Would You Like to Understand the Flood Control Benefits of Urban Drainage and Green Infrastructure

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Watearth, Inc.

- Water Resources + Green Infrastructure
- SBE/DBE/WBE Firm
Follow-Up Questions

• Jennifer J. Walker, P.E., D.WRE, CFM, QSD
  o President, Watearth
  o jwalker@watearth.com
  o 1.877.302.2084
  o www.watearth.com
<table>
<thead>
<tr>
<th>Land Use</th>
<th>Location</th>
<th>GI Feature</th>
<th>Rainfall (in)</th>
<th>Drainage Area (ac)</th>
<th>Impervious Cover (%)</th>
<th>% Drainage Area</th>
<th>% Peak Flow Reduction</th>
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<tbody>
<tr>
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<td>San Francisco</td>
<td>PP</td>
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<td>95</td>
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<td></td>
<td></td>
<td>B</td>
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<td>12</td>
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</table>

- PP = Permeable Pavement, B = Bioretention, VS = Vegetated Swale, SI = Subsurface Infiltration, SW = Stormwater Wetlands
Fontana USD

- 1.22-acre drainage area
- LID 59% of area
- Sandy Soils
- 100% Infiltration in 100-Year
Fontana USD

- 2.29-acre drainage area
- LID 21% of area
- Sandy Soils
- 100% Infiltration in 100-Year

<table>
<thead>
<tr>
<th>Direction ID</th>
<th>LID Type</th>
<th>LID Area (sq ft)</th>
<th>LID Drainage Area (sq ft)</th>
<th>LID Impervious Contributing Area</th>
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<td>1</td>
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<td>1,175.85</td>
<td>7,960.03</td>
<td>7,960.03</td>
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</table>

PA = Porous Asphalt
PC = Porous Concrete
Nuview USD Stormwater Infiltration Project (Prop. 84)

• 1.7-Acre Parking Lot
• Infiltrates 100% of Annual Runoff
• Reduces Structural Flooding
• 100-Yr, 3-hr = 2.1 in/6-hr = 2.9 in
• 100-Yr, 24-hr = 5.4 in
• Annual Rainfall = 12.2 in/yr
• Hydraulic Conductivity = 1.2 in/hr
Porous Asphalt/Infiltration Trenches

Nuview Elementary School Green Parking Lot and Demonstration Project Site Layout

Project Infiltrates/Evaporates
100% of Runoff (87,989 cubic feet/year or 658,157 gallons/year)

Legend for Green Infrastructure Retro-fits
- Porous Asphalt (30,399 sq. ft.)
- Conventional Asphalt
- Pipe
- Infiltration Trench (2,185 sq. ft.)
- Sheet Flow
- Vegetated Buffer
- Sheet flow from impermeable surfaces to permeable surfaces
- Area Treated (69,020 sq. ft.)

Lakeview Avenue

Watearth
Overflow to Infiltration and Playfield

Nuview Elementary School Green Parking Lot and Demonstration Project Site Layout

Project Infiltrates/Evaporates
100% of Runoff (87,989 cubic feet/year or 658,157 gallons/year)

Legend for Green Infrastructure Retro-fits

- Porous Asphalt (30,399 sq. ft.)
- Conventional Asphalt
- Existing Piped Flow
- Three-Inch Outlet Pipes
- Infiltration Trench (2,185 sq. ft.)
- Vegetated Buffer
- Curb
- Stormwater Sheet Flow
- Existing Swale
- Infiltration Basin (under construction)
- New District Office Building
- Direction of sheet flow
- Area Treated (69,020 sq. ft.)
San Francisco

- 42-Acre Redevelopment
- Soils Primarily Well-Drained
- Average Hydraulic Conductivity 0.43 in/hr
LID Options and Extent

- 25% Reduction in 2-year, 24-hour event of 2.85 inches
- 0.71-inch reduction

<table>
<thead>
<tr>
<th>LID Feature</th>
<th>LID Surface Area (sq. ft.)</th>
<th>LID % of Site</th>
<th>% of Site Draining to LID</th>
<th>Storage (gallons)</th>
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<td>54,886</td>
<td>3.0%</td>
<td>50.0%</td>
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<td>Permeable Pavement</td>
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<td>3.0%</td>
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<td>246,985</td>
<td>13.5%</td>
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</table>
LAC+USC Medical Center Master Plan

- Planning-Level for EIR for 84-acre Redevelopment
- Soils Hydraulic Conductivity = 0.085 in/hr
- Permeable Pavement
- Bioretention
- Stormwater Wetlands
Figure 3: 100-Year, 24-Hour (7.9"")
Design Storm Runoff Hydrographs

- **Undeveloped Conditions**
- **Existing Conditions**
- **Proposed LID Conditions**

The graph shows the discharge (cfs) over time (hr) for different conditions.
Figure 9: Maximum Annual Peak Discharge from Continuous Simulation Analysis (15.4" Average Annual Rainfall)

- **Proposed LID Conditions**
- **Undeveloped Conditions**
- **Existing Conditions**
## New Development

- **Compared to Proposed, No LID**
- *No additional flood control required*
- B = Bioretention, VS = Vegetated Swale, HM = Hydromodification Management (Deeper Bioretention), BF = Biofiltration (No Infiltration)

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Location</th>
<th>GI Feature</th>
<th>Rainfall (in)</th>
<th>Drainage Area (ac)</th>
<th>Impervious Cover (%)</th>
<th>% Drainage Area</th>
<th>% Peak Flow Reduction</th>
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<td>Industrial*</td>
<td>Los Angeles</td>
<td>BF</td>
<td>5.9</td>
<td>0.18</td>
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<td>Major Thoroughfare</td>
<td>Houston</td>
<td>B, VS</td>
<td>12.4</td>
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<td>*B, VS</td>
<td>12.4</td>
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<td>100</td>
<td>15</td>
<td>90</td>
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</table>
- Major Thoroughfare in Industrial Park uses LID
- Regional Detention
- Channel Improvements
- Stream Mitigation
• Sandy Clay Soils
• Saturated Hydraulic Conductivity = 0.145 in/hr
Figure 7: Hydrographs (Vegetated Swale) at M125
Figure 8: Hydrographs (Bioretention) at M125

- 2-Yr, 24-Hr Surface Storage
- 2-Yr, 24-Hr Drain Rock Depth
- 10-Yr, 24-Hr Surface Storage
- 10-Yr, 24-Hr Drain Rock Depth
- 100-Yr, 24-Hr Surface Storage
- 100-Yr, 24-Hr Drain Rock Depth

Depth (in) vs. Time (hr)
West Holderrieth Aerial Photograph
M124 LID Median

M124 ROW MEDIAN SECTION BETWEEN HCID 17 PROPERTY LINE AND TREE
40% Vegetated Swale, 60% Bioretention

60% Bioretention
30' Top Width, 4' Bottom Width, 52'' Deep,
3:1 Side Slopes
Bottom Slope: 0.0%

40% Vegetated Swale
30' Top Width, 4' Bottom Width, 52'' Deep,
3:1 Side Slopes
Bottom Slope: 0.2%
LID Median Sections

M124 Vegetated Swale

M124 Bioretention
Vegetated Swale Section

- Height = 52"
- Bottom Width = 4'
- Top Width = 30'
- Native Soil
- 3:1 H:V
- Densely Planted

Native Trees In Swale: Red Oak, Montezuma Cypress, Water Oak, Willow Oak.
Lined Bioretention

- Hydrology & Water Quality Model of Site & Grand Canal
Figure 7: 100-Year Hydrographs from Proposed Conditions at Site

- **100-Yr, 24-Hr Surface Storage (Alt 1 Bioretention)**
- **100-Yr, 24-Hr Drain Rock Depth (Alt 1 Bioretention)**
- **100-Yr, 24-Hr Surface Storage (Alt 2 Bioretention)**
- **100-Yr, 24-Hr Drain Rock Depth (Alt 2 Bioretention)**
- **100-Yr, 24-Hr Surface Storage (Alt 2 Planter Box)**
- **100-Yr, 24-Hr Drain Rock Depth (Alt 2 Planter Box)**
Figure 4A: 100-Year, 24-Hour Design Storm Runoff Hydrographs From Site

- **Existing Conditions**
- **Alternative 1:** Lined Bioretention with Underdrain
- **Alternative 2:** Lined Bioretention with Underdrain & Planter Box

**SHC** = 0.04 in/hr

100-Yr Mitigated
Figure 9A: Maximum Annual Peak Discharge from Continuous Simulation Analysis at Site

Figure 9B: Maximum Annual Peak Discharge from Continuous Simulation Analysis at Grand Canal

Figure 12: Exceedance Frequency Curves from Continuous Simulation Analysis at Site

Existing Conditions
Alt 1: Lined Bioretention with Underdrain
Alt 2: Lined Bioretention with Underdrain & Planter Box

Max. Annual Peak Flow (cfs)

Year

Max. Annual Peak Flow (cfs)

Year

Discharge (cfs)

Exceedance Frequency
Water Quality?

- Pre-treatment recommended with vegetated filter strip or other

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<tr>
<th>Pollutant Effluent Concentration</th>
<th>TSS</th>
<th>COD</th>
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<th>Lead</th>
<th>Zinc</th>
<th>Fecal Coliform</th>
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<td><strong>Model</strong></td>
<td><strong>2-Year Annual lbs</strong></td>
<td><strong>2-Year Annual lbs</strong></td>
<td><strong>2-Year Annual lbs</strong></td>
<td><strong>2-Year Annual lbs</strong></td>
<td><strong>2-Year Annual lbs</strong></td>
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233-Acre Mixed Use

Vegetated Swales
Bioretention
Larger
Hydromodification Mgmt. Facilities

Hydraulic Conductivity = 0.06 in/hr
Figure 6-6 Bioretention Facility

Top Width Varies by Location See Plans

12" Minimum Storage Depth
12" Freeboard
Maximum Side Slope 4:1

2' Min. Width at Flat Bottom

Native Soil

18" Deep Growing Media

12" Drain Rock. Exact width and depth to be determined

Underdrain System per Civil if Required

90% Vegetated Cover
Water Budget vs. No LID

- 53% Reduction in Runoff for 37 Years
- 154% Increase in Evaporation
- 18% Increase in Infiltration

[Diagram of water budget with labels for rainfall, ET, infiltration, percolation, and underdrain]
## Watershed/Flood Control Retrofits

**Land Use** | **Location** | **GI Feature** | **Rainfall (in)** | **Drainage Area (ac)** | **Impervious Cover (%)** | **% Drainage Area** | **% Peak Flow Reduction**
---|---|---|---|---|---|---|---
Watershed Retrofit | SF Bay/Sonoma* | PP, B, VS | 7.2 | 1,988.62 | 9 | 11 | 29
 | PP, B, VS | 7.2 | 1,988.62 | 60 | 11 | 52
Flood Control Channel Backslope Swale Retrofit | Houston | VS | 12.4 | 1.56 | 6 | 26 | 5
 | B | 12.4 | 1.56 | 6 | 26 | 10
Mixed Use Redevelopment/ Watershed Retrofit | Fort Worth | B | 9.12 | 12.42 | 53 | 2 | 2
 | B | 9.12 | 16.31 | 48 | 13 | 37
 | B | 9.12 | 1.33 | 77 | 27 | 97

- *Mix of Types B and D soils with minimal Type C
- PP = Permeable Pavement, B = Bioretention, VS = Vegetated Swale
Watearth Youtube – Bay Area
Green Infrastructure Master Plan

- Watershed-level implementation of Green Infrastructure with the San Francisco Estuary Institute

- https://www.youtube.com/watch?v=-8JOvPtmsus
New Infiltration Trenches
Tree Boxes

Watearth

Plus
Wet Ponds
Stormwater Wetlands

Porous Concrete

The parking stalls in this lot are paved with Porous Concrete. Most concrete is made from four constituents: cement, water, gravel and sand. The sand typically fills all the void space in the concrete, making it impermeable. Porous Concrete uses a special gravel mix with very little sand. Carefully controlled amounts of water and cement make a paste that fills the gravel aggregate particles together in a way that creates porous interconnected voids without weakening the concrete.

Stormwater passes freely through these voids to a Gravel Filter Basin beneath. As the water passes through the Gravel Reservoir, teens and pollutants are filtered from the water.

In a typical installation, the filtered water would seep into the underground. However, we want to monitor the effectiveness of the Porous Concrete/Filter Reservoir system and test it against a conventional installation with typical driveway and storm drain. We have installed an impermeable layer that prevents infiltration. The filtered water trapped by the filter is carried by a monitoring station where it is analyzed and compared to runoff from a traditional parking lot at this facility.
Rural vs. 60% Imp.

- 10-Yr (7.24”)
  -29% vs. -52%

- 2-Yr (2.63”)
  -54% vs. -74%

Jennifer J. Walker, P.E., D.WRE, CFM, QSD (jwalker@watearth.com)
• 0.01 in/hr Saturated Hydraulic

• 9.12 in. 100-yr event
O&M Plan Fact Sheets

- Envision includes points for O&M Planning
# O&M Checklist (Santa Monica)

**PERMEABLE PAVEMENT (POROUS ASPHALT PARKING LOT) INSPECTION SHEETS – WET SEASON**

**O&M Fact Sheet:** O&M Fact Sheet 3: Permeable Pavement  
**Location:** Airport Ave. at Airport Park; north parking lot

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<thead>
<tr>
<th>Activity</th>
<th>Names (Print)</th>
<th>Dept./Division</th>
<th>Total Time All Staff (hrs)</th>
<th>Total Labor Cost ($)</th>
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<td>Monitor infiltration/flow-through rates</td>
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<td>Inspect for structural issues</td>
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<td></td>
</tr>
<tr>
<td>Inspect for damaged pavement</td>
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<tr>
<td>Inspect for trash, debris, weeds, vegetation, leaf litter, and sediment accumulation</td>
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<tr>
<td><strong>Maintenance</strong></td>
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<tr>
<td>Powerwash with proper disposal</td>
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<tr>
<td>Vacuum sweep (high pressure)</td>
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<tr>
<td>Weed as necessary</td>
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<tr>
<td>Remove trash and debris</td>
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<tr>
<td>Seep or rake leaf litter and sediment</td>
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City of Santa Monica BMP Inspection Sheets
What’s under this street helps the Bay
In-Line Storm Drain Demonstration Project

Our urban environment has created an ongoing water pollution problem that occurs when rainwater, washing activities or over-irrigation flows untreated from buildings, yards, sidewalks, roads, and parking areas into the Santa Monica Bay. This type of pollution is called urban runoff.

The City of Santa Monica works to shape policies that influence the design, construction, and long-term management of new and existing developments to eliminate or reduce urban runoff pollution from its source.

Rainwater and stormwater are now considered a resource, as this project demonstrates, rather than a potential flooding hazard needing to be quickly ushered off to sea.

A cleaner Santa Monica Bay means a healthier marine ecosystem and improved quality of life for Santa Monica’s residents, visitors and businesses alike.

This In-Line Storm Drain Demonstration Project harvests stormwater for treatment and infiltration (the system treats the incoming water and allows it to be slowly absorbed by the soil where it receives further treatment).

This innovative strategy of harvesting stormwater, by inserting an in-line treatment and infiltration system into an existing storm drain, can be replicated in any community due to its simplicity and unobtrusive design placing beneath streets and parkways.

Completed in 2013, this project demonstrates the feasibility of harvesting runoff to recharge groundwater for future extraction, reducing dependence on imported water and removing water pollution from entering Santa Monica Bay.

To storm drain
Catch Basin

Three feet below the parkway on the west side of Franklin Street is a 12,800 gallon storage chamber built from rain boxes that snap together. The entire chamber measures 40 feet x 6 feet x 7.5 feet.

Collection and Treatment
Rain that falls on Franklin Street will enter a catch basin via a curb grate which prevents trash or debris from entering the storage chamber.

Infiltration
The stormwater will infiltrate into the soil over time and slowly return to the water table rather than simply rushing through the storm drain system carrying trash, debris and pollution to Santa Monica Bay.

More information at: sustainablesm.org/runoff

The individual rain boxes that make up the storage chamber are strong enough to support the weight of traffic passing over, yet are 95% void space to allow the maximum amount stored water. Compare these rain boxes to a rock basin (a more traditional approach to stormwater storage). Rock basins are roughly 20% void space, so the same size storage area would be able to hold only 2,693 gallons, vs. the 12,800 gallon capacity of this chamber.
Our urban environment has created an ongoing water pollution problem that occurs when rainwater, washing activities or over-irrigation flows untreated from buildings, yards, sidewalks, roads, and parking areas into the Santa Monica Bay. This type of pollution is called urban runoff.

The City of Santa Monica works to shape policies that influence the design, construction, and long-term management of new and existing developments to eliminate or reduce urban runoff pollution from its source.

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A cleaner Santa Monica Bay means a healthier marine ecosystem and improved quality of life for Santa Monica’s residents, visitors and businesses alike.

Collection
Stormwater is diverted to this treatment system from an existing storm drain on Hill Street instead of flowing untreated to the Bay.

Treatment
Stormwater collects in the first chamber. As it sits, trash and sediment settle out. Once water fills the first chamber, it flows to the adjacent chamber for further treatment and infiltration.

A floating hydrocarbon capture pillow filled with unique polymer beads captures a wide range of hydrocarbons (oil and gasoline) picked up from the street.

Infiltration
Treated water is then allowed to flow out of this chamber through a sieve and infiltrate through the soil to the water table.

Routine maintenance hydrovacuums the sediment and trash from the two chambers and the hydrocarbon capture pillows can be replaced as needed.

This In-Line Storm Drain Demonstration Project harvests stormwater for treatment and infiltration (the system treats the incoming water and allows it to be slowly absorbed by the soil where it receives further treatment).

This innovative strategy of harvesting stormwater, by inserting an in-line treatment and infiltration system into an existing storm drain, can be replicated in any community due to its simplicity and unobtrusive design placing beneath streets and railways.

Completed in 2013, this project demonstrates the feasibility of harvesting runoff to recharge groundwater for future extraction, reducing dependence on imported water and removing water pollution from entering Santa Monica Bay.

More information at: sustainablesm.org/runoff
Bioretention is a Low Impact Development Best Management Practice (BMP) that improves storm water management by diminishing the overall volume of storm water runoff and also reducing the pollution carried by that reduced level of runoff. This is accomplished through retention, evapotranspiration, infiltration, and natural filtration.

In addition to measuring the results of this approach to storm water volume reduction and pollutant removal, we are also monitoring design and maintenance successes / problems.

Storm water runoff enters a Ponding Zone – a depressed area – planted with California-friendly plants which require minimal upkeep and whose deep roots help stabilize the soil. Ponding provides time for larger particles to settle out of the retained storm water as it percolates into the engineered soil.

Engineered Soil promotes the growth of Mycorrhizal fungi which attach to the roots of plants and extend microfilaments into the soil, massively increasing the functional surface area of plant roots. The fungi, soil and roots act as a sponge, holding water in the soil giving plants and their root structures a longer time to absorb and evapotranspire that water back into the atmosphere. The soil also filters debris and pollutants from the water.

Water not evapotranspired or retained by the soil layer is held in the Stone Reservoir Layer and allowed to slowly percolate into the native soil. Because this water has been filtered through plant roots and the engineered soil, it is considerably cleaner than the original runoff. In areas with poorly drained native soils, a sub-drain is provided to avoid creating a nuisance or mosquito habitat.

For more information about this project, please visit our website rcflood.org/BioretentionBMP.aspx.
Porous Asphalt

Although the parking stalls in this lot are paved in traditional asphalt, they slope towards a center strip that is surfaced with **Porous Asphalt**. Water passes freely through the Porous Asphalt to a gravel reservoir that filters out most of the grit and oil picked up from the parking lot. Porous Asphalt is a Low Impact Development (LID) Best Management Practice (BMP) that improves storm water management by reducing the amount of storm water runoff flowing into storm drains and filtering impurities that would otherwise be deposited in local waterways. In most applications of this LID feature, the stormwater would be allowed to infiltrate into the sub-soils. In this installation, an impermeable liner prevents infiltration. A subdrain collection system carries the water from the reservoir/filter layer to a central monitoring station where the quality and quantity of the runoff will be measured and compared to the runoff from a standard impervious asphalt parking lot nearby.

This parking lot is paved with **Porous Asphalt**. Most asphalt concrete is made from three constituents: a binder (asphalt), gravel, and sand. The sand typically fills all the void space in the asphalt mix, making it impervious. Porous Asphalt Concrete uses a special gravel mix that nearly eliminates the need for sand. The binder pastes the special gravel mix together in a way that creates porous interconnected voids without weakening the asphalt.

Water that passes through the Porous Asphalt surface then flows through a **Gravel Filter Basin** below the Porous Asphalt. This filters debris and pollutants from the water.

In a typical installation, the filtered water would seep into the subsoil. Because we want to monitor the effectiveness of the Porous Asphalt/Filter Basin system and test it against a control installation with typical asphalt pavement and storm drains, we have installed an impermeable liner that prevents infiltration. The filtered water trapped by the liner is carried to a monitoring station where it is analyzed and compared to runoff from a traditional asphalt parking lot at this facility.

Low Impact Development and Water Conservation Demonstration and Testing Facility

For more information about this project, please visit our website [rflnd.org/AsphaltBMP.aspx](http://rflnd.org/AsphaltBMP.aspx).
Between November and March, average rainfall in Sacramento County is almost 3 inches/month. The ground can't absorb this much water so most of it becomes runoff. As the rain rushes off the roofs and down the street, it collects trash and oil and lawn chemicals, dumping everything in the storm drain. The storm drains fill quickly and flood the rivers and streams they flow into. The force of all that rushing water erodes river banks, toppling trees and uprooting plants. Eventually, the now turbid water reaches the bay, where it dumps silt, pollution and chemicals. Stormwater runoff is one of the major causes of water pollution in Sacramento.

Rain gardens like this one, prevent much of this damage. A rain garden creates a temporary pond to capture rainfall and runoff. The differing soil layers allow the water to slowly percolate through to a gravel retention layer. Water is filtered by the soil and plant roots until it is pretty clean. Then it slowly works its way to the bay, nourishing the plants on the river banks as it slowly flows by.

Rain gardens like this one are perfect for public spaces and private homes alike. To find out more about how you can build your own rain garden, you can start at raingardens.org.
STORM DRAINS PREVENT FLOODS  
BUT CAUSE OTHER PROBLEMS

Before we started building buildings and paving roads, rain fell and when it did, it just soaked into the ground. But now, when rain falls, it hits roofs, streets, sidewalks, and parking lots, where it picks up trash, oil and other pollution. Even a small rainstorm pushed all at once through the storm drains becomes a huge rushing flood in the creeks and rivers. It washes away the river banks, topples trees, and uproots plants. Eventually, that water reaches San Jacinto River, Canyon Lake and Lake Elsinore, where it dumps pollution that harms fish and other animals that live there.

NUVIEW KEEPS RAIN OUT OF THE DRAIN

Porous Asphalt: The parking lot is covered in porous asphalt. It has little holes in it that let stormwater filter through the pavement into a storage basin below rather than wash away.

Infiltration Trenches: Rock-filled trenches in the parking lot provide another place where stormwater can collect and soak into the ground slowly.

Storage Basin: Under the parking lot is a huge storage basin so the water that falls through the pavement has somewhere to go. Inside the basin are layers of gravel that filter pollution out of the water. Eventually, that cleaner water has time to soak into the ground, just like it would if it fell before anything at all was ever built.

Collect Every Drop: Paved areas are sloped towards the parking lot so more water will reach the gravel basin. If we ever get a really huge rain, more than the basin can hold, the water will flow over the parking lot to a shallow ditch (a rock swale) that carries overflow to another gravel basin behind the District Office. If we get a monster rain, so huge that even those basins can’t contain it, the rain will flow out of the second basin into the athletic fields where, again, it can soak into the ground.

In a typical year, over half a million gallons of water will fall on this facility. The improvements described here will allow 100% of that rainfall to either evaporate or soak into the ground.

Native Plants: Along Lakeview Avenue are vegetated buffers full of California-friendly drought-resistant plants. They provide habitat for birds and insects, and also provide a physical barrier to blowing dust that might clog up the porous asphalt.

MAINTENANCE

To keep the pollution-control elements at Nuvista working properly, some maintenance must be performed:

Porous asphalt: needs to be vacuumed, swept and power washed.

Infiltration basins: make sure there is no trash or debris accumulating in the trenches. Also make sure not to pour any chemical fertilizer or pesticides near the trenches.

Vegetated buffers: pull weeds, pick up trash and make sure not to use any chemical fertilizers or pesticides.

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Final Thoughts

• GI Meets Multiple Goals: Water Quality, Flood Control, Aesthetics, Hydromodification Management

• GI Integrates with Flood Control

• O&M Critical for Long-Term Function

• Customize Design to Meet Goals
Follow-Up Questions

- Jennifer J. Walker, P.E., D.WRE, C FM, Q SD
  - President, Watearth
  - jwalker@watearth.com
  - 1.877.302.2084
  - www.watearth.com