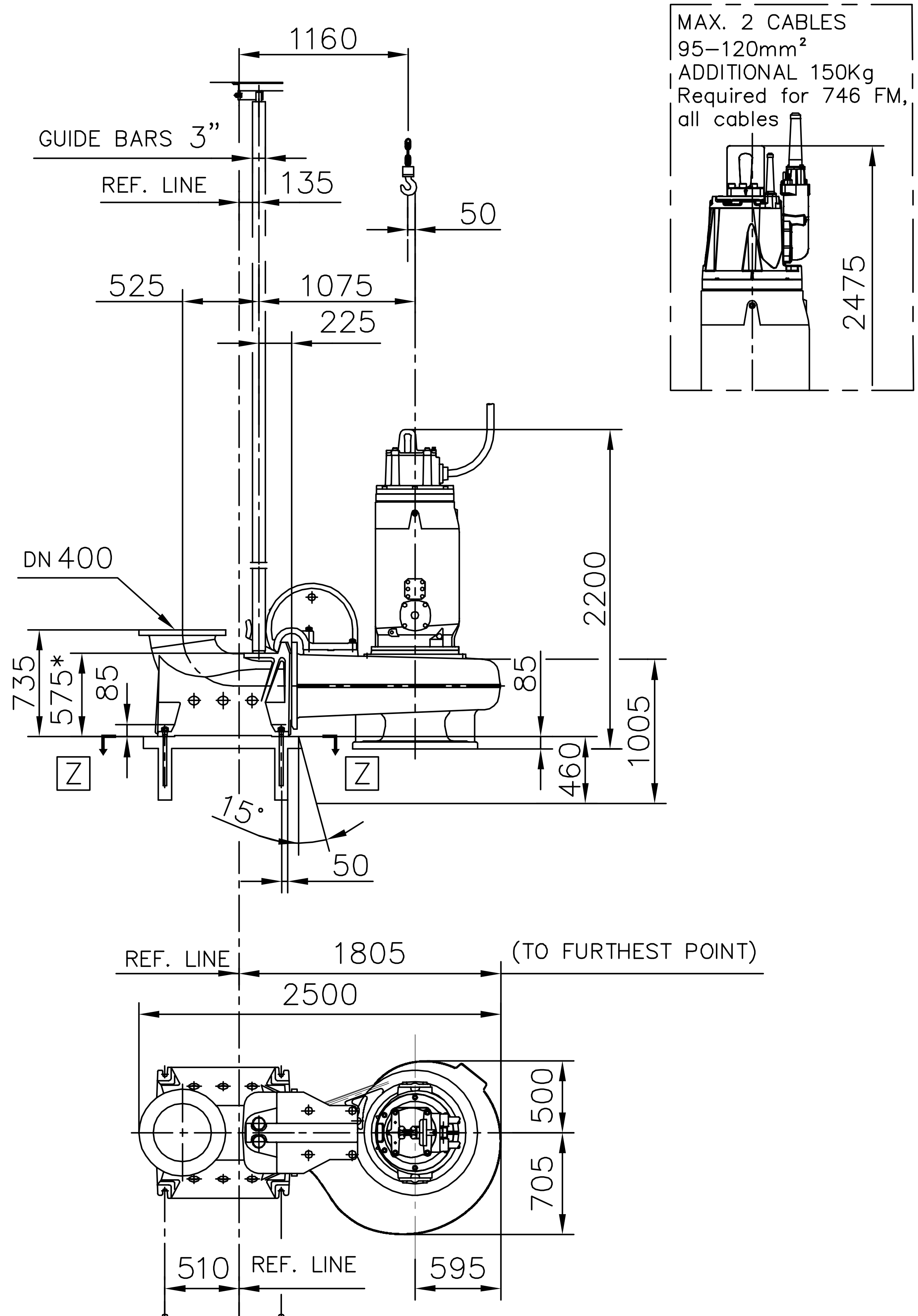
	Individual pump			Total					
Pumps running /System	Flow	Head	Shaft power	Flow	Head	Shaft power	Pump eff.	Specific energy	NPSHre
2	36300 US g.p.m.	17.9 ft	265 hp	72600 US g.p.m.	17.9 ft	530 hp	61.8 %	96 kWh/US MG	20.5 ft
1	38100 US g.p.m.	12.2 ft	246 hp	38100 US g.p.m.	12.2 ft	246 hp	48 %	85.1 kWh/US MG	22 ft

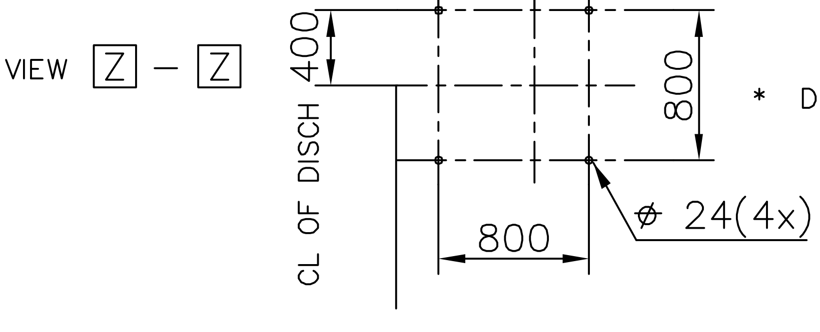
Project	Project ID	Created by	Created on	Last update
			2015-04-16	

CT 3800/905 3~ 1240
Dimensional drawing



Motor	Weight (Lbs)		
	Pump	Stand	Inlet Elbow
66-46-XX	17200	1700	–
66-56-XX	17640	1700	–





* DIMENSION TO ENDS OF GUIDE BARS

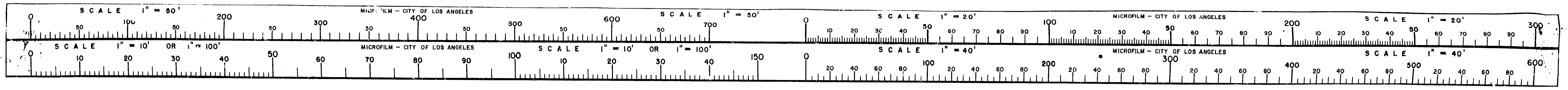
	Weights (kg)	
Drive unit	Pump	Disch
735 / 745	2700	500
736 / 746	2900	500

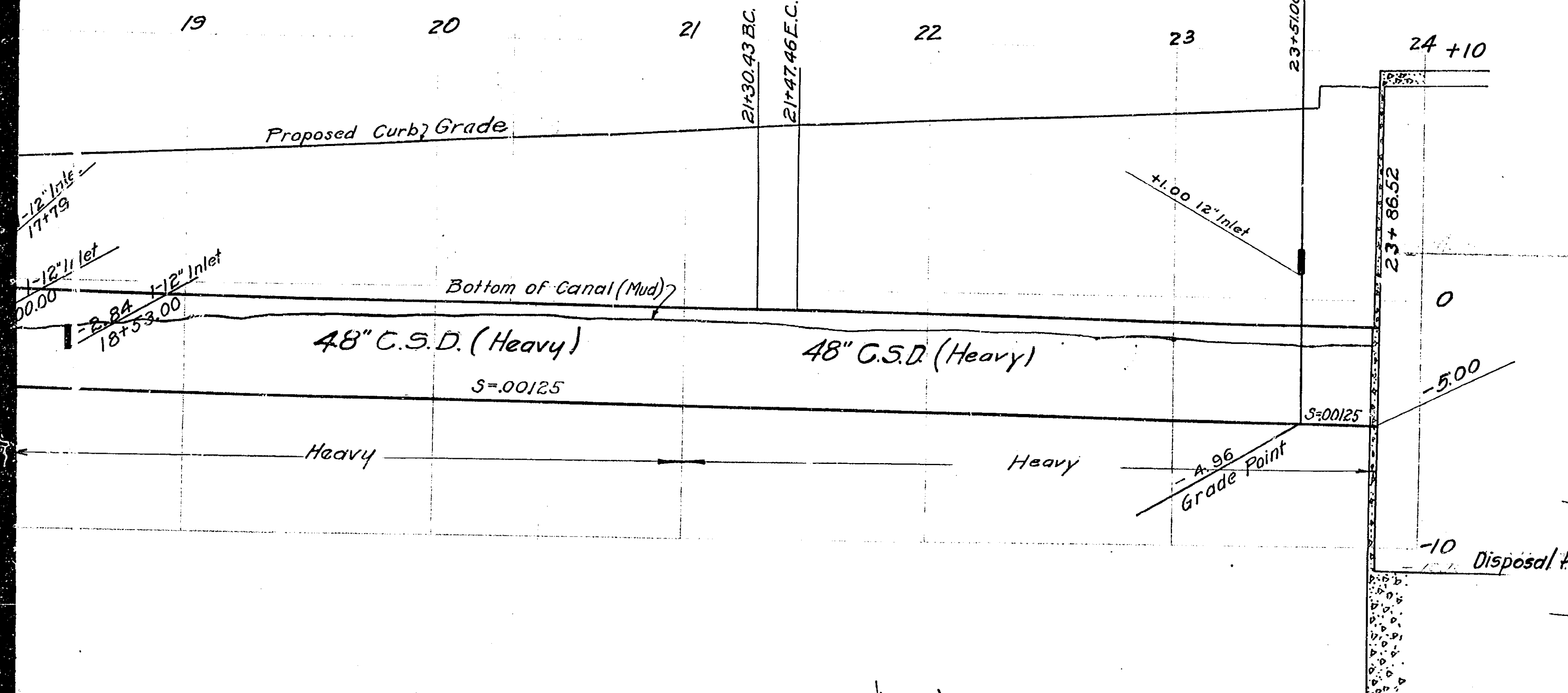
FLYGT
AUTOCAD
DRAWING

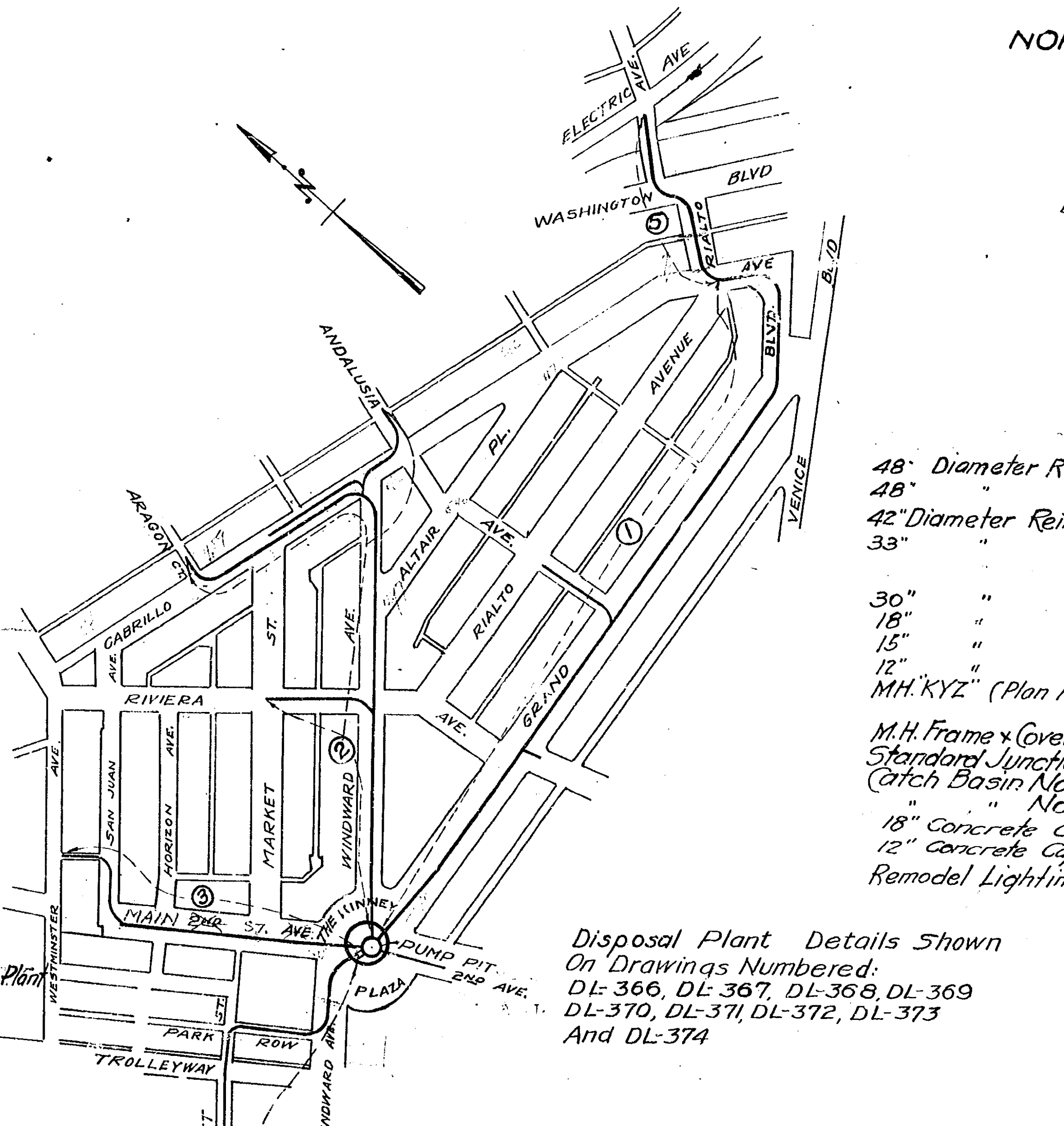
Denomination
Dimensional drwg
CP,NP 3400 735/745/736/746
DN 400

Drawn by IW	Checked by JP	Date 140115
Scale 1: 40		Reg no 5399
6441700		6

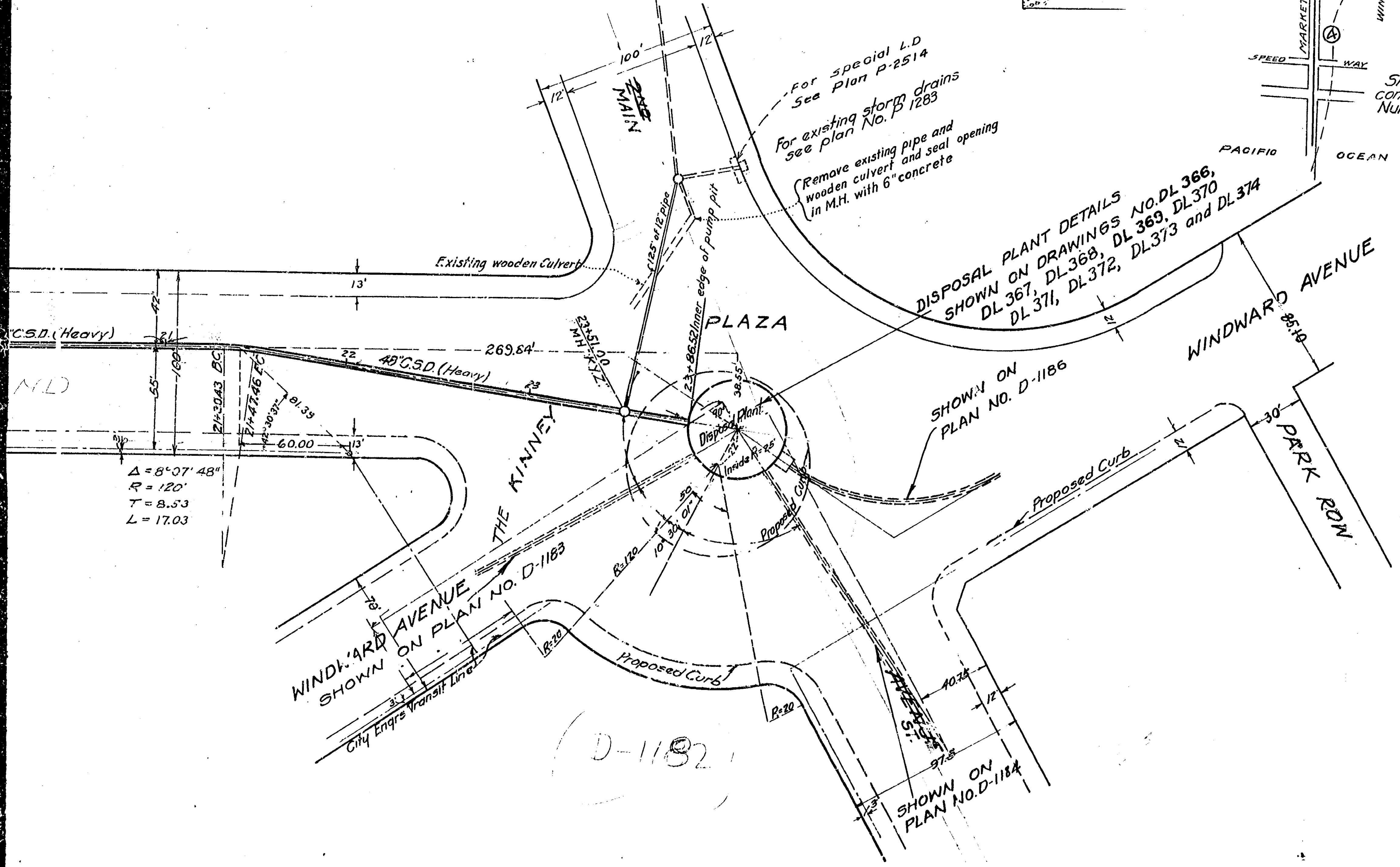
Appendix D – BOE "D" Plans







Disposal Plant Details Shown
On Drawings Numbered:
DL-366, DL-367, DL-368, DL-369
DL-370, DL-371, DL-372, DL-373
And DL-374



KEY MAP

Showing locations of Storm Drains to be constructed. ←—O—→ indicates sheet Numbers and show limits
Scale 300 - 1" (Approximate)

NORTH CANALS STORM DRAIN SYSTEM
CITY OF LOS ANGELES
John C. Shaw, City Engineer

STORM DRAINS IN
GRAND BOULEVARD
BETWEEN RIALTO AVE AND THE KINNEY PLAZA
AND IN
THE KINNEY PLAZA
AT WINDWARD AVENUE

References - F.B. No. 11605

SUMMARY

LENGTHS REQUIRED FOR CONSTRUCTION

48" Diameter Reinforced Concrete Pipe (Medium)	119	Lin. Ft.
48" " " " " (Heavy)	557	" "
42" Diameter Reinforced Concrete Pipe (Medium)	436	" "
33" " " " " (Medium)	938	" "
30" " " " " (Medium)	330	" "
18" " Pipe	330	" "
15" " "	3.0	" "
12" " "	888	" "
MH "KYZ" (Plan No D 975)	5	
M.H. Frame & Cover Sets (Plan No 29205)	5	
Standard Junction Chamber No 1 (" " 26890)	1	
Catch Basin No. 18 (" " 27669)	6	
" " No 23 (" " 28944)	7	
18" Concrete Cap	1	
12" Concrete Cap	1	
Remodel Lighting Conduit (Plan No 29860)	1	

Sheet 1
" 2
" 3

Notice to Contractors

Work shall be done in accordance with Plan No. D-828.
All pipe not otherwise specified shall be cement pipe.
Schedule for Additional work as per Note 56, Plan No. D 828.

_______ per cubic yard Class "A" Concrete.
_______ per cubic yard Class "C" Concrete.
_______ per cubic yard for excavation. (including back fill + haulaway)
_______ per lb. for reinforcing steel in place.
_______ per lineal foot for 6" House Connection Sewers.
_______ per lineal foot for 6" House " " (reinforced as per Plan No 11147)
_______ Piles per ft below cutoff line

Front Wall of catch basin No. 18, No. 23, and No 24, shall be constructed on the Curb line instead of outside the curb line as shown on the Standard Plans.
Where construction of stubs to receive catch basin connections is specified, such stubs shall be set in proper line to conform to location of proposed basins as shown and the end capped.
Where abandoned pipes or culverts are broken into the end of same shall be sealed with 8 inches of concrete.
Water tight connections shall be made between the wall of the pump pit and the storm drain pipes at points where such pipes enter the wet well of the pump pit. No such connection shall be made, however, until 28 days after the pouring of the pump pit walls.
All round piles used in this improvement, shall be straight and sound from end to end and be free from defects and cracks, and all piles shall be creosoted and said creosoting shall penetrate into each pile a distance of not less than one (1) inch from any point of the circumference of each pile throughout the entire length of said piles and the creosoting of each pile shall be done by the standard drying and pressure method for applying this treatment.
Attention of the Contractor is called to the fact that the storm drain to be built is largely below ground water level and the requirements are that special care shall be exercised to so construct the drains that infiltration of ground water will be the minimum, not to exceed, in any event, at the completion of the work or any portion thereof, a rate of flow at any point of measurement of 200 gallons per internal inch of diameter per mile of drain per 24 hours.
In making the crossing under the Kinney Tunnel at Park Row, the Contractor shall maintain all pipe lines within said tunnel during construction.
In the construction of the Outfall under the pleasure pier at the end of Market St. the contractor shall not interfere with the operation of any of the concessions on the pier without the consent of the owners of said concessions.
Although soil conditions along the route of the proposed drain are beleived to be as shown on the plans and as actually determined by test holes on the ground, the City of Los Angeles does not guarantee the same.
Except on Venice Blvd. and Washington Blvd. street lighting conduits and light posts have been abandoned for use and contractor may remove same where interference with new construction is encountered.
This improvement also includes work shown on. DL 366, DL 367, DL 368, DL 369, DL 370, DL 371, DL 372, DL 373, DL 374, P2512, P2513, P2514, P2515, P2516, P2517, D1174, D1003, D1183, D1184, D1186, and D1208
(The summary does not include items for which unit prices are to be bid)

RESURFACING SCHEDULE
See Plan No D1186

LIST OF STANDARD PLANS

	PLAN NO.
Manhole "KYZ"	D-975
Standard Jct. Chamber #1	26890
Local Depression #3	D-893
M.H. Frame & Cover Sets	29205
Catch Basin No 18	27669
Catch Basin No 23	28944
Local Depression #4	D 894
Remodel Light Conduit	29860
Pipe Junction	29164

WINDWARD AVENUE AND 2ND AVENUE IMPROVEMENT DISTRICT A11-1-63112

Designed by W.D. Potter
Checked by Truckey-Price
Submitted 8/25 1927
Venice District Engineer
Approved 8-27- 1927
By E.A. Tuttle
Engr. Metropolitan Storm Drain Div.

Drawn by L.J. Truckey
Sanitary Sewer Substructure Engr. 8/1/27
Approved Aug 29, 1927
JOHN C. SHAW
City Engineer
Chief Deputy

	Signature	Date
O+W. Engr.	[illegible]	[illegible]
St. Design Engr.	[illegible]	9-12-27
Water Dept. Engr.	[illegible]	[illegible]
St. Lighting Engr	[illegible]	9/12/27
Bridge Design Engr.	M.B. per H.H.W	8-27-27
Sanitary Swr. Design Engr.	[illegible]	8-27-27

These Elevations are based on the U.S.G.S datum adopted July 1st 1925, Ordinance No 52,222.

D-1182

Sheet No 1 of 5 Sheets

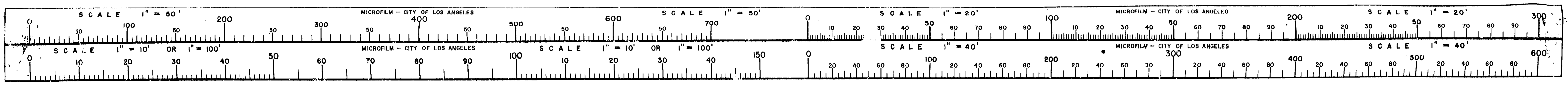
D1182 1

CERTIFICATE

I hereby certify that this is a true and accurate copy of the official city record described there, made in accordance with Section 434 of the Charter of the City of Los Angeles and Section 34090.5 of the Government Code.

Date 1-3-69

REX E. [illegible], City Clerk
By L.C. Janus
Deputy



D1182 2

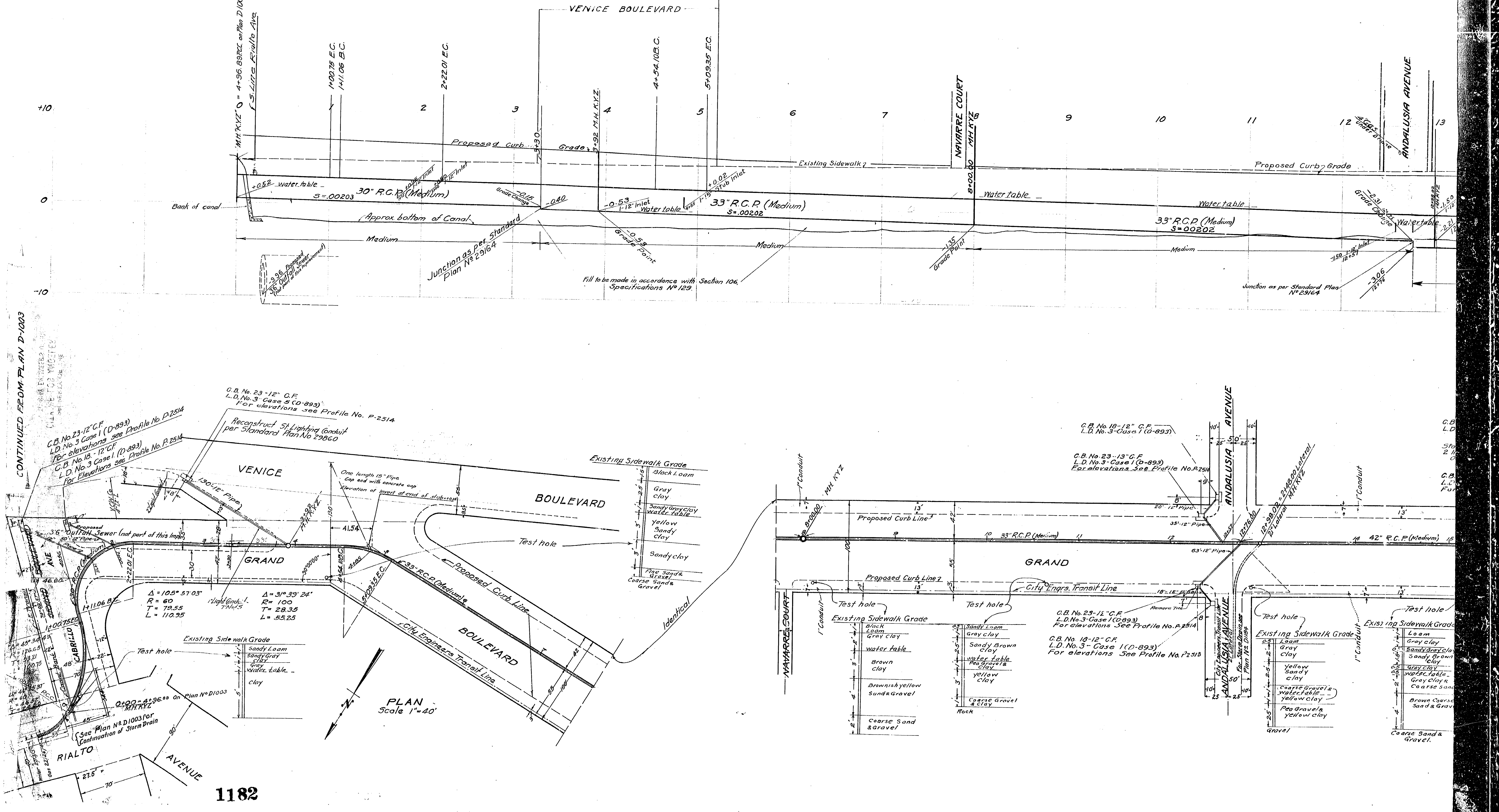
CERTIFICATE

I hereby certify that this is a true and accurate copy of the official city record described there, made in accordance with Section 434 of the Charter of the City of Los Angeles and Section 34090.5 of the Government Code.

REX E. LAYTON, City Clerk

Date 4-3-67

by L E Janus
Deputy



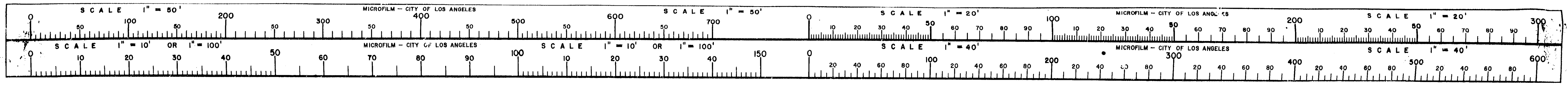
D1182 3

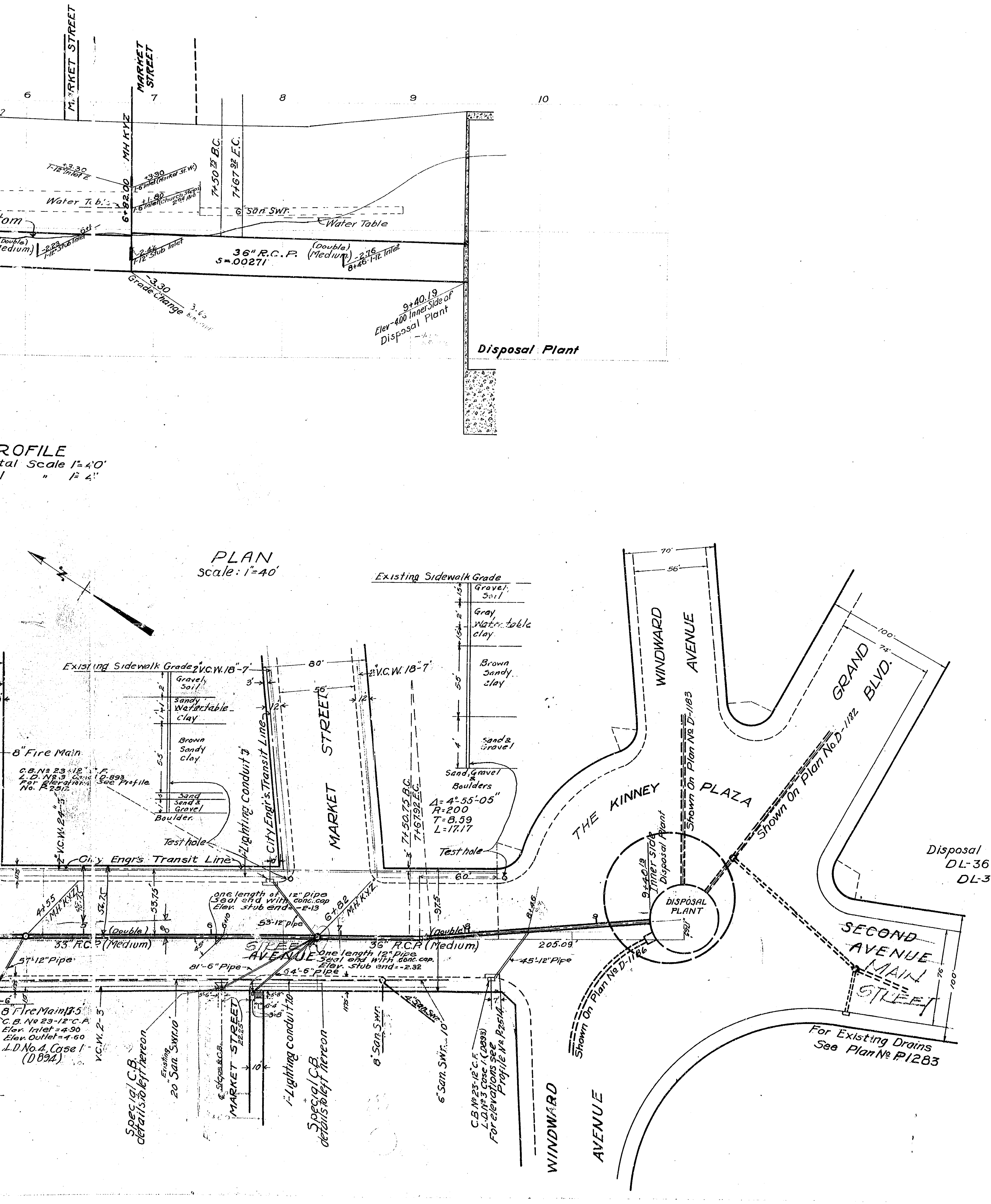
CERTIFICATE

I hereby certify that this is a true and accurate copy of the official city record described there, made in accordance with Section 434 of the Charter of the City of Los Angeles and Section 34090.5 of the Government Code.

Date 1-3-69

REX E. LAYTON, City Clerk
By L.E. Janus
Deputy





Disposal Plant Details Shown On Plans Numbered:
DL-366, DL-367, DL-368 DL-369, DL-370
DL-371, DL-372, DL-373, And DL-374

NORTH CANALS STORM DRAIN SYSTEM
CITY OF LOS ANGELES
John C. Shaw, City Engineer

STORM DRAINS in
1st ALLEY WESTERLY OF RIVIERA AVENUE
BETWEEN WESTMINSTER AVENUE AND SAN JUAN AVENUE
IN
SAN JUAN AVENUE
BETWEEN 1st ALLEY WESTERLY OF RIVIERA AVE. & SECOND AVE.
IN
SECOND AVENUE
BETWEEN SAN JUAN AVE. & THE KINNEY PLAZA
IN
THE KINNEY PLAZA
AT SECOND AVENUE
IN
ANDALUSIA AVENUE
BETWEEN RIALTO AVENUE AND GRAND BOULEVARD

References:- F.B. 11605, 11506 11532, 11560-11535-11602

SUMMARY
LENGTHS REQUIRED FOR CONSTRUCTION

36" Diameter Reinforced Concrete Pipe (Double Medium)	256	Lin. ft.
33" " " " " " "	448	" "
27" " " " " (Heavy)	97	" "
27" " " " " (Medium)	196	" "
21" " Pipe	242	" "
18" " "	32	" "
15" " "	80	" "
12" " "	469	" "
Catch Basin No. 18 Standard Plan No 27669	4	
Catch Basin No. 23 " " No 28944	6	
Catch Basin No. 24 " " No 29101 (2 Opening)	1	
Catch Basin No. 22A " " No D.L. 22 (1 Grating)	3	
Catch Basin (Special)	2	
Catch Basin No 21A " " No D.L. 22 (1 Grating)	2	
6" Pipe	145	Lin. ft.
Manhole KYZ Standard Plan No D-975	7	
" Frame and Cover Sets " " 29205	7	
12" Concrete Caps	2	

Notice to Contractors
For Notice to Contractors see Plan No D-1182

For Resurfacing Schedule see Plan No D-1186

	Signature	Date
Opening and Widening Engineer		
Street Design Engineer	See Plan D-1182	
Water Department Engineer		
Steet Lighting Engineer		
Bridge Design Engineer		
Sanitary Sewer Design Engineer		

These elevations are based on the U.S.G.S. datum adopted, July 1st 1925, Ordinance No. 52,222.

List of Standard Plans

	Plan No
C.B. No 18	27669
C.B. No 23	28944
C.B. No 24	29101
C.B. No 22A	DL22
M.H. KYZ	D975
M.H. Frame & Cover	29205
C.B. Depressions	D893
" "	D894

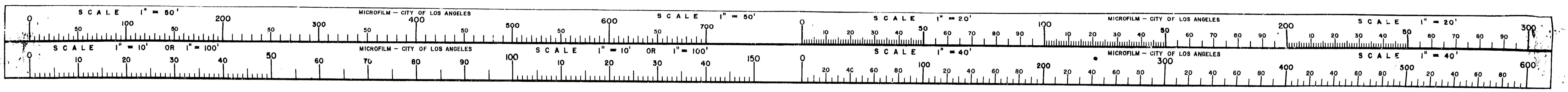
WINDWARD AVE. AND SECOND AVE. IMP. DIST.
A'11-62112
Designed by: Potter Drawn by: Price
Checked by: Price-Kirkgaard Sanitary Sewer: 880 thru
Substructures: L.L.
Submitted 8/25 1927 Approved Aug 27 1927
Venice District Engineer
John C. Shaw
City Engineer
Approved: 8-27-1927
E.A. Tuttle
Eng. Mgr. Storm Drain Div.
Chief Deputy

Sheet No 3 of 5 Sheets

D-1184

D1184 1

CERTIFICATE
I hereby certify that this is a true and accurate copy of the official city record described there, made in accordance with Section 434 of the Charter of the City of Los Angeles and Section 34090.5 of the Government Code.
REX E. LAYTON, City Clerk
Date 7-3-69
By L.E. James Deputy



1184

D1184 2

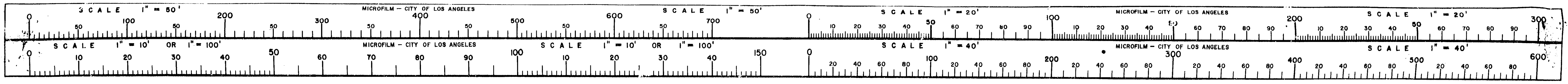
CERTIFICATE

I hereby certify that this is a true and accurate copy of the official city record described there, made in accordance with Section 434 of the Charter of the City of Los Angeles and Section 34090.5 of the Government Code.

Date 7-2-69

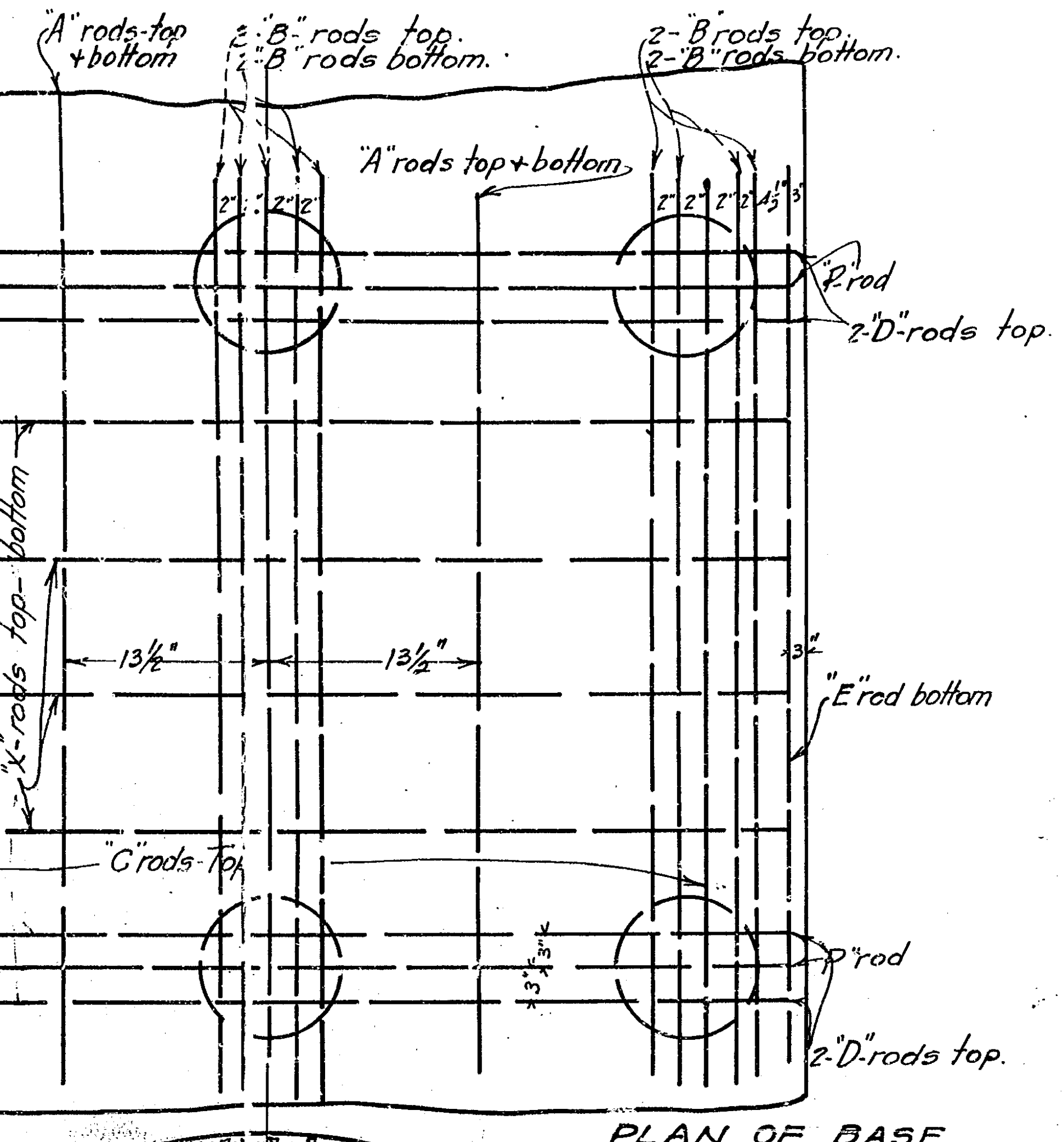
REX E. LAYTON, City Clerk

By L. E. Janus Deputy



DETAILS OF OUTLET STRUCTURE (SECTION "A")

Between Sta. 15+70.00 and Sta. 16+72.50
Scale 1"=1'



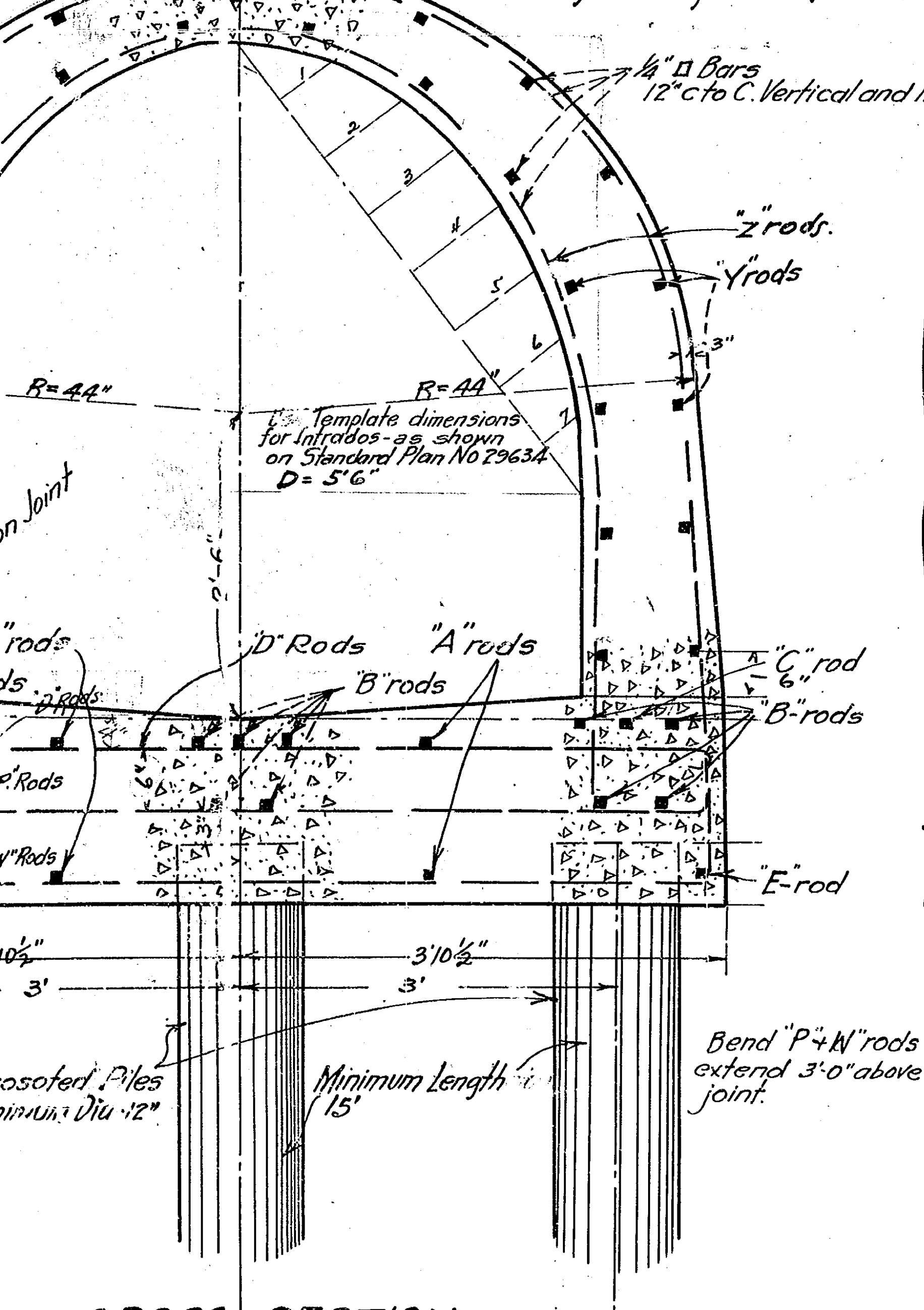
PLAN OF BASE
Showing arrangement of steel

OUTLET STRUCTURE
Approved Aug. 30, 1927
LOS ANGELES MUNICIPAL ART COMMISSION
by F. W. Blanchard President
Secretary

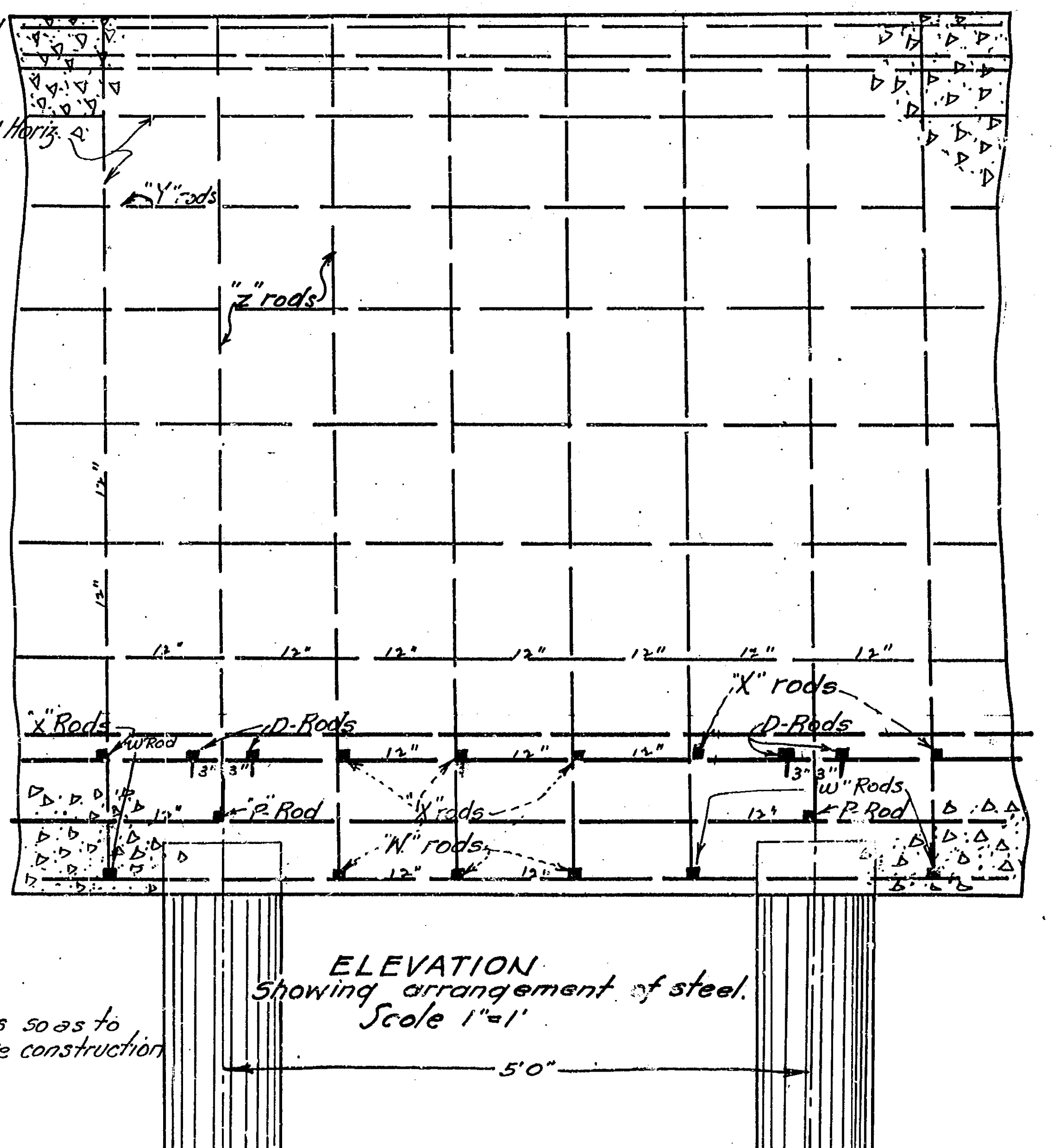
TABLE OF REINFORCING STEEL

No.	BARS		LENGTH
4-"A" rods	¼ □	straight-continuous	100'
13-"B" "	⅜ □	" "	100'
2-"C" "	½ □	" "	100'
4-"D" "	½ □	hook both ends	7'3"
2-"P" "	¼ □	see detail	7'3"
81-"X" "	¼ □	straight continuous	7'3"
30-"Y" "	¼ □	" "	100'
101-"Z" "	¼ □	as shown	18'
81-"W" "	¼ □	See detail	7'3"
101-"Z" "	¼ □	as shown	16'
2-"M" Bars	⅝ □		25'-6"

All laps not less than 40xt



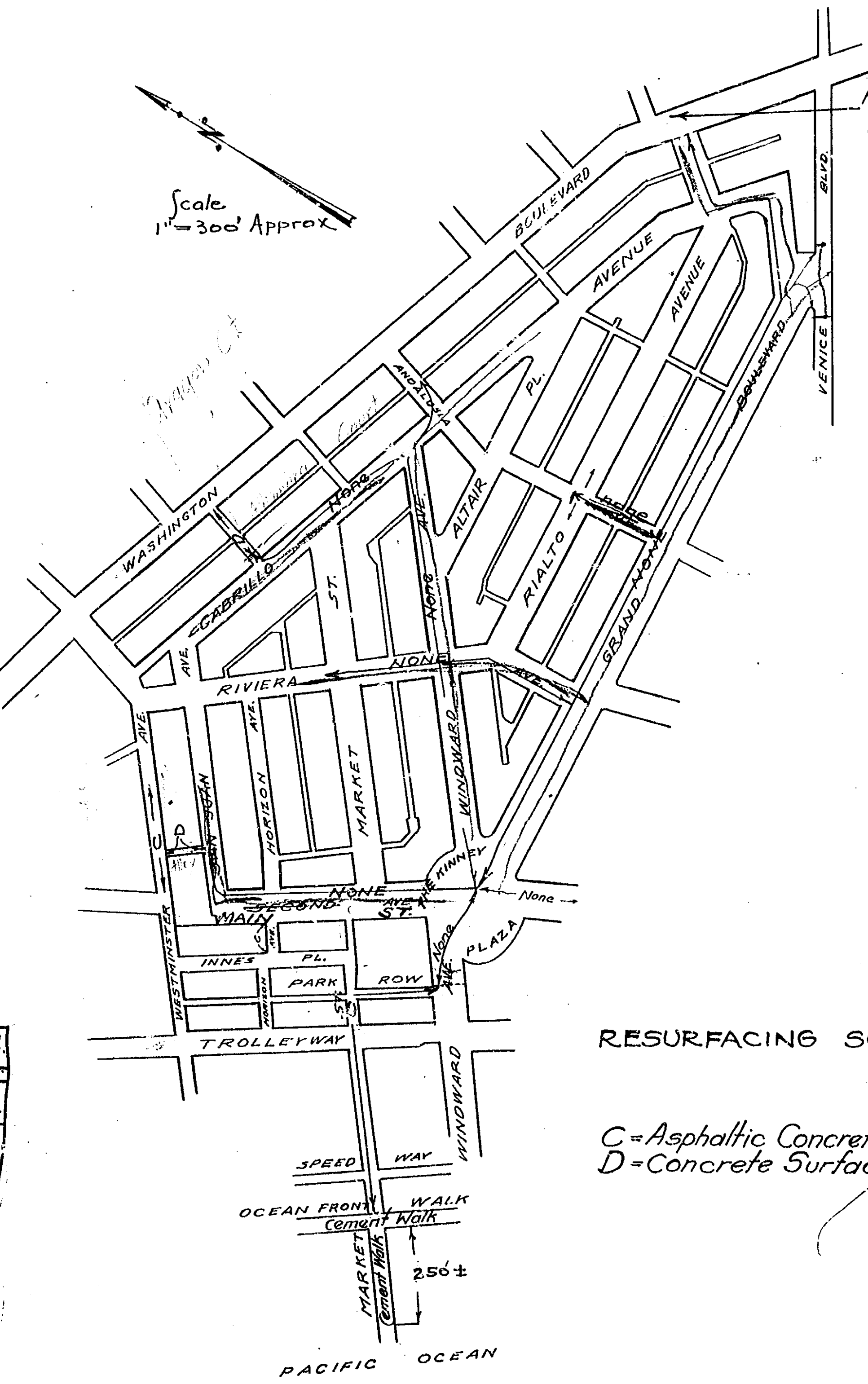
CROSS SECTION



Bend "P" + "W" rods so as to extend 3'0" above construction joint.

ELEVATION
Showing arrangement of steel.
Scale 1"=1'

DETAILS OF OUTLET STRUCTURE (SECTION A)
(From Sta 15+70 to 16+72.50)



For additional Resurfacing See Plan No D-1003.

RESURFACING SCHEDULE

C=Asphaltic Concrete Surface.
D=Concrete Surface.

PILING SCHEDULE 3800# Drop Hammer.

Bent No. Location.	Pile No.	Original Length	Length below Cut-off.	Length Under Gd.	Avg. Final Drop-Hammer	Avg Final Penetration.	Date Driven.
1-16+70	2	16'	15'	14.5'	6'	2"	11-9-29
" "	3	16'	15'	14.5'	6'	1"	"
" "	1	16'	15'	14.5'	6'	2"	"
2-16+65	5	16'	15'	14.5'	8'	2"	"
" "	4	20'	15'	14.5'	5'	1"	"
" "	6	20'	15'	14.5'	6'	2"	"
3-16+60	8	16'	15'	14.5'	5'	2"	11-10-29
" "	9	15'	15'	14.5'	4'	1"	"
" "	7	22'	15.3'	14.8'	6'	2"	"
4-16+55	11	20'	15'	14.5'	8'	2"	"
" "	10	21'	15.8'	15.3'	8'	2"	"
" "	12	20'	15.3'	14.8'	6'	2"	"
5-16+50	14	20'	15.1'	14.6'	10'	2"	"
" "	15	16'	15.2'	14.7	8'	2"	11-11-29
" "	13	22'	16.5'	16.'	6'	1"	"
6-16+45	17	20'	15.5'	15.'	6'	2"	"
" "	18	22'	15.5'	15.'	8'	2"	"
" "	16	21'	16'	15.5'	6'	2"	"
7-16+40	20	20'	15'	14.5'	12'	2"	"
" "	19	22.3'	15'	14.5'	12'	1"	"
" "	21	22.3'	15'5'	15.'	10'	2"	"
8-16+35	23	20.1'	15.7'	15.2'	8'	2"	"
" "	24	20'	15.1'	14.6'	10'	2"	"
" "	22	20'	15.2'	14.7'	6'	2"	"
9-16+30	26	16'	15'	14.5'	12'	2"	"
" "	27	20'	15.2'	14.7'	12'	3"	"
" "	25	22'	15'	14.5'	10'	2	"
10-16+25	29	23'	15'	14.5'	8'	2"	"
" "	28	20'	15.5'	15.'	8'	2"	"
" "	30	20'	15'	14.5'	8'	2"	"
11-16+20	32	20'	15.1'	14.6'	12'	2"	"
" "	33	22'	15.5'	15.'	8'	2"	11-12-29
" "	31	20'	15.2'	14.7'	6'	2"	"
12+16+15	35	16'	15.7'	15.2'	8'	1"	"
" "	34	20'	15.2'	14.7'	8'	2"	"
" "	36	20'	15.5'	15.0'	6'	2"	"
13-16+10	38	16'	15'	14.5'	10'	1"	"
" "	39	22'	15.4'	14.9'	8'	1"	"
" "	37	20'	15.3'	14.8'	6'	1"	"
14-16+05	40	20'	15'	14.5'	12'	1"	"
" "	41	16'	15'	14.5'	10'	1"	"
" "	42	21'	15'	14.5'	10'	1"	"
15-16+00	44	20'	15.6'	15.1'	12'	1"	"
" "	45	20'	15'	14.5'	12'	1"	"
" "	43	20'	16.4'	15.9'	12'	1"	"
16-15+95	47	20'	16.1'	15.6'	12'	2"	11-13-29
" "	48	22'	16.5'	16'	10'	1"	"
" "	46	20'	16.4'	15.9'	8'	1"	"
17-15+90	50	20'	15.5'	15'	6'	2"	"
" "	49	20'	15.3'	14.8'	8'	2"	"
" "	51	21'	15.1'	14.6'	10'	1"	"
18-15+85	53	21'	15.4'	14.9'	8'	2"	"
" "	54	20'	15'	14.5'	10'	2"	"
" "	52	20'	15.7'	15.2'	6'	2"	"
19-15+80	56	20'	15.2'	14.7'	6'	1"	"
" "	57	20'	15.9'	15.4'	4'	2"	"
" "	55	21'	15.3'	14.8'	4'	2"	"
20-15+75	59	21'	15.6'	15.1'	6'	2"	"
" " "	60	22'	16.'	15.5'	8'	1"	"
" " "	58	20'	15'	14.5'	10	2"	"
21-15+70	61	19'	15.5'	15.'	8'	2"	"
" " "	62	16'	15'	14.5'	6'	2"	"
" " "	63	16'	15'	14.5'	8'	2"	"

NORTH CANALS STORM DRAIN SYSTEM

CITY OF LOS ANGELES
John C. Shaw, City Engineer

STORM DRAINS in
THE **KINNEY PLAZA**
AT WINDWARD AVENUE
IN
WINDWARD AVENUE
BETWEEN KINNEY PLAZA AND PARK ROW
IN
PARK ROW
BETWEEN MARKET STREET AND WINDWARD AVENUE
IN
MARKET STREET
BETWEEN PARK ROW AND THE PACIFIC OCEAN

References. F.B 11605, 10521, 11515, 11517, 11529

SUMMARY

Section "A" (Detail hereon)	102.50 Lin ft.
Section "B" (Detail hereon)	8.33 "
5'-0" Monolithic Concrete Storm Drain. (Reinf. Elliptical Arch) Plan No 29634	176.67 "
5'-6" " " " " (" " ") " " "	1130.00 "
12" Diameter Pipe	36.00 "
12" Dia. San. Swr. Pipe	15.00 "
Manhole "X" (Plan No 29164)	4
Special San. Swr. Manhole "A" (Detail hereon)	1
Catch Basin No 23 (Plan No 28944)	2
Manhole Frame and Cover Sets (Plan No 29205)	4
Section "C" (Detail hereon)	200. Lin ft
Section "C," (" ")	55.00 " "

— NOTICE TO CONTRACTORS —
For Notice to Contractors see Plan No. D1182

Resurfacing Schedule
See Sketch to left hereon.

These Elevations are based on the U.S.G.S. datum adopted July 1, 1925, Ord 52,222.

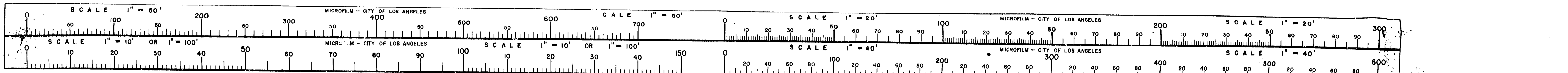
LIST OF STANDARD PLANS

Manhole "X"	29164
Manhole Frame & Covers	29205
Catch Basin No 23	28944
Monolithic Concrete Storm Drain	29634

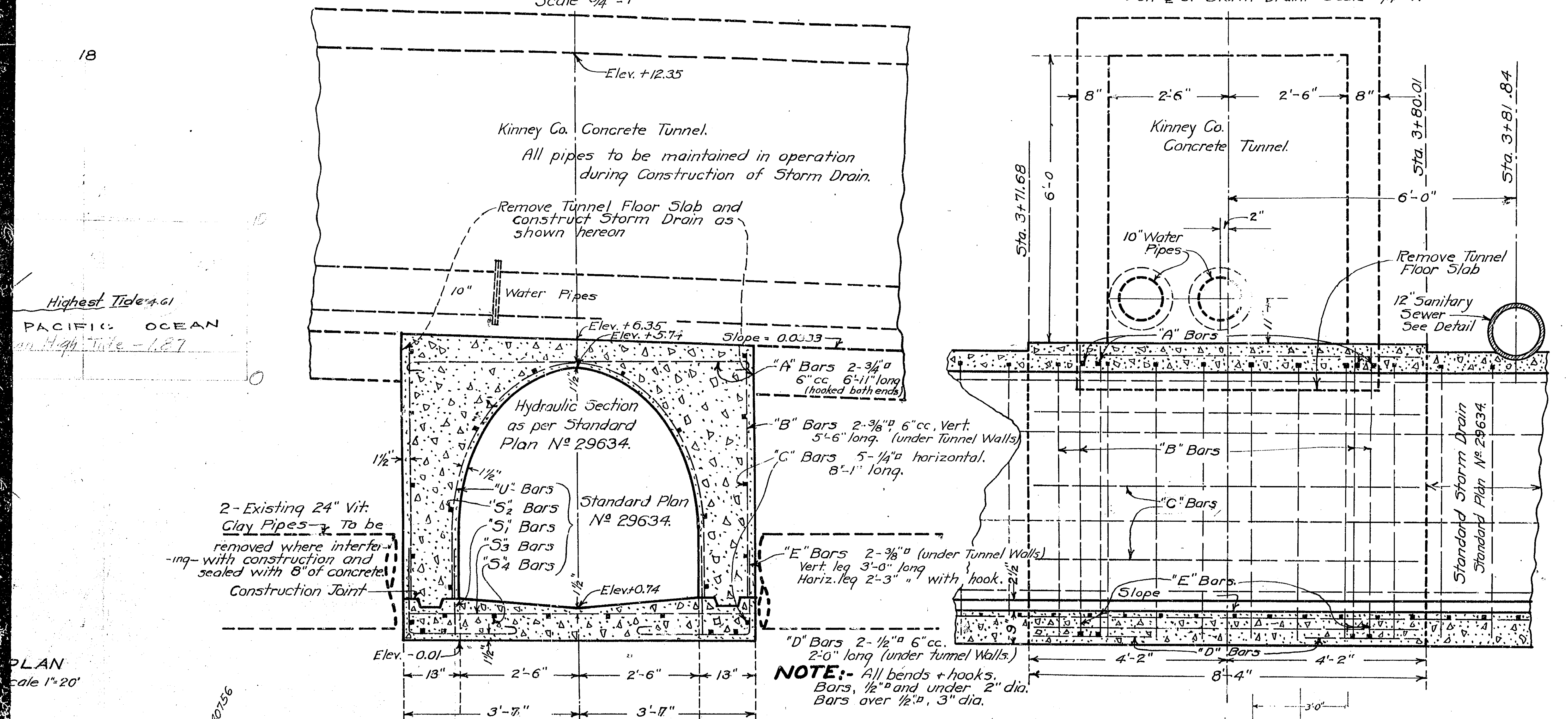
WINDWARD AVE. AND ~~SECOND AVE.~~ MAIN ST. IMP. DIST.
Designed by: Potter-Truckey Williams
Checked by: Price
Drawn by Truckey-Hogan
Sanitary Sewer 8-19-27
Substructure
Submitted 8/25 1927 Approved Aug. 29, 1927
J. H. Davidson
Venice District Engineer
John C. Shaw
City Engineer
Approved 8-21- 1927
E. A. Tuttle
Engr. Metropolitan Storm Drain Div.
Chief Deputy

D-1186
Sheet No 4 of 5 Sheets

CERTIFICATE
I hereby certify that this is a true and accurate copy of the official city record described there, made in accordance with Section 434 of the Charter of the City of Los Angeles and Section 34090.5 of the Government Code.
REX E. LAYTON, City Clerk
Date 7-3-69
By L. E. James
Deputy

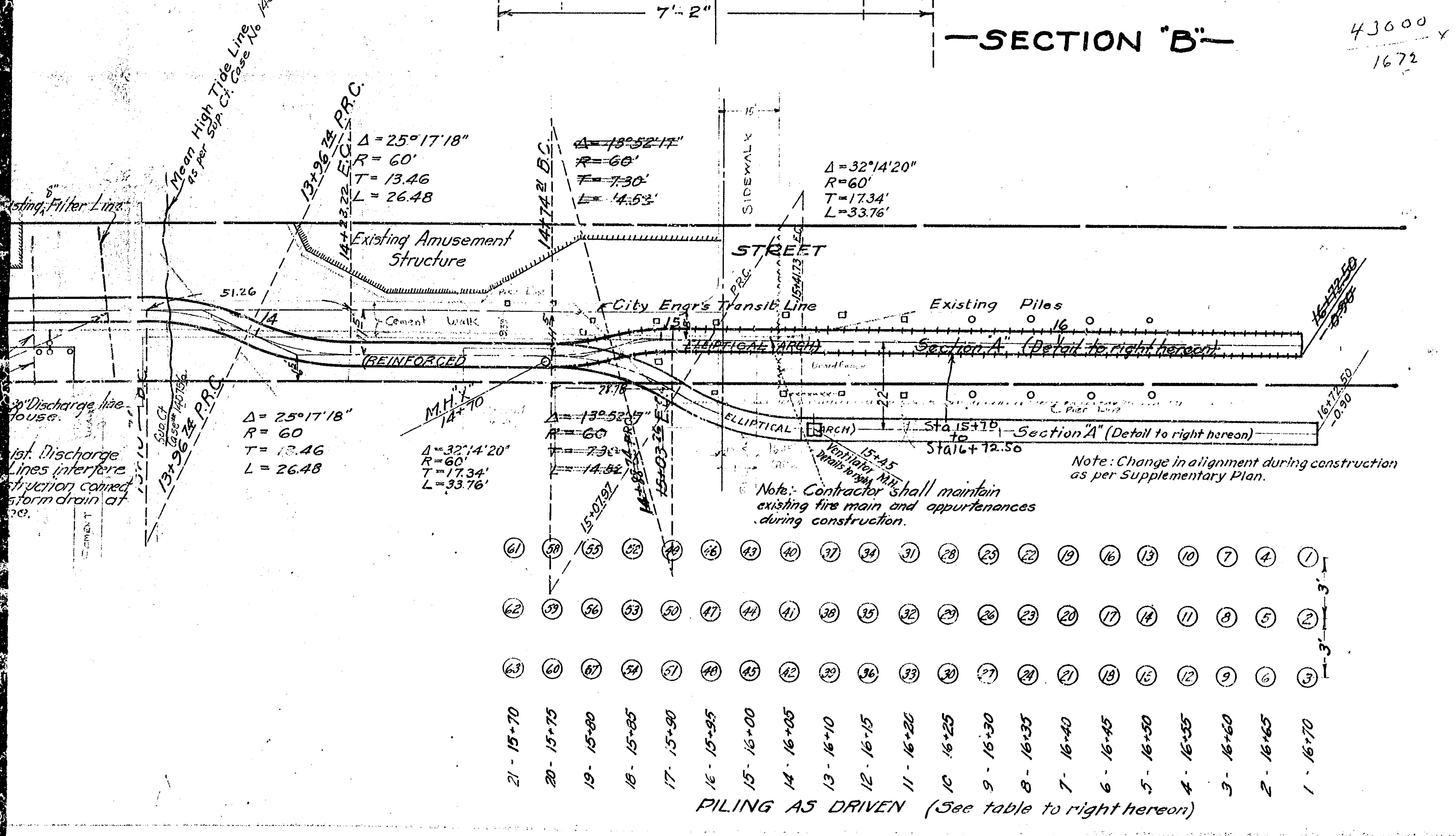


DETAILS; TUNNEL CROSSING. Sta. 3+71.88 to 3+80.21

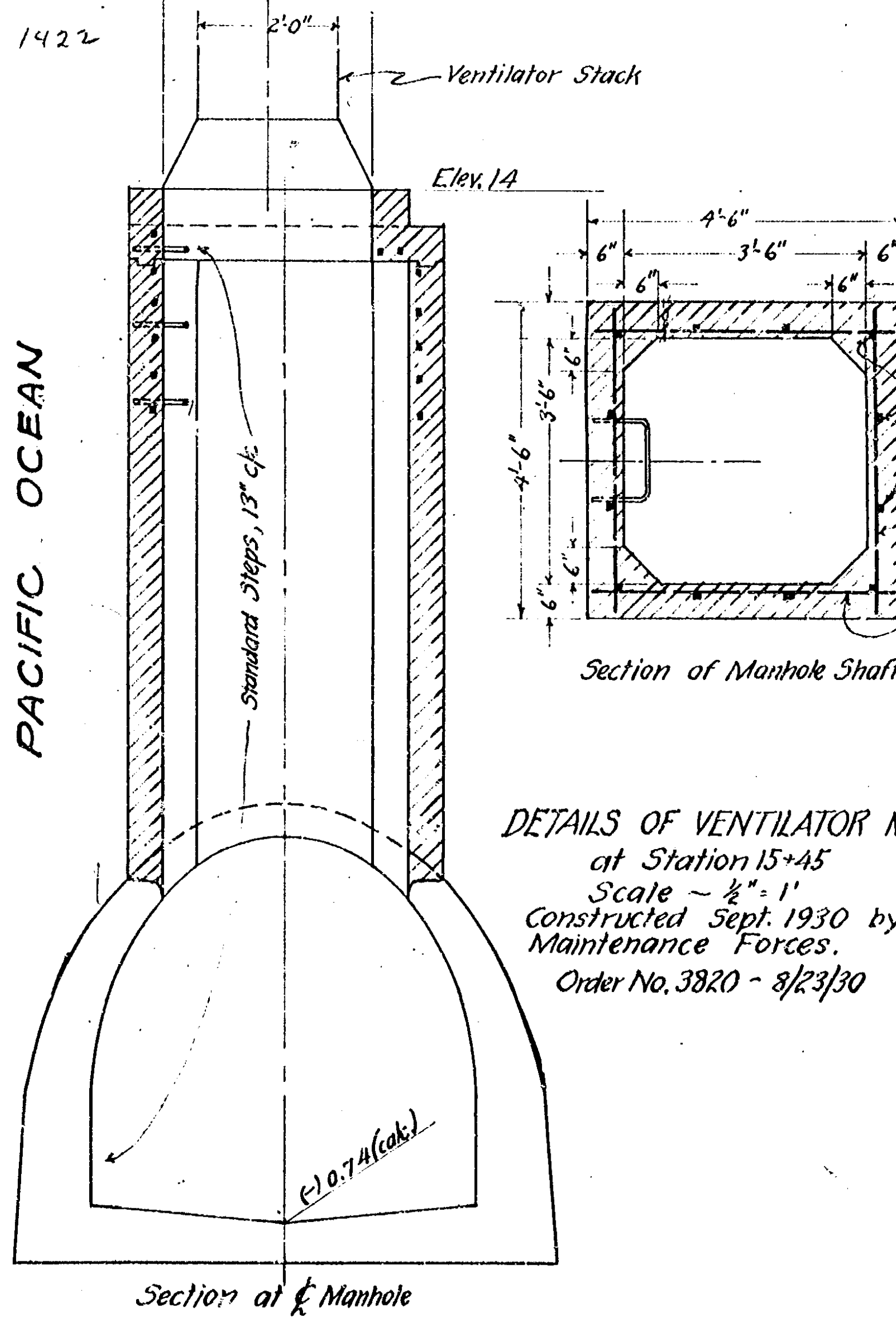


—SECTION "B"—

43600 x 1422
1672

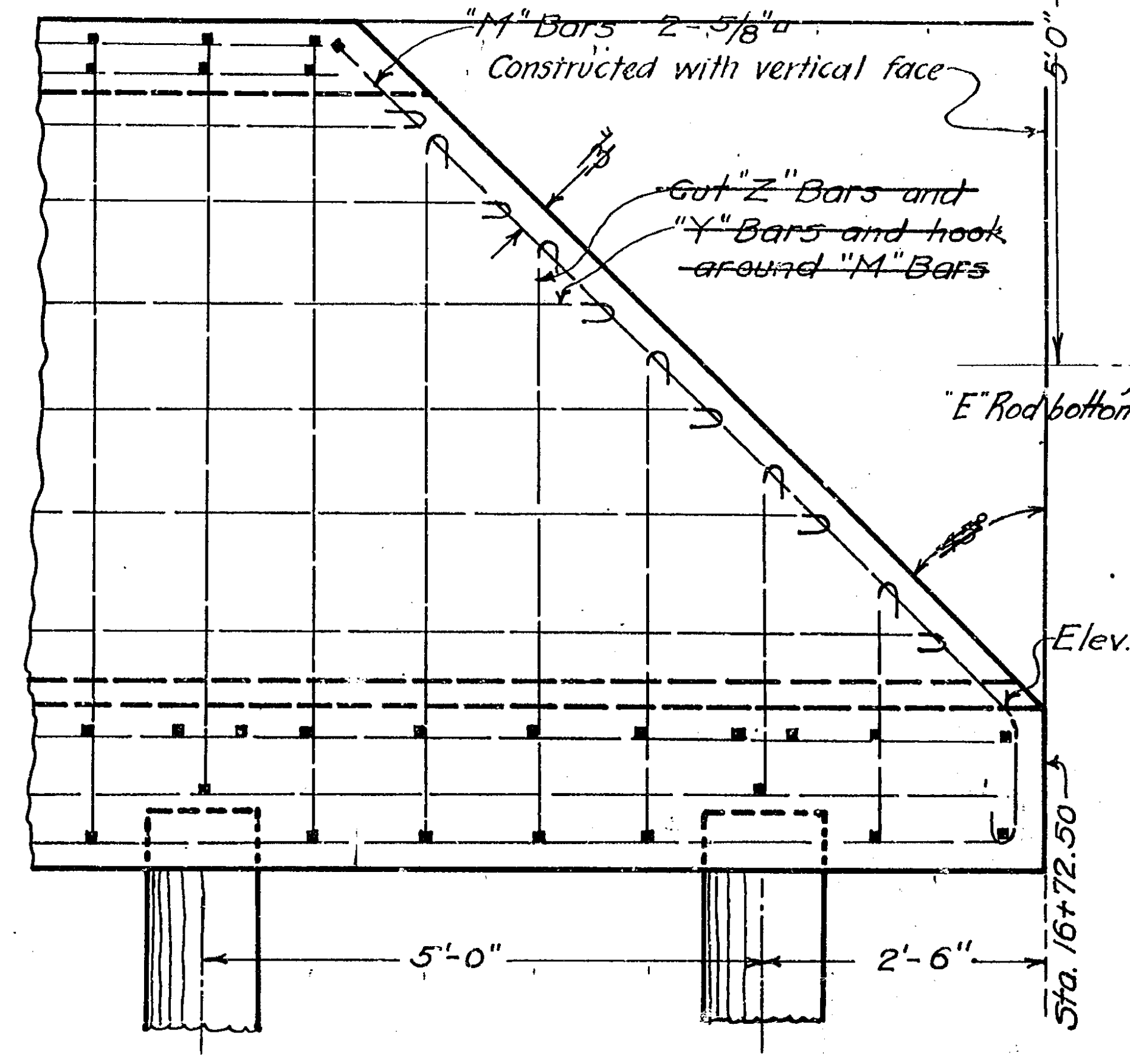


PILING AS DRIVEN (See table to right hereon)



DETAILS OF VENTILATOR M.H.
at Station 15+45
Scale - 1/2"=1'
Constructed Sept. 1930 by Maintenance Forces.
Order No. 3820 - 8/23/30

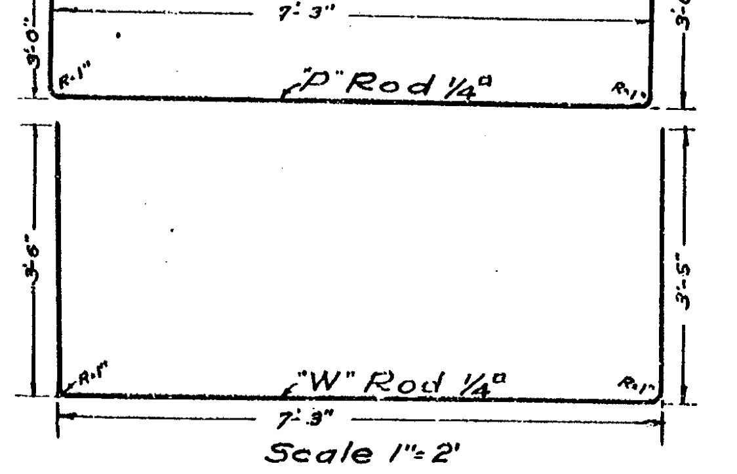
DETAIL:- Elevation showing Discharge of 5'-6" Section at Station 16+72.50
Scale 3/4"=1'



Note: All transverse and Vertical Steel to be 3" Clear of face of cement except where otherwise shown.

Construct Section A identical to Monolithic Concrete Sewer (Reinforced Elliptical Arch) Standard Plan No 29634 except as modified hereon. (D= 5'6")

1 - 9 3/4
2 3/4
1' - 7"
3

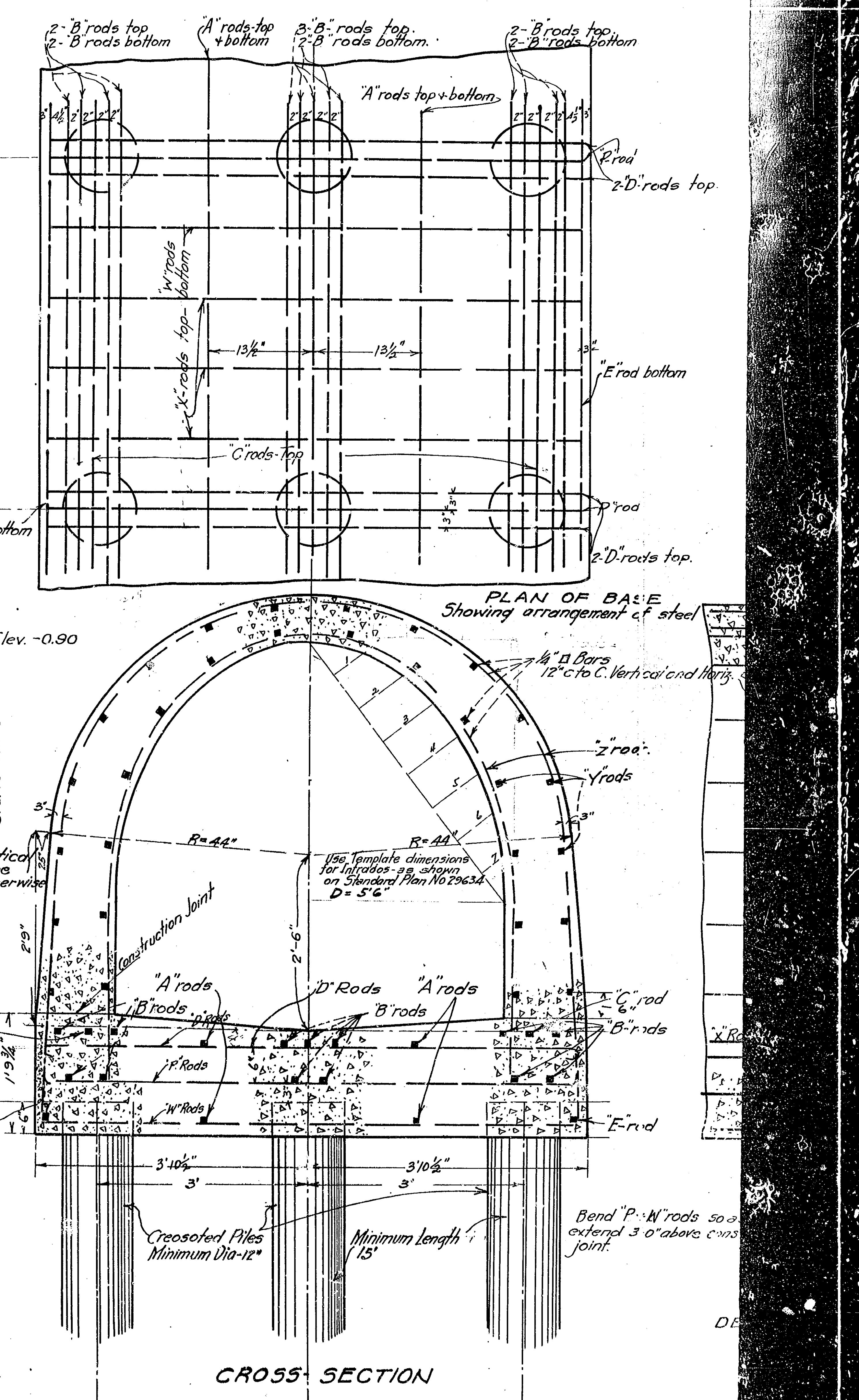


Scale 1"=2'

DETAILS OF OUTLET STR

(SECTION "A")

Between Sta. 15+70.00 and
Scale 1"=1'



CROSS-SECTION

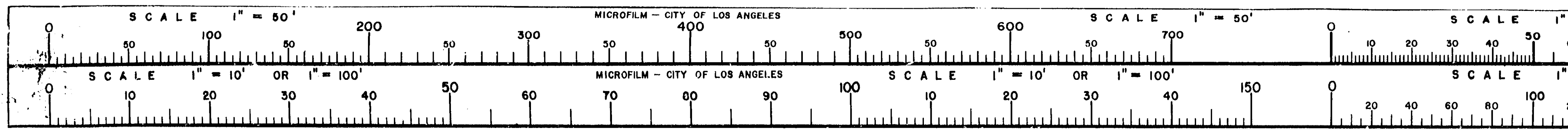
D1186 2

CERTIFICATE
I hereby certify that this is a true and accurate copy of the official city record described there, made in accordance with Section 434 of the Charter of the City of Los Angeles and Section 34090.5 of the Government Code.

REX E. LAYTON, City Clerk

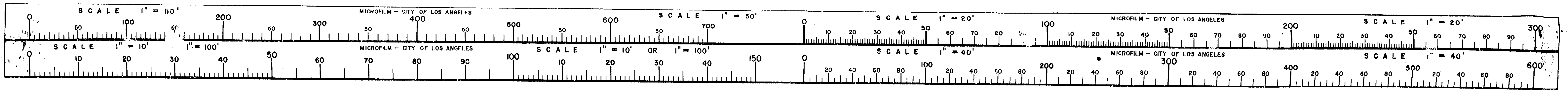
Date 7-3-69

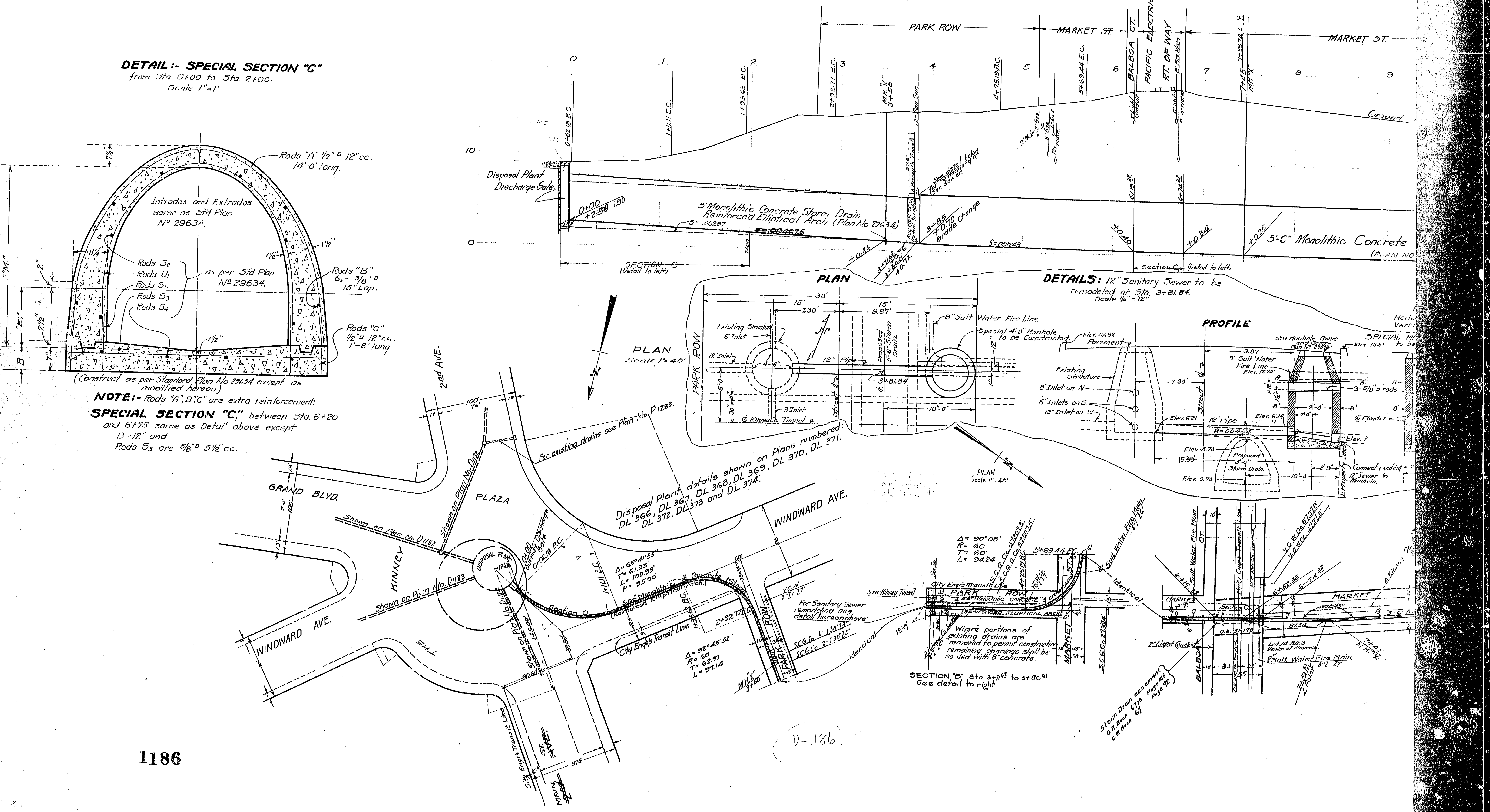
By L E Janus
Deputy



D1186 3

CERTIFICATE
I hereby certify that this is a true and accurate copy of the official city record described there, made in accordance with Section 434 of the Charter of the City of Los Angeles and Section 34090.5 of the Government Code.
Date 7-2-69
REX E. LAYTON, City Clerk
By L E Janus
Deputy





D-1186

1186

D1186 4

CERTIFICATE

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REX E. LAYTON, City Clerk

Date 1-3-69

By L E James Deputy

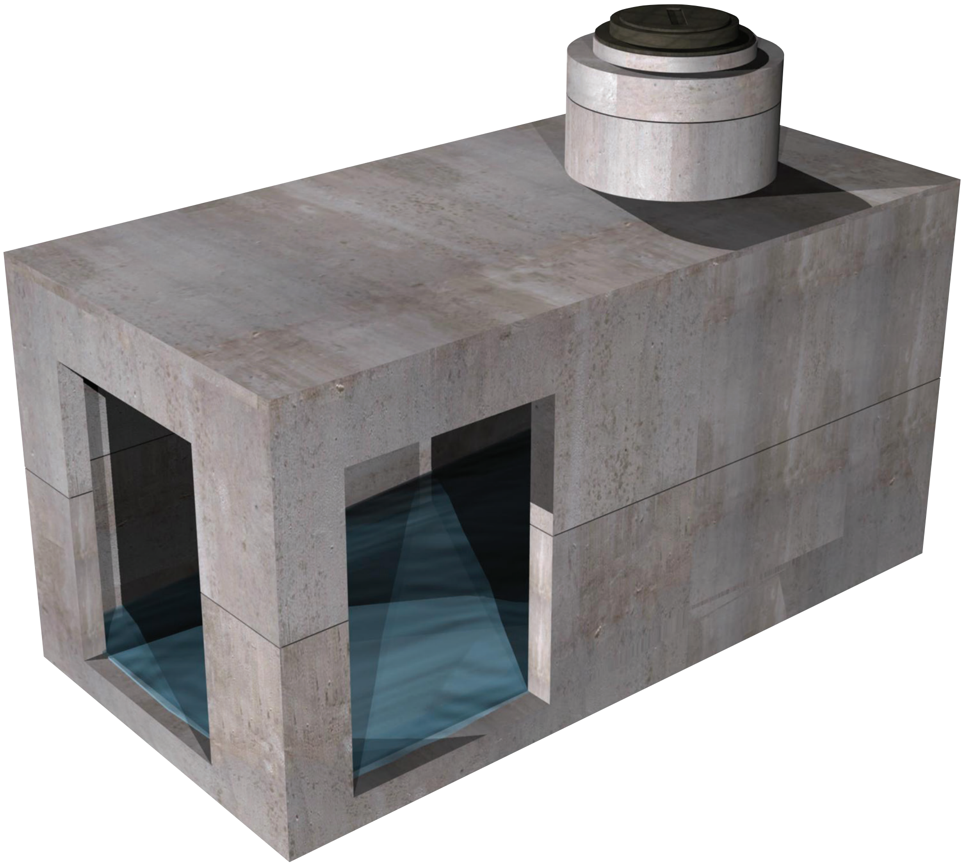
Appendix E – Product Information

STORM CAPTURE

Detention / Infiltration

TOTAL STORMWATER MANAGEMENT SYSTEM

From Oldcastle Stormwater Solutions Comes Storm Capture, A Modular Stormwater Management System for Infiltration, Detention, Retention, and Treatment.



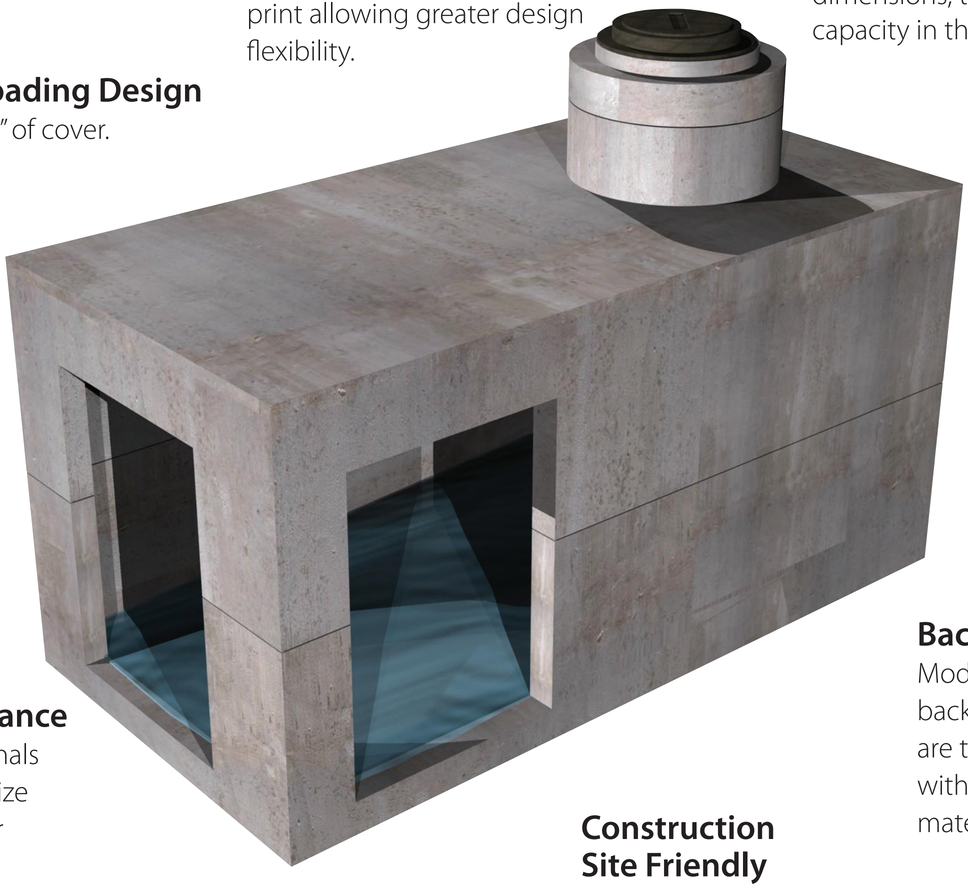
Oldcastle
Stormwater Solutions™

Storm Capture Module

Description
7′ x 15′ with a 14′ maximum/adjustable height inside dimensions, the largest capacity in the industry.

Large Storage Capacity
results in smaller system footprint allowing greater design flexibility.

Traffic Loading Design
with only 6″ of cover.



Flexible Heights
Available in heights from 2′ to 14′ to best-fit site needs.

Easy to Install
modules for fast installation.

Backfill
Modules do not rely on backfill for storage, and are typically backfilled with existing site materials.

Design Assistance
Let our professionals help you customize an application for your needs.

Construction Site Friendly
Contractor does not have to give up any of the site once the Storm Capture system is installed.

Treatment Train
Available with treatment train capability, pretreatment, post treatment, or both.

Same day staging and installation of StormCapture project.

StormCapture Project using Linkslab design.

StormCapture modules are designed for HS20 traffic loading.

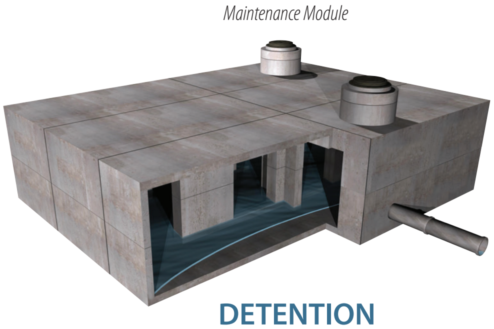
StormCapture infiltration system.

Storm Capture Benefits

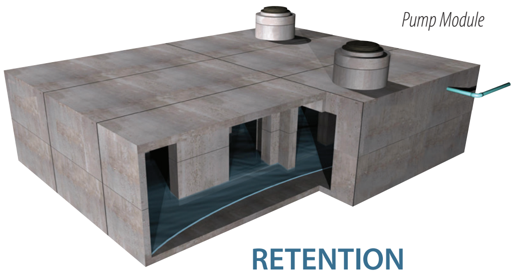
- **Fast service** - Quick and easy project help by our national engineering team with layouts and specifications to meet each project's requirements.
- **Cost savings** - Highly competitive installed and life-cycle costs.
- **Manufactured** to the rigid standards of the Oldcastle quality control program at Oldcastle facilities around the country.
- **Codes** - Designed to the latest codes for HS-20-44 (full truck load plus impact).
- **Sustainability** - The system is maintainable for long-term sustainability.
- **LID** - Ideal for Low Impact Development (LID).
- **LEED** - Manufactured locally with recycled material for potential LEED credits. *LEED 2009 for New Construction & Major Renovation, US Green Building Council: Sustainable Sites (5.1, 5.2, 6.1, 6.2), Materials & Resources (4.1, 4.2, 5.1, 5.2), Water Efficiency (1.1, 1,2, 3.1, 3.2)*

Applications

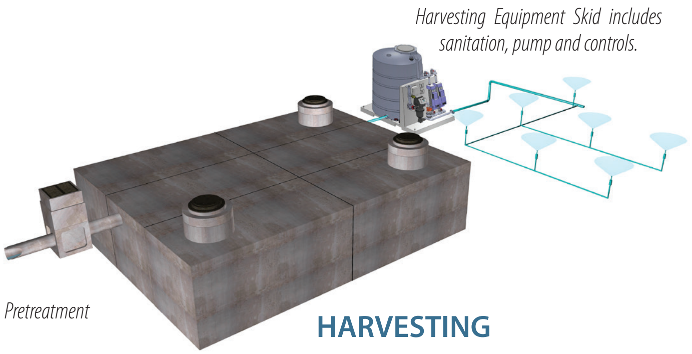
Storm Capture has many solutions for detention, retention, treatment, and harvesting that involve a combination of many parts designed to solve your stormwater management needs. Let us show you how we can design and customize a solution for you.



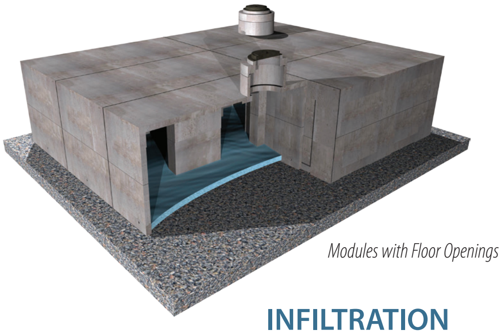
DETENTION



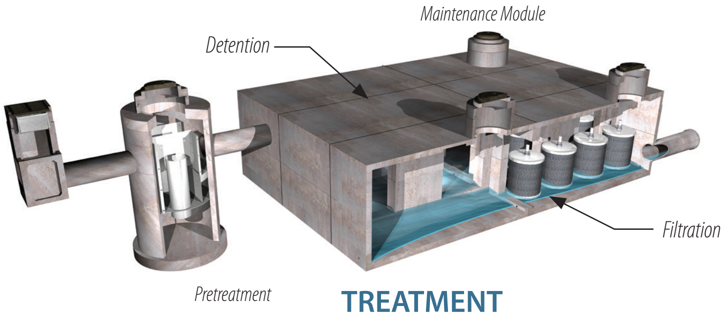
RETENTION



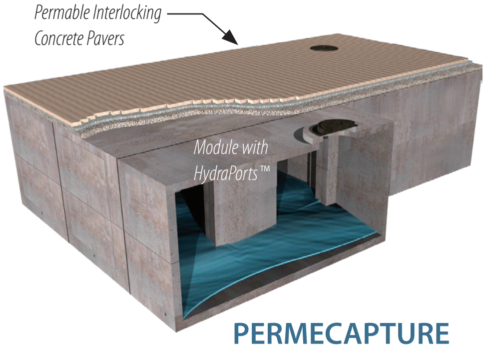
HARVESTING



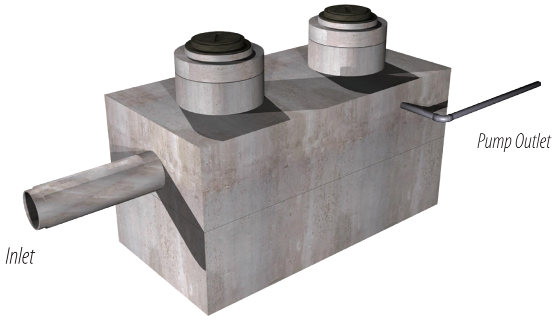
INFILTRATION



TREATMENT



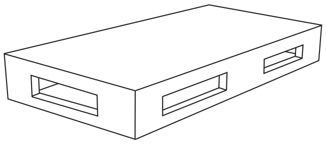
PERMECAPTURE



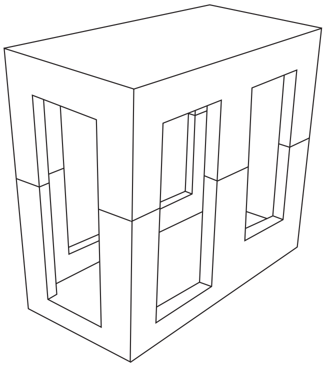
CISTERNS

INSTALLED IN ONE DAY

Module Sizes



SC1 – one piece modules can be used for applications from 2' to 7' tall. These are appropriate for cisterns, infiltration, detention, and retention systems. SC1 modules are typically installed on a minimal compacted gravel base, dependent on specific project requirements.

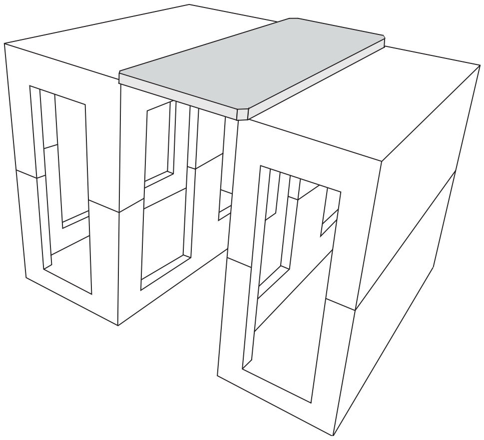


SC2 – two piece modules can be used for applications from 7' all the way up to 14' tall for maximum storage capacity in the smallest footprint. These are appropriate for cisterns, infiltration, detention, and retention systems. SC2 modules are typically installed on a compacted native subgrade.

Module Capacity

Size (ft.)	Capacity (ft^3.)	Size (ft.)	Capacity (ft^3.)
7x15x2	226	7x15x9	1027
7x15x3	343	7x15x10	1144
7x15x4	460	7x15x11	1257
7x15x5	577	7x15x12	1374
7x15x6	690	7x15x13*	1491
7x15x7	807	7x15x14*	1608
7x15x8	910		

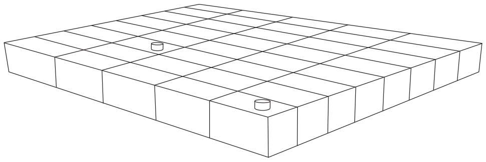
* Special design considerations required and limited availability
All dimensions are inside dimensions

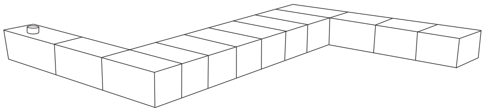


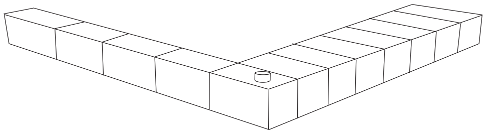
Link Slab – for large storage assemblies, the unique link slab design allows significant reduction in the quantity of modules and associated costs, while providing the maximum in storage capacity.

Endless Configurations

Contact us today to start designing your system!







Oldcastle
Stormwater Solutions™

(800) 579-8819

www.oldcastlestormwater.com
www.stormcapture.com

KRISTAR

Humes
Water Solutions

Strength. Performance. Passion.

StormTrap® system Installation guide

SingleTrap™ model

Contents

The StormTrap® system **1**
Design and installation standards 1
Specifications **2**
Module details 2
  Masses and dimensions 2
Handling and installation **3**
Safety 3
Pre-delivery 3
  Equipment requirements 3
  Site preparation 4
Delivery 5
Lifting 5
Module installation 6
Contact information **9**

The StormTrap® system

The StormTrap® system is a purpose-built stormwater detention and infiltration solution which provides a fully trafficable, below ground on-site detention system (OSD).

The system takes a unique design approach by connecting individual precast concrete modules into a single layer configuration that meets each project's requirements. This delivers a simple and flexible design solution without compromising above ground land use.

The growing popularity of the StormTrap® system is not only driven by its unique design and performance benefits, but by the significant installation economies it can provide. The modular design of the system means large detention volumes are delivered with the installation of each module. And because installers are able to use traditional construction processes, the installation can be completed in minimal time. Generally, it is expected that an individual StormTrap® module can be set in position in less than 10 minutes.

The StormTrap® system is available in two configurations to provide conventional detention, high early discharge or infiltration to ground water. The SingleTrap™ system and DoubleTrap™ system provide design solutions to meet volume requirements. This guide refers to the installation of the SingleTrap™ system.

The SingleTrap™ system is either founded on a strip footing to create a large infiltrative surface area, or founded on a conventional concrete slab for use as either a traditional detention basin or a basin with high early discharge.

The installation of the StormTrap® system is very simple:

1. Establish a suitable foundation.
2. Place modules row-by-row.
3. Apply StormWrap™ mastic tape across the top of the module joins.
4. Backfill.

There are a number of time-lapse videos available from humeswatersolutions.com.au which demonstrate the construction sequence and methodologies undertaken during the installation of a StormTrap® system. The library of videos includes a variety of project sizes and configurations.

As the system is made from precast concrete it is extremely strong and trafficable to AS 5100 traffic loadings (light duty designs are also available). Once the system has been installed there is no requirement for any further structural work in the trafficable pavement. The system will not deflect during construction loading, which allows rapid backfilling, and it won't suffer creep, as can be experienced with some lightweight systems.

Design and installation standards

The StormTrap® system is designed and installed in accordance with the requirements of the following Australian standards:

- AS 3600-2001 – Concrete Structures Code
- AS 5100-2004 – Bridge Design Code
- AS 5100.2-2004 – Bridge Design – Design Loads
- AS 1597.2-1996 – Precast Reinforced Concrete Box Culverts - Large Culverts
- AS/NZS 1170.1-2002 – Structural Design Actions – Part 1: Permanent, Imposed and other Actions.

Specifications

Module details

There are a number of different StormTrap® modules available and their use and placement will depend on design requirements and site layout (refer to Figure 1).

While the length and width of the modules remains constant, the height, and subsequently the mass, will vary according to the leg height for the system. The leg height varies from 600 mm to 1,500 mm, and is adjustable at 25 mm increments within this range.

Some modules will contain openings to allow for stormwater pipes or culverts and maintenance access points. Inlets and outlets may be placed at varying inverts and positions around the perimeter of the structure.

Depending on the overall size, each StormTrap® system will generally be designed with either 600 mm or 1,050 mm diameter openings for access through the roof at either end of the system. However, access openings may be in any location to fit in with specific site requirements. Designs can be modified to accommodate 900 mm x 900 mm grates.

Masses and dimensions

SingleTrap™ modules have a maximum internal leg height of 1,500 mm. The maximum mass of each module is shown in Table 1.

Table 1 – Masses and dimensions (1,500 mm height)

Module type	Mass (kg)	Length x width (mm)
I	6,730	4,000 x 2,350
II	4,320	2,000 x 2,350
III	7,660	4,000 x 2,350
IV	4,810	2,000 x 2,350
V	4,810	2,000 x 2,350
VI	8,590	4,000 x 2,350
VII	5,280	2,000 x 2,350
Light duty I	4,400	4,000 x 2,350

Figure 1 – A sample layout of a SingleTrap™ system

V	III	III	IV
II	I	I	II
II	I	I	II
IV	III	III	V

Standard type I

Standard type II

Standard type III

Standard type IV

Standard type V

Standard type VI

Standard type VII

Light duty type I

Handling and installation

Safety

Safety is a priority for Humes. It is important for all parties to observe safety requirements and regulations during transportation, handling, storage and installation, including wearing appropriate personal safety protection equipment.

It is the responsibility of the main contractor or installation contractor to produce a Safe work method statement; we recommend that this statement complies with both the National Code of Practice for Precast Tilt-up and Concrete Elements in Building Construction, and local and state codes (where they exist). Personnel should follow any safety advice provided by the main contractor/installation contractor.

The precast concrete component should only be lifted using the appropriate lifting clutches which are fitted into the designated lift points via the cast-in anchors. All lifting equipment must be certified to lift the specific mass and approved for lifting heavy components. The mass of the StormTrap® modules will vary depending on its geometry; weights will be clearly marked on the precast units and in the relevant project drawings.

All lifting and placement must proceed with caution and strictly in accordance with all relevant occupational health and safety standards. Bumping or impact of modules can cause damage and should be avoided.

The advice in this publication is of a general nature only. Where any doubt exists as to the safety of a particular lift or installation procedure, seek the guidance of a professional engineer or contact Humes for advice.

Pre-delivery

To ensure the safe and efficient installation of the StormTrap® system it is important to undertake sufficient planning prior to its arrival on site.

Equipment requirements

The following list of equipment is required for a safe and efficient installation:

- tape measure
- a can of marking spray
- chalk line/masonry string
- pinch/crowbar
- stanley knife
- two ladders
- broom
- level
- four chains
- four five-tonne Swiftlift® clutches
- Swiftlift® clutches for manhole covers or risers
- swivel for chains
- 20 mm spacers or gap gauge (available from Humes)
- safety harness for working at height
- StormMastic™ sealant
- StormWrap™ mastic tape.

Left:
Gap gauge

Site preparation

Before the StormTrap® system is installed, the concrete foundation must be poured (refer to the approval drawings supplied by Humes). The foundation details will depend on whether the system is required to provide stormwater detention or infiltration (refer to Figure 2 and Table 2 for an example).

Once the foundation is cured mark the outside edges of the system on the slab (as per the layout dimensions of the approval drawings).

Figure 2 – Example of a foundation plan

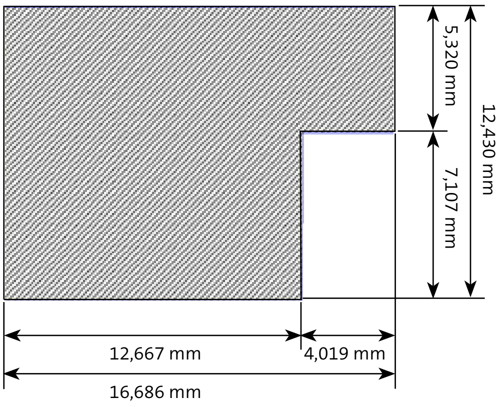
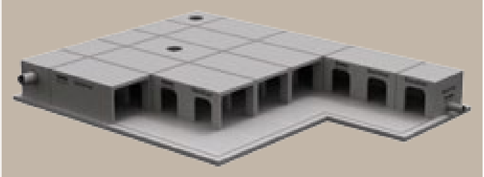
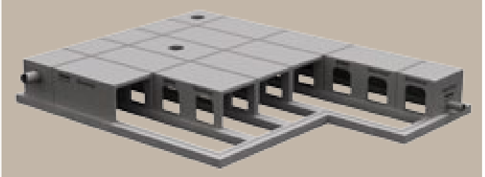
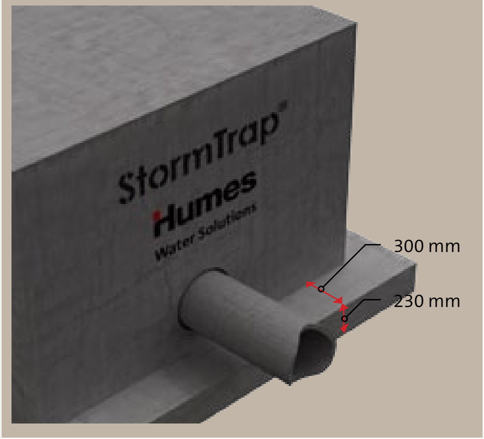
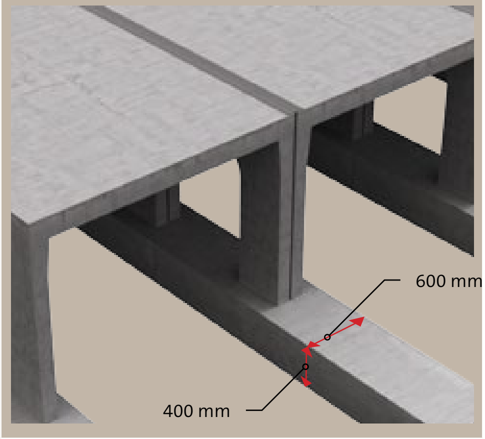


Table 2 – Foundation details

System type	Detention	Infiltration
		
Foundation	Continuous concrete slab	Strip footing
Dimensions	Slab is 230 mm thick* and extends 300 mm past outer edge of the system. 	Slab 'strips' are 400 mm thick and 600 mm wide running underneath the line of StormTrap® feet. 
Recommended cure period	7 days	7 days

Note:
*Slab design is based on in-situ material having a bearing capacity of 150 KPa; this may differ according to engineer's specifications.

Delivery

Prior to deliveries commencing, a pre-installation site meeting will occur with the contractor to finalise shipping plans including the sequencing of deliveries and the order of unloading and installing each of the modules.

The shipping plan will help to alleviate the double-handling of modules; save time and effort, make more efficient use of the crane, and reduce site congestion. The shipping plan will be provided to both the specifying engineer and contractor for sign off prior to commencing the delivery of modules to site (refer to Figure 3).

The StormTrap® modules will be delivered to site either on a semi-trailer or B-double depending on site access and the number of modules to be delivered. Each truck will typically contain 3-6 modules depending on the particular module type and mass. The first truck will typically take about 45 minutes to unload, the second truck about 30-45 minutes, and then each subsequent truck about 20-30 minutes.

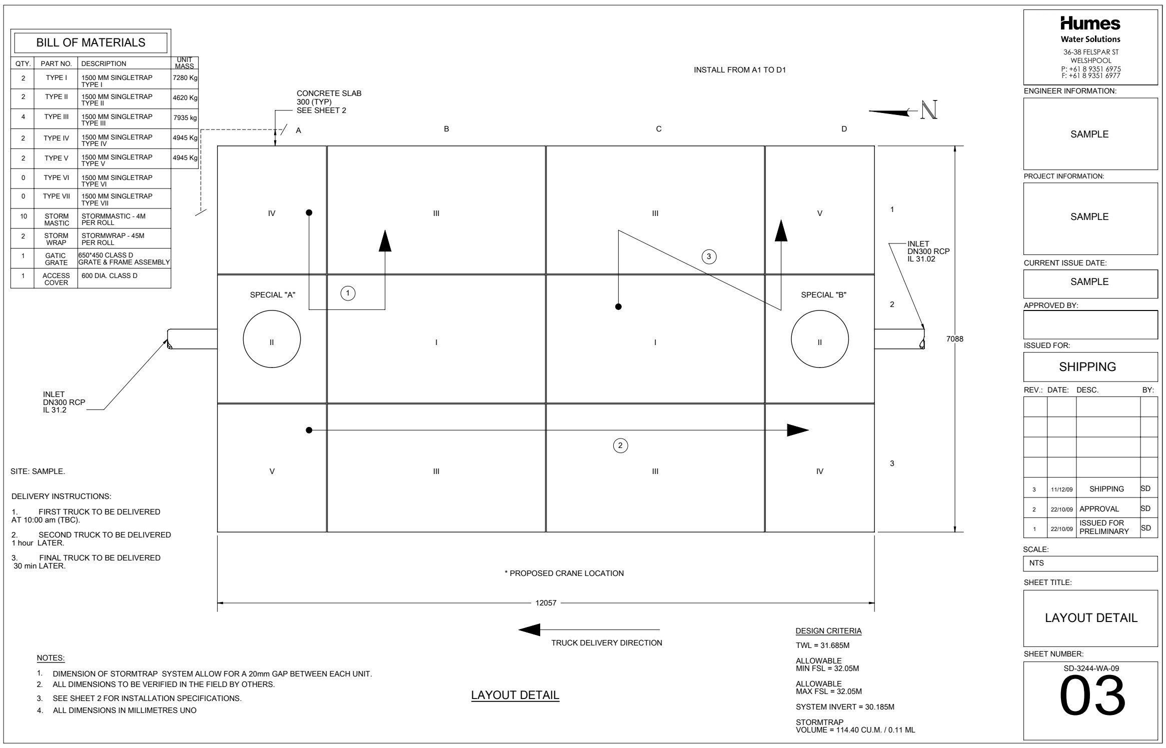
Lifting

All the precast units are supplied with cast-in lifting anchors to enable safe handling. To prevent stress and possible concrete cracking, all units must be handled using the cast-in lifting anchors and associated lifting clutches (lifting clutches can be obtained from the crane contractor or Humes). Installers should use tagged lifting equipment only. It is the installation contractor's responsibility to ensure the lifting clutches are available on site. The lifting points of anchors are clearly shown on the Humes drawings.

Wherever possible, all modular components should be lifted from the delivery truck and set directly onto the prepared substructure. Each module will take approximately 5-10 minutes to unload and set into position.

If for some reason temporary storage of the modules is required on site, they should be placed carefully on level, even ground, free of rocks and uniformly supported across the entire leg surface by using timbers. Modules should not be stacked on top of each other.

Figure 3 – Example of a shipping plan



BILL OF MATERIALS

QTY.	PART NO.	DESCRIPTION	UNIT MASS
2	TYPE I	1500 MM SINGLETRAP TYPE I	7280 Kg
2	TYPE II	1500 MM SINGLETRAP TYPE II	4620 Kg
4	TYPE III	1500 MM SINGLETRAP TYPE III	7935 kg
2	TYPE IV	1500 MM SINGLETRAP TYPE IV	4945 Kg
2	TYPE V	1500 MM SINGLETRAP TYPE V	4945 Kg
0	TYPE VI	1500 MM SINGLETRAP TYPE VI	
0	TYPE VII	1500 MM SINGLETRAP TYPE VII	
10	STORM MASTIC	STORMMASTIC - 4M PER ROLL	
2	STORM WRAP	STORMWRAP - 45M PER ROLL	
1	GATIC GRATE	650*450 CLASS D GRATE & FRAME ASSEMBLY	
1	ACCESS COVER	600 DIA. CLASS D	

SITE: SAMPLE.

DELIVERY INSTRUCTIONS:

1. FIRST TRUCK TO BE DELIVERED AT 10:00 am (TBC).
2. SECOND TRUCK TO BE DELIVERED 1 hour LATER.
3. FINAL TRUCK TO BE DELIVERED 30 min LATER.

NOTES:

1. DIMENSION OF STORMTRAP SYSTEM ALLOW FOR A 20mm GAP BETWEEN EACH UNIT.
2. ALL DIMENSIONS TO BE VERIFIED IN THE FIELD BY OTHERS.
3. SEE SHEET 2 FOR INSTALLATION SPECIFICATIONS.
4. ALL DIMENSIONS IN MILLIMETRES UNO

DESIGN CRITERIA

TWL = 31.685M

ALLOWABLE MIN FSL = 32.05M

ALLOWABLE MAX FSL = 32.05M

SYSTEM INVERT = 30.185M

STORMTRAP VOLUME = 114.40 CU.M. / 0.11 ML

Humes Water Solutions
36-38 FELSPAR ST
WELSHPOOL
P: +61 8 9351 6975
F: +61 8 9351 6977

ENGINEER INFORMATION: SAMPLE

PROJECT INFORMATION: SAMPLE

CURRENT ISSUE DATE: SAMPLE

APPROVED BY:

ISSUED FOR: SHIPPING

REV.:	DATE:	DESC.	BY:
3	11/12/09	SHIPPING	SD
2	22/10/09	APPROVAL	SD
1	22/10/09	ISSUED FOR PRELIMINARY	SD

SCALE: NTS

SHEET TITLE: LAYOUT DETAIL

SHEET NUMBER: SD-3244-WA-09 03

Module installation

Top:
Step one

Middle:
Step two

Bottom:
Step three

A representative of Humes Water Solutions will be present on site at the commencement of the installation (as required) to provide support to the contractor and observe deliveries and installation.

The StormTrap® system is typically installed as follows:

1. Sweep the concrete slab/footings clean of dirt and debris.

2. Lay a bead of StormMastic™ sealant on the slab approximately 60 mm inside the perimeter line marking.

3. Secure the first module with four Swiftlift® anchors. Take care not to strike the modules together when you are unloading and lowering them. Be aware of pinch hazard at all times and don't walk or work under suspended loads.

4. When lowering the first module into position, pause 50 mm above the concrete slab, then gradually lower it into position once it is aligned with the perimeter markings. Ensure the unit is square and the bottom of the module is on the foundation before you remove the lifters.

Top:
Step four

Middle:
Step five

Bottom:
Step six

5. Align the next module with the edge markings and position it adjacent to, but no more than 20 mm from the first block (check with a gap gauge). Use a pinch or crowbar to assist with the finer adjustment of the modules.

6. Continue to install the modules row-by-row, in the order shown on the shipping plan.

Top:
Step seven

Bottom:
Step eight

7. Once two rows of modules have been laid and checked, apply StormWrap™ tape across the joins.

8. When four rows of modules have been laid, checked and sealed, backfilling can then occur (refer per note F. on page 2 of the approval drawings).

Note: During the installation check the overall dimensions of the system to make sure creep is not occurring. Adjust the laying gap when necessary to recover any discrepancies.

Contact information

National sales 1300 361 601
humeswatersolutions.com.au
info@humeswatersolutions.com.au

Head Office

18 Little Cribb St
Milton 4064 QLD
Ph: (07) 3364 2800
Fax: (07) 3364 2963

Queensland

Brisbane/Gold Coast
Ph: (07) 3866 7100
Fax: (07) 3866 7101

Bundaberg
Ph: (07) 4152 2644
Fax: (07) 4152 5847

Rockhampton
Ph: (07) 4924 7900
Fax: (07) 4924 7901

Sunshine Coast
Ph: (07) 5472 9700
Fax: (07) 5472 9711

Toowoomba
Ph: (07) 4694 1420
Fax: (07) 4634 3874

Townsville
Ph: (07) 4758 6000
Fax: (07) 4758 6001

New South Wales

Canberra
Ph: (02) 6285 5309
Fax: (02) 6285 5334

Grafton
Ph: (02) 6644 7666
Fax: (02) 6644 7313

Kempsey
Ph: (02) 6562 6755
Fax: (02) 6562 4235

Lismore
Ph: (02) 6621 3684
Fax: (02) 6622 1342

Newcastle
Ph: (02) 4032 6800
Fax: (02) 4032 6822

Sydney
Ph: (02) 9832 5555
Fax: (02) 9625 5200

Tamworth
Ph: (02) 6763 7300
Fax: (02) 6763 7301

Victoria

Echuca
Ph: (03) 5480 2371
Fax: (03) 5482 3090

Melbourne
Ph: (03) 9360 3888
Fax: (03) 9360 3887

Tasmania

Invermay
Ph: (03) 6335 6300
Fax: (03) 6335 6330

South Australia

Adelaide
Ph: (08) 8168 4544
Fax: (08) 8168 4549

Western Australia

Gnangara
Ph: (08) 9302 8000
Fax: (08) 9309 1625

Perth
Ph: (08) 9351 6999
Fax: (08) 9351 6977

Northern Territory

Darwin
Ph: (08) 8984 1600
Fax: (08) 8984 1614

Water Solutions

National sales 1300 361 601
humeswatersolutions.com.au
info@humeswatersolutions.com.au

A Division on Holcim Australia

ACPT

THE ADVANCED CONCRETE PAVEMENT TECHNOLOGY (ACPT) Products Program is an integrated, national effort to improve the long-term performance and cost-effectiveness of the Nation's concrete highways. Managed by the Federal Highway Administration through partnerships with State highway agencies, industry, and academia, the goals of the ACPT Products Program are to reduce congestion, improve safety, lower costs, improve performance, and foster innovation.

The ACPT Products Program identifies, refines, and delivers for implementation available technologies from all sources that can enhance the design, construction, repair, and rehabilitation of concrete highway pavements. The ACPT Marketing Plan enables technology transfer, deployment, and delivery activities to ensure that agencies, academia, and industry partners can derive maximum benefit from promising ACPT products in the quest for long-lasting concrete pavements that provide a safe, smooth, and quiet ride.

www.fhwa.dot.gov/pavement/concrete

U.S. Department of Transportation
Federal Highway Administration

TechBrief
DECEMBER 2012 | FHWA-HIF-13-006

Pervious Concrete

This TechBrief presents an overview of pervious concrete and its use in pavement applications. General information on the composition of pervious concrete is provided, along with a summary of its benefits, limitations, and typical properties and characteristics. Important considerations in mix proportioning, hydrological design, structural design, construction, and maintenance are also described.

Introduction

Pervious concrete, sometimes referred to as no-fines, gap-graded, permeable, or enhanced porosity concrete, is an innovative approach to controlling, managing, and treating stormwater runoff. When used in pavement applications, pervious concrete can effectively capture and store stormwater runoff, thereby allowing the runoff to percolate into the ground and recharge groundwater supplies.

Pervious concrete contains little or no fine aggregate (sand) and carefully controlled amounts of water and cementitious materials. The paste coats and binds the aggregate particles together to create a system of highly permeable, interconnected voids that promote the rapid drainage of water (Tennis et al. 2004; ACI 2010). Typically, between 15 and 25 percent voids are achieved in the hardened concrete, and flow rates for water through the pervious concrete are generally in the range of 2 to 18 gal/min/ft^2 (81 to 730 L/min/m^2), or 192 to 1,724 inch/hr (488 to 4,379 cm/hr) (ACI 2010). Figure 1 shows a typical cross section of a pervious concrete pavement.

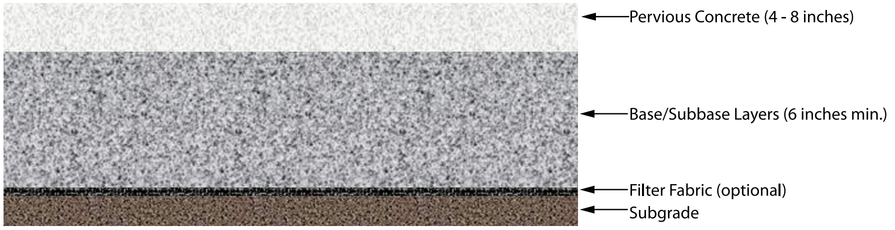


FIGURE 1. Typical pervious concrete pavement cross section (adapted from EPA 2010).

Benefits and Limitations

Table 1 summarizes some of the major benefits and limitations associated with pervious concrete. As described above, perhaps the most significant benefit provided by pervious concrete is in its use as a stormwater management tool. Stormwater runoff in developed areas (often the result of or exacerbated by the presence of conventional impervious pavement) has the potential to pollute surface and groundwater supplies, as well as contribute to flooding and erosion (Leming et al. 2007).

Pervious concrete can be used to reduce stormwater runoff, reduce contaminants in waterways, and renew groundwater supplies. With high levels of permeability, pervious concrete can effectively capture the "first flush" of rainfall (that part of the runoff with a higher contaminant concentration) and allow it to percolate into the ground where it is filtered and "treated" through soil chemistry and biology (Tennis et al. 2004; ACI 2010).

Other major benefits provided by pervious concrete include reduction in heat island effects (water percolating through the pavement can exert a cooling effect through evaporation, and convective airflow can also contribute to cooling (Cambridge 2005)), reductions in standing water on pavements (and associated hydroplaning and splash/spray potential), and reduced tire–pavement noise emissions (due to its open structure that helps absorb noise at the tire–pavement interface) (ACI 2010). In addition, pervious concrete can contribute toward credits in the LEED® (Leadership in Energy and Environmental Design) rating system for sustainable building construction (Ashley 2008).

Along with its many benefits, there are some limitations associated with the use of pervious concrete. First and foremost, pervious concrete has typically been used on lower trafficked roadways, although there are a number of installations on higher volume facilities, and research is being conducted on the structural behavior of pervious concrete slabs (see, for example, Suleiman et al. 2011; Vancura et al. 2011). In addition, pervious concrete exhibits material characteristics (primarily lower paste contents and higher void contents) and produces hardened properties (notably density and strength) that are significantly different from conventional concrete; as a result, the current established methods of quality control/quality assurance (e.g., slump, strength, air content) are in many

TABLE 1. Summary of Pervious Concrete Benefits and Limitations (Tennis et al. 2004; ACI 2010)

Benefits/Advantages	Limitations/Disadvantages
• Effective management of stormwater runoff, which may reduce the need for curbs and the number and sizes of storm sewers. • Reduced contamination in waterways. • Recharging of groundwater supplies. • More efficient land use by eliminating need for retention ponds and swales. • Reduced heat island effect (due to evaporative cooling effect of water and convective airflow). • Elimination of surface ponding of water and hydroplaning potential. • Reduced noise emissions caused by tire–pavement interaction. • Earned LEED® credits.	• Limited use in heavy vehicle traffic areas. • Specialized construction practices. • Extended curing time. • Sensitivity to water content and control in fresh concrete. • Lack of standardized test methods. • Special attention and care in design of some soil types such as expansive soils and frost-susceptible ones. • Special attention possibly required with high groundwater.

cases not applicable (ACI 2010). Moreover, a number of special practices, described later, are required for the construction of pervious concrete pavements. And, while there have been concerns about the use of pervious concrete in areas of the country subjected to severe freeze–thaw cycles, available field performance data from a number of projects indicate no signs of freeze–thaw damage (Delatte et al. 2007; ACI 2010).

Applications

Pervious concrete has been used in pavement applications ranging from driveways and parking lots to residential streets, alleys, and other low-volume roads (Tennis et al. 2004). Within these applications, pervious concrete has been used as the surface course, as a drainable base course (often in conjunction with edge drains to provide subsurface drainage), or as a drainable shoulder (to help provide lateral drainage to a pavement and prevent pumping). The focus in recent years has been on its use as a surface course as a means of providing stormwater management.

Typical Properties and Characteristics

As noted previously, many of the properties of pervious concrete are different from those of conventional concrete. These properties are primarily a function of the porosity (air void content) of the pervious concrete, which in turn depends on the cementitious content, the water-to-cementitious materials (w/cm) content, the compaction level, and the aggregate gradation and quality (ACI 2010). Table 2 summarizes some of the typical material properties associated with pervious concrete. These properties and characteristics must be considered during the structural design and pavement construction.

The cost of pervious concrete may be 15 to 25 percent higher than conventional concrete, but cost can vary significantly depending on the region, the type of application, the size of the project, and the inclusion of admixtures.

Mixture Proportioning

Like conventional concrete, pervious concrete is a mixture of cementitious materials, water, coarse aggregate, and possibly admixtures, but it contains little or no fines; however, note that a small amount of fine aggregate, typically 5 to 7 percent, is required for freeze–thaw durability (Schaefer et al. 2006; Kevern et al. 2008). Table 3 shows the typical range of materials proportions that have been used in pervious concrete. Commentary on the components of a pervious concrete is provided below (Tennis et al. 2004; Delatte et al. 2007; ACI 2010):

Cementitious materials. As with conventional concrete mixtures, conventional portland cements or blended cements are used as the primary binder in pervious concrete, although supplementary cementitious materials may also be used.

TABLE 2. Typical Pervious Concrete Properties (Tennis et al. 2004; Obla 2007)

Property	Common Value / Range
Plastic Concrete	
Slump	N/A
Unit weight	70% of conventional concrete
Working time	1 hour
Hardened Concrete	
In-place density	100 to 125 lb/ft^3
Compressive strength	500 to 4,000 lbf/in^2 (typ. 2,500 lbf/in^2)
Flexural strength	150 to 550 lbf/in^2
Permeability	2 to 18 gal/ft^2/min (384 to 3,456 ft/day)

1 in = 25.4 mm; 1 lb/ft^3 = 16 kg/m^3; 1 lbf/in^2 = 6.89 kPa; 1 gal/ft^2/min = 40.8 L/m^2/min

Coarse aggregate. Coarse aggregate is kept to a narrow gradation, with the most common gradings of coarse aggregate used in pervious concrete meeting the requirements of ASTM C33/C33M—aggregate sizes of 7, 8, 67, and 89. Coarse aggregate size 89 (top size 0.375 inch (9.5 mm)) has been used extensively for parking lot and pedestrian applications. Rounded and crushed aggregates, both normal and lightweight, have been used to make pervious concrete.

Water. The control of water is important in the development of pervious concrete mixtures, and the selection of an appropriate w/cm value is important for obtaining desired strength and void structure in the concrete. A high w/cm can result in the cement paste flowing off of aggregate and filling the void structure, whereas a low w/cm can result in mixing and placement difficulties and reduced durability. Commonly, w/cm values between 0.27 and 0.34 are used.

Admixtures. As with conventional concrete, chemical admixtures can be used in pervious concrete to obtain or enhance specific properties of the mixture. In particular, set retarders and hydration stabilizers are commonly used to help control the rapid setting associated with many pervious concrete mixtures. Air-entraining admixtures are required in freeze–thaw environments although no current method exists to quantify the amount of entrained air in the fresh paste. Air entrainment can be determined on hardened samples according to ASTM C457.

TABLE 3. Typical Pervious Concrete Materials Proportions (ACI 2010)

Mix Constituent or Design Parameter	Range
Coarse aggregate	2,000 to 2,500 lb/yd³
Cementitious materials	450 to 700 lb/yd³
Water-to-cementitious ratio	0.27 to 0.34
Aggregate-to-cementitious ratio (by mass)	4 to 4.5:1

1 lb/yd³ = 0.59 kg/m³

Mix proportioning for pervious concrete is based on striking a balance between voids, strength, paste content, and workability (ACI 2010). As such, the development of trial batches is essential to determining effective mix proportions using locally available materials. Detailed information on mix proportioning is available from ACI (2010).

Some limited work has been done investigating the freeze–thaw characteristics of pervious concrete and mix design for cold weather climates (NRMCA 2004; Schaefer et al. 2006). The freeze–thaw resistance of pervious concrete appears to be dependent on the saturation level of the voids; consequently a drainable base layer with a minimum thickness of 6 inches (150 mm) is recommended to help keep the pervious concrete layer from becoming saturated. Furthermore, as previously noted, the freeze–thaw resistance of pervious concrete has been shown to improve when sand is included in the pervious concrete mixture (Schaefer et al. 2006; Kevern et al. 2008).

Design of Pervious Pavements

Two primary considerations enter into the determination of the thickness of pervious concrete pavements: 1) hydrologic design to meet environmental requirements and 2) structural design to withstand the anticipated traffic loading applications (Leming et al. 2007; ACI 2010). These design considerations are briefly described below.

Hydrologic Design

In evaluating the hydrologic design capabilities of a pervious pavement, the approach is to determine whether the characteristics of the pervious concrete pavement system are sufficient to infiltrate, store, and release the expected inflow of water (which

includes direct rainfall and may also include excess runoff from adjacent impervious surfaces). As such, information required in a hydrologic analysis includes the precipitation intensity levels, the thickness and permeability characteristics of the pervious concrete pavement, cross slopes and geometrics, and permeability properties and characteristics of the underlying base, subbase, and subgrade materials.

Many hydrological design methods exist that can be used when designing pervious concrete pavement systems, including the Natural Resources Conservation Service Curve Number Method and the Rational Method (Leming et al. 2007). In essence, the hydrologic design of pervious concrete pavements should consider two possible conditions to ensure that excess surface runoff does not occur (Leming et al. 2007):

1. Low permeability of the pervious concrete material that is inadequate to capture the "first flush" of a rainfall event.
2. Inadequate retention provided in the pervious concrete structure (slab and subbase).

Often, the thickness of a pervious concrete pavement is first determined based on structural requirements and then analyzed to determine its suitability to meet the hydrologic needs of the project site. If the thickness is found to be insufficient, adjustments can be made to the thickness of the pervious pavement or the underlying base course. Details on hydrologic design are beyond the scope of this document but are available in the literature (Leming et al. 2007; Wanielista et al. 2007; Rodden et al. 2011).

Structural Pavement Design

Pervious concrete pavements can be designed using virtually any standard concrete pavement procedure (e.g., American Association of State Highway and Transportation Officials, Portland Cement Association, StreetPave) (Delatte 2007). The American Concrete Pavement Association has recently developed a comprehensive program, PerviousPave, that can be used to develop both structural and hydrological designs for pervious pavements (Rodden et al. 2011). Regardless of the procedure used, there are critical factors to consider in the design of pervious concrete pavements (ACI 2010):

Subgrade and subbase. In the design of pervious pavements, foundation support is typically characterized by a composite modulus of subgrade reaction, which should account for the effects of both the subgrade and the subbase. An open-graded subbase is commonly used beneath pervious concrete pavements not only to provide an avenue for vertical drainage of water to the subgrade, but also to provide storage capabilities. Special subgrade conditions (such as frost susceptibility or expansive soils) may require direct treatment.

Concrete flexural strength. The flexural strength of concrete is an important input in concrete pavement structural design. However, testing to determine the flexural strength of pervious concrete may be subject to high variability; therefore, it is common to measure compressive strengths and to use empirical relationships to estimate flexural strengths for use in design (Tennis et al. 2004).

Traffic loading applications. The anticipated traffic to be carried by a pervious pavement is commonly characterized in terms of equivalent 18,000-lb (80 kN) single-axle load repetitions, which many procedures compute directly based on assumed truck-traffic distributions. Most pervious concrete pavements are used in low-truck-traffic applications.

Currently there are no thickness standards for pervious concrete pavements, but many pervious pavements for parking lots are constructed 6 inches (150 mm) thick, whereas pervious pavements for low-volume streets have been

constructed between 6 and 12 inches (150 and 300 mm) thick (ACI 2010).

Construction Considerations

Because of its unique material characteristics, pervious concrete has a number of special construction requirements. Key aspects of pervious concrete construction include the following (Tennis et al. 2004; ACI 2010):

Placement and consolidation. Most pervious concrete is placed using fixed-form construction. For smaller projects, a hand-held straightedge or vibrating screed may be acceptable for placement, whereas for larger projects an A-frame, low-frequency, vibrating screed may be used. A few projects have used laser screeds and concrete slipform equipment. Consolidation is generally accomplished by rolling the concrete with a steel roller. Overall, the low water content and porous nature of pervious concrete require that delivery and placement be completed as quickly as possible.

Finishing. Pervious concrete pavements are not finished in the same manner as conventional pavements. In essence, the final surface finish is achieved as part of the consolidation process, which leaves an open surface. Normal concrete finishing procedures, such as with bull floats and trowels, should not be performed.

Jointing. Jointing is commonly done on pervious concrete to control random crack development. These joints are commonly formed (using a specially designed compacting roller-jointer) to a depth between one-fourth and one-third of the slab thickness.

Curing and protection. After the concrete has been jointed, it is important that the concrete be effectively cured; this is commonly achieved through the placement of thick (typically 6 mil (0.15mm)) plastic sheeting over all exposed surfaces. The plastic sheeting should be applied no later than 20 minutes following discharge of the concrete, and should remain in place for at least 7 days (longer times may be required under cold weather placement conditions or if supplementary cementitious materials are used in the mix). Liquid membrane curing compounds are not commonly used because they prevent surface moisture loss and do nothing to prevent evaporation from within the pervious concrete (Kevern et al. 2009).

Inspection and testing. The American Concrete Institute has prepared a summary of recommended inspection and testing activities that should be performed during construction of pervious concrete pavements (ACI 2010), as well as a specification for pervious concrete construction (ACI 2008). Acceptance testing for pervious concrete is typically limited to density (ASTM C1688) and thickness (ASTM C42). Test methods specific to pervious concrete are listed below:

- ASTM C1688, *Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete.*
- ASTM C1701, *Standard Test Method for Infiltration Rate of In Place Pervious Concrete.*
- ASTM C1747, *Standard Test Method for Determining Potential Resistance to Degradation of Pervious Concrete by Impact and Abrasion.*
- ASTM C1754, *Standard Test Method for Density and Void Content of Hardened Pervious Concrete.*

In recognition of the special construction requirements of pervious concrete, the National Ready Mixed Concrete Association has developed a program designed to educate, train, and certify contractors in pervious concrete placement (see http://nrmca.org/Education/Certifications/Pervious_Contractor.htm).

Maintenance

Over time, sand, dirt, vegetation, and other debris can collect in pervious concrete's voids and reduce its porosity, which can negatively affect

the functionality of the system. Thus, periodic maintenance may be needed to remove surface debris and restore infiltration capacity. Two common maintenance methods are pressure washing and power vacuuming (ACI 2010).

Performance

The performance of pervious concrete pavements may be assessed in a number of ways, including monitoring changes in the permeability/porosity of the system (which would indicate clogging of the void structure), the presence of distress (both structural and surficial), and resistance to freeze–thaw damage. Unfortunately, there are limited long-term performance data on pervious concrete, but generally performance is considered satisfactory. For example, a study in Florida indicated that pervious concrete pavements that were 10 to 15 years old were operating in a satisfactory manner without significant amounts of clogging (Wanielista et al. 2007). In another study, field inspections of 22 projects located in freeze areas were conducted, with reported good performance and no visual signs of freeze–thaw damage (although all projects were less than 4 years old at the time of inspection) (Delatte et al. 2007).

Where the performance of pervious concrete pavements has not been satisfactory, poor performance is often attributed to contractor inexperience, higher compaction of soil than specified, and improper site design (ACI 2010).

Summary and Future Needs

The use of pervious concrete has increased significantly in the last several years, perhaps largely because it is considered an environmentally friendly, sustainable product. The use of pervious concrete provides a number of benefits, most notably in the effective management of stormwater runoff. Other significant benefits include reducing contaminants in waterways, recharging groundwater supplies, reducing heat island effects, and reducing pavement–tire noise emissions.

Still, there are a number of areas that need additional developmental work to improve or enhance the capabilities of pervious concrete pavements. One area is the continued monitoring of the performance of pervious concrete so that long-term performance trends can be documented; this will also help in evaluating the suitability of pervious concrete for other applications, such as overlays. Tied in with this is the assessment of the suitability of current structural design approaches to provide competent designs, particularly regarding the fatigue behavior of pervious concrete. Finally, a third area is in the testing and evaluation of pervious concrete, as current test methods for conventional concrete are not generally applicable to pervious concrete.

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Contact—For more information, contact the following:

Federal Highway Administration (FHWA)
Office of Pavement Technology
Sam Tyson, P.E.—sam.tyson@dot.gov

ACPT Implementation Team
Shiraz Tayabji, Ph.D., P.E., Fugro Consultants, Inc.—
stayabji@aol.com

Research—This TechBrief was developed by Kurt D. Smith, P.E., and James Krstulovich (Applied Pavement Technology, Inc.), as part of FHWA's ACPT product implementation activity. The TechBrief is based on research cited within the document. The ACPT Implementation Team acknowledges Dr. John Kevern of the University of Missouri–Kansas City for his technical review of this document.

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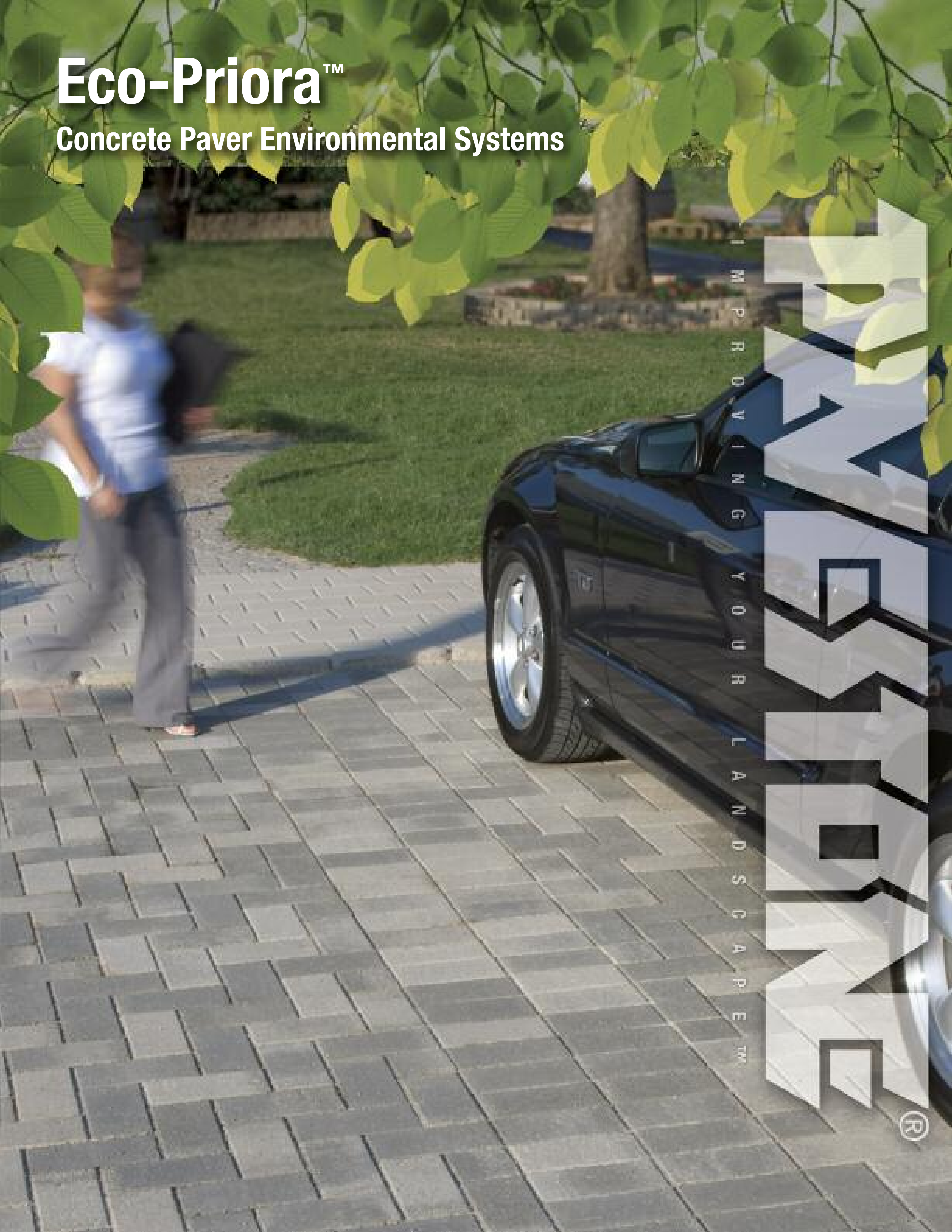
Key Words—concrete pavement construction, design, drainage, LEED® credit, maintenance, pavement design, pavement construction, permeability, pervious concrete, porous concrete, stormwater, sustainability

DECEMBER 2012 **FHWA-HIF-13-006**

Eco-Priora™

Concrete Paver Environmental Systems



UNILOCK®

IMPROVING YOUR LANDSCAPE™

Eco-Priora™

Pavestone Eco-Priora™ is the sustainable solution for permeable pavements. Eco-Priora™ is produced in a 120mm x 240mm rectangular module that is 80mm in thickness with a patented interlocking joint and a micro-chamfered top edge profile. This ingenuity is singular to the Pavestone Eco-Priora™ product and insures optimum pavement performance unequaled in the permeable paver industry. The unique Eco-Priora™ joint profile allows surface water to infiltrate into the pavement and its sub-layers. With initial permeability average flow rates of over 100 inches per hour, the Eco-Priora™ product, even with a clogging factor, will still meet the majority of current storm water management plans (SWMP). The structural interlocking capability is achieved by the paving unit having interlocking joints with a minimum of two vertically aligned horizontal interlocking spacer bars on each of its sides. These spacer bars interlock throughout the depth of the block and nest adjacently with neighboring paving units. This interlocking function resists lateral and vertical displacement when the unit is exposed to load. The dynamics of pavement stress are better distributed providing a structurally superior permeable paving system.

The micro-chamfered top edge profile produces a horizontal edge to edge dimension that is nominally 7mm including installation gapping. This small joint complies dimensionally with current ADA requirements for walking surfaces with spaces no greater than 1/2 inch. This narrow jointed surface diminishes vibration for wheelchairs and shopping carts when compared to all other permeable paving products. Eco-Priora™ can assist in meeting current EPA storm water regulations and LEED certification. The Eco-Priora™ product best achieves the balance of aesthetic segmental paving and the function of permeable pavement.

APPLICATIONS

Parking Lots • Driveways • Patios • Entrance Areas • Sidewalks
Terraces Garden Pathways • Pool Decks • Pedestrian Malls • Roof Gardens • Streets

COMPOSITION AND MANUFACTURE

Eco-Priora™ is available in one size. Height = 80mm. Eco-Priora™ is made from a "no slump" concrete mix made under extreme pressure and high frequency vibrations. Eco-Priora™ has a compressive strength greater than 8000 psi, a water absorption maximum of 5% and will meet or exceed ASTM C-936. Note: Requires modifying the ASTM C 140 - Paver Annex A4 - "The test specimen shall be 60 ± 3 mm thick and, if necessary, cut to a specimen size having a Height/Thickness (width) [H/T] aspect ratio of 0.6 ± 0.1

INSTALLATION

1. Excavate unsuitable, unstable or unconsolidated subgrade material. Compact the area, which has been cleared as per the engineer's of record (EOR) requirements. Backfill and level with open graded aggregates as per the EOR's structural and hydraulic design.
2. Place bedding course of hard and angular material conforming to the grading requirements of ASTM No. 8 or No. 9 to a uniform minimum depth of 1 1/2" -2". (38mm) screeded to the grade and profile required.
3. Install Eco-Priora™ with joints approximately 1/4". (7mm).
4. Where required, cut pave stones with an approved cutting device to fit accurately, neatly and without damaged edges.
5. Tamp pave stones with a plate compactor, uniformly level, true to grade and free of movement.
6. Spread a thin layer of hard angular material conforming to the grading requirements of ASTM No. 8 or No. 9 aggregate over entire paving area.
7. Make one more pass with plate compactor to nest the aggregate and fill joints to the top.
8. Sweep and remove surplus joint material.

Complete installation & specification details are available by contacting your Pavestone Sales Representative.

Note: ✔ Permeable pavements require both civil and hydraulic engineering. All final pavements design shall be approved by a licensed engineer familiar with local site conditions, building codes and storm water management plans.

PRODUCT INFORMATION

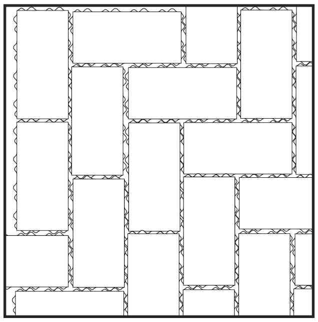
Eco-Priora™ is available in one size. Height = 80mm

ECO-PRIORA™
(120mm x 240mm)

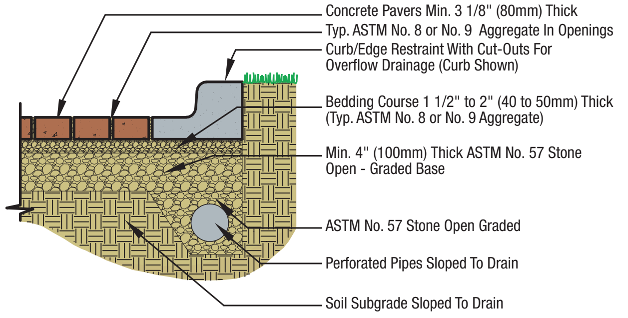
Eco-Priora™

Dimensions:	**4 3/4" W x 9 7/16" L x 3 1/8" H**
Wt./Stone:	11.5 lbs.
Stones/Pallet:	280
Approx. Wt./Pallet:	3,255 lbs.
Sq. Ft./Pallet:	88
Product Number:	699

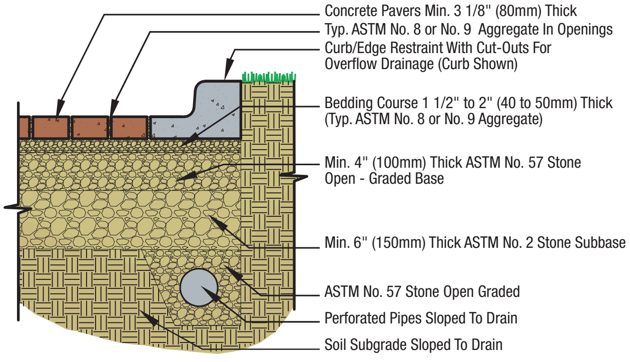
INSTALLATION PATTERN

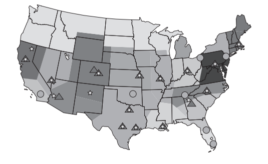


PERMEABLE PAVERS TREATMENT



PERMEABLE PAVERS TREATMENT AND DETENTION





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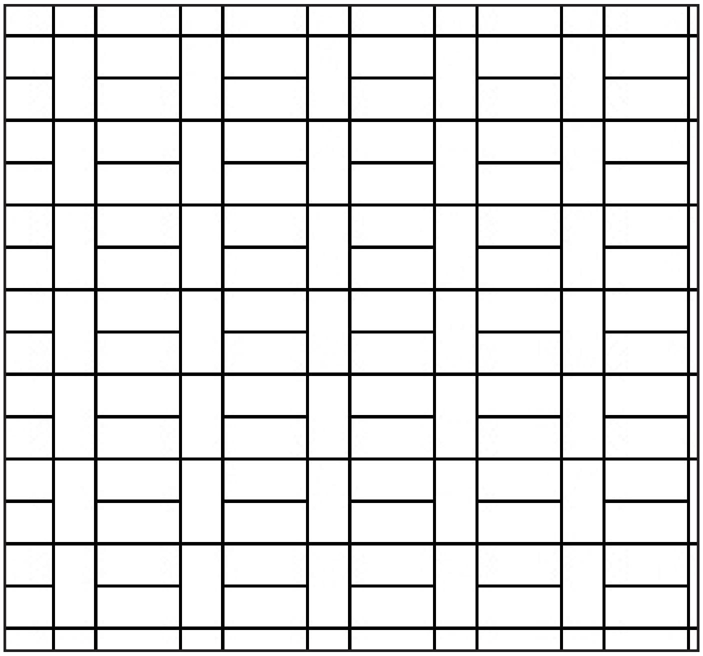
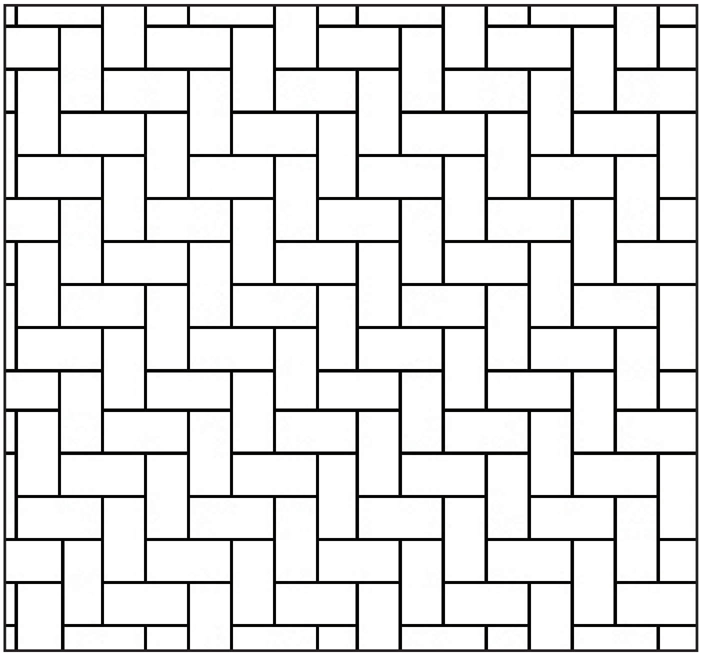
SKU# CDC 266V4 5/10

Eco-Priora™ 699 Installation Patterns



BASKETWEAVE (1)



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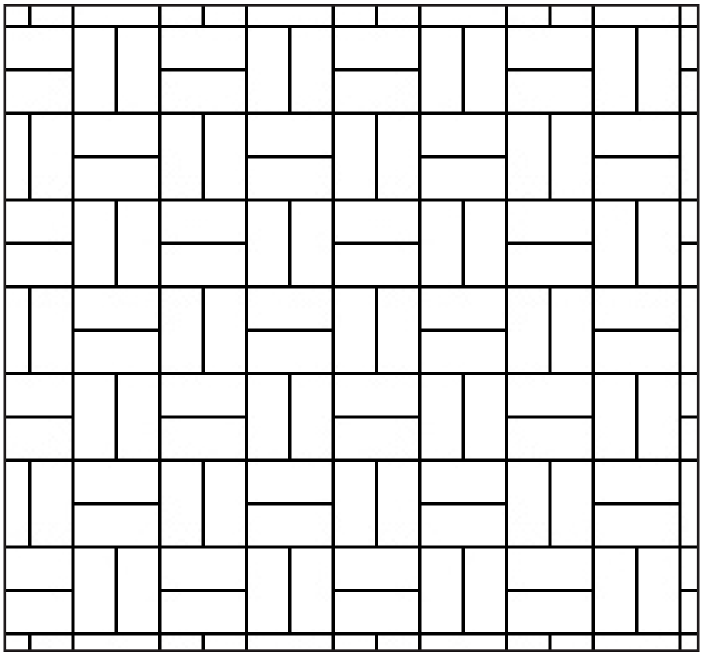
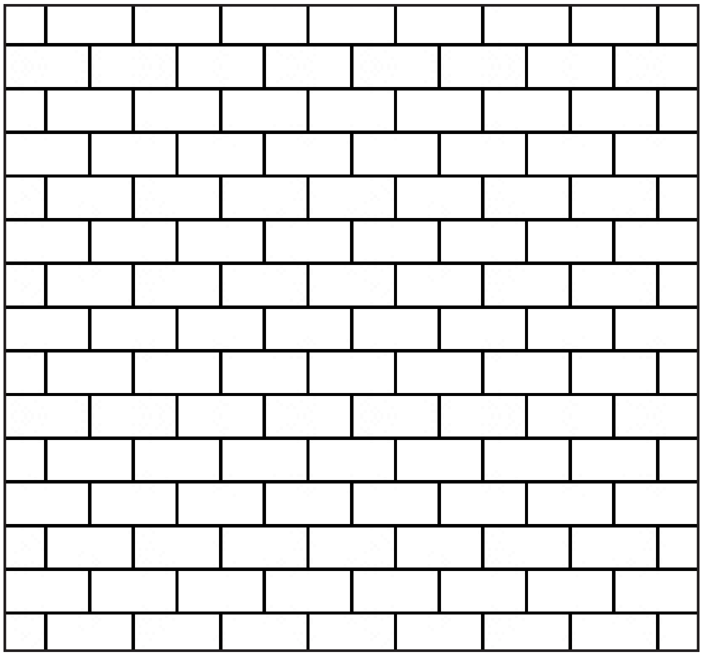


PARQUET (5)



RUNNER BOND (7)

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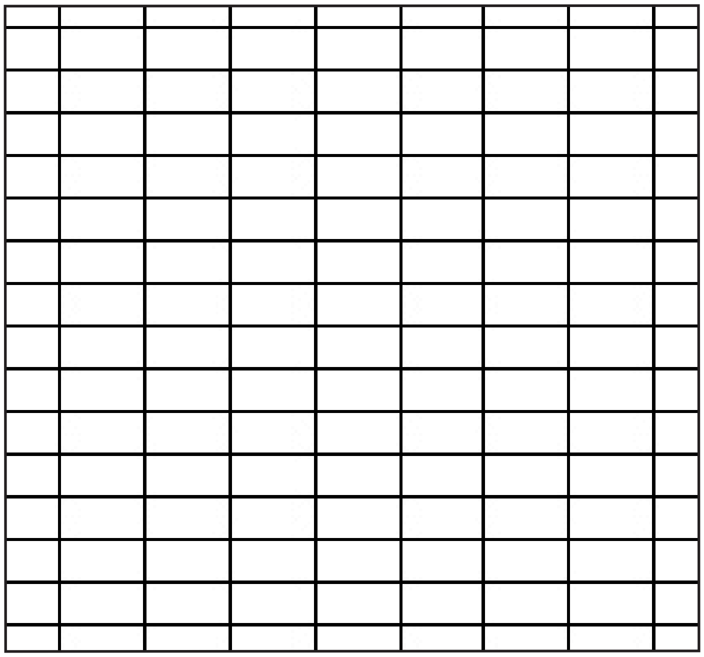
CREATING BEAUTIFUL LANDSCAPES℠

Eco-Priora™ 699 Installation Patterns



STACK (8)

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Belgard Environmental Product

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AquaLine™ L-stone Multi-Cobble

Environmental Collection

Beauty, functionality and quality are hallmarks of the Belgard® Commercial AquaLine™ paver series, while the innovative design features of L-shape make it the perfect pavement choice for plazas, sidewalks, parking lots, alleys and small roadways. It is available in a variety of nationally offered colors, finishes and surface textures, including Texturgard™ - an ultra-durable wearing course that virtually eliminates the appearance of aging.

ADA COMPLIANT ♿ *HEAVY VEHICULAR—100MM* *VEHICULAR—80MM* *MECHANICAL INSTALLATION*

Designed to provide an aesthetically pleasing large format permeable surface that is pedestrian friendly and functional for vehicular traffic. AquaLine combines structural joints and infiltrating voids to optimize system performance. Easier to install due to the additional interlock provided by the L-shape. It is the result of years of research on existing permeable paver products.

Benefits of AquaLine™ L-stone Multi-Cobble

STRENGTH

Manufactured to exceed the minimum standards specified in ASTM C936. Test results from an independent third party are available upon request.

ECOLOGICAL SOLUTIONS

Engineered to infiltrate up to 140 inches per hour which greatly exceeds even the heaviest storms. Where water quality improvements are required, select aggregates can be used in the voids to optimize contaminant removal.

ECONOMICAL

Permeable Pavement Systems serve as both the driving surface and stormwater management system, eliminating the need for traditional infrastructure, allowing more property to be used for revenue generation. Pavers have also been proven to last in excess of 50 years, greatly benefitting life cycle costs.

LOW MAINTENANCE

Maintenance is similar to what is commonly required for other pavement surfaces. If voids become plugged, aggregate and debris can be vacuum extracted and new aggregate material inserted, restoring the original infiltration rate.

AFFORDABILITY

Packaged for mechanical installation, resulting in a cost effective installed price.

COMFORT

ADA compliant walking surface that is high-heel and pedestrian friendly. Causes low-vibration for strollers, bikes, shopping carts and wheelchairs.

LEED POINTS

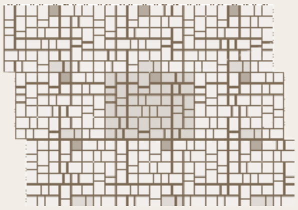
Can contribute to credits for stormwater quality and quantity, recycled materials, heat island effect, and innovation in design, among others.

AquaLine™ L-stone Multi-Cobble

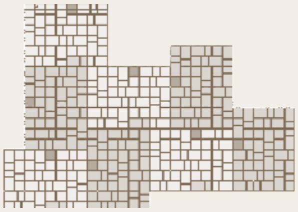
Size: 12” x 12” x 3 1/8” (or 12” x 12” x 4”)
Colors: 9 national colors, local custom colors available upon request
Finishes: Smooth, Shot Blast, Ground Face
Processes: Colorgard, Texturgard
Chamfer: 2mm
Spacers: Dual positive-interlocking integrated bars
Joint/Void: Maximum 8 mm non-structural voids
Appearance: Random 3 size cobble

BELGARD AQUALINE™ L-SHAPE	
Dimensions	12” x 12” x 80mm
sold by	sf
sf/plt	96
lbs/plt	3380
layers/plt	8
lf/plt	96*
units/plt	128
sf/layer	12
sf/unit	0.75
lf/unit	0.75
lbs/unit	26.4

*Linear feet measured when used as 12” soldier course installed in pairs (see front photo).



Stitched Pattern



Non-Stitched Pattern

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Eco Dublin™
Environmental Collection

Beauty, functionality and quality are hallmarks of the Belgard® Commercial brand, and our Environmental Collection of permeable pavers is no exception. Belgard permeable pavers combine the best of Belgard with innovative stormwater management for a superior product line that provides sustainable solutions and aesthetically appealing designs.

ADA COMPLIANT ♿ *LT. VEHICULAR—80MM* *MECHANICAL INSTALLATION*

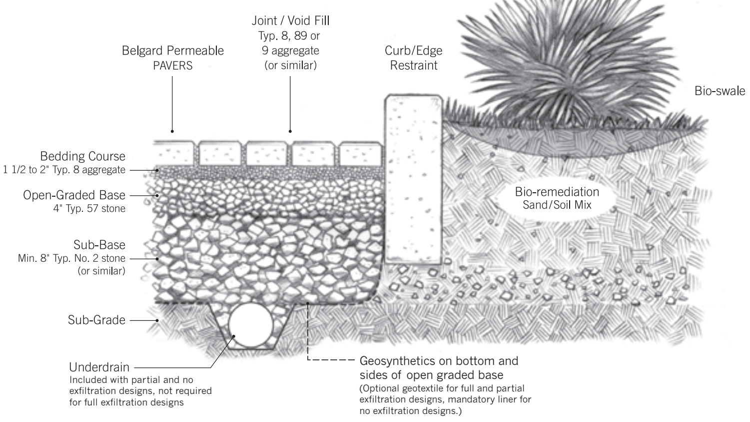
Eco Dublin™

Smart-looking style meets smart science. The classic look of cut stone and contemporary materials technology combine in Eco Dublin™, the latest addition to Belgard's Environmental Series of permeable pavers.

Benefits of Belgard® Permeable Paving Stone Systems

- On the US Environmental Protection Agency's (EPA) menu for structural Low Impact Development (LID) BMPs
- Can contribute toward several LEED NC-2009 points
- Reduces stormwater runoff by up to 100%
- Can be used to achieve total maximum daily load (TMDL) limits for a range of pollutants
- Certified SRI colors reduce heat island effect
- Can reduce or eliminate the need for traditional drainage and detention requirements, saving space and money
- Can be designed to accommodate all native soil types
- 50-year design life based on proven field performance

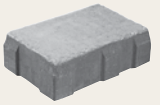
SAMPLE PICP SYSTEM CROSS SECTION



The availability of specific aggregate will often vary from region to region. In cases where it becomes necessary to substitute a similar size, your project engineer should always be consulted.

3 7/16″ x 6 7/8″ x 3 1/8″
(87.78mm x 174.57mm x 80mm)

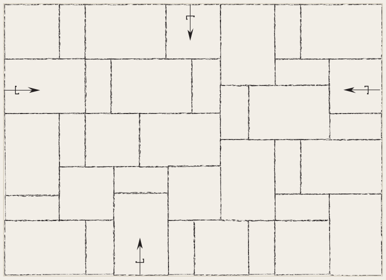
6 7/8″ x 6 7/8″ x 3 1/8″
(174.57mm x 174.57mm x 80mm)



Large Rectangle
6 7/8″ x 10 1/4″ x 3 1/8″
(174.57mm x 261.35mm x 80mm)

Shapes

(All three shapes come in each bundle.)



Mechanical Installation Laying Pattern

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Aqua Roc™
Environmental Collection

Beauty, functionality and quality are hallmarks of the Belgard® Commercial brand, and our Environmental Collection of permeable pavers is no exception. Belgard permeable pavers combine the best of Belgard with innovative stormwater management for a superior product line that provides sustainable solutions and aesthetically appealing designs.

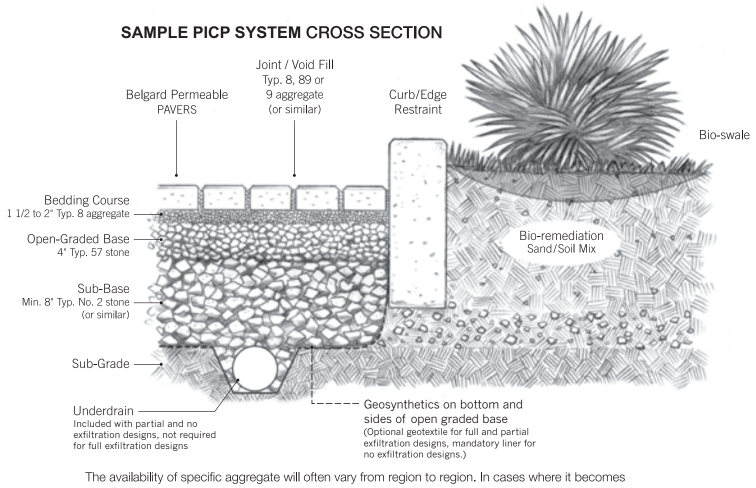
ADA COMPLIANT ♿ VEHICULAR—80MM LT. VEHICULAR—80MM MECHANICAL INSTALLATION

Aqua Roc™

Aqua Roc is a versatile paver featuring not only the environmentally-friendly benefits of a permeable paver, but also high visual appeal, low maintenance, and proven durability. Aqua Roc's versatile pattern range allows for flexible design options, making it an excellent choice for vehicular use.

Benefits of Belgard® Permeable Paving Stone Systems

- On the US Environmental Protection Agency's (EPA) menu for structural Low Impact Development (LID) BMPs
- Can contribute toward several LEED NC-2009 points
- Reduces stormwater runoff by up to 100%
- Can be used to achieve total maximum daily load (TMDL) limits for a range of pollutants
- Certified SRI colors reduce heat island effect
- Can reduce or eliminate the need for traditional drainage and detention requirements, saving space and money
- Can be designed to accommodate all native soil types
- 50-year design life based on proven field performance



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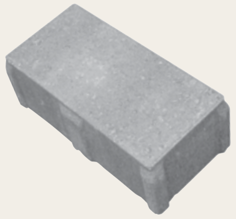
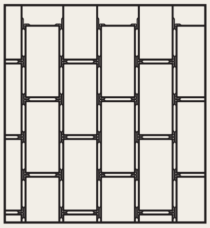
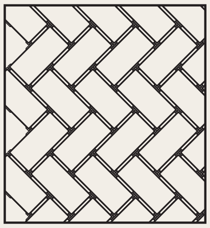


Shape

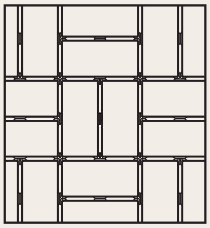
4 1/2" x 9" x 3 1/8"
(114.3mm x 228.6mm x 80mm)



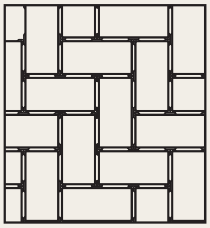
Running Bond



Herringbone 45 Degree



Basket Weave



Herringbone 90 Degree

Laying Patterns

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Marina Landscape, Inc.	Anaheim	CA
VERSAI Design and Development, Pavers Division	Beverly Hills	CA
Pacific Coast Pavers	Brea	CA
Peterson Brothers Construction	Brea	CA
AJ's Landscaping	Brentwood	CA
Paver Decor Masonry, Inc.	Calimesa	CA
System Pavers - San Diego	Carlsbad	CA
OLVERA MASONRY INC.	Carpinteria	CA
Landmark Site Contractors	Corona	CA
Stepping Stone Landscape	Coronado	CA
Castlelite Block, LLC	Dixon	CA
Paver Plus, Inc.	Downey	CA
Paving Stone of San Diego, Inc.	El Cajon	CA
Coyote Construction - Pavers	Escondido	CA
Claddagh Paving	Fallbrook	CA
Aloha Pavers, Inc.	Huntington Beach	CA
I.M. Masonry Construction, Inc.	Lancaster	CA
Precision Contractors, Inc.	Lancaster	CA
Earth Shelter Developers	Lodi	CA
Go Pavers	Los Angeles	CA
Stowe Contracting, Inc.	Marina	CA
Stowe General Construction	Modesto	CA
Sierra Madre Landscape	Monrovia	CA
Systems Paving - Dallas	Newport Beach	CA
System Pavers - Novato	Novato	CA
Haney Landscape Inc.	Ojai	CA
System Pavers - Inland Impire	Ontario	CA
Alan Smith Pools	Orange	CA
Farley Interlocking Paving	Palm Desert	CA
Sunshine Landscape	Palm Desert	CA
DMA Construction	Paso Robles	CA
Edsons Pavers, Inc.	Perris	CA
Viking Pavers Inc.	Point Richmond	CA
System Pavers - Sacramento	Rancho Cordova	CA
McEntire Landscaping, Inc.	Redding	CA
INSTALL IT DIRECT	San Diego	CA
Landscapes West	San Diego	CA
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Prime Gardens, Inc.	Sherman Oaks	CA
Alford's English Gardens INC	Signal Hill	CA
JFK Pavestone, Inc.	Simi Valley	CA

Tahoe Outdoor Living DBA Tahoe Paving Stones	South Lake Tahoe	CA
Pacific Pavingstone, Inc.	Sun Valley	CA
Weiland & Associates, Inc.	Swall Meadows	CA
System Pavers - Northern California	Union City	CA
System Pavers - Northern California	Union City	CA
Scarlett's Landscape, Inc.	Ventura	CA
System Pavers - Ventura	Ventura	CA
Southwest Specialties of California, Inc.	Walnut	CA
Southwest Specialties of California, Inc.	Walnut	CA

PERVIOUS

First Name	Intial	Last Name	Suffix	Company	City	State	ZIP	Cert Type	Expiration Date
Anthonie		Smith		T.B. Penick	San Diego	CA	92128	Pervious Concrete Craftsman	6/3/2016
Bill		Beeson		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Craftsman	2/5/2019
Danny		Stewart		T.B. Penick	San Diego	CA	92128	Pervious Concrete Craftsman	6/3/2016
David		Liguori		Bay Area Pervious Concrete	San Carlos	CA	94070	Pervious Concrete Craftsman	11/14/2019
Dennis	M.	Collins		Enviro-Crete, Inc.	Orangevale	CA	95662	Pervious Concrete Craftsman	10/1/2017
Guy		Collignon		Enviro-Crete, Inc.	Orangevale	CA	95662	Pervious Concrete Craftsman	6/13/2016
Steven	J.	Carrera		S 7 J Carrera Construction, Inc.	Watsonville	CA	95076	Pervious Concrete Craftsman	2/24/2016
Wayne		Jenness		T.B. Penick	San Diego	CA	92120	Pervious Concrete Craftsman	6/3/2016

First Name	Intial	Last Name	Suffix	Company	City	State	ZIP	Cert Type	Expiration Date
Alejandro		Ruiz Villalobos		Robert A. Bothman	Salinas	CA		Pervious Concrete Installer	10/26/2017
Alexander		Renteria		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
Arturo		Rosas		Beeson Masonry	Lake Hughes	CA	93532	Pervious Concrete Installer	8/6/2019
Daniel		Rodriguez Avalos		Robert A. Bothman, Inc.	Salinas	CA		Pervious Concrete Installer	10/26/2017
Edward		Ramirez		GPF Concrete	Perris	CA	92574	Pervious Concrete Installer	1/16/2017
Hector		Vela Villagrana		Robert A. Bothman Inc.	Antioch	CA	94509	Pervious Concrete Installer	10/26/2017
Humberto		Tovalin		T.B. Penick	San Diego	CA	92128	Pervious Concrete Installer	6/3/2016
Isaias		Ruiz		Melo Concrete Construction	Gilroy	CA		Pervious Concrete Installer	10/26/2017
Jaime		Sanitillan		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
Jaime		Villegas		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
James		Lamping		T.B. Penick	San Diego	CA	92128	Pervious Concrete Installer	6/3/2016
Joey		Lankford		Beeson Masonry	Lake Hughes	CA	93532	Pervious Concrete Installer	8/6/2019
Jose		Ceron		Bay Area Pervious Concrete	San Carlos	CA	94070	Pervious Concrete Installer	11/8/2015
Juan		Munoz		Galvan's Place and Finish	Perris	CA	92574	Pervious Concrete Installer	1/16/2017
Luis		Castellanos		Robet A. Bothman Inc.	San Jose	CA		Pervious Concrete Installer	10/26/2017
Mario		Ortiz		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
Michael		Orosz		Beeson Pervious Concrete	Lake Hughes	CA	93532	Pervious Concrete Installer	2/5/2019
Mike		Beczak		T.B. Penick	San Diego	CA	92128	Pervious Concrete	6/3/2016

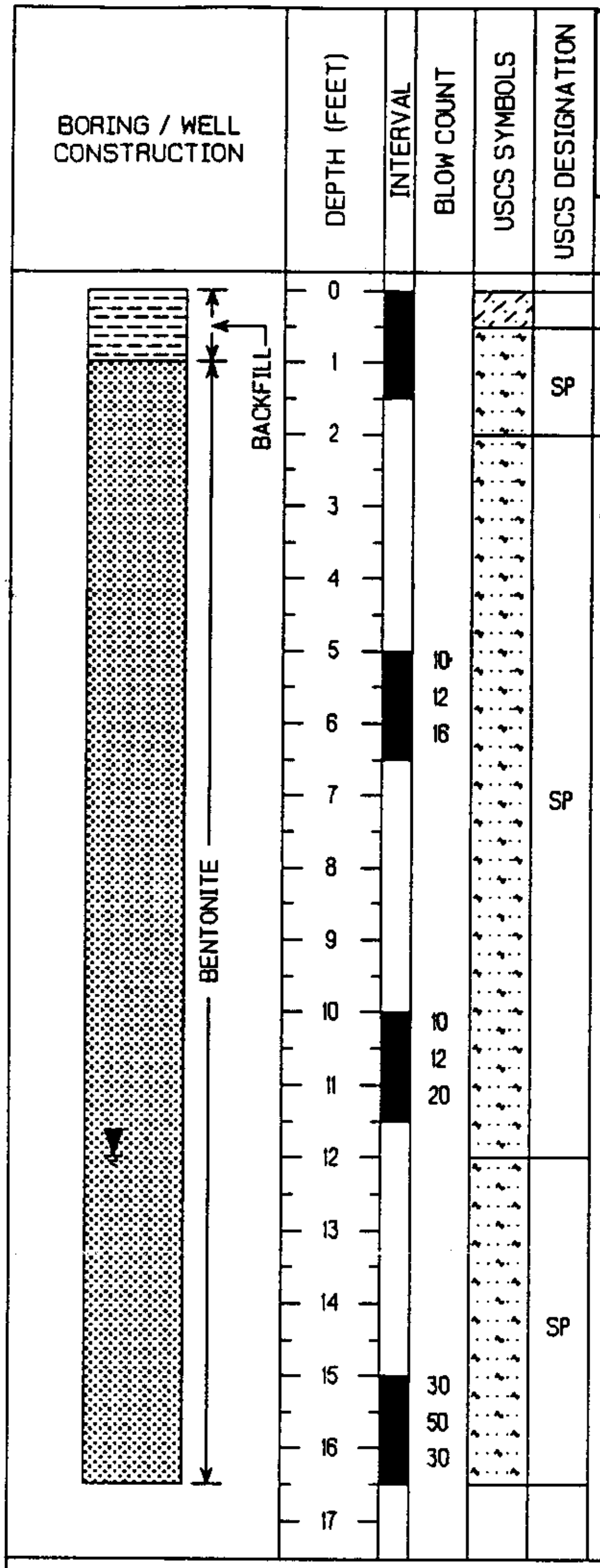
First Name	Intial	Last Name	Suffix	Company	City	State	ZIP	Cert Type	Expiration Date
								Installer	
Piedad		Menchara Solorio		Robert A. Bothman Inc.	Salinas	CA	93905	Pervious Concrete Installer	10/26/2017
Ricardo	R.	Galvan		Galvan's Place and Finish	Perris	CA	92571	Pervious Concrete Installer	1/16/2017
Robert		Estrada		Bay Area Pervious Concrete	San Carlos	CA	95040	Pervious Concrete Installer	5/4/2017
Ron		Parietti			Pilot Hill	CA	95664	Pervious Concrete Installer	6/30/2015
Salvador		Rosas		Robert A. Bothman Inc.	San Jose	CA	95116	Pervious Concrete Installer	10/26/2017
Sergio		Grageda		Bay Area Pervious Concrete	San Carlos	CA	94070	Pervious Concrete Installer	11/8/2015
Victor		Santana		Robert A. Bothman Inc.	Salinas	CA	93906	Pervious Concrete Installer	10/26/2017

Appendix F – Soil Report

917550B12A

LOG OF BORING B-12A

BORING / WELL CONSTRUCTION | DEPTH (FEET) | INTERVAL | BLOW COUNT | USCS SYMBOLS | USCS DESIGNATION



BLOW COUNT	USCS DESIGNATION	SOIL DESCRIPTION	SAMPLE ID	PID / FID	8020 BTEX	8015e	8015m	418.1	LEAD
		ASPHALT PAVEMENT 4 INCHES THICK.							
	SP	SAND, FINE TO MEDIUM GRAINED, TRACE CLAY BINDER, SOME SMALL PEBBLES, SLIGHTLY MOIST, LOOSE TO MEDIUM DENSE, DARK BROWN, NO PRODUCT ODOR.							
	SP	SAND, FINE TO MEDIUM GRAINED, SLIGHTLY MOIST, LOOSE TO MEDIUM DENSE, LIGHT BROWN, NO PRODUCT ODOR							
10 12 16			B12-5	0					
10 12 20			B12-10	0					
	SP	SAND, FINE TO MEDIUM GRAINED, WET, DENSE, GRAYISH BROWN, NO PRODUCT ODOR.							
30 50 30			B12-15	0					

ANALYSES (mg/Kg) ppm: FIELD | LABORATORY

SURFACE ELEVATION: UNKNOWN
TOTAL DRILL DEPTH: 15 ft.
FINAL SAMPLE DEPTH: 1.5 ft.
TOTAL DEPTH: 16.5 ft.
TYPE OF SAMPLER: 3" O.D. MODIFIED PORTER SAMPLER

DATE DRILLED: 12-5-91
LOGGED BY: DEBBIE WILSON
SUPERVISED BY: RICK PILAT
DIAMETER OF BORING: 6 in.
WATER ENCOUNTERED AT: 12 ft.

ALT
ACTIVE LEAK TESTING, INC.
1300 SOUTH BEACON STREET SUITE #120
SAN PEDRO, CA 90731

CLIENT: DAMSON OIL CORP.
1 MARKET STREET
VENICE, CA.

Page 1 of 1 in log

Page 3 of 8 in project

BORING NO. B4

AREA 2 Storage Buildings

Part 1 of 1

9175500B4

SAMPLE NUMBER	PENETRATION BLOW COUNT	SAMPLE	UNIFIED SOIL CLASS	LITHOLOGY	DESCRIPTION	WELL DETAIL–BACKFILL	FEET
							0
B4-2		■	SP	▨	SAND and GRAVEL		
B4-5		■	SP	▨	SAND, Light Brown, Loosely Consolidated, Well Sorted, Medium Grained, No Odor. Terminated Boring at 5 Feet, Electrical Conduits Encountered.		5
							10
							15
							20
							25

SUPERVISED BY: John Nicolich
LOGGED BY: Dan Louks
DATE STARTED: TIME:
DATE FINISHED: TIME:
DATE DRAWN: 7/8/91

SAMPLE SPOON LENGTH/SLEEVE DIA.:
WATER ENCOUNTERED AT: N/A
TOTAL DEPTH: 5 FEET
GROUND SURFACE ELEVATION:
DIAMETER OF BORING: 4 INCHES
DRILL RIG: Hand Auger

DASH/12-90

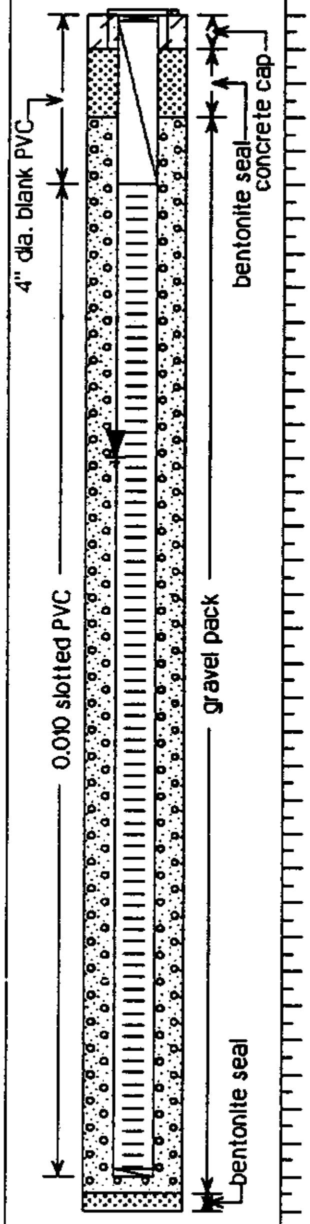
DIAGNOSTIC ENGINEERING INC.
50 E. Foothill Boulevard, Arcadia, Ca. 91006

NAME: Damson Oil Corporation
SITE: 40 West Horizon Avenue
CITY, STATE: Venice, California
PROJECT NO.: 1A2908AA001

917550B14A

LOG OF BORING B-14A

BORING / WELL CONSTRUCTION



DEPTH (FEET)	INTERVAL	BLOW COUNT	USCS SYMBOLS	USCS DESIGNATION	SOIL DESCRIPTION	SAMPLE ID	ANALYSES (mg/Kg) ppm FIELD	ANALYSES (mg/Kg) ppm LABORATORY				
							PID / FID	8020 BTEX	8015g	8015m	418.1	8240
0 1 2 3 4				SW	SAND, FINE TO COARSE GRAINED, OCCASIONAL SMALL PEBBLES, SLIGHTLY MOIST, LOOSE TO MEDIUM DENSE, DARK BROWN, NO PRODUCT ODOR.							
5 6 7 8		5 8 15		SW	SAND, FINE TO COARSE GRAINED, OCCASIONAL SMALL PEBBLES, SLIGHTLY MOIST, MEDIUM DENSE, BROWN, NO PRODUCT ODOR.	B14-5	0	ND ND ND ND			ND	
9 10 11 12		10 16 25		SW	SAND, FINE TO COARSE GRAINED, OCCASIONAL SMALL PEBBLES, SLIGHTLY MOIST, MEDIUM DENSE, LIGHT BROWN, NO PRODUCT ODOR.	B14-10	0	ND NC ND ND			200	
13 14 15 16 17		25 25 30		SW	SAND, FINE TO COARSE GRAINED, OCCASIONAL SMALL PEBBLES, WET, DENSE, LIGHT BROWN, NO PRODUCT ODOR.	B14-15	28	ND ND ND ND			ND	ND
18 19 20 21 22 23 24 25 26 27 28				SW	SAND, FINE TO COARSE GRAINED, WET, DENSE, DARK GRAY, SLIGHT PRODUCT ODOR. UNABLE TO RETAIN SAMPLES BELOW 16.5 FEET.	B14-20 B14-25	7 0					
29 30 31 32 33 34 35 36				SW	SAND, FINE TO COARSE GRAINED, WITH NUMEROUS SMALL PEBBLES, WET, DENSE, DARK GRAY, SLIGHT PRODUCT ODOR. GRAB SAMPLE OBTAINED AT APPROXIMATELY 35 FEET.	B14-30 B14-35	0 0	 ND			 200	

SURFACE ELEVATION: UNKNOWN
TOTAL DRILL DEPTH: 35 ft.
FINAL SAMPLE DEPTH: 35 ft.
TOTAL DEPTH: 35 ft.
TYPE OF SAMPLER: 3" O.D. MODIFIED PORTER SAMPLER

DATE DRILLED: 12-5-91
LOGGED BY: DEBBIE WILSON
SUPERVISED BY: RICK PILAT
DIAMETER OF BORING: 8 in.
WATER ENCOUNTERED AT: 13 ft.

ACTIVE LEAK TESTING, INC.
1300 SOUTH BEACON STREET SUITE #120
SAN PEDRO, CA 90731

CLIENT: DAMSON OIL CORP.
1 MARKET STREET
VENICE, CA.

Page 1 of 1 in log

Page 4 of 8 in project

BORING NO. B5

Part 1 of 1

9175500B5

AREA 1 Pump Building

SAMPLE NUMBER	PENETRATION BLOW COUNT	SAMPLE	UNIFIED SOIL CLASS	LITHOLOGY	DESCRIPTION	WELL DETAIL-BACKFILL	FEET
							0
				▓	14" Concrete Slab		
B5-2		■	SP	░	SAND, Light Brown, Loosely Consolidated, Well Sorted, Medium Grained, No Odor		
B5-5		■	SP	░	SAND, Light Brown, Loosely Consolidated, Well Sorted, Medium Grained, No Odor		5
B5-10		■	SP	░	SAND, Light Brown, Loosely Consolidated, Well Sorted, Medium Grained, No odor		10
							15
							20
							25

SUPERVISED BY: John Nicolich
LOGGED BY: Dan Louks
DATE STARTED: TIME:
DATE FINISHED: TIME:
DATE DRAWN: 7/8/91

SAMPLE SPOON LENGTH/SLEEVE DIA.:
WATER ENCOUNTERED AT: N/A
TOTAL DEPTH: 10 FEET
GROUND SURFACE ELEVATION:
DIAMETER OF BORING: 4 INCHES
DRILL RIG: Hand Auger

DASH/12-90

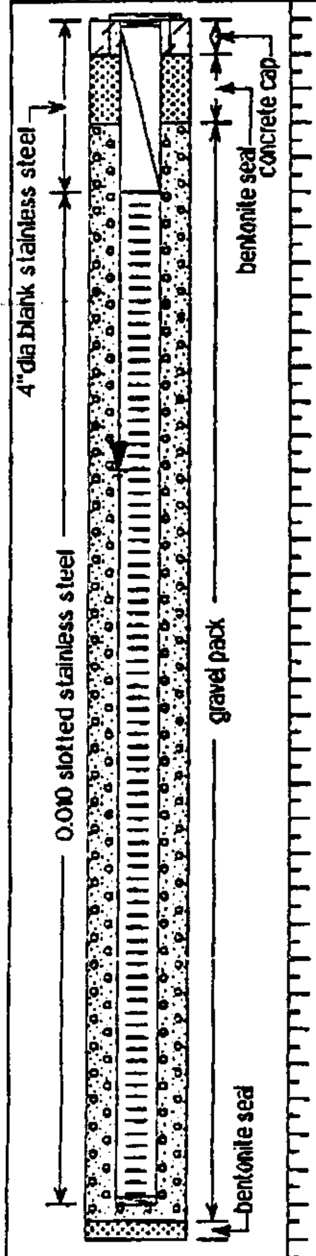
DIAGNOSTIC ENGINEERING INC.
50 E. Foothill Boulevard, Arcadia, Ca. 91006

NAME: Damson Oil Corporation
SITE: 40 West Horizon Avenue
CITY, STATE: Venice, California
PROJECT NO.: 1A2908AA001

917550B17A

LOG OF BORING B-17A

BORING / WELL CONSTRUCTION



DEPTH (FEET)	INTERVAL	BLOW COUNT	USCS SYMBOLS	USCS DESIGNATION	SOIL DESCRIPTION	SAMPLE ID	FIELD PID / FID	LABORATORY 8020 BTEX	8015d	8015m	418.1	8240
0				SP	SAND, FINE TO MEDIUM GRAINED, TRACE CLAY BINDER, SOME SMALL PEBBLES, SLIGHTLY MOIST, MEDIUM DENSE, BROWN, NO PRODUCT ODOR.							
5	■	7 11 11		SP	SAND, FINE TO MEDIUM GRAINED, SLIGHTLY MOIST, MEDIUM DENSE, LIGHT BROWN, NO PRODUCT ODOR.	B17-5	0	ND ND ND ND			ND	
10	■	10 10 20				B17-10	0	ND ND ND ND			ND	
13				SP	SAND, FINE TO MEDIUM GRAINED, WET, MEDIUM DENSE, LIGHT BROWN, STRONG PRODUCT ODOR.							
15	■	30 50				B17-15	0	ND ND			100	

ANALYSES (mg/Kg) ppm

SURFACE ELEVATION: UNKNOWN

TOTAL DRILL DEPTH: 35 ft.

FINAL SAMPLE DEPTH: 35 ft.

TOTAL DEPTH: 35 ft.

TYPE OF SAMPLER: 3" O.D. MODIFIED PORTER SAMPLER

DATE DRILLED: 12-5-91

LOGGED BY: DEBBIE WILSON

SUPERVISED BY: RICK PILAT

DIAMETER OF BORING: 6 in.

WATER ENCOUNTERED AT: ± 13 ft.

ACTIVE LEAK TESTING, INC.
1300 SOUTH BEACON STREET SUITE #120
SAN PEDRO, CA 90731

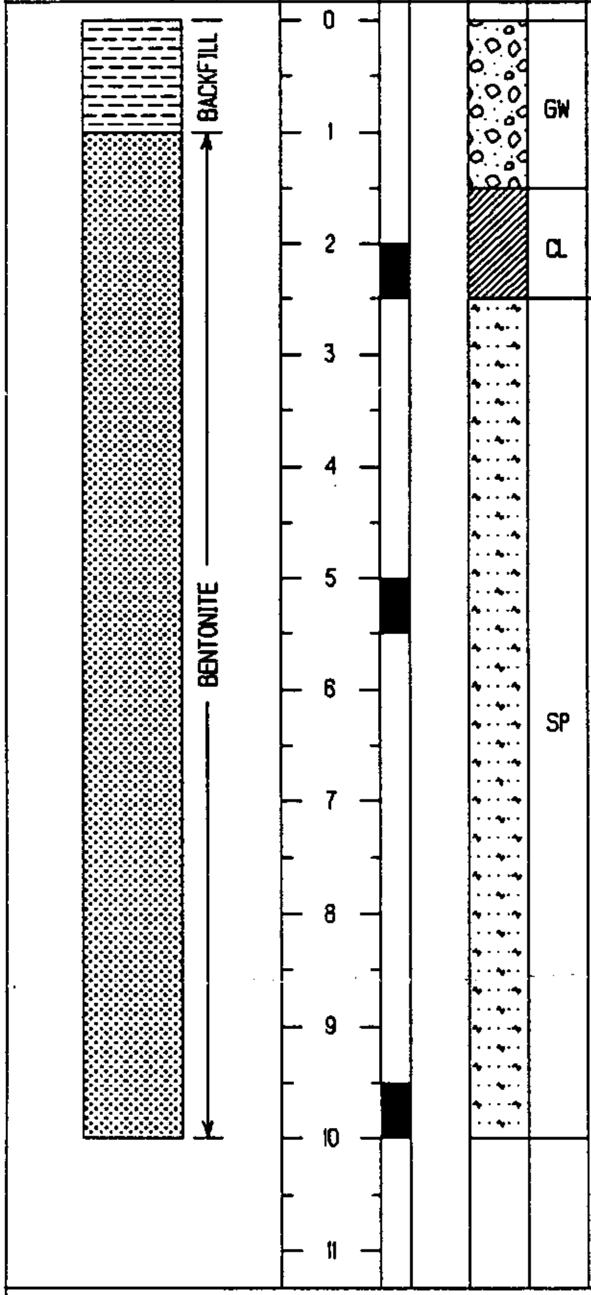
CLIENT: DAMSON OIL CORP.
1 MARKET STREET
VENICE, CA.

Page 1 of 1 in log

Page 7 of 8 in project

917550B18 A

LOG OF BORING B-18A



DEPTH (FEET)	USCS DESIGNATION	SOIL DESCRIPTION	SAMPLE ID	FIELD PID / FID	LABORATORY 8020 BTEX	8015a	8015m	418.1	8240
0	GW	GRAVEL, COARSE TO VERY COARSE WITH SOME SILTY FINE TO COARSE SAND, SOME COBBLES AND DEBRIS, LOOSE, DRY, GRAY, NO PRODUCT ODOR.							
1.5	CL	CLAY, SANDY, FINE TO COARSE GRAINED WITH SOME SILT AND FINE GRAVEL, STIFF, MOIST, BROWN, NO PRODUCT ODOR.	B18-2	0	ND ND ND ND			ND	
2.5	SP	SAND, MEDIUM GRAINED WITH SOME FINE AND COARSE SAND, MEDIUM DENSE, MOIST, GRAY-BROWN TO TAN, NO PRODUCT ODOR.							
5			B18-5	0	ND ND ND ND			ND	
10			B18-10	0	ND			ND	

ANALYSES (mg/Kg) ppm

SURFACE ELEVATION: UNKNOWN
TOTAL DRILL DEPTH: 10 ft.
FINAL SAMPLE DEPTH: 10 ft.
TOTAL DEPTH: 10 ft.
TYPE OF SAMPLER: 3" HAND AUGER

DATE DRILLED: 12-5-91
LOGGED BY: LARRY NEUVIRTH
SUPERVISED BY: LARRY NEUVIRTH
DIAMETER OF BORING: 3 in.
WATER ENCOUNTERED AT: ⊻ NOT ENCOUNTERED

ALT
ACTIVE LEAK TESTING, INC.
1300 SOUTH BEACON STREET SUITE #120
SAN PEDRO, CA 90731

CLIENT: DAMSON OIL
1 MARKET STREET
VENICE, CA.

Page 1 of 1 in log
Page 8 of 8 in project

BORING NO. B8
Part 1 of 1

AREA 6 Water Injection Pump

9175500B8

SAMPLE NUMBER	PENETRATION BLOW COUNT	SAMPLE	UNIFIED SOIL CLASS	LITHOLOGY	DESCRIPTION	WELL DETAIL-BACKFILL	FEET
				▨			0
B8-2		■	SP	▨	SAND, Light Brown, Loosely Consolidated, Well Sorted, Medium Grained, No Odor		
B8-5		■	SP	▨	SAND, Light Brown, Loosely Consolidated, Well Sorted, Medium Grained, No Odor		5
B8-10		■	SP	▨	SAND, Light Brown, Loosely Consolidated, Well Sorted, Medium Grained, No Odor		10
							15
							20
							25

SUPERVISED BY: John Nicolich
LOGGED BY: Dan Louks
DATE STARTED: TIME:
DATE FINISHED: TIME:
DATE DRAWN: 7/8/91

SAMPLE SPOON LENGTH/SLEEVE DIA.:
WATER ENCOUNTERED AT: N/A
TOTAL DEPTH: 10 FEET
GROUND SURFACE ELEVATION:
DIAMETER OF BORING: 4 INCHES
DRILL RIG: Hand Auger

DASH/12-90

DIAGNOSTIC ENGINEERING INC.
50 E. Foothill Boulevard, Arcadia, Ca. 91006

NAME: Damson Oil Corporation
SITE: 40 West Horizon Avenue
CITY, STATE: Venice, California
PROJECT NO.: 1A2908AA001

LOG OF TEST BORING

LAB NO.:140- 4440 **PROJECT:** SAN JUAN AVE. - MAIN ST. TO CABRILLO AVE. SEWER REPL.

BORING NO.: MW-1 **ELEV.:** 8' **DATE:** 06-27 & 6-28-95

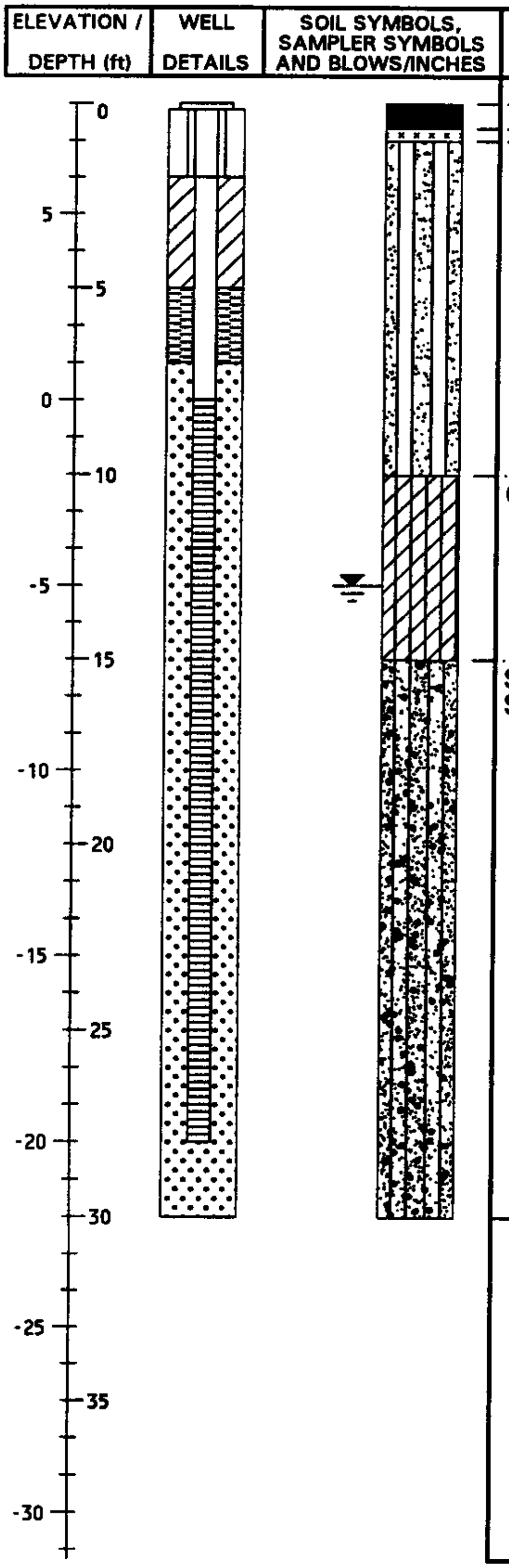
BORING LOCATION: @ C/L Main St. and 55' SE/o C/L Market St.

950280 MW1

DRILL RIG TYPE: CME-75 using 10" diameter hollow stem augers.

DRILLER: Ramirez **LOGGER:** Redlin **ENGINEER:** Haskett

DEPTH TO WATER: 13' **DEPTH TO WATER SEEPAGE:** None



USCS	Field Description
	8" AC pavement in fair condition.
	4" Crushed Miscellaneous Base material.
SM	Light brown silty sand. Moist and fairly loose. Moisture content is increasing with depth.
CL-ML	Brown silty clay/clayey silt with some sand. Moist and fairly soft. Sand content is increasing with depth. Encountered groundwater at 13' depth, rising to 10' depth.
SW-SM	Light brown well-graded sand with some silt and gravel. Wet and dense.

Encountered groundwater at 13' depth.

Installed 4" diameter monitoring well to 28' depth.

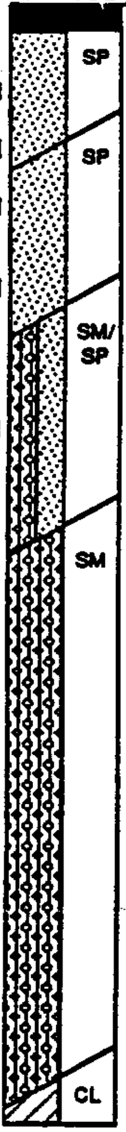
Well Construction
0'-2' depth Concrete Cap (Isolate Well)
2'-5' depth Silty Sand Backfill
5'-7' depth Bentonite Pellet Cap (Isolate Slotted Casing)
7'-30' depth No. 3 Filter Sand (Encasing 20' of Slotted Casing from 8' to 28' depth.)

928580001

BORING B-1

LABORATORY TEST DATA

DEPTH IN FEET	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS		STRENGTH TEST DATA				MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT.	SAMPLE
		LIQUID LIMIT (%)	PLASTICITY INDEX (%)	TYPE OF TEST	NORMAL OR CONFINING PRESSURE (PSF)	SHEAR STRENGTH (PSF)	DEVIATOR STRESS (PSF)				
0											
								2	99	18	■
5	SA -200 (2)							18	101	14	■
								13	98	13	■
10								3	106	7	■
15	-200 (56)							25	103	6	■
20								13	120	19	■
25								9	130	31	■
30								9	131	74	■
35								10	121	52	■
40								55	66	23	■
45											



DESCRIPTION

12-inch asphalt pavement and base material

Light brown fine to medium sand (loose)

FILL

Grades with fine gravel

Brown fine to medium sand with trace of silt (loose)

Grades with silt lenses

Gray silty fine sand (loose)

Grades brown below 20 feet

Brown silty fine to coarse sand with some gravel (medium dense to dense)

Grades to very dense

Yellowish-brown silty clay (stiff to very stiff)

Boring completed to a depth of 40.5 feet on February 27, 1990
Ground water observed at a depth of 5.5 feet on February 28, 1990
Backfilled with soil and asphalt placed on top

LOG OF BORING

PROPOSED STUDIO FACILITY
Venice, California
For Mr. Robert Graham

Dames & Moore
PLATE 5

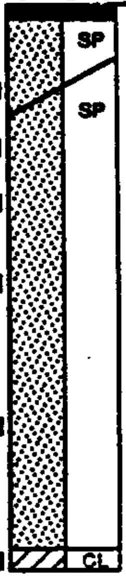
928580002

BORING B-2

LABORATORY TEST DATA

DEPTH IN FEET	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS		STRENGTH TEST DATA				MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT.	SAMPLE
		LIQUID LIMIT (%)	PLASTICITY INDEX (%)	TYPE OF TEST	NORMAL OR CONFINING PRESSURE (PSF)	SHEAR STRENGTH (PSF)	DEVIATOR STRESS (PSF)				
0											
								19		11	■
5								12	106	6	■
	-200 (0.5)							3	99	11	■
10								9	104	9	■
15								24	105	17	■
20				DS/CU	2000 3000 4000	2160 2688 2952		24	105	20	■
25											

SYMBOL



DESCRIPTION

6-inch asphalt pavement

Brown fine to medium sand with some silt (loose)

FILL

Brown fine to medium sand with some silt (very loose to loose)

Grades with less silt and light brown

Grades grayish-brown and with more fines

Brown silty clay (stiff to very stiff)

Boring completed to a depth of 20.5 feet on February 27, 1990

Ground water obseved at a depth of 6.0 feet on February 28, 1990

Backfilled with soil and asphalt placed on top

LOG OF BORING

PROPOSED STUDIO FACILITY
Venice, California
For Mr. Robert Graham

Dames & Moore
PLATE 6

BORING NO. B6

AREA 4 Production Pumps

Part 1 of 1

9175500B6

SAMPLE NUMBER	PENETRATION BLOW COUNT	SAMPLE	UNIFIED SOIL CLASS	LITHOLOGY	DESCRIPTION	WELL DETAIL-BACKFILL	FEET
				▨	12" Concrete Slab		0
B6-3		■	SP	▨	SAND, Light Brown, Loosely Consolidated, Well Sorted, Medium Grained, No Odor. Auger Refusal at 3 Feet, Large Rock or Asphalt Block.		
							5
							10
							15
							20
							25

SUPERVISED BY: John Nicolich
LOGGED BY: Dan Louks
DATE STARTED: TIME:
DATE FINISHED: TIME:
DATE DRAWN: 7/8/91

SAMPLE SPOON LENGTH/SLEEVE DIA.:
WATER ENCOUNTERED AT: N/A
TOTAL DEPTH: 3 FEET
GROUND SURFACE ELEVATION:
DIAMETER OF BORING: 4 INCHES
DRILL RIG: Hand Auger

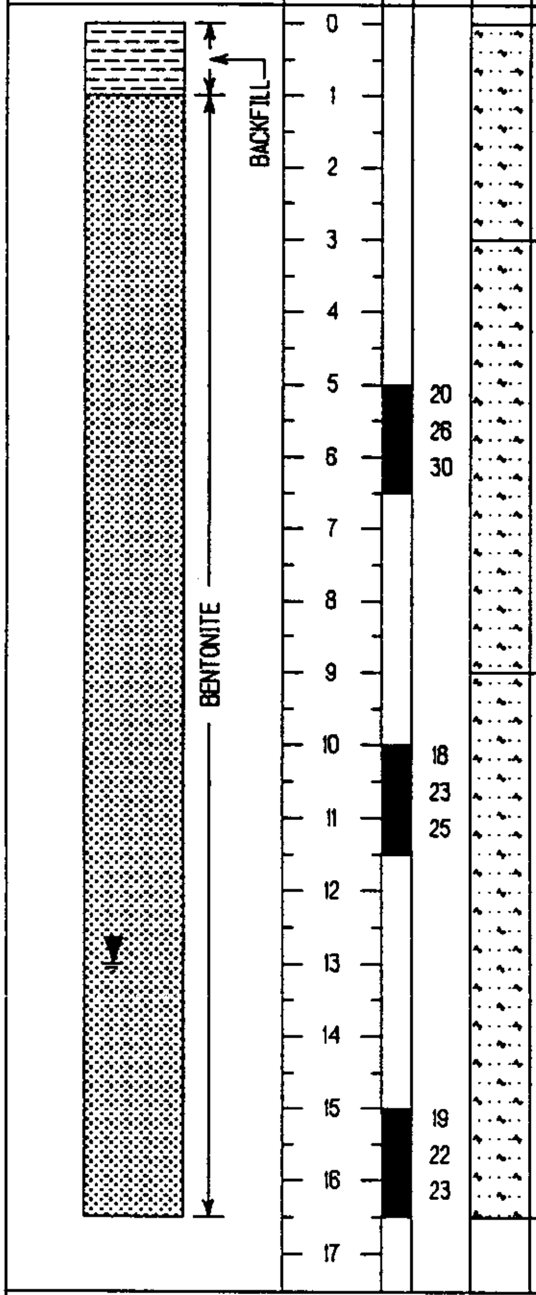
DASH/12-90

DIAGNOSTIC ENGINEERING INC.
50 E. Foothill Boulevard, Arcadia, Ca. 91006

NAME: Damson Oil Corporation
SITE: 40 West Horizon Avenue
CITY, STATE: Venice, California
PROJECT NO.: 1A2908AA001

917550B15A

LOG OF BORING B-15A



DEPTH (FEET)	BLOW COUNT	USCS DESIGNATION	SOIL DESCRIPTION	SAMPLE ID	ANALYSES (mg/Kg) ppm FIELD PID / FID	LABORATORY 8020 BTEX	8015g	8015m	418.1	8240
0		SP	SAND, FINE TO MEDIUM GRAINED, TRACE CLAY BINDER, SOME SMALL PEBBLES, SLIGHTLY MOIST, MEDIUM DENSE, DARK BROWN, NO PRODUCT ODOR.							
3		SP	SAND, FINE TO MEDIUM GRAINED, SLIGHTLY MOIST, MEDIUM DENSE, DARK BROWN, NO PRODUCT ODOR.							
5	20 26 30			B15-5	0	ND ND ND ND			250	
9		SP	SAND, FINE TO MEDIUM GRAINED, WET, MEDIUM DENSE, LIGHT BROWN, NO PRODUCT ODOR.							
10	18 23 25			B15-10	0	ND ND ND ND			2300	
15	19 22 23			B15-15	0				ND	ND

SURFACE ELEVATION: UNKNOWN
TOTAL DRILL DEPTH: 15 ft.
FINAL SAMPLE DEPTH: 1.5 ft.
TOTAL DEPTH: 16.5 ft.
TYPE OF SAMPLER: 3" O.D. MODIFIED PORTER SAMPLER

DATE DRILLED: 12-5-91
LOGGED BY: DEBBIE WILSON
SUPERVISED BY: RICK PILAT
DIAMETER OF BORING: 8 in.
WATER ENCOUNTERED AT: ±13 ft.

ACTIVE LEAK TESTING, INC.
1300 SOUTH BEACON STREET SUITE #120
SAN PEDRO, CA 90731

CLIENT: DAMSON OIL CORP.
1 MARKET STREET
VENICE, CA.

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BORING NO. B2

AREA 7 Open Storage Area

Part 1 of 1

9175500B2

SAMPLE NUMBER	PENETRATION BLOW COUNT	SAMPLE	UNIFIED SOIL CLASS	LITHOLOGY	DESCRIPTION	WELL DETAIL-BACKFILL	FEET
							0
B2-4		■	SP	▨	SAND, Light Brown, Loosely Consolidated, Well Sorted, Medium Grained, No Odor. Auger Refusal at 4 Feet - Large Rock		
							5
							10
							15
							20
							25

SUPERVISED BY: John Nicolich
LOGGED BY: Dan Louks
DATE STARTED: TIME:
DATE FINISHED: TIME:
DATE DRAWN: 7/8/91

SAMPLE SPOON LENGTH/SLEEVE DIA.:
WATER ENCOUNTERED AT: N/A
TOTAL DEPTH: 4 FEET
GROUND SURFACE ELEVATION:
DIAMETER OF BORING: 4 INCHES
DRILL RIG: Hand Auger

DASH/12-90

DIAGNOSTIC ENGINEERING INC.
50 E. Foothill Boulevard, Arcadia, Ca. 91006

NAME: Damson Oil Corporation
SITE: 40 West Horizon Avenue
CITY, STATE: Venice, California
PROJECT NO.: 1A2908AA001

Part 1 of 1

9175500B3

BORING NO. B3
AREA 3 LACT Unit

SAMPLE NUMBER	PENETRATION BLOW COUNT	SAMPLE	UNIFIED SOIL CLASS	LITHOLOGY	DESCRIPTION	WELL DETAIL-BACKFILL	FEET
							0
B3-5		■	SP	▨	SAND, Light Brown, Loosely Consolidated, Well Sorted, Medium Grained, No Odor		5
B3-10		■	SP	▨	SAND, Light Brown, Loosely Consolidated, Well Sorted, Medium Grained, No Odor		10
							15
							20
							25

SUPERVISED BY: John Nicolich
LOGGED BY: Dan Louks
DATE STARTED: TIME:
DATE FINISHED: TIME:
DATE DRAWN: 7/8/91

SAMPLE SPOON LENGTH/SLEEVE DIA.:
WATER ENCOUNTERED AT: N/A
TOTAL DEPTH: 10 FEET
GROUND SURFACE ELEVATION:
DIAMETER OF BORING: 4 INCHES
DRILL RIG: Hand Auger

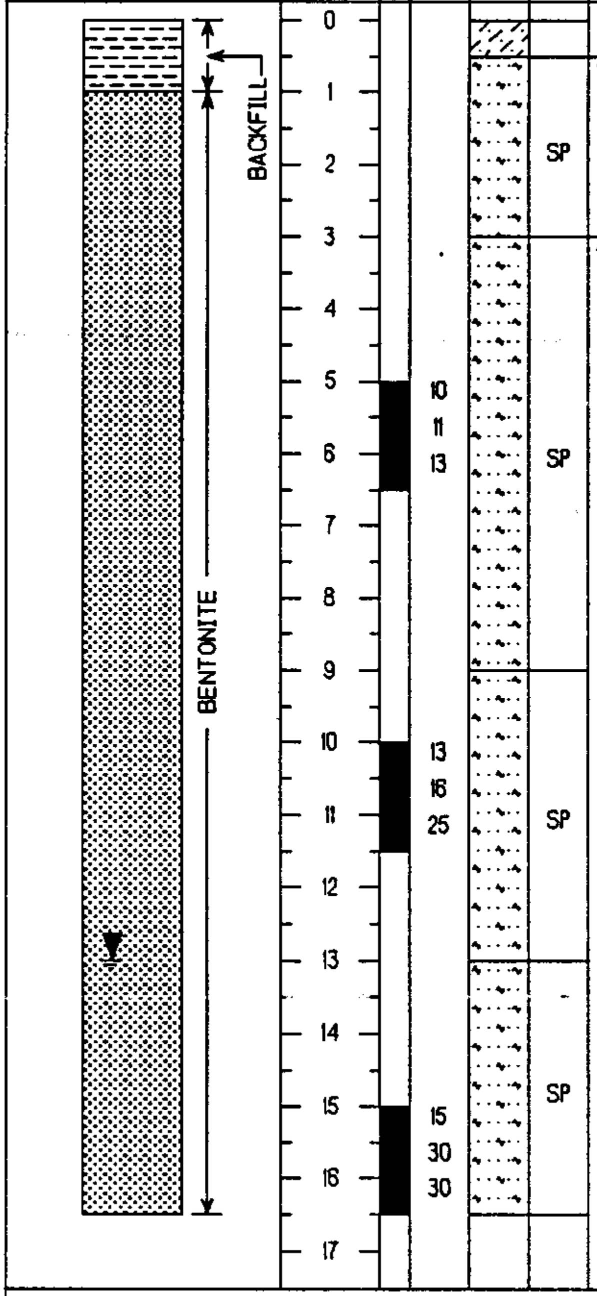
DASH/12-90

DIAGNOSTIC ENGINEERING INC.
50 E. Foothill Boulevard, Arcadia, Ca. 91006

NAME: Damson Oil Corporation
SITE: 40 West Horizon Avenue
CITY, STATE: Venice, California
PROJECT NO.: 1A2908AA001

911550B11A

LOG OF BORING B-11A



DEPTH (FEET)	BLOW COUNT	USCS DESIGNATION	SOIL DESCRIPTION	SAMPLE ID	FIELD PID / FID	LABORATORY 8020 BTEX	8015e	8015m	418.1	LEAD
0			ASPHALT PAVEMENT 4 INCHES THICK.							
1		SP	SAND, FINE TO MEDIUM GRAINED, TRACE CLAY BINDER, SOME SMALL PEBBLES, SLIGHTLY MOIST, LOOSE TO MEDIUM DENSE, DARK BROWN, NO PRODUCT ODOR.							
3		SP	SAND, FINE TO MEDIUM GRAINED, SLIGHTLY MOIST, MEDIUM DENSE, LIGHT BROWN, NO PRODUCT ODOR.							
5	10 11 13			B11-5	0	ND ND ND ND			ND	
9		SP	SAND, FINE TO MEDIUM GRAINED, SLIGHTLY MOIST, MEDIUM DENSE, BLACK, STRONG PRODUCT ODOR.							
10	13 16 25			B11-10	5000	ND ND 4.10 23.0			ND	
13		SP	SAND, FINE TO MEDIUM GRAINED, SLIGHTLY MOIST, MEDIUM DENSE, DARK BROWN TO BLACK, STRONG PRODUCT ODOR.							
15	15 30 30			B11-15	1	ND ND ND ND			250	

ANALYSES (mg/Kg) ppm

SURFACE ELEVATION: UNKNOWN
TOTAL DRILL DEPTH: 15 ft.
FINAL SAMPLE DEPTH: 1.5 ft.
TOTAL DEPTH: 16.5 ft.
TYPE OF SAMPLER: 3" O.D. MODIFIED PORTER SAMPLER

DATE DRILLED: 12-5-91
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