

APPENDIX C

PRELIMINARY DRAINAGE STUDY

TECHNICAL MEMORANDUM

Date: January 17, 2020

BKF Job Number: 20166080-12

Deliver To: Winehaven Legacy LLC

From: Sravan Paladugu, P.E.,

Subject: **Point Molate – Preliminary Drainage Study**

A. Introduction

The Winehave Legacy LLC is proposing a mixed-use development project in the City of Richmond (City) on the former Point Molate Navy Fuel Depot and Winehaven Historic District (Point Molate Site or Project Site). The Point Molate Site is located on the San Pablo Peninsula and is bounded by the San Francisco Bay to the west, open space parcels to the north and south, and the Chevron Richmond refinery to the east, with Potrero Ridge's 480-foot hillsides separating these two sites. Approximately 138 acres of the roughly 413-acre of the Point Molate Site is submerged in the San Francisco Bay, leaving approximately 275 acres above water. The Point Molate Site is approximately 1.5 miles north of Interstate 580 (I-580) and the Richmond-San Rafael Bridge, and has direct freeway access through Stenmark Drive, a City-owned roadway. Refer to Figure 1 for Project Vicinity Map.

The purpose of this technical memorandum is to identify preliminary storm drainage infrastructure needed to serve the proposed Project.

B. Background

The Point Molate Site was used primarily for fishing, commercial, and naval activities in the 20th century. From around 1890 to 1912, a Chinese shrimp camp was established at Point Molate where Chinese shrimpers lived and worked. From 1907 to 1919, the historic Winehaven winery occupied the northern portion of the Point Molate Site. In the late 1930s the site was sold to Santa Cruz Oil and later bought by the U.S. Navy. Beginning in 1942 during World War II, the Point Molate Site served as a U.S. Navy fuel storage and transfer facility. The Navy installed twenty (20) 50,000-barrel and four (4) 28,000-barrel underground fuel storage tanks in the hills onsite as well as a number of ancillary smaller underground and aboveground tanks in later years.

The Navy closed the facility on September 30, 1995, and later transferred it to the City. In 1997, the City as the Local Reuse Authority developed Point Molate Reuse Plan (Reuse Plan) which contemplated a development scenario at the Point Molate Site with 670 residential units and preservation of approximately 70 percent of the land within the Point Molate Site as open space. In addition, the Reuse Plan envisioned that the Winehaven Historic District, listed on the National Register of Historic Places, would be preserved for adaptive reuse.

Since that time, the City has engaged community and developers to implement the Reuse Plan. In 2004, the City entered into an agreement with Upstream Point Molate LLC to develop the Project Site. Upstream Point Molate LLC proposed a Casino Project for which the City prepared a Draft Environmental Impact Statement/Environmental Impact Report in July 2009 (2009 DEIS/EIR). The 2009 DEIS/EIR fully analyzed five development alternatives for the Point Molate Site, including one that contained substantial commercial and residential components without a casino. The EIR was finalized and certified in 2011. However, after certifying the 2011 EIR, the Richmond City Council discontinued consideration of the destination resort and casino project.

B.1 Proposed Project

The Project will include a variety of residential and commercial uses, as well as supporting road and utility infrastructure. The proposed Project would be divided into eight Development Areas A through H. Development Areas A through E would be developed with up to 910 residential units and Development Areas F through H would be developed with up to 1,130 new residential units and will include rehabilitation of existing historic buildings in Winehaven historic district for either commercial or residential uses, or a mix of the two. In total, up to 2,040 units could be developed on the Project Site. Table A below provides a summary of proposed land uses. Table A below provides a summary of proposed land uses.

Table A – Proposed Project Land Use Summary

Land Use	Number	Unit
Residential (Areas A-H)	2,040	Units
Office/Retail/Commercial/Restaurant (Area F-H)	40,000	Square Feet

C. Existing Storm Drainage

The existing drainage system is made up of road side concrete gutters that capture runoff from undeveloped hillside and the roadway itself, and convey the runoff to catch-basins connected to storm drain pipe that outfall to the San Francisco Bay. The storm drainage system was constructed in piecemeal as development occurred over many years ago. There are a total of eleven (11) existing outfalls within the Project area that currently discharge runoff to the Bay. According to the City GIS data, the existing storm drain system pipe sizes vary from 6-inches to 36-inches. The outfall pipes daylight to the shoreline a few feet upstream from the edge of the water. Refer to Figure 2 for existing drainage system layout.

D. Proposed Drainage System

The proposed drainage system is designed to convey 10-year design storm in the pipe with hydraulic grade line below the rim of the catch-basin or manhole. For storms larger than 10-year, runoff will be carried in the street

right-of-way including runoff from the 100-year storm. Low points in the street and terrain where overland release or conveyance will flood property or has potential to damage surrounding areas will be intercepted and conveyed in the pipe. The Contra Costa County drainage guidelines are used to size the proposed storm drain system and to verify the capacity of the existing outfall to which the proposed system will connect to.

D.1 Design Criteria

The following summarizes the criteria and parameters used for hydrologic and hydraulic analyses and for designing of storm drain system.

Design Runoff: Determination of site design runoff flow rates are based on the Rational Method. The Rational Method is defined as $Q = C I A$, where:

- Q = peak flow (cfs)
- C = runoff coefficient factor
- I = rainfall intensity (in/hr)
- A = area (acres)

Design Storm: All drainage facilities (i.e., inlets, pipes, ditches, street conveyance, outfalls) are evaluated using a 100-year design storm event as noted above.

Datum: Project plans and design calculations are based on NAVD 88 datum. The horizontal datum is California State Plane Zone III.

Computer Software: Bentley StormCAD V8i was used to evaluate the performance of the existing and proposed underground storm drainage pipe. This program is a Rational Method based program with hydraulic analysis for both free flow and pressure flow conditions.

Time of Concentration: The minimum time-of-concentration used is 5 minutes. A 5 minute time-of-concentration is also used where only streets are contributing flow to the inlet. Additional time-of-concentration for sheet flow across hillside and from gutter to the inlet is calculated using Kirpich's equation provided below. The total initial time-of-concentration is used for evaluating inlet capacity. The storm drain system time-of-concentration is computed by the StormCAD program at different nodes using actual pipe flow velocity.

$$T_c = 0.0078 \left(\frac{L^{3/2}}{H^{1/2}} \right)^{0.77}$$

where: L = the maximum length of travel, in feet.

H = the difference in elevation along the effective slope line, in feet.

Tc = the additional time of concentration from gutter to inlet, in minutes

Rainfall Intensity: The County Mean Annual Precipitation Map (MAP) and the Duration-Frequency-Depth Curves were used to estimate the 10- and 100-year intensity. The Project site has a mean annual precipitation of 20-inches. The table below presents rainfall intensities corresponding to the MAP.

Rainfall Intensities		
Duration (min)	Return Period (years)	
	10 (in/hr)	100 (in/hr)
5	2.88	4.08
10	2.04	2.88
15	1.68	2.40
30	1.20	1.76

Runoff Coefficient: Runoff coefficients developed are based on USGS Soil Survey data and the County Rational Methodology. A runoff coefficient of 0.4 for pervious open space areas and 0.95 for impervious roof and asphalt.

Roughness Coefficient: A Manning's roughness coefficient of 0.013, 0.011 and 0.024 is used for concrete pipe, HDPE/PVC, and CMP pipes, respectively.

Head Losses: Head losses are calculated using the HEC-22 energy method which considers bend angles, change in flow rate and change in pipe size.

Rim Elevations: Rim elevations are based on aerial borne survey and USGS LiDAR.

Tailwater: The Mean Higher High Water elevation was used as tail water elevation for outfall to the Bay.

Inlet Design: Inlet location and size is based on the amount of flow that needs to be intercepted to maintain at least a 10-ft dry lane for access. Another factor that governs inlet design is the geometric design of the roadway. An inlet is required where the roadway transitions from a crowned street to a super elevated street and vice versa. Inlet interception capacity is based on inlet equations published in the Federal Highway Administration's Hydraulic Engineering Circular No. 22 (HEC-22) Urban Drainage Design Manual. A spreadsheet was used to solve HEC-22 inlet equations. On steep gutter slopes where flow reaches high velocity, side opening inlets are used as they are efficient in capturing the entire flow approaching the inlet.

Storm Drain Design: New storm drain is placed within the right-of-way for proposed development and within footprint of existing storm drain where upsizing of existing pipe is needed to meet design criteria. A minimum pipe size of 12-inches was used for ease of maintenance. The storm drain is design to convey runoff from a 10-year storm 6-inches below the rim of existing or new catch-basin and/or manhole.

D.2 Capacity Analyses

A StormCAD model was developed to size the proposed backbone system for each outfall system. The model includes depth of pipe at catch-basin, outgoing pipe size, material and number of pipes. The analyses showed that the proposed pipe size needs to be 12- to 36-inches in diameter to adequate to convey 10-year flow. Refer to Figure 3 for proposed pipe sizes and location. The analyses also showed that some of the existing pipes and the outfall to be under capacity to convey the 100-year storm. Tables 1 to 4 present the results of the StormCAD pipe capacity analyses.

E. Conclusion

The Project will maintain existing drainage pattern and outfall locations. Where existing outfall is found to be under capacity, the Project will consolidate the existing outfalls to minimize environmental impacts and permitting required to upsize the existing outfall. Based on our preliminary analyses, the proposed Project will need fewer outfalls than existing. We currently anticipate that Outfalls 2 and 10 will need to be upsized.

We recommend that during Project design stage, the existing storm drain system be field surveyed to confirm the pipe sizes and material used for this preliminary analyses and revise the analyses accordingly. If existing pipe and/or outfall has adequate capacity to convey design flow, then it is recommended to perform condition assessment to confirm structural strength of the pipe. If the existing outfall is not used by the Project and does not serve areas outside the Project, then it is recommended to abandon the outfall pipe in place.

It is also recommended that energy dissipaters be installed to prevent erosion and to reduce post-project flow velocities to be less than the pre-project. Since the outfall pipes currently daylight to the shoreline above the edge of the water, these improvements will not impact habitat below water.

The Project is not subjected to Hydromodification Management (HMP) and detention to reduce peak flow as it discharges directly to the Bay. The Project however is subjected to San Francisco Municipal Regional Permit (MRP) C.3 treatment requirements. To comply with Provision C.3, the project will use Integrated Management Practices (IMP) that will implement Low Impact Development (LID) treatment facilities and flow-control facilities that may include any of the combination of the following: bioretention areas, flow through planters, pervious pavements, depressed landscaped areas, and green roofs in series with cisterns, vaults, and/or dry wells. Refer to Appendix A for Contra Costa C.3 LID fact sheets. A preliminary location of the centralized bioretention treatment basins is shown on Figure 3.

During detailed design, the Project will further evaluate the size and location of these centralized storm water capture facilities and incorporating low impact development (LID) features to treat runoff prior to discharging to the Bay to meet MRP requirements.

ATTACHMENTS

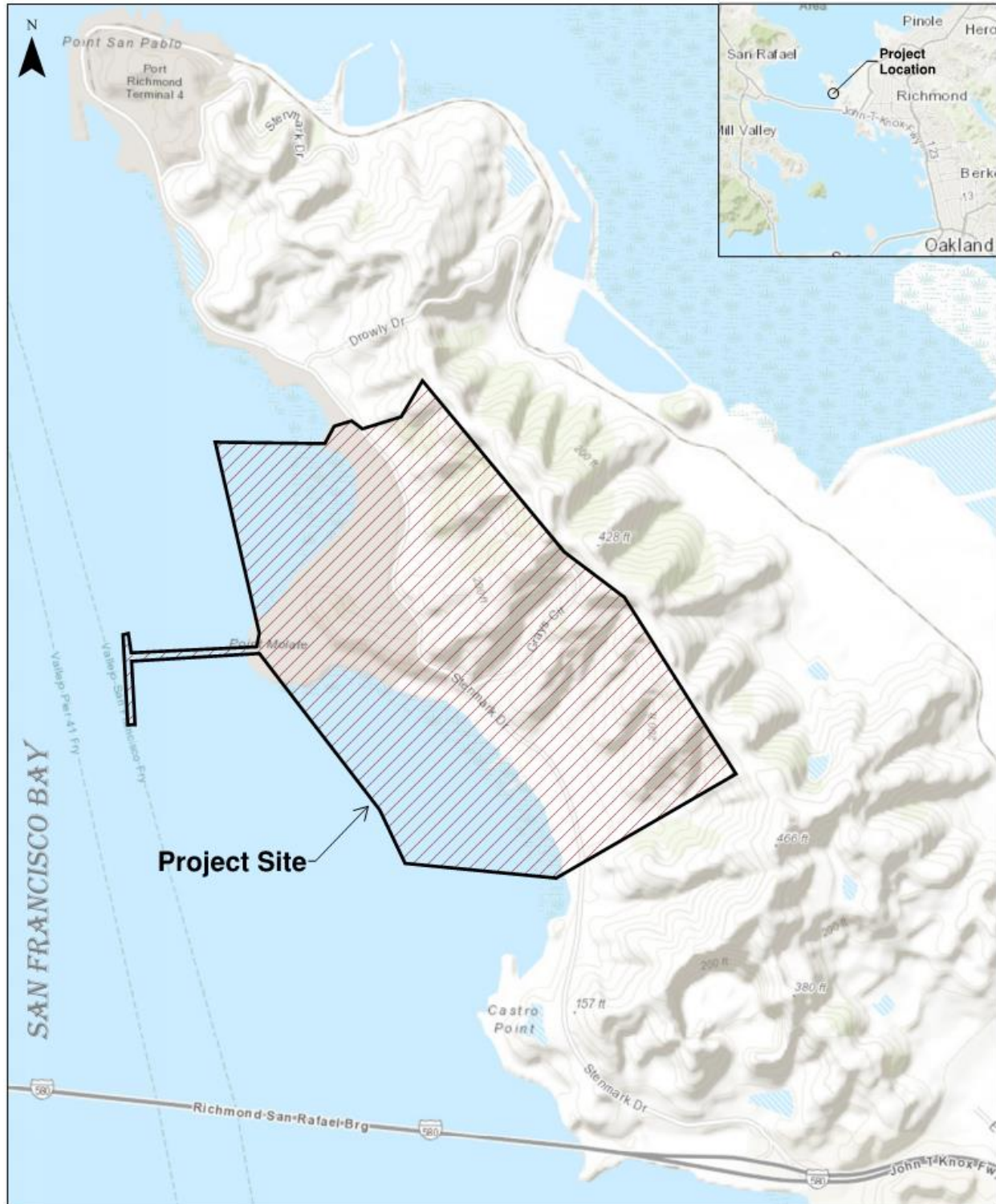
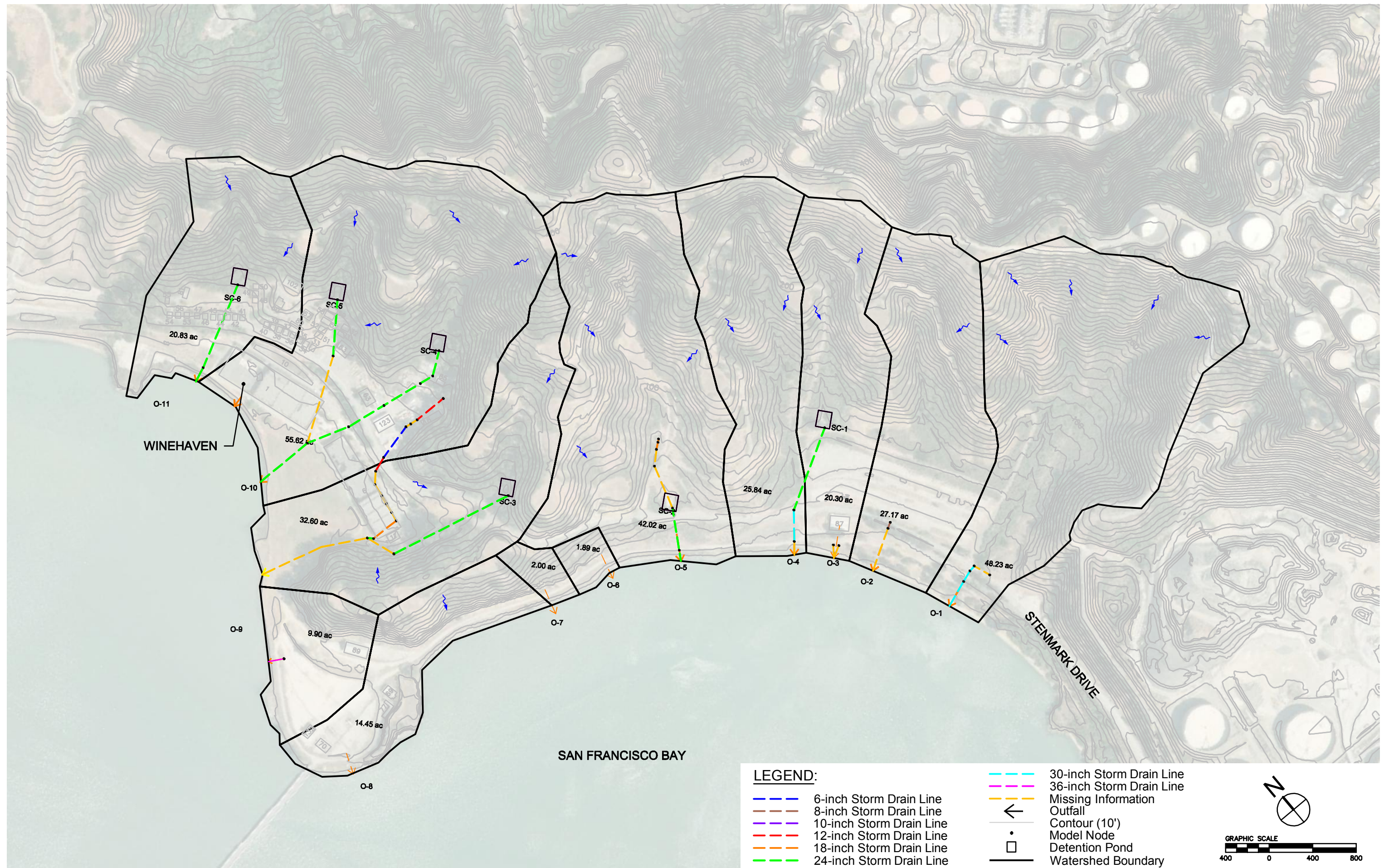
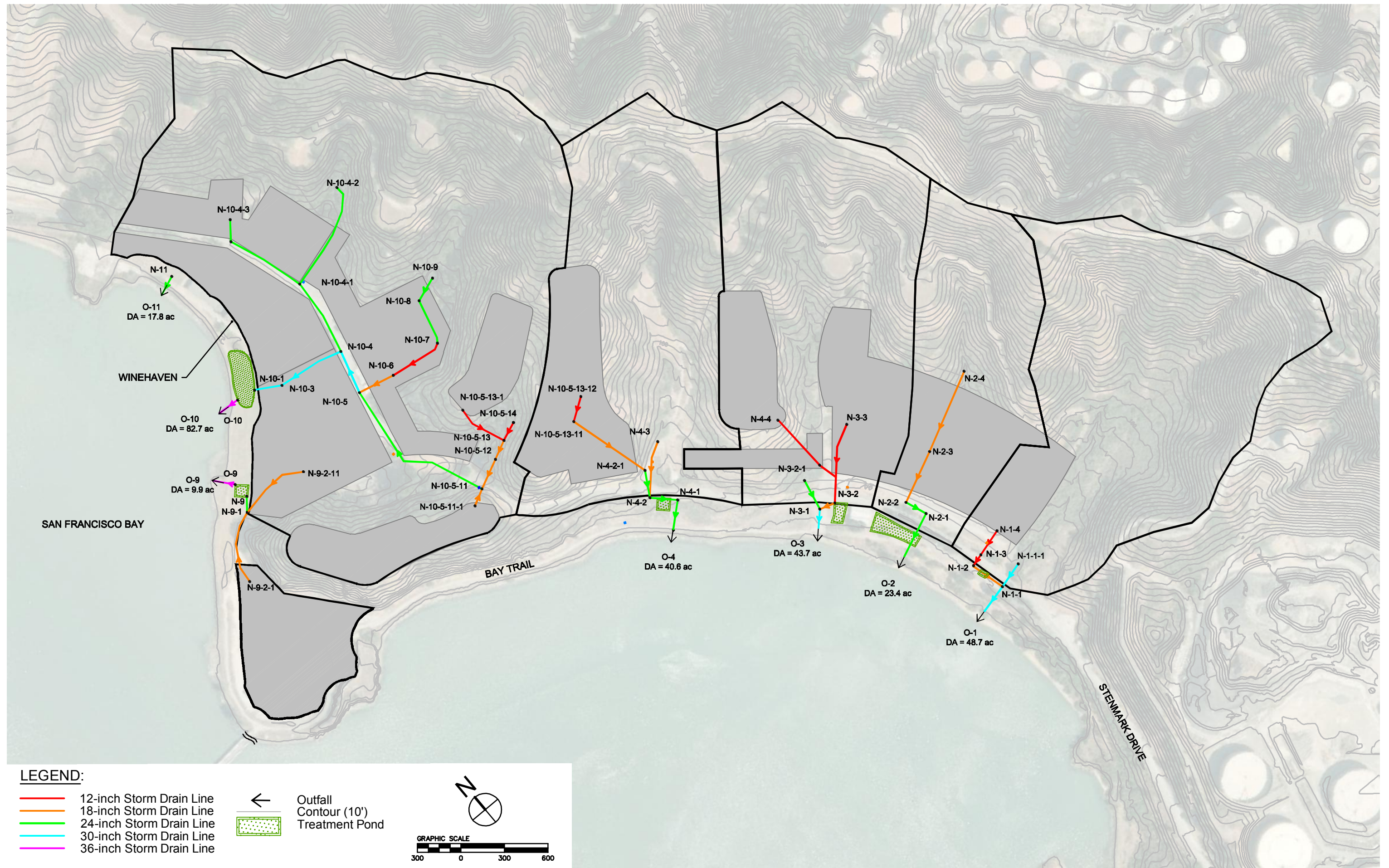


Figure 1 – Vicinity Map



**FIGURE 2: EXISTING STORM DRAIN SYSTEM
POINT MOLATE DEVELOPMENT**

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**FIGURE 3: PROPOSED DRAINAGE AREAS & STORM DRAIN SYSTEM
POINT MOLATE DEVELOPMENT**

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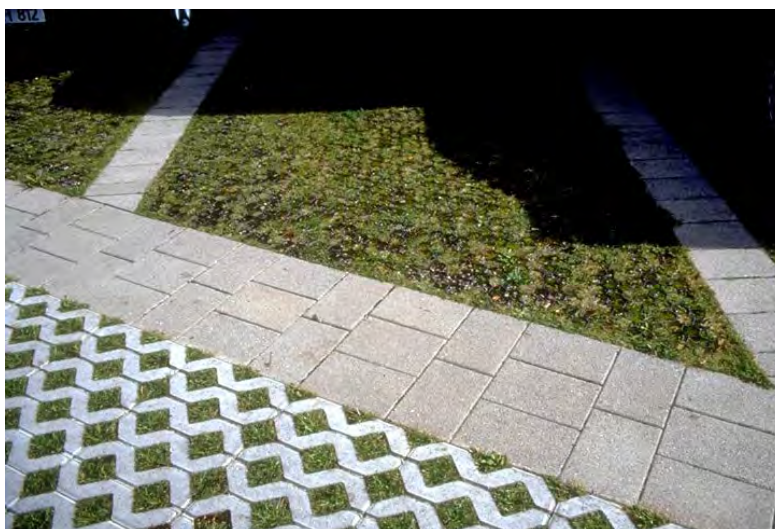
APPENDIX A

Pervious Pavements



Impervious roadways, driveways, and parking lots account for much of the hydrologic impact of land development. Pervious pavements allow rainfall to collect in a gravel or sand base course and infiltrate into native soil instead of creating runoff.

Pervious pavements are often costly to build and maintain when compared to conventional pavement draining to bioretention facilities. However, in some applications the aesthetic or practical benefits of a flat surface unbroken by drainage structures may be worth the additional cost.



Best Uses

- Flat areas (< 2% slope)
- Areas with competent, permeable native soils
- Low-traffic areas
- Where aesthetic quality can justify higher cost

Advantages

- No maintenance verification requirement for installations < 3000 SF
- Surface treatments can complement landscape design

Limitations

- Initial cost
- Placement requires specially trained crews
- Geotechnical concerns, especially in clay soils
- Concerns about pavement strength and surface integrity



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Pervious pavements are not treatment facilities. However, they may be configured as self-retaining areas. In specific, limited circumstances, pervious pavements configured as self-retaining areas may receive some runoff from roofs or conventional pavement—if it can be shown that the required amount of runoff, as well as rain falling on the pervious pavement, will infiltrate into the underlying soil.

Solid unit pavers—such as bricks, stone blocks, or precast concrete shapes—are considered to reduce runoff compared to impervious pavement, when the unit pavers are set in sand or gravel with $\frac{3}{8}$ " gaps between the pavers. Joints must be filled with an open-graded aggregate free of fines.

If pervious pavement areas drain to IMPs, use the runoff factors in Table 3-2 when sizing the IMPs.

► DETAILS

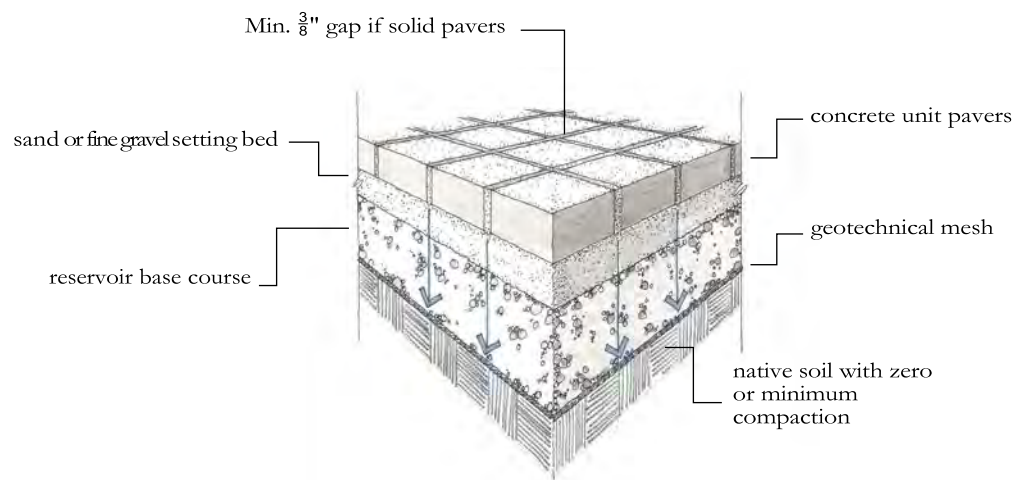
Permeable pavements can be used in clay soils; however, special design considerations, including an increased depth of base course, typically apply and will increase the cost of this option. Geotechnical fabric between the base course and underlying clay soil is recommended.

Permeable pavements are best used on grades from flat to approximately 2%. Installations on steeper grades, particularly on clay soils, require cut-off trenches lateral to the slope—to intercept, store, and infiltrate drainage from the base course.

Pavement strength and durability typically determines the required depth of base course. If underdrains are used, the outlet elevation must be a minimum of 3 inches above the bottom elevation of the base course.

Pervious concrete and porous asphalt must be installed by crews with special training and tools. Industry associations maintain lists of qualified contractors.

Parking lots with crushed aggregate or unit pavers may require signs or bollards to organize parking.



TYPICAL CONFIGURATION for a pervious pavement. The base course is a minimum 3" depth for runoff retention. A deeper base course is typically required for pavement stability.

► **CRITERIA FOR PERVIOUS PAVEMENTS**

- ☐ Installation is flat or < 2% grade.
- ☐ No erodible areas drain on to pavement.
- ☐ Subgrade is uniform and slopes are not so steep that subgrade is prone to erosion. Compaction is minimal.
- ☐ Reservoir base course is of open-graded crushed stone. Base depth is adequate to retain rainfall and support design loads.
- ☐ If a subdrain is provided, outlet elevation is a minimum of 3 inches above highest point of bottom of base course.
- ☐ Rigid edge is provided to retain granular pavements and unit pavers.
- ☐ Solid unit pavers, if used, are set in sand or gravel with minimum $\frac{3}{8}$ " gaps between the pavers. Joints are filled with an open-graded aggregate free of fines.
- ☐ **Permeable concrete and porous asphalt, if used, are installed by qualified professionals according to vendor's recommendations.**
- ☐ Selection and location of pavements incorporates Americans with Disabilities Act requirements, site aesthetics, and uses.
- ☐ Pavement design and/or grading design incorporates management of design flows to avoid local flooding (typically a 10-year storm).

► **RESOURCES**

National Ready Mix Concrete Association

<http://www.perviouspavement.org/>

National Asphalt Pavement Association

www.asphaltpavement.org

Interlocking Concrete Pavement Institute

<http://www.icpi.org/>

Start at the Source Design Manual for Water Quality Protection, pp. 47-53. <http://www.cccleanwater.org/c3-resources.html>

Porous Pavements, by Bruce K. Ferguson. 2005. ISBN 0-8493-2670-2.

Caltrans. 2014. *Pervious Pavement Design Guidance*.

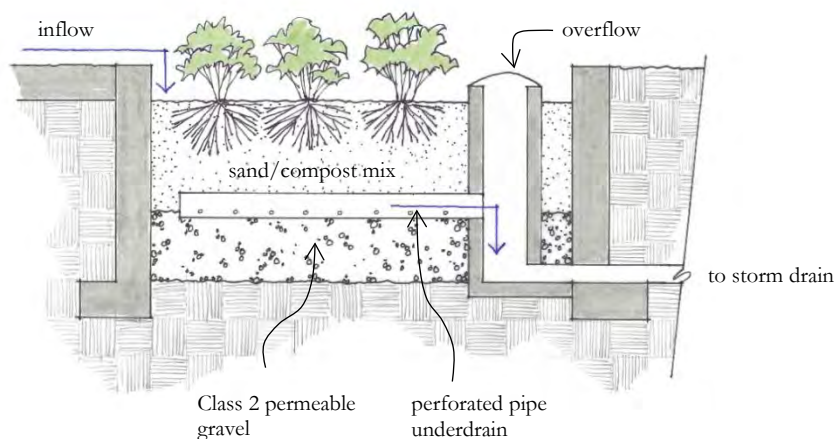
http://www.dot.ca.gov/hq/oppd/stormwtr/bmp/DG-Pervious-Pvm_082114.pdf

Bioretention Facilities



Bioretention facilities can be rectangular, linear, or nearly any shape.
Photo by Scott Wikstrom

Bioretention facilities capture runoff in a shallow reservoir on the soil surface, then filter the runoff through plant roots and a biologically active soil mix. The treated runoff then trickles into a subsurface gravel layer. Runoff is held in the gravel layer until it infiltrates it into the ground. If the entire gravel layer becomes saturated, an underdrain conveys excess treated runoff to a storm drain or to surface drainage.



Best Uses

- Commercial areas
- Residential subdivisions
- Industrial facilities
- Roadways
- Parking lots
- Fit in setbacks, medians, and other landscaped areas

Advantages

- Can be any shape
- Low maintenance

Limitations

- Require 4%-15% of tributary impervious square footage
- Typically require 3-4 feet of head
- Irrigation may be required



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LAYOUT AND SITE DRAINAGE

See the guidance on page 28 regarding how to incorporate bioretention facilities into your site. Also see “Integrating Your LID Design into Your Project” on page 42.

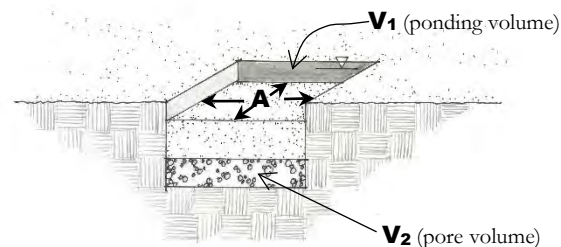
- Place bioretention facilities in visible, well-trafficked areas and make them a focal point in the landscape.
- On flatter sites, use surface drainage, rather than underground pipes, to convey runoff to the bioretention facility inlets. The top of soil elevation should be as high as possible—typically 6 to 12 inches below surrounding grade.
- Where possible, design site drainage so only impervious roofs and pavement drain to the bioretention facility. Avoid high walls or steep slopes adjacent to bioretention facilities. Avoid side slopes within bioretention areas as much as possible. The bioretention soil mix will tend to rill even on very mild slopes (>8:1).
- Integrate bioretention facilities with the landscape design.
- Make the bioretention facilities level around their perimeter.
- Where possible, grade tributary paved areas to sheet flow runoff and disperse it among curb cuts, rather than concentrating flow at one inlet location.
- Place each facility in a common, accessible area. Avoid locating facilities on private residential lots.

► DIMENSIONS AND MATERIALS

For development projects subject only to **runoff treatment requirements**, the following minimum dimensions apply.

Parameter	Criterion
Surface reservoir mean depth	6" minimum
Soil mix surface area	0.04 times tributary impervious area (or equivalent)
Soil mix depth	18" minimum
Gravel layer	12" min. Class 2 permeable
Underdrain discharge	At top of gravel layer

Where **flow-control requirements** also apply, the bioretention facility must be designed to meet the minimum surface area (A), surface volume (V_1), and subsurface volume (V_2) using Equation 3-3 and the sizing factors and equations in Tables 3-6 and 3-7. The IMP Sizing Calculator should be used.



Minimum subsurface volume. For treatment-and-flow-control facilities the minimum subsurface volume V_2 specified in Table 3-6 is the void space, not the entire volume of gravel. Where the native soils are Hydrologic Soil Group C or D, V_2 may be achieved by a 30" deep layer of gravel **of 40% porosity**, extending under the minimum footprint "A". Note that if the facility area is increased, the required depth to achieve the same volume is correspondingly decreased.

Gravel. "Class 2 permeable," Caltrans specification 68-2.02(F)(3), is preferred. Open-graded crushed rock, washed, may be used, but requires 4"-6" washed pea gravel be substituted at the top of the crushed rock layer. **Do not use filter fabric** to separate the soil mix from the gravel drainage layer or the gravel drainage layer from the native soil.

If desired, voids created by buried structures such as pipes or arches, may be substituted, as long as the voids are hydraulically interconnected and the minimum subsurface volume calculated by Equation 3-3 is achieved.

Soil mix. Criteria for the required mix of sand and compost are in Appendix B. It is similar to a loamy sand and must maintain a minimum percolation rate of 5" per hour throughout the life of the facility. It must be suitable for maintaining plant life with a minimum of fertilizer use. A list of suppliers is on the C.3 web pages.

► FACILITY DETAILS

Inlets. Curb cuts should be wide (12" is recommended) to avoid clogging with leaves or debris. Allow for a minimum reveal of 6" between the inlet and soil mix elevations to ensure turf or mulch buildup does not block the inlet. In addition, place an apron of stone or concrete, a foot square or larger, inside each inlet to prevent vegetation from growing up and blocking the inlet.

If the linear slope along the curb is greater than the orthogonal slope of the gutter pan, runoff flows will not enter the inlet efficiently. Use a drop inlet with a grate instead.

Where runoff is concentrated and conveyed to the facility in pipes or swales, protect the landscaping from high-velocity

flows with energy-dissipating cobble of appropriate size. In larger installations, provide cobble-lined channels to better distribute flows throughout the facility.

“Bubble ups” can be used to dissipate energy when runoff is piped from roofs and up-gradient paved areas.

Surface storage and overflow. For treatment-only facilities, the surface reservoir should be a minimum 6" deep. In treatment-and-flow-control facilities, the overflow elevation must be set to achieve the minimum surface storage volume calculated using Equation 3-3 and the V_1 sizing factor.

Ensure the soil mix is installed level and at the specified elevation, and that the elevation does not change when plants are installed.

Overflow structure. A precast concrete catch basin or manhole is best. The overflow elevation is critical and must be designed to achieve the surface reservoir requirements. The outlet should be designed to exclude floating mulch and debris. Design in **freeboard** if needed to prevent flooding or protect adjacent structures.

Underdrains. Underdrains must have their discharge elevation set at the top of gravel layer elevation. Perforated pipe can be laid in a shallow groove dug across the top of the gravel layer, holes facing down, and connected to the overflow structure. Underdrains must be constructed of rigid pipe (SDR 35 or equivalent) and provided with a cleanout.

Flow-control orifice. For treatment-and-flow-control facilities, the underdrain must be routed through a device designed to limit flows to that specified in Equation 3-10 or 3-11 (page 40). Typically, a section of solid pipe is designed to protrude slightly into the overflow structure. The pipe is threaded and fitted with a standard cap; a hole of the specified diameter is drilled into the cap. The cap can then be easily removed for cleaning or adjustment and reinstalled.

► APPLICATIONS

Multi-purpose landscaped areas. Bioretention facilities are easily adapted to serve multiple purposes. The loamy sand soil mix will support either turf or a plant palette suitable to the location and a well-drained soil. See Appendix B for additional guidance on soil, plant selection, and irrigation.

Residential subdivisions. In the design of many subdivisions, it has proven easiest and most effective to drain roofs and driveways to the streets (in the conventional manner) and then drain the streets to bioretention areas, with one bioretention area for each 1 to 10 lots, depending on subdivision layout and topography.



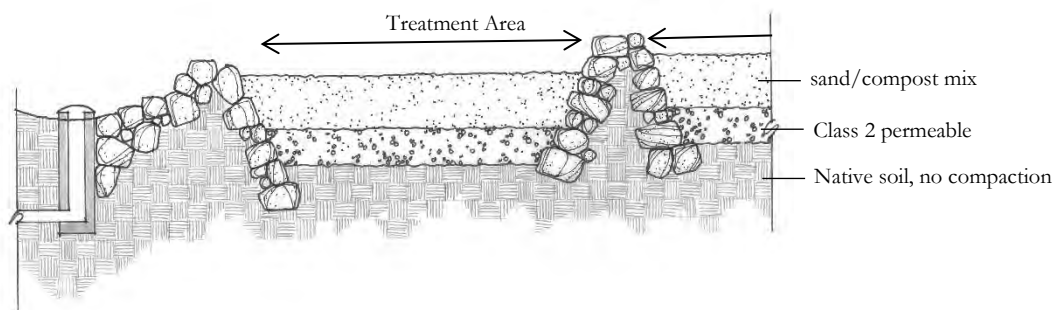
Bioretention facility in El Cerrito with active and passive recreational uses.

Bioretention areas can be placed on one or more separate, dedicated parcels with joint ownership.

Sloped sites. Bioretention facilities must be constructed as a basin or as a series of basins, with the circumference of each basin level.

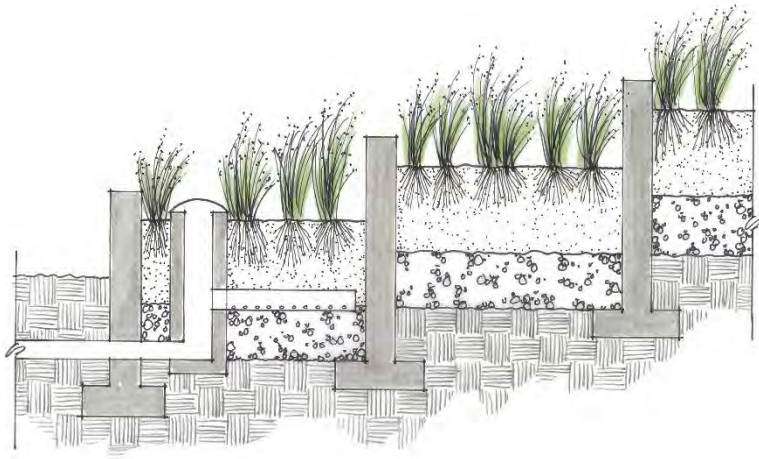
On the surface, a bioretention facility should be one level, shallow basin—or a series of basins. As runoff enters each basin, it should flood and fill throughout before runoff overflows to the outlet or to the next downstream basin. This helps prevent movement of surface mulch and soil mix.

Swales can be used on mild slopes. Check dams should be placed every 4 to 6 inches of elevation change and so that the lip of each dam is at least as high as the toe of the next upstream dam.



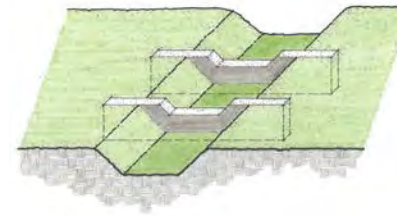
Swale with check dams. Not suitable for steeper slopes. Movement of soil can be a problem even at mild slopes. Design must ensure ponding behind each check dam.

A series of planters is a more robust solution and is required for steeper slopes.



Concrete check dams are a better solution on steeper slopes.

Solutions for surface storage. Placing a steep-sided depression in an urban landscape poses aesthetic challenges as well as practical challenges. First, use sheet flow, valley gutters, and trench drains, instead of pipes, to move runoff to the bioretention facility, so that inlets can be at or near ground level.



Key check dams into bottom and side slopes.

To further avoid the effects of high and steep drop offs, consider:

- Increasing the facility area and reducing the surface depth accordingly.
- Incorporating steps down into the facility.
- Specifying taller, woody plants to block or discourage entry.

Mulch can be mounded a few inches deeper at walkway edges to transition to the top of soil elevation.

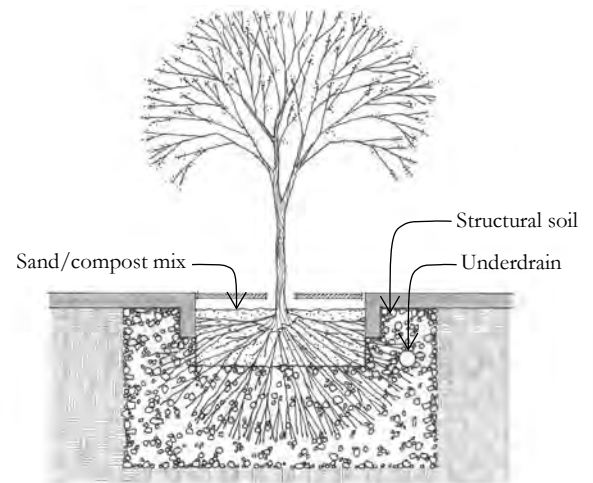
Vaults, utility boxes, backflow preventers, and light standards. Utility features and structures must be located outside the bioretention facility—in adjacent walkways or in a separate area set aside for this purpose.

Emergency overflow. The site grading plan should anticipate extreme events and potential clogging of the overflow, and should route emergency overflows safely.

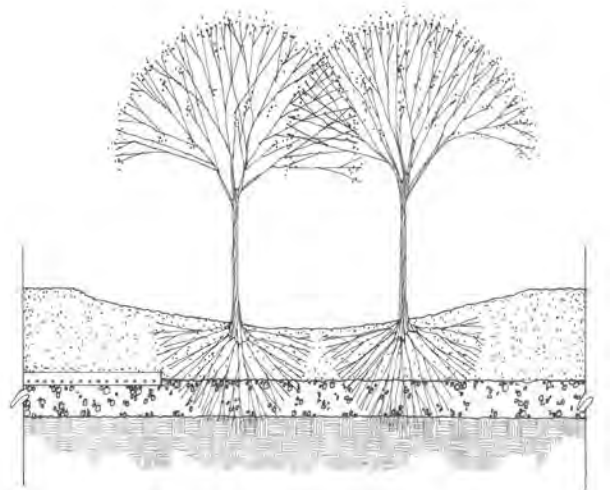
Trees. Bioretention areas can accommodate small or large trees within the minimum areas and volumes calculated by Equation 3-3. Tree canopies intercept rain, and tree roots maintain soil permeability and help retain runoff. Normal maintenance of a bioretention facility should not affect tree lifespan.

Consider the following when designing bioretention facilities to accommodate trees, especially large trees:

- The bioretention facility requires 18" of soil mix over the minimum surface area. Trees can be planted in this soil mix; the area occupied by the tree counts toward the minimum area requirement.
- Trees require sufficient rooting volume to thrive. [Structural soils](#) can be used below or around the soil mix.
- Most tree roots extend horizontally near the soil surface.
- The bioretention soil mix has low moisture-holding capacity. Consider planning for tree roots to access native clay soils through the side walls as the tree grows. However, where needed, adjacent paving or structures can be protected with a root barrier.
- A podium of native soil is sometimes constructed so that the root ball can be installed at the correct elevation (so that bioretention soil mix and mulch do not cover the tree's root collar).
- Large trees should be spaced appropriately for their size at maturity.
- Trees may need to be staked for longer because the bioretention soil mix provides little structural support against trees being toppled by wind.



Bioretention facility configured as a tree well.



Larger bioretention facility with trees.

Criteria for Bioretention

- ☐ Bioretention facilities are located in a visible, well-trafficked area where possible.
- ☐ Top of soil elevation is as high as possible. High walls and steep slopes adjacent to the facility are avoided.
- ☐ Location and footprint of facility are congruent on site plan, landscaping plan, and grading plan.
- ☐ Bioretention area is designed as a basin (level edges) or a series of basins, and grading plan is consistent with these elevations. Check dams, if any, are set so the lip or weir of each dam is at least as high as the toe of the next upstream dam.
- ☐ Volume or depth of surface reservoir meets or exceeds minimum. Freeboard above overflow (1"-2" recommended) is not included in surface reservoir volume.
- ☐ 18" depth specified soil mix (reference *Guidebook* Appendix B).
- ☐ Area of soil mix meets or exceeds minimum.
- ☐ Perforated pipe (PVC SDR 35 or approved equivalent) underdrain with discharge elevation **at the top** of the "Class 2 perm" layer. Holes facing downward. Connection and sufficient head to storm drain or approved discharge point.
- ☐ No filter fabric.
- ☐ Underdrain has a clean-out port consisting of a vertical, rigid, non-perforated PVC pipe, with a minimum diameter of 4 inches and a watertight cap.
- ☐ Curb inlets are 12" wide, have 4"-6" reveal and an apron or other provision to prevent blockage when vegetation grows in, and energy dissipation as needed.
- ☐ Overflow catch basin or manhole connected to a downstream storm drain or approved discharge point.
- ☐ Emergency spillage will be safely conveyed overland.
- ☐ Plantings are suitable to the climate, exposure, and a well-drained soil, and occasional inundation during large storm events.
- ☐ Irrigation system with connection to water supply, on a separate zone. See Appendix B.
- ☐ Vaults, utility boxes, backflow preventers, and light standards are located outside the minimum soil mix surface area.

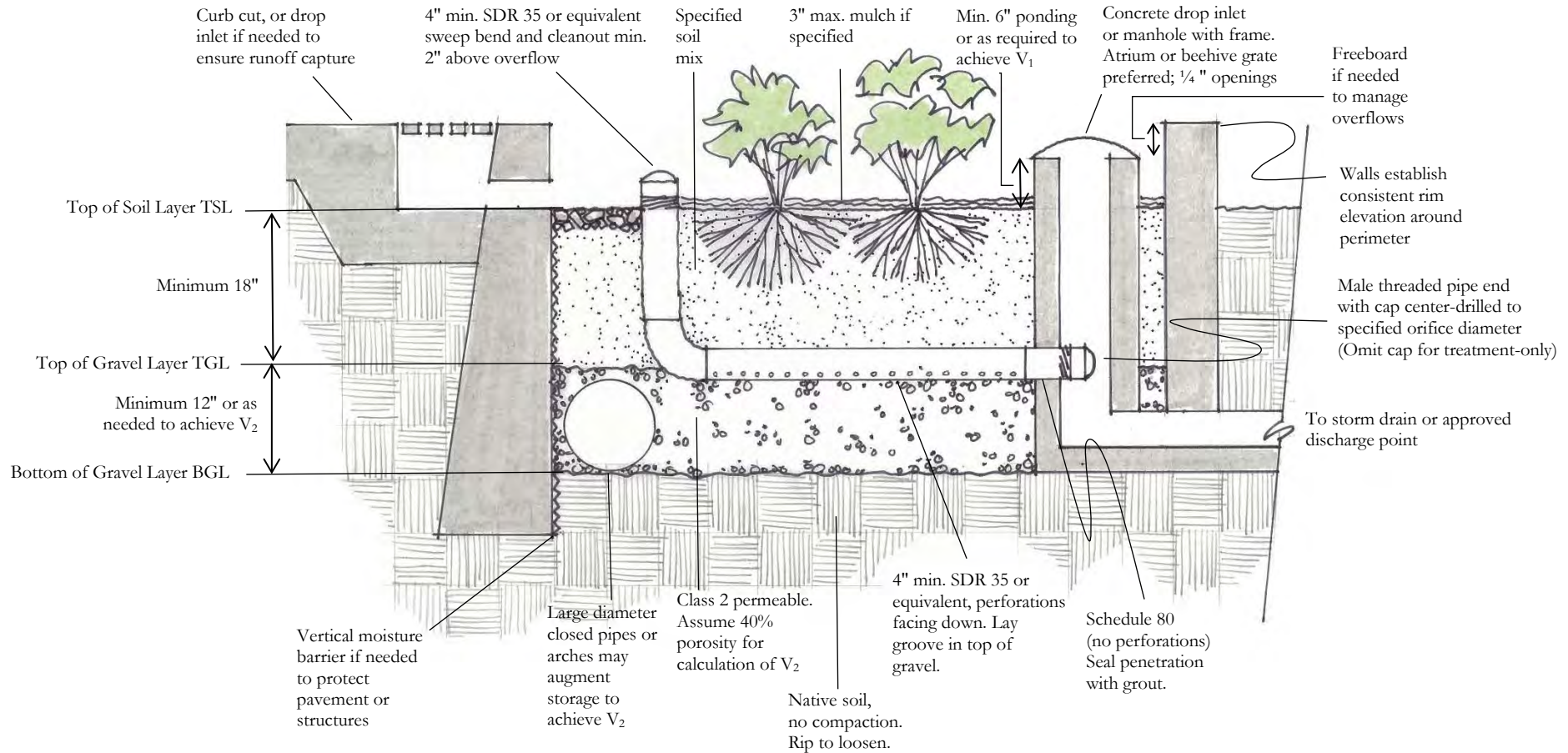
For treatment-and-flow-control facilities only

- ☐ Volume of surface storage meets or exceeds minimum (V_1).
- ☐ Volume of subsurface storage meets or exceeds minimum (V_2).
- ☐ In "C" and "D" native soils, underdrain is connected to discharge through an appropriately sized orifice or other flow-limiting device.

Bioretention Facility

Cross-section

Not to Scale

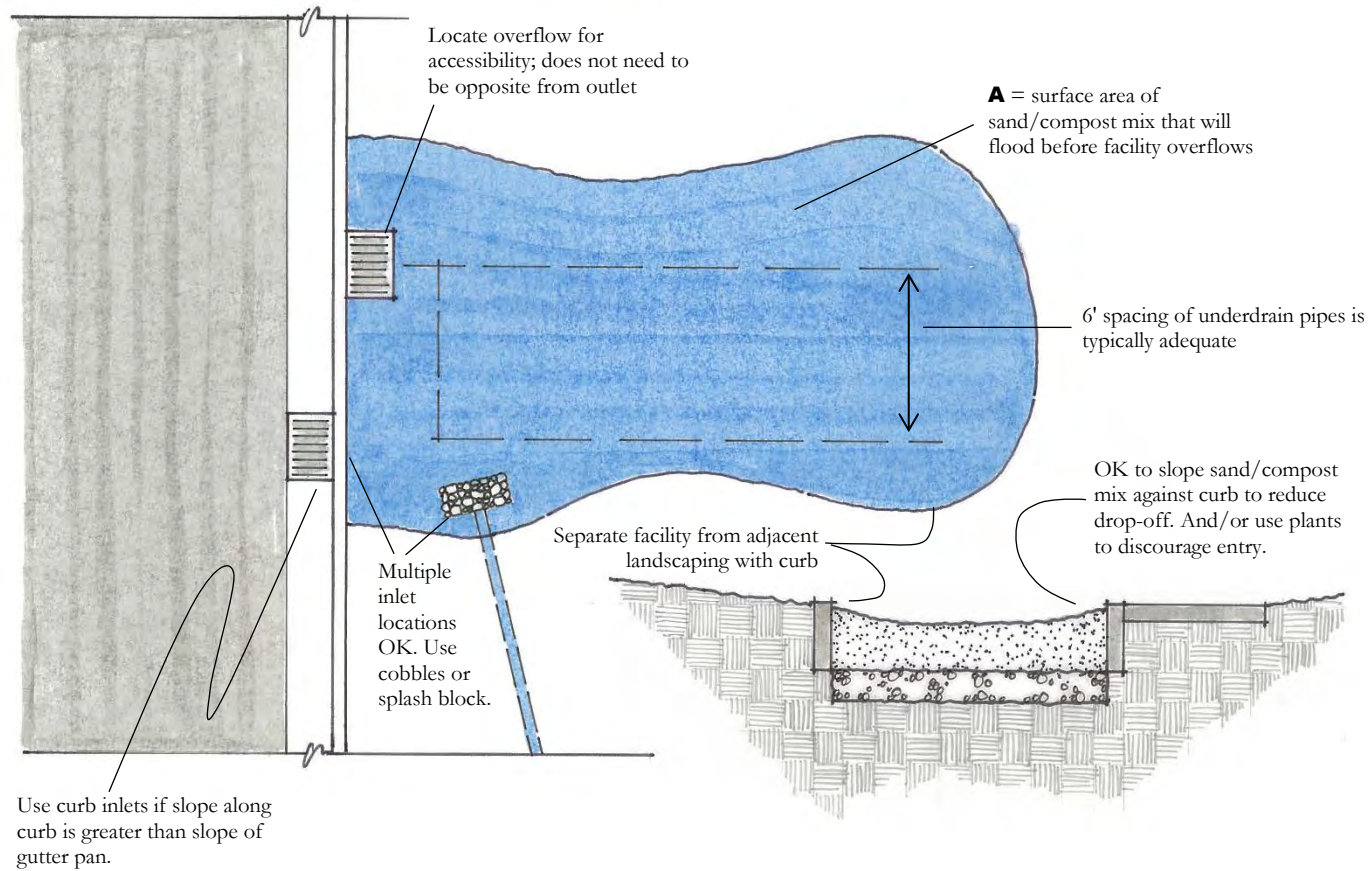


Notes:

- No liner, no filter fabric, no landscape cloth.
- Maintain BGL, TGL, TSL throughout facility area at elevations to be specified on drawing.
- Class 2 perm layer may extend below and underneath drop inlet.
- Elevation of perforated pipe underdrain is atop gravel layer.
- See Appendix B for soil mix specification, planting and irrigation guidance.
- See Chapter 3 for factors and equations used to calculate V_1 , V_2 and orifice diameter.

Bioretention Facility

Plan
Not to Scale



Flow-through Planter

Unlike bioretention facilities, flow-through planters are designed to discharge all influent runoff following treatment, rather than infiltrating some treated runoff into the underlying soil.

Flow-through planters are contained within a concrete box, or plastic liners may be used on the sides and bottom. An underdrain is constructed with the discharge elevation near the bottom of the gravel layer (that is, there is no “dead” storage).”

Flow-through planters may be used as an alternative to bioretention under certain conditions:

- Upper-story plazas
- Where bioretention facilities could cause mobilization of pollutants in soil or groundwater.
- Other situations where infiltration is a concern, such as locations with potential geotechnical hazards that cannot be mitigated except by preventing infiltration.

Best Uses

- Management of roof runoff
- Podium-style developments
- On building plazas

Advantages

- Versatile
- Can be any shape
- Low maintenance

Limitations

- Can only be used where infiltration is not possible
- May not be used for flow control (HM) where underlying soils are Hydrologic Soil Group “A” or “B”
- Requires underdrain
- Requires 3-4 feet of head



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► DIMENSIONS AND MATERIALS

Treatment only. For development projects subject only to runoff treatment requirements, the following criteria apply:

Parameter	Criterion
Surface reservoir depth	6" minimum
Soil mix surface area	$0.04 \times$ tributary impervious area
Soil mix depth	18" minimum
Gravel layer	12" min. Class 2 permeable
Underdrain	At bottom of gravel layer

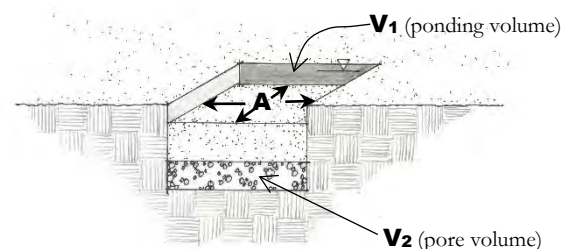
Where **flow-control requirements** also apply, the flow-through planter must be designed to meet the minimum surface area (A), surface volume (V_1), and subsurface volume (V_2) using Equation 3-3 and the sizing factors and equations in Tables 3-6 and 3-7. The IMP Sizing Calculator should be used.

Minimum surface and subsurface volume. In a vertical-sided box-like planter for treatment-and-flow-control with the minimum surface area A , the minimum surface volume V_1 can be achieved with an overflow height of 10" (12" total height of walls with 2" of freeboard).

For treatment-and-flow-control facilities the minimum subsurface volume V_2 specified in Table 3-8 is the void space, not the entire volume of gravel. The minimum subsurface volume V_2 can be achieved with a gravel (Class 2 permeable) depth of 30". This combination results in a planter approximately 5' high. The planter height can be reduced by incorporating void-creating underdrain pipes, other pipes, or arches, or by increasing the planter area so that the minimum V_2 is achieved.

Gravel. "Class 2 permeable," Caltrans specification 68-2.02(F)(3), is preferred. Open-graded crushed rock, washed, may be used, but requires 4"-6" washed pea gravel be substituted at the top of the crushed rock layer. **Do not use filter fabric** to separate the soil mix from the gravel drainage layer or the gravel drainage layer from the native soil.

If desired, voids created by buried structures such as pipes or arches may be substituted, as long as the voids are hydraulically interconnected and the minimum subsurface volume calculated by Equation 3-3 is achieved.



Soil mix. Criteria for the required mix of sand and compost are in Appendix B. It is similar to a loamy sand and must maintain a minimum percolation rate of 5" per hour throughout the life of the facility, and it must be suitable for maintaining plant life with a minimum of fertilizer use. A list of suppliers is on the C.3 web pages.

Underdrains. Underdrains must have their discharge elevation set as flush with the planter bottom as possible. Underdrains must be constructed of rigid pipe (SDR 35 or equivalent) and provided with a cleanout.

Flow-control orifice. For treatment-and-flow-control facilities, the underdrain must be routed through a device designed to limit flows to that specified in Equation 3-10 or 3-11 (page 38). Typically a section of solid pipe is designed to protrude slightly into the overflow structure. The pipe is threaded and fitted with a standard cap; a hole of the specified diameter is drilled into the cap. The cap can then be easily removed for cleaning or adjustment and reinstalled.

► APPLICATIONS

At plaza level. Flow-through planters have been successfully incorporated into podium-style developments, with the planters placed on the plaza level and receiving runoff from the tower roofs above. Runoff from the plaza level is typically managed separately by additional flow-through planters or bioretention facilities located at street level.

Adjacent to buildings. Designers should aim to use bioretention facilities (that is, facilities open at the bottom to allow infiltration) adjacent to buildings. An impermeable vertical cutoff wall between the facility and the building may be incorporated. Where it is not feasible to adjust the building and foundation design, flow-through planters may be used. Planter vegetation can soften the visual effect of the building wall. A setback with a raised planter box may be appropriate even in some neo-traditional pedestrian-oriented urban streetscapes.

Steep slopes. Flow-through planters provide a means to detain and treat runoff on very steep slopes that cannot accept infiltration from a bioretention facility. The planter can be built into the slope similar to a retaining wall. The design should consider the need to access the planter for maintenance. Flows from the planter underdrain and overflow must be directed in accordance with local requirements. It is sometimes possible to disperse these flows to the downgradient hillside.



Flow-through planters on the plaza level of a podium-style development.



Bioretention facility adjacent to building. An impermeable cutoff wall between the facility and the building may be incorporated.



Flow-through planter built into a hillside. Flows from the underdrain and overflow must be directed in accordance with local requirements.

Design Checklist for Flow-through Planter

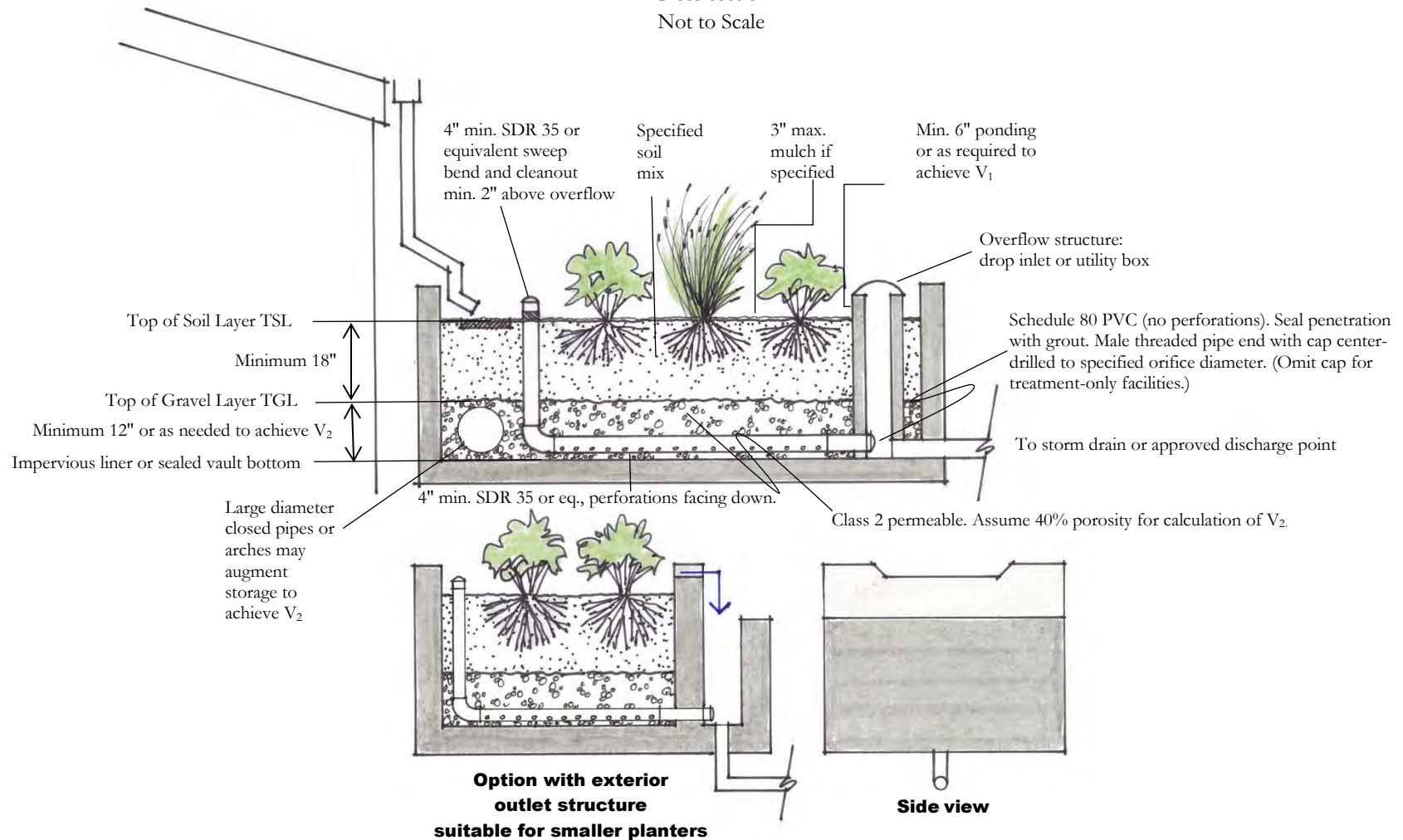
- ☐ Location and footprint of facility are shown on site plan and landscaping plan.
- ☐ Planter is set level.
- ☐ Location is on an upper-story plaza, adjacent to a building foundation, where mobilization of pollutants in soil or groundwater is a concern, or where potential geotechnical hazards are associated with infiltration
- ☐ Volume or depth of surface reservoir meets or exceeds minimum.
- ☐ 18" depth specified soil mix (reference *Guidebook* Appendix B).
- ☐ Area of soil mix meets or exceeds minimum.
- ☐ "Class 2 perm" drainage layer.
- ☐ No filter fabric.
- ☐ Perforated pipe (PVC SDR 35 or approved equivalent) underdrain with outlet located flush or nearly flush with planter bottom.
- ☐ Connection with sufficient head to storm drain or discharge point.
- ☐ Underdrain has a clean-out port consisting of a vertical, rigid, non-perforated PVC pipe, with a minimum diameter of 4" and a watertight cap.
- ☐ Overflow outlet connected to a downstream storm drain or approved discharge point.
- ☐ Emergency spillage will be safely conveyed overland.
- ☐ Plantings are suitable to the climate, exposure, and a well-drained soil.
- ☐ Irrigation system with connection to water supply, on a separate zone. See Appendix B.

For treatment-and-flow-control flow-through planters only

- ☐ Volume of surface storage meets or exceeds minimum.
- ☐ Volume of subsurface storage meets or exceeds minimum.
- ☐ Underdrain is connected via an appropriately sized orifice or other flow-limiting device.

Flow-through Planter

Cross-section
Not to Scale



Notes:

- Underdrain to be min. 4" PVC SDR 35 or equiv. with holes facing down.
- Locate underdrain as close as possible to bottom.
- No filter fabric, no landscape cloth.
- See Appendix B for soil mix specification, planting and irrigation guidance.
- See Chapter 3 for factors and equations used to calculate V_1 V_2 and orifice diameter.

Dry Wells and Infiltration Basins

The typical dry well is a prefabricated structure, such as an open-bottomed vault or box, placed in an excavation or boring. The vault may be empty, which provides maximum space efficiency, or may be filled with rock.

An infiltration basin has the same functional components—a volume to store runoff and sufficient area to infiltrate that volume into the native soil—but is open rather than covered.

► CRITERIA

Dry wells and infiltration basins must be designed with the minimum volume and infiltrative area calculated by Equation 3-3 using the sizing factors in Table 3-6.

Consult with the local municipal engineer regarding the need to verify soil permeability and other site conditions are suitable for dry wells and infiltration basins. Some proposed criteria are on Page 5-12 of Caltrans' 2004 *BMP Retrofit Pilot Study Final Report* (CTSW-RT-01-050).

► DETAILS

Dry wells should be sited to facilitate maintenance and allow for the potential future need for removal and replacement.

In locations where native soils are coarser than a medium sand, the area directly beneath the facility should be over-excavated by two feet and backfilled with sand as a groundwater protection measure.

Best Uses

- Projects on sites with permeable soils

Advantages

- Compact footprint
- Can be installed in paved areas

Limitations

- Can be used only on sites with Group “A” or Group “B” soils
- Requires minimum of 10' from bottom of facility to seasonal high groundwater
- Not suitable for drainage from some industrial areas or arterial roads
- Must be maintained to prevent clogging.
- Typically not as aesthetically pleasing as bioretention facilities

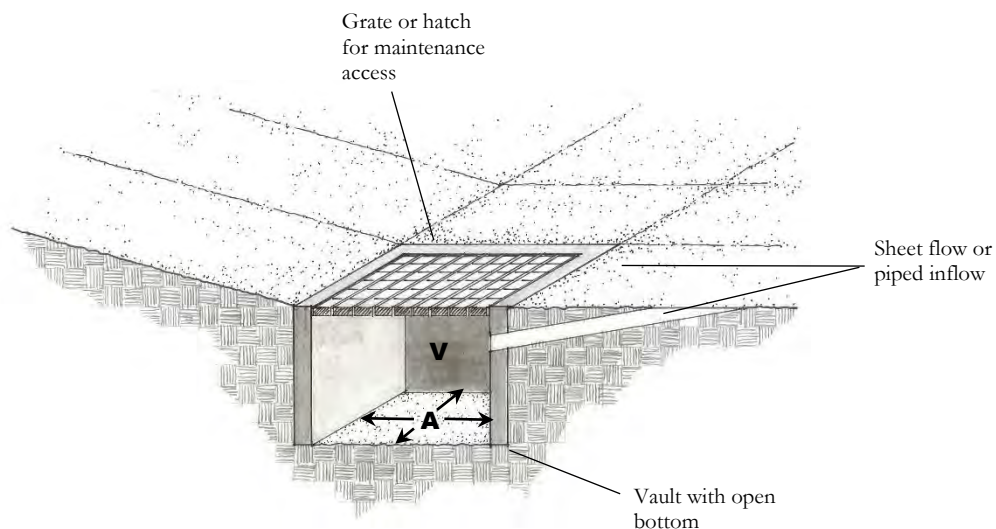


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Criteria for Dry Wells and Infiltration Basins

- ☐ Volume (V) and infiltrative area (A) meet or exceed minimum.
- ☐ Emergency spillage will be safely conveyed overland.
- ☐ Depth from bottom of the facility to seasonally high groundwater elevation is $\geq 10'$.
- ☐ Areas tributary to the facility do not include automotive repair shops; areas subject to high vehicular traffic (25,000 or greater average daily traffic on main roadway or 15,000 or more average daily traffic on intersecting roadway), car washes; fleet storage areas (bus, truck, etc.); nurseries, or other uses that may present an exceptional threat to groundwater quality.
- ☐ Underlying soils are in Hydrologic Soil Group A or B. Infiltration rate is sufficient to ensure a full basin will drain completely within 72 hours. Soil infiltration rate has been confirmed.
- ☐ 10' setback from structures or as recommended by structural or geotechnical engineer



Cistern + Bioretention Facility

A cistern in series with a bioretention facility or flow-through planter can meet treatment and flow-control requirements where space is limited. The cistern includes an orifice for flow control. The downstream bioretention facility or flow-through planter is sized to accommodate the maximum flow from the cistern orifice.

► CRITERIA

Cistern. Size the cistern using Equation 3-3 (page 38) and the factors and rainfall adjustment equations in Tables 3-6 and 3-7. The cistern must also include an orifice or other device to limit outflow to the calculated maximum release rate.

Bioretention facility. Size the bioretention facility or flow-through planter based on the cistern maximum release rate and a maximum surface loading rate of 5" per hour.

► DETAILS

Preventing mosquito harborage. Cisterns should be designed to drain completely, leaving no standing water. Drains should be located flush with the bottom of the cistern. Alternatively—or in addition—all entry and exit points should be provided with traps or sealed or screened to prevent mosquito entry. Note mosquitoes can enter through openings $\frac{1}{16}$ " or larger and will fly for many feet through pipes as small as $\frac{1}{4}$ ".

Exclude debris. Provide leaf guards and/or screens to prevent debris from accumulating in the cistern.

Ensure access for maintenance. Design the cistern to allow for cleanout. Avoid creating the need for maintenance workers to enter a confined space. Ensure the outlet orifice can be easily accessed for cleaning and maintenance.

► APPLICATIONS

Shallow ponding on a flat roof. The “cistern” storage volume can be designed in any configuration, including simply storing rainfall on the roof where it falls and draining it away slowly. In sites with Group “D” soils, the required average depth amounts to about $\frac{3}{4}$ ".

Best Uses

- To meet flow-control requirements in limited space.
- Management of roof runoff
- Dense urban areas

Advantages

- Storage volume can be in any configuration
- Small footprint

Limitations

- Somewhat complex to design, build, and operate
- Requires head for both cistern and bioretention facility



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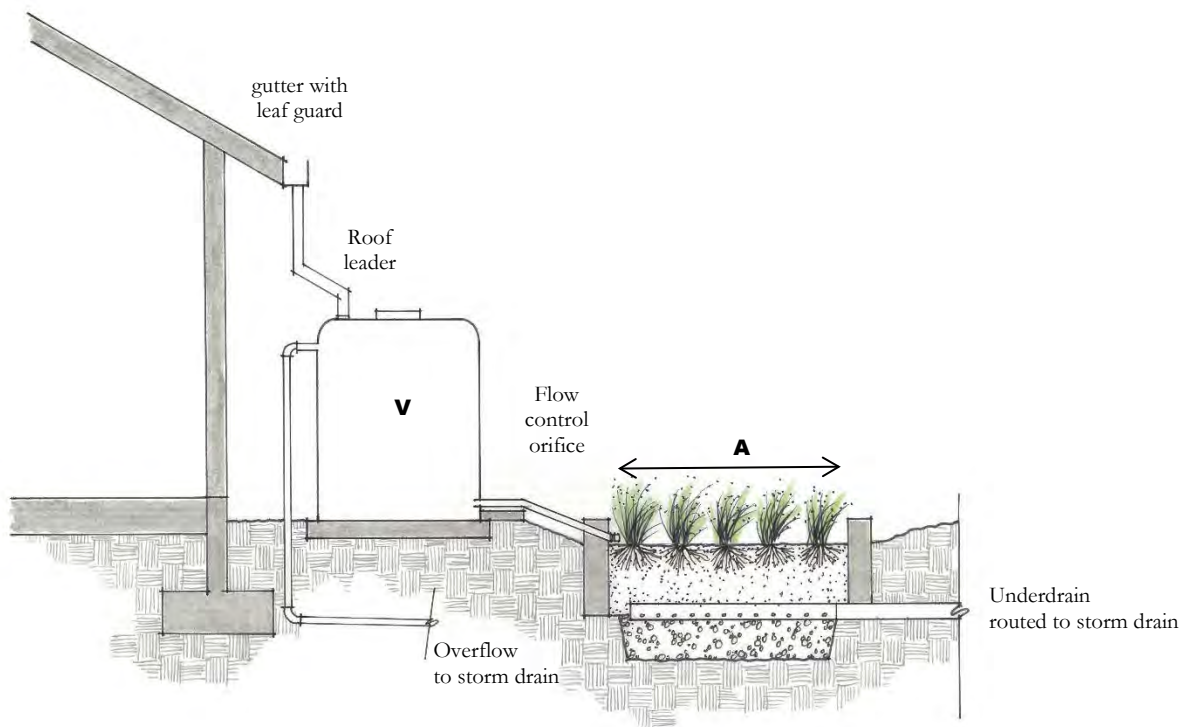
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Cistern attached to a building and draining to a planter.

This system for treatment-and-flow-control can be constructed with a flow-through planter at a height as low as 30".

Criteria for Cistern + Bioretention

- ☐ Cistern volume meets or exceeds calculated minimum V (Eq. 3-3).
- ☐ Cistern outlet with orifice or other flow-control device restricts flow to calculated maximum. A drilled, threaded cap is suggested for easy maintenance.
- ☐ Cistern outlet is piped to bioretention area or flow-through planter.
- ☐ Bioretention surface area meets or exceeds the calculated minimum.
- ☐ Except for surface area, bioretention facility is designed to the criteria for "treatment only" in the "Bioretention Facility" design sheet (p. 59) or "Flow-through Planter" design sheet (p. 69).
- ☐ Cistern is designed to drain completely and/or sealed to prevent mosquito harborage.
- ☐ Design provides for exclusion of debris and accessibility for maintenance.
- ☐ Overflow connected to a downstream storm drain or approved discharge point.
- ☐ Emergency spillage will be safely conveyed overland.



Bioretention + Vault

A bioretention facility in series with a vault can meet treatment and flow-control requirements where space is limited. In this configuration, the bioretention facility is sized to a minimum of 4% of the tributary impervious area. The underdrain and overflow from the bioretention facility are routed to a storage vault, which can be located beneath a plaza, sidewalk, or parking area. An orifice limits the rate of discharge from the vault to the storm drain system.

► CRITERIA

Bioretention facility. Size and design the bioretention facility to the treatment-only criteria (see Bioretention Facility design sheet, p. 69.)

Vault. Size the vault using Equation 3-3 (page 52) and the factors and rainfall adjustment equations in Tables 3-6 and 3-7. The vault must include an orifice or other device to limit outflow.

Dead storage in the bioretention facility (volume of the gravel pore space or other free volume below the elevation of the underdrain discharge) may be credited toward the required V_2 .

► DETAILS

Preventing mosquito harborage. Vaults must be designed to drain completely, leaving no standing water, and have an open bottom to allow infiltration into the native soil.

Ensure access for maintenance. Design the vault to allow for cleanout. Avoid creating the need for maintenance workers to enter a confined space. Ensure the outlet orifice can be easily accessed for cleaning and maintenance.

► APPLICATIONS

Parking lot. Because the required landscaped bioretention facilities is only 4% of the tributary impervious area, the bioretention component can in many cases be integrated into parking lot medians and islands. The vault component can be located beneath aisles or driveways.

Best Uses

- To meet flow-control requirements in limited space
- Parking lots
- Dense urban areas

Advantages

- Smaller footprint than bioretention facility sized for flow control

Limitations

- Somewhat complex to design, build, and operate
- Requires head for both bioretention facility and vault



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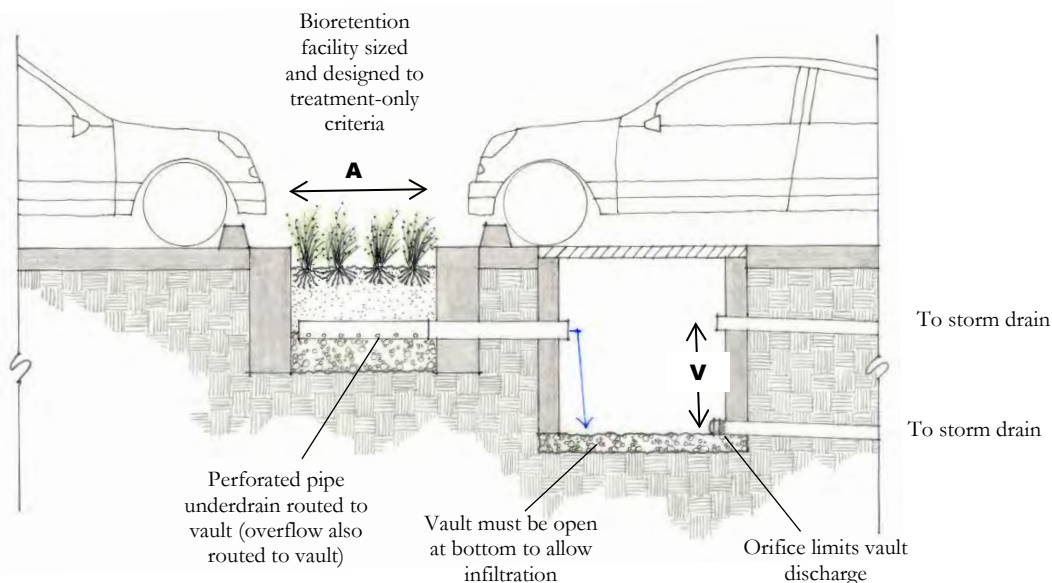
Multiple bioretention facilities draining to a single vault.

Two or more bioretention areas can be connected to a single vault. The vault minimum volume and outlet maximum flow rate are the sum of those calculated for each individual bioretention facility.

Vault with pumped discharge. Where insufficient head exists, vaults may be equipped with pumps to discharge (at a rate no greater than the calculated maximum) to a storm drain or approved discharge point.

Design Checklist for Bioretention + Vault

- ☐ Bioretention facility is designed to the treatment-only criteria in the “Bioretention Facility” design sheet (pp. 59-68).
- ☐ Vault retention volume meets or exceeds calculated minimum.
- ☐ Vault outlet with orifice or other flow-control device restricts flow to calculated maximum.
- ☐ Bioretention facility underdrain is routed to the vault.
- ☐ Bioretention facility overflow is routed to the vault.
- ☐ Sufficient head exists to convey flow from the underdrain to the vault and from the vault to the discharge point.
- ☐ Bottom of vault is open to allow infiltration.
- ☐ Vault design provides for exclusion of debris and accessibility for maintenance.
- ☐ Vault outlet and overflow are connected to a downstream storm drain or approved discharge point.
- ☐ Emergency spillage will be safely conveyed overland.



Items to Be Inspected During Construction

Successful construction of IMPs requires attention to detail during **every stage** of the construction process, from initial layout to rough grading, installation of utilities, construction of buildings, paving, landscaping, and final clean-up and inspection.

Construction project managers need to understand the purpose and function of IMPs and know how to avoid common missteps that can occur during construction. For bioretention facilities, the following operating principles should be noted at a pre-construction meeting.

- Runoff flow from the intended tributary drainage management area must flow into the facility.
- The surface reservoir must fill to its intended volume during high inflows.
- Runoff must filter rapidly through the layer of imported soil mix.
- Filtered runoff must infiltrate into the native soil to the extent possible (or allowable).
- Remaining runoff must be captured and drained to a storm drain or other approved location.

See the model construction inspection checklist on the following pages.