




# Slow the Flow!



**Designing the  
built environment to  
protect urban watersheds**





Clean Water Services manages water resources in urban areas of the Tualatin River Watershed in Washington County, Oregon. Its Field Operations Facility was designed to integrate stormwater management on the site, and to showcase how to protect urban watersheds while building the community.

The Field Operations Facility evolved from a unique partnership between Clean Water Services and TriMet, the regional transit authority. Clean Water Services was looking for land to build a new facility centrally-located in its service area. TriMet owned land in a suitable location that was adjacent to a fleet facility that needed stormwater management upgrades. The two public agencies collaborated on a master plan that met the needs of both, and the partnership continued with TriMet leasing office space in Clean Water Services' new facility.

<b>Location:</b>	2025 SW Merlo Court in Beaverton, Oregon
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<b>Project Size:</b>	430,500 square feet; 46,155 sf building
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<b>Project Cost:</b>	\$7.9 million; \$4.3 million building
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<b>Project Duration:</b>	August, 2002 – August, 2003
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<b>Client:</b>	Clean Water Services, and Tri-County Metropolitan Transportation District of Oregon (TriMet)
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<b>General Contractor:</b>	Skanska, USA - Oregon division, Beaverton, Oregon
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<b>Architect:</b>	WBGs Architecture and Planning, PC, Eugene, Oregon
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<b>Mechanical Engineer:</b>	Interface Engineering
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<b>Landscape Architect:</b>	Murase Associates
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<b>Landscape Contractor:</b>	Wilcott Landscaping Co.
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<b>Civil Engineer:</b>	URS/BRW
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<b>Structural Engineer</b>	Biggs Cardosa Associates, Inc.
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<b>Geotechnical Engineer:</b>	Fujitani Hilts and Associates
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# Slow the Flow!

## Design mimics nature

Clean Water Services opened its Field Operations Facility in the fall of 2003. This 217,800 square foot, state-of-the-art facility includes special design features and construction methods to manage stormwater runoff on-site. Instead of drainage pipes and catch basins that would carry water away, landscape plantings and porous “softscaping” allow rain to soak into the ground and filter through vegetation. Runoff is reduced, slowed, and cleaned as it makes its way to streams and wetlands.

Clean Water Services is leading the way toward more sustainable building. Its Field Operations Facility is an example of how to use innovative technologies within a realistic and competitive budget. Creativity and collaboration by the project partners made this a successful demonstration site that is functional and aesthetically pleasing. The buildings, parking lots and landscape features form an integrated system that mimics a natural landscape. To a drop of rain, the roof is a meadow, the parking lot a field. No stormwater runoff flows directly from a pipe to the downstream creeks and wetlands. To more fully appreciate this, notice where the water goes from your building or street.

Protecting our watersheds will require creative solutions that integrate stormwater into site designs.

This brochure documents the various design and construction elements of the Field Operations Facility and the costs, advantages and limitations for each.

## Shared vision and holistic approach

The entire Field Operations Facility was designed to protect nearby streams and wetlands by reducing stormwater runoff and increasing infiltration of rainfall. From the outset, the project team was committed to a holistic approach with open communication and shared trust. The partners and contractors met regularly to brainstorm and develop new approaches to the innovative techniques being showcased. They discussed every aspect of design and construction, from the initial installation of erosion and sediment control measures to the final landscaping and naturescaping.

The design elements of the project’s on-site stormwater management are described in detail throughout this booklet.

*Effective impervious area (EIA) represents impervious surfaces that drain directly to a piped storm system, natural stream or wetland. The Field Operations Facility has an EIA of nearly zero.*



*“Most of the innovative techniques were new to the region, and that placed an additional burden on the general contractor. In some cases, new construction methods were developed to make the measures work correctly.”*

Chris Bowles,  
field operations manager,  
Clean Water Services



## Site description

The Field Operations Facility is located at 2025 SW Merlo Court in Beaverton, Oregon and is adjacent to the Tualatin Hills Nature Park. The site was an abandoned drive-in theater with gravel and pavement abutting the nature park. As part of the Beaverton Creek sub-basin, this site has direct impacts on nearby Cedar Mill Creek and the Tualatin River.

The general topography of the site, located approximately 200 feet above mean sea level, is relatively flat with a slight sloping to the south. Surface water runoff flows to Cedar Mill Creek. The surface soils were characterized by three pavement sections, ranging from .3 to 1.7 feet deep, with asphalt and aggregate base gravels. Below the pavements, three major soil units range from stiff clays to sandy and clay silts. Below the recent alluvium are approximately 1,100 feet of Recent to Pliocene age clay, silt, fine sand and a few gravel beds. Groundwater generally occurs between eight and ten feet below ground surface, and flows southward. A falling head infiltration test in July, 2001 measured a .4-inch head loss over a 24-hour period.

## On-site stormwater management design elements

The following design elements provide an integrated stormwater management system designed to mimic a natural landscape, capturing rainfall and allowing it to be absorbed into the ground.



### Swales and “softscaping” landscape design

Landscaping and design features mimic an undisturbed natural landscape. As water flows through the series of swales, it is slowed down, treated and absorbed by the soils and native plants. A 50-foot wide by 600-foot long vegetated swale runs the length of the project site, capturing and treating any water that makes it that far. The native plant communities provide desirable habitat for a variety of birds, insects, and small mammals. Maintenance costs are minimized because native plants require less water and fertilizer. The landscaping is attractive and also helps cool the surrounding air.

### Erosion prevention and sediment control

From start to finish, the project protected water quality with a comprehensive erosion and sediment control plan. Two settling ponds were constructed to receive any sediments and runoff from the site. At any time during construction, no more than 5 percent of the site surface was uncovered. Erosion barriers and check dams captured as many solids as possible before the water entered the settling ponds. An organic flocculent was used in the settling ponds during heavy rains to help settle particulates. And finally, a project manager was on-site at all times to monitor the system and ensure erosion and sediment prevention was working.

### Green street

The access road to the Field Operations Facility has no curb and gutter system on the south side of the street. Stormwater flows into adjacent swales where it can be absorbed into the soil or the roots of native plants. Swales minimize potential sediment impacts during construction. And, they replace costly catch basins and underground pipes.



*“Our goal was for the site to be a demonstration project so contractors, engineers, plan review staff, and the public could see these techniques in action.”*

Chris Bowles,  
field operations manager,  
Clean Water Services

*“The hydrology of our watersheds is out of balance—too little flow in the summer and too much scouring flow in the winter. Mimicking natural watershed functions in urban environments is a key component to improving stream health.”*

Kendra Smith,  
water resource program manager,  
Clean Water Services

## Porous (pervious) concrete

Traditional asphalt and concrete surfaces are nearly 100 percent impervious, but porous concrete allows rainfall to be absorbed directly into the ground below. Groundwater is recharged, runoff is reduced, and evapotranspiration keeps the surface cool and minimizes any warm water surface flows to nearby streams or wetlands. The facility’s 18,000 square foot parking lot provides space for 60 vehicles.

## Porous pavers and structural gravels

Seven parking spaces at the public entrance to the administrative building were constructed with Uni EcoStone® semi-pervious pavers. Structural gravels supported by a 10-inch Geoweb synthetic grid provide 3,000 square feet of storage area in the maintenance yard. Both of these technologies provide a cost-effective surface that also allows stormwater to be absorbed into the soils below.

## Ecoroof (green roof)

The 8,000 square foot green roof system has drought-resistant plants that absorb rainfall and help insulate the building. Nearly all rain is expected to be retained in warm, dry months. Nearly 80 percent of water is expected to be returned to the atmosphere through evapotranspiration, which will cool the roof and the surrounding air. Ecoroofs have been shown to reduce cumulative annual runoff by 50 to 70 percent in temperate climates.

# Clean Water Services’ Effective Impervious Area (EIA) Reduction Program

*Effective impervious area (EIA) represents impervious surfaces that drain directly to a piped storm system, natural stream or wetland.*

This program demonstrates new technologies and designs for pervious surfaces, providing guidelines for future development practices to reduce effective impervious area (EIA) within the urban Tualatin Basin. To identify potential management actions to reduce EIA and resulting stormwater runoff, Clean Water Services convened a task force of stakeholders to shape the program. The EIA Reduction Program supports compliance with the Clean Water Act and the Endangered Species Act.

## What is Effective Impervious Area?

Impervious surfaces such as sidewalks, streets, rooftops and parking lots stop rain from infiltrating into the ground. Water runoff from impervious surfaces is usually concentrated into pipes designed to carry water off the site and to neighboring streams or wetlands. These concentrated flows carry pollutants and negatively impact stream hydrology and ecology.

The amount of effective impervious area is directly related to the overall water quality of urban streams and watersheds. Research indicates that watersheds with more than 10 percent effective impervious area have significantly degraded water quality and aquatic habitat. Unlike most development that increases impervious area, the Field Operations Facility has an EIA of nearly zero.

EIA can be reduced by dispersing runoff through landscape and construction designs that mimic natural soils and vegetation cover. Instead of draining impervious surfaces directly through pipes to the streams (high EIA), we can protect urban streams by allowing rainfall to be absorbed by the soils and plants, and to recharge the groundwater.

An important first step in protecting the biological and physical integrity of urban watersheds is to decrease the amount of water that flows directly into streams or wetlands. Stormwater management technologies must be designed to address the region's rainfall patterns, which in the Tualatin Basin and the Pacific Northwest are typically smaller and more frequent storm events.

## Water quality and quantity monitoring and education

The Field Operations Facility provides a case study of the long-term practicability and performance of stormwater design innovations. Runoff flow rates and quality are being monitored, documented and analyzed for the major vegetated swales. The volume of runoff from the ecoroof is also monitored. This data will be available on the web page at [www.CleanWaterServices.org](http://www.CleanWaterServices.org).

Interpretative signs at the facility provide a self-guided tour for visitors to learn how the building and landscape design protects downstream creeks and wetlands by dispersing stormwater at its source, allowing the water to be infiltrated and retained on the site.

The Field Operations Facility showcases comprehensive on-site stormwater management technologies and alternatives to impervious surfaces. Other public and private sites with porous pavement and softscaping in the Tualatin Basin are featured in a brochure, *The Rain Runs Through It*, published by Clean Water Services.

*“People stop in and ask, ‘Are those flowers growing on your roof?!’ It’s a great opening to explain about stormwater and how our facility helps protect our streams.”*

Jani Carmichael,  
administrative assistant,  
Clean Water Services



*“We all pitched in to restore the habitat, not just engineer a treatment swale. We put some meanders in the channel, dragged in some root wads, and planted native plants and shrubs that will make this area more natural.”*

Mike McCallen,  
field construction technician,  
Clean Water Services

# Vegetated swales, biofiltration and “softscaping”

*“The most compelling feature of this project is its comprehensive nature. It begins with rain falling on the ecoroof or spilling down to scupper gardens, and winding its way through landscaped swales to a neighboring natural area. An industrial site is softened by plants. Water is slowed and cleansed and a large wetlands habitat was restored.”*

Eric Gunderson,  
principal architect, WBGs

The Field Operations Facility was designed to mimic a natural landscape and manage stormwater runoff on site. Instead of underground pipes, catch basins and large detention ponds, there is an integrated system of vegetated swales. Planted with trees, shrubs and herbaceous perennials, the swales provide the stormwater conveyance system. This biofiltration system disperses stormwater on site, controls the rate and volume of runoff and improves water quality. All landscaped



areas were designed to retain as much rainfall as possible, and drain their runoff to swales. Even the runoff from the traditional parking lots flows to swales. The adjacent Nature Park is protected by a 50-foot wide by 600-foot long water quality swale that runs the downstream length of the site.

Dispersing stormwater runoff at its source is especially suited for the rainfall patterns here in the Pacific Northwest, where nearly 90 percent of all 24-hour rainfall events are less than 1/2 inch. These small events are easily managed with “softscaping” or biofiltration landscaping that absorbs rain, recharges groundwater, reduces winter runoff and virtually eliminates summer runoff.

In contrast, typical pipe conveyance systems concentrate and accelerate flows creating artificially high peaks and volumes that negatively impact stream hydrology and aquatic habitat. Warm weather rains can increase water temperature, especially when runoff courses over hot pavement and roofs. Warm water temperatures lower the available oxygen for aquatic organisms, critical for healthy streams and wetlands. Piped systems rush rain downstream, disrupting the natural process of replenishing groundwater.



The facility's vegetated conveyance swales were designed as major or minor, with 2:1 or 3:1 slopes respectively. The depth and width of the swales vary by location. All swales were lined with 6-inches of topsoil, jute mat and a 3-inch layer of 2-inch to  $\frac{3}{4}$ -inch river run rock.

## Examples of the native plant species used in the swales:

### Trees

- *Acer circinatum* (Vine maple)
- *Alnus rubra* (Red alder)
- *Pseudotsuga menziesii* (Douglas fir)
- *Thuja plicata* (Western red cedar)

### Shrubs

- *Cornus stolonifera* (Red osier dogwood)
- *Ribes sanguineum* (Red flowering currant)
- *Spirea douglasii* (Douglas spirea)

### Herbaceous Perennials

- *Carex obnupta* (Slough sedge)
- *Scirpus microcarpus* (Small fruited bulrush)
- *Sagittaria latifolia* (Wapato)
- *Polystichum munitum* (Western sword fern)

Instead of downspouts four scuppers direct runoff to freefall to the ground into rock-lined areas planted with wetland species. These scupper gardens allow water to infiltrate directly into the ground or flow into an adjacent swale. In most rainfall events, the scupper gardens retain all runoff.



# Vegetated swales, biofiltration and “softscaping”

## RESOURCES

Clean Water Services’ Design and Construction Standards  
[www.CleanWaterServices.org](http://www.CleanWaterServices.org)

Stormwater Management Manual for Western Washington  
[www.ecy.wa.gov](http://www.ecy.wa.gov)

City of Portland, Bureau of Environmental Services  
[www.cleanrivers-pdx.org](http://www.cleanrivers-pdx.org)

Center for Watershed Protection  
[www.stormwatercenter.net](http://www.stormwatercenter.net)

## Costs and savings

The landscaping budget for the Field Operations Facility was about 30 percent more than a traditional industrial facility of this kind. While direct cost comparisons may be imprecise, this “softscaping” approach was significantly cheaper than traditional catch basin and underground pipe stormwater management systems. Maintenance costs are comparable to traditional landscape systems, although extra attention is required in the first few years to ensure plants become well-established.

## More advantages

- Less trenching and underground piping minimizes potential erosion and sediment impacts during construction
- A “softscaping” design saves time in the early stages of site development, helping to complete site preparation before winter rains
- Vegetated swales significantly reduce stormwater runoff, especially during small rainfall events
- Swales planted with a diverse array of native plants provide habitat for insects, birds and other wildlife
- More vegetated landscaping cools the surrounding air through evapotranspiration, reducing the urban “heat island” effect
- Native plant landscaping requires less water, fertilizer and overall maintenance
- Native plants are attractive and provide a comfortable environment for people
- Effective impervious area is reduced and may earn stormwater credits and decrease overall stormwater fees

## Limitations

- The potential impact on ground water quality must be carefully analyzed; existing soils and site conditions may not be suitable for infiltration stormwater strategies
- Swales require extra space which may not be available in some development sites
- Conveyance swales are not suitable for sites with slopes greater than 15 percent

## Maintenance

Until plant communities are established, periodic weeding and mulching is needed. Conveyance swales require periodic inspection to ensure proper stormwater flows. To ensure proper functioning, potential problems must be monitored and corrected, including accumulation of sediment, standing water, poor vegetation coverage and erosion or scouring within the swales.

This 50' x 600' swale lies between the Field Operations Facility and the Nature Park. At first, it was a straight swale planted with grass that protected water quality during construction of the facility. After the construction was completed, crews from Clean Water Services regraded the swale to create meanders, and naturalized the swale with large woody debris and native plants to provide habitat for insects, birds and wildlife.

## Stage 1



## Stage 2



## Stage 3



## Stage 4





# Erosion prevention and sediment control

All construction projects in the Tualatin River watershed are required to include an Erosion Prevention and Sediment Control (EPSC) plan to protect streams and wetlands from sedimentation. The EPSC plan is designed and monitored to meet the specific project and site conditions. A variety of Best Management Practices can prevent erosion, including maintaining existing vegetation and covering any bare soils.



*“We all recognized the need to manage erosion and sediment, and our weekly project meetings always included EPSC.*

*Cooperation and trust were key to our success, and communication was critical. This was a complex construction project with lots of maintenance required throughout. We had a manager on-site and we closely monitored the work.”*

Weston York,  
project manager, Skanska USA

The EPSC for the Field Operations Facility was designed to meet the highest standards and to demonstrate effective technologies and designs. Using a comprehensive approach throughout construction, many elements were incorporated into the final landscaping. Although the plan and bid documents were typical of any large construction project, Clean Water Services added 20 percent to the EPSC budget in anticipation of additional maintenance and upgrades.

The facility is located on an abandoned drive-in theater site, adjacent to the 219-acre Tualatin Hills Nature Park and Cedar Mill Creek. Asphalt, concrete and gravel dominated the site. In order to implement the comprehensive stormwater and management plan, the entire site was cleared. This created a challenge to keep the newly formed swales from eroding and sediments from entering the adjacent creek. However, the erosion prevention and sediment control met or exceeded water quality standards required by Clean Water Services and the City of Beaverton. Elements of the plan included:

- Any exposed soils were covered with gravel or bark compost
- No more than 5 percent of the site was uncovered at any time
- Stockpiled soils were sprayed with an organic membrane
- Bark chips were used for early temporary access and surface management
- A berm constructed of filter fabric and compost material was placed along the 600-foot long swale
- Compost from the filter berm was later used to landscape the swale
- Jute-lined swales and gravel check dams captured sediment as close to the source as possible, allowing sediments to settle before entering the settling ponds
- Two grass-lined settling ponds constructed in the far downstream corner of the site captured runoff
- Organic flocculants were used to speed the settling process in the ponds
- Water runoff quantity and quality were monitored throughout construction
- The contractor was on site during storm events to see that erosion and sediment prevention measures were working

**Clean Water Services' Field Operations Facility received the 2003 Environmental Achievement Award from the International Erosion Control Association.**

## RESOURCES

Clean Water Services EPSC Planning and Design Manual  
<http://www.CleanWaterServices.org>

City of Beaverton, Engineering Design Manual  
<http://www.ci.beaverton.or.us>

City of Portland, Title 10 ESC Regulations  
<http://www.portlandonline.com>

Center for Watershed Protection  
[www.stormwatercenter.net](http://www.stormwatercenter.net)

# Green street

The access road to the Field Operations Facility is a “green” street with no curb and gutter on the south side of the street. Vegetated swales planted with native trees and shrubs replace traditional catch basins and conveyance pipes. Stormwater is absorbed into the soil and plant roots instead of being concentrated and directed to a storm drain, stream or wetland. Green streets treat stormwater within the right of way, while providing maximum tree canopy to intercept rainfall and to cool road surfaces.



*“If you have the space in your development site, green streets are the way to go. Eliminating the engineering and installation of traditional catch basins and underground pipes reduces time and overall costs. In addition, there is less work to be completed before the wet weather season.”*

Weston York,  
project manager, Skanska USA

## Costs and savings

There were no extra costs for this access road, compared to a standard street development. Swales replaced traditional catch basins and underground pipes, which reduced costs and minimized potential sediment impacts during construction.

However, one study of construction costs found a “green” boulevard was 22 percent more costly than a conventional boulevard. The 2002 study was conducted by Metro regional government, comparing costs in Washington County, Oregon. Still, stormwater credits may be available to offset extra costs.



## More advantages

- Green streets do not use curbs and gutters, saving money, materials and time
- Landscaped swales replace expensive catch basins, pipes and detention facilities
- Tree canopy intercepts rainfall and shades the road surface, reducing ambient air temperature and warm stormwater runoff during warmer months
- Effective impervious area is reduced as swales capture, store and filter stormwater runoff
- Green streets can be narrower, reducing the amount of impervious surface and related stormwater runoff
- Less trenching and underground piping minimizes potential erosion and sediment impacts while saving time in the early stages of site development
- Swales, planted with native species, provide habitat for insects, birds and other wildlife
- Green streets are well-suited to areas with low traffic and low speed such as residential, interconnected commercial areas and dead-end streets

## Limitations

- Local codes may require curb and gutter design, and may prohibit narrow “skinny” streets
- Swales require extra space which may be limited in development sites
- Site topography, groundwater depth and soil types may limit green street applications
- Not appropriate for high traffic and high speed areas such as major collectors, arterials or highways

## Maintenance

Green street maintenance is similar to traditional streets. Swales must be maintained to provide proper function and safe, aesthetically pleasing landscape.

## RESOURCES

Green Streets – Innovative Solutions for Stormwater and Stream Crossings, Metro, 2002  
[www.metro-region.org](http://www.metro-region.org)

Sustainable Streets, City of Vancouver, B.C.  
[www.city.vancouver.bc.ca](http://www.city.vancouver.bc.ca)

Center for Watershed Protection  
[www.cwp.org](http://www.cwp.org)  
[www.stormwatercenter.net](http://www.stormwatercenter.net)

# Porous concrete

## Size:

18,000 square feet, 680 cubic yards of concrete

## Concrete specifications:

3/8 inch aggregate, Portland cement, admixtures  
12-inch thickness. 14-21% void space

## Supplier:

Glacier Northwest

## Installation contractor:

Gary Merlino Construction Company

## Cost:

\$11 per square foot

*“We did significant pre-planning to ensure a successful outcome. Our attention to detail paid off – everyone is really proud of the final product. It’s nice to know that this parking lot is good for the environment.”*

Ryan Thread, *Glacier NW, porous concrete provider*



The Field Operations Facility’s employee parking lot is paved with porous concrete. Porous concrete allows rainfall to be absorbed directly into the soils below, recharging groundwater and reducing or eliminating any surface runoff. The porous parking lot acts as a retention facility, slowing the flow and replicating natural hydrology. The cost of porous concrete is offset in part by the elimination of catch basins and pipe conveyance systems.



Because of the clay soils typically found in the Tualatin River basin, the parking lot has an 18-inch base and sub-base to capture and store a 25-year storm event. (Note: On other sites, the depth of this base might be much less depending upon the soil type and characteristics determined by a geotechnical analysis.) Geotextile fabric placed below the ballast rock keeps fine sediments from migrating upward. A 6-inch perforated pipe with filter sock placed in the sub-base and running the length of the parking lot helps keep any potential water from rising to the surface,

Several months of planning preceded the actual installation of the 18,000 square foot employee parking lot. The project required a test pour, which was successful allowing the 10 x 14-foot test slab to be left in place. Each day the contractors completed about 150 cubic yards of the 680 cubic yard job.

Porous concrete presents unique installation challenges because the concrete is thick, sticky and barely flows. Pump trucks could not be used, so a conveyor system was the best option. The concrete was poured one-half inch above final finished grade, then covered with plastic and rolled to final grade using an automated 400-pound steel pipe. The concrete remained covered with plastic for seven days. During construction, extra care must be taken to keep the sub-grade clean and damp, and to minimize any compaction that would reduce the void structure. Expansion joints were cut 10-feet on center using a special concrete saw that captured the slurry, protecting the concrete from becoming clogged.

## Costs and savings

The complete installation cost of the 12-inch thick porous concrete parking lot (materials and labor) was \$300 per square yard. However, the cost can be lowered to about \$100 per yard by reducing the thickness to six inches, and is much closer to the cost of typical concrete. The higher installation costs are offset by no engineering, installation or maintenance of conveyance systems, including pipes, catch basins and detention facilities.

Porous concrete technology is improving rapidly. The 12-inch depth at this site might have been more than needed, but it was specified to ensure successful long-term performance based on limited research data at the time of construction. Another porous concrete lot in Gresham, Oregon specified a 6-inch depth. A 10-inch depth is currently recommended for heavy traffic, higher volume surfaces.

## More advantages

- Allows rainfall runoff to infiltrate soils to recharge groundwater
- Significantly reduces stormwater runoff
- Less thermal capacity which reduces heat gain and radiation
- Longer lifespan than asphalt
- Maximum utilization of property area because the parking area is also a stormwater facility

## Limitations

- New technology with fewer qualified suppliers and contractors
- Limited to low traffic volume and speeds
- Limited long term studies of durability and maintenance issues

## Maintenance

Periodic vacuum sweeping is needed to keep fine materials from embedding in the pore spaces. Careful attention is needed during construction and final landscaping to protect surfaces from contamination.



## RESOURCES

Glacier Northwest  
[www.glacienw.com](http://www.glacienw.com)

Texas, Inc. (Ecocreto)  
[www.ecocreto.com](http://www.ecocreto.com)

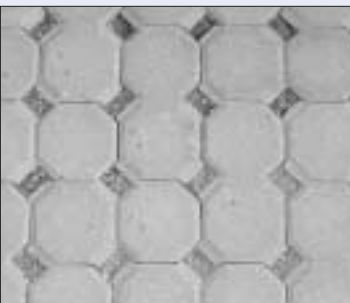
Center for Watershed Protection  
[www.stormwatercenter.net](http://www.stormwatercenter.net)

The Rain Runs Through It brochure,  
Clean Water Services, 2004



# Porous pavers

Concrete paver blocks provide seven additional parking places (945 square feet) for visitors to the Field Operations Facility. Spaces between the interlocking pavers allow stormwater to be absorbed into the sub-base and soils below. Porous pavers are commonly used and readily available, and can be more attractive than asphalt or conventional pavement.



## Costs and savings

Although pavers were installed by hand at the facility, mechanical installation is available for larger projects. The cost to install the pavers (3.5 pavers per square foot) was \$8.50 per square foot. In addition, the cost for the sub-base was \$3.15 per square foot.

## More advantages

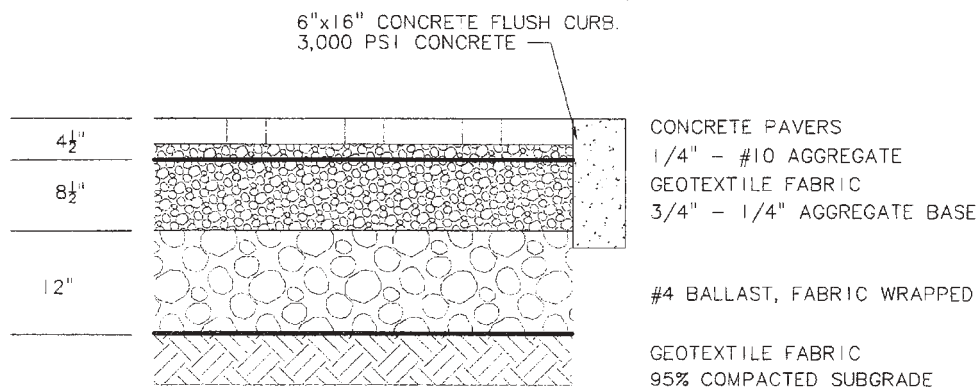
- Allows rainfall runoff to infiltrate soils to recharge groundwater
- Significantly reduces stormwater runoff
- Less thermal capacity which reduces heat gain and radiation
- Repairs or access to sub-grade can be done easily and inexpensively by removing only the affected area
- No engineering, installation or maintenance of conveyance systems, including pipes, catch basins and detention facilities
- Maximum utilization of property area because the parking area is also a stormwater facility

## Limitations

- Limited to low traffic volume and speeds
- Limited long-term studies to determine durability and maintenance issues

## Maintenance

Periodic vacuum sweeping is recommended to keep fine materials from embedding in the pore spaces. Careful attention is needed during construction and final landscaping to protect surfaces from contamination.



## RESOURCES

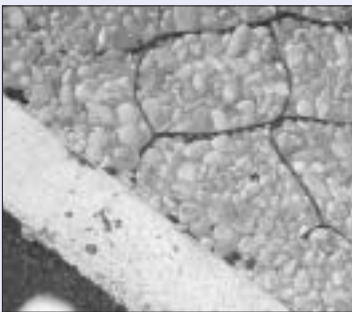
Uni-group, USA.  
[www.uni-groupusa.com](http://www.uni-groupusa.com)

Mutual Materials  
[www.mutualmaterials.com](http://www.mutualmaterials.com)

The Rain Runs Through It brochure  
published by Clean Water Services,  
2004

# Structural gravels

Structural gravels supported by an 8-inch deep synthetic grid provide 3,000 square feet of storage area in the Field Operations Facility maintenance yard. The three-dimensional network of interconnected, perforated cells was filled with 1½-inch to ¾-inch open graded river gravel.



## Costs and savings

The structural gravel storage area is one of the most cost-effective porous technologies on the site. The gravels, sub-base and Geoweb® Cellular Confinement System cost \$3.85 per square foot.



## More advantages

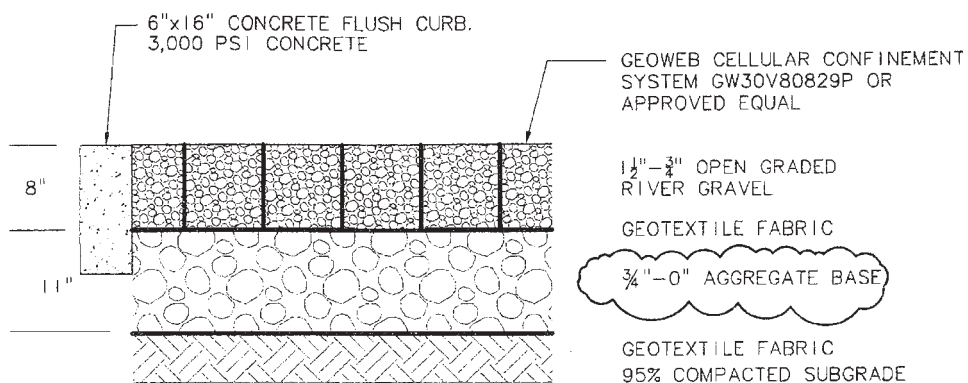
- Allows rainfall runoff to infiltrate soils to recharge groundwater
- Significantly reduces stormwater runoff
- Less thermal capacity which reduces heat gain and radiation
- No engineering, installation or maintenance of conveyance systems, including pipes, catch basins and detention facilities
- Maximum utilization of property area because detention facilities are not needed

## Limitations

- Limited to low traffic volume and speeds
- Open graded river gravels shift with heavy loads and need periodic grading; angular rock minimizes shifting and requires less maintenance
- Grid may migrate upward; perforated grid minimizes this risk
- May not be optimal where equipment may regularly disturb the rock

## Maintenance

Careful attention is needed during construction and final landscaping to protect surfaces from contamination. Re-grading gravels may be necessary to maintain even surface.



## RESOURCES

Presto Products Company  
[www.prestogeo.com](http://www.prestogeo.com)

# Ecoroof

## Size:

8,000 square feet

## Cover:

17,000 plants with 4 inches growing medium

## Roof type:

2:12 pitch, north facing, 4-ply hot mop base, extensive ecoroof

## Roof manufacturer:

Soprema, Inc.

## Landscaping:

Wilcott Landscaping

## Total system cost:

\$14 per square foot  
Four-ply hot mop roof system:  
\$6/sf  
Ecoroof: \$8/sf

## Planting plan

17,000 drought-resistant plants were placed, by hand, on the roof. Four-inch potted plants (some planted 12" and some 6" on center), cuttings (4 per square foot) and bulbs were in asymmetrical, non-uniform blocks according to the plan. The following species, chosen because they do not grow tall and require little maintenance, were planted:

*Achillea millefolium* (Yarrow)

*Coreopsis auriculata* 'nana'

*Crocus vernus* (Dutch Crocus)

*Dianthus deltoids*

*Lavendula angustifolia* 'hidcote'  
(Lavendar)

*Muscari armeniacum* (Grape  
Hyacinth)

*Sedum* spp. (Stonecrop)

*Thymus* spp. (Thyme)

*Verbena* spp.

*Veronica prostrata* (Speedwell)

An ecoroof, also called a green roof, is a vegetated roof system. An ecoroof mimics a natural landscape by absorbing rainfall and carbon dioxide and releasing water and oxygen back into the atmosphere through evapotranspiration. Runoff from the ecoroof is slowed and cleaned. The Field Operations Facility ecoroof is an extensive system that required only a 10 percent increase in the roof structure costs.



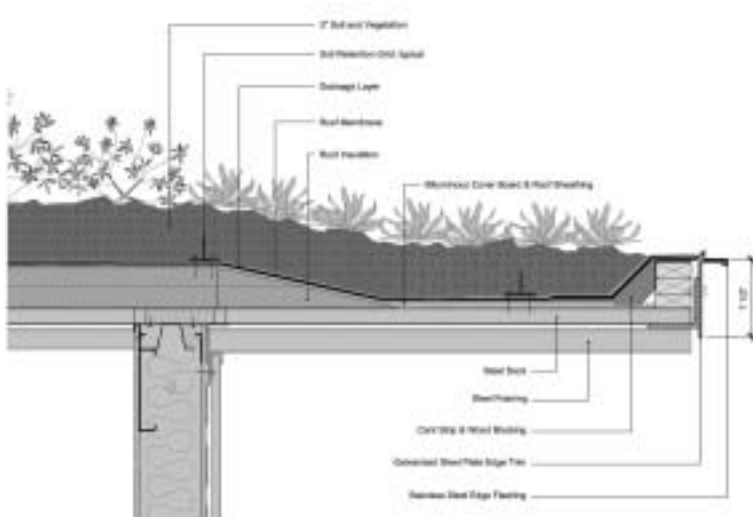
Blowing soil on the ecoroof

The 8,000 square foot north-facing roof was designed and built in two stages. First, a typical four-ply hot mop application roof system was installed. The final cap sheet was specified for the soil interface. Then, a mesh drainage layer and a free-standing lightweight aluminum soil retention grid were placed on top of the finished roof to hold the soil. The growing medium, consisting of 30% sandy loam, 15% compost, 25% pumice, 15% perlite and 15% coir, was blown on to the roof four inches deep, and 17,000 plants were placed by hand. A temporary irrigation system helped establish the new plants. Safety ties were permanently installed at the top of the roof pitch for future maintenance.

The roof framing plan is a typical steel joist and steel decking system, engineered for a total dead load of 45 pounds per square foot (psf). The metal roof decking was upgraded to 1.5-inch 20 gauge galvanized steel to handle the approximately 30 psf increased load for the water saturated ecoroof.

The 2:12 roof slope required a soil stop of continuous stainless steel the length of the roof. The stop was raised in order for water to flow through the drainage layer and off the roof into the 1/4 inch bent steel plate gutters.





## Costs and savings

The base roof system cost was \$6 per square foot, which is typical for any standard four-ply hot mop application in this region. The ecoroof landscaping cost an additional \$8 per square foot and included the irrigation system, and unique flashing, gutters and stops necessary to hold the soils on the sloped roof. The higher installation costs will be offset by long-term energy and maintenance savings.

## More advantages

- Will last twice as long as conventional roofs (approximately 40 years) due to protection from ultraviolet radiation and weather
- Drought-resistant plants absorb rainfall and reduce runoff. In drier, warmer months, 70 to 100% of the rainfall is expected to be returned to the atmosphere through evapotranspiration, cooling the building and the surrounding air
- Insulates the building, resulting in lower energy costs
- Ecoroof plants reduce carbon dioxide levels in the atmosphere
- Evapotranspiration cools and humidifies the surrounding air, reducing heat island effects
- Important habitat is provided for birds, butterflies and other insects
- Improves opportunities to develop or redevelop in dense urban areas by using the roof for stormwater management
- May earn stormwater credits and decrease overall stormwater fees

## Limitations

- Ecoroofs can be more expensive to design and install
- Although ecoroofs are generally considered to be less likely to leak than a traditional roof, any potential leak may be more difficult to find and repair
- Sloped roofs, as the Field Operations Facility ecoroof, require special attention to erosion control and soil retention

## Maintenance

- Temporary irrigation may be needed until plants become established
- Periodic weeding and mulching may be needed until plants become established
- Periodic inspection of plants, flashing, and gutters is recommended to maintain drainage

## RESOURCES

City of Portland, Bureau of Environmental Services and the Office of Sustainable Development.  
[www.cleanrivers-pdx.org](http://www.cleanrivers-pdx.org) and  
[www.sustainableportland.org](http://www.sustainableportland.org)

Center for Watershed Protection  
[www.stormwatercenter.net](http://www.stormwatercenter.net)

Additional web sites:  
[www.Greenroofs.com](http://www.Greenroofs.com)  
[www.Greenroofs.ca](http://www.Greenroofs.ca)  
[www.ecoroofseverywhere.org](http://www.ecoroofseverywhere.org)





Clean Water Services employees at the Field Operations Facility beneath the ecoroof.



Clean Water Services is a public utility committed to protecting water resources in the Tualatin River Watershed. Nearly 473,000 customers enjoy clean water and healthy rivers and streams through innovative wastewater and stormwater services, flood management projects, water quality and stream enhancement projects, fish habitat protection, and more.

2550 SW Hillsboro Highway  
Hillsboro, Oregon 97123  
(503) 681-3600  
[www.CleanWaterServices.org](http://www.CleanWaterServices.org)