SUSTAINABLE WATERFRONT

FRAMEWORK PLAN AND CONCEPT DESIGN

JULY 2012

SUSTAINABILITY

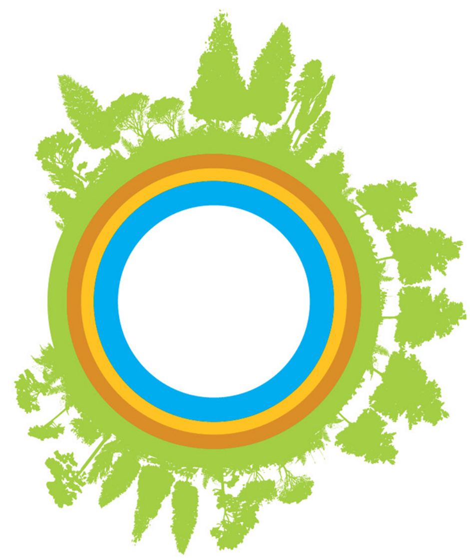
The City of Seattle Guiding Principles commits the project to putting the shoreline and innovative, sustainable design at the forefront. The goals are to bring people to the water's edge to experience the water and ecology of Elliott Bay, to improve shoreline ecology while preserving and enhancing maritime activities, and to reflect Seattle's commitment to sustainability and innovation.

The Central Waterfront is at the heart of some of the oldest communities of Seattle. It is easily accessible to pedestrians and bicyclists as well as by several types of public transportation, such as ferries, trains, light rail, buses and street cars. Creating a public open space in the heart of Seattle will serve the global environment because it will channel future development to urban neighborhoods and by so doing reduce pressure on undeveloped land outside the city. This will contribute to reducing pollution and development impacts, support the local economy and improve human health.

The waterfront is particularly interesting from a local environmental perspective. It is located within a region of transition between two ecological communities, the aquatic communities of Elliott Bay and the upland communities in the urban neighborhoods abutting the waterfront. Both ecosystems have suffered decades of pollution and degradation, and are in great need of some repair.

The City of Seattle Office of Sustainability and Environment has been coordinating and developing policies and initiatives to protect Seattle's environment. The waterfront project has assembled a multidisciplinary team of professionals experienced in sustainable practices to collaborate in the design process and draft an integrated sustainable design and implementation strategy. As the waterfront project develops, the team will need to coordinate with the Office of Sustainability and Environment as well as the many local environmental advocates, including public agencies such as the Seattle Public Utilities, the Port of Seattle, the Puget Sound Partnership, the Washington State Department of Ecology, the US EPA, NOAA, the Army Corps of Engineers, as well as some of the more than 50 non-profit organizations whose missions address the Puget Sound environment and water.

Opportunities for improving the environment on the waterfront are discussed below and will continue to be explored and inform design, construction, operation and maintenance decisions throughout the life of the project. Construction and maintenance guidelines will be considered to ensure that every effort is made to maintain and improve the waterfront towards sustainability in the long term. Site users and other stakeholders will continue to be engaged in meaningful participation to identify needs and to supplement professional expertise with local knowledge.



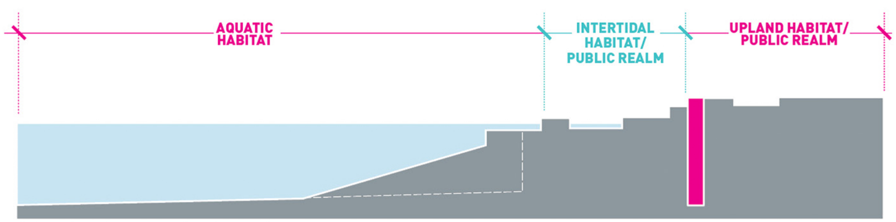
SUSTAINABILITY

WATER

Marine Water

The waterfront is separated from Elliott Bay by the Seawall. Due to a long history of industry and development, the environment in marine waters along the central waterfront has been severely degraded by pollution, combined sewer discharge, dredging, dumping and large surfaces of overwater coverage. The quality of marine water environments along the central waterfront depends on many factors which are beyond the scope of this project, but every effort will be made to coordinate with and encourage initiatives to improve the quality of water in the marine environment.

EXISTING LAND/WATER CONDITION
NOT TO SCALE



PROPOSED LAND/WATER CONDITION
NOT TO SCALE

SUSTAINABILITY

WATER

Water Use

The design and maintenance of all water features created in the public realm will consider minimal or no make-up water from potable sources or other natural surface or subsurface water resources. Every effort will be made to reduce the use of potable water for irrigation. The swimming pool proposed at Pier 62/63 will be designed as a salt water pool to prevent the use of chlorine and its potential impact on marine environments.

SUSTAINABILITY

WATER

Storm Water

Managing the quality and quantity of storm water runoff is essential to the improvement of urban ecosystems along the waterfront. Although the rehabilitation of lost streams, wetlands and shorelines is not possible here, some of the functions of those elements can be restored to some degree through innovative storm water management techniques. Drainage control facilities can be engineered to use infiltration, evapotranspiration, and stormwater reuse, to more closely mimic natural hydrology within this urban setting. Well designed drainage control facilities can help prevent or minimize the generation, mobilization and transport of common storm water pollutants and watershed-specific pollutants through combined sewers or storm water systems to receiving waters, including marine environments, surface water and groundwater.

The design team conducted a preliminary site storm water analysis which can be found in the Appendix. It maps existing drainage patterns and infrastructure, identifies existing drainage basins and system types (drainage, combined sewer, etc.), and catalogues proposed surface treatments, slopes and uses throughout the project area.

Opportunities and constraints related to storm water management were identified as follows:

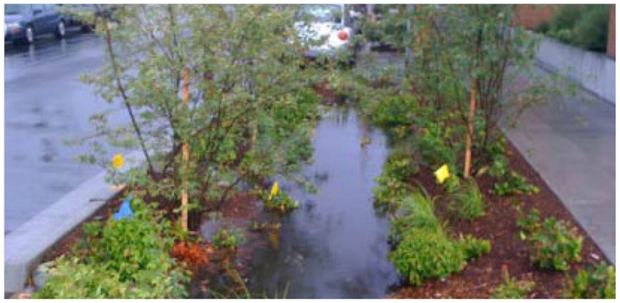
Opportunities

- Increase green spaces and plantings to provide environmental functions as well as an enhanced urban habitat;
- Improve the quality of stormwater runoff into Elliott Bay;
- Reduce the volume of runoff captured in the City's combined sewer system;
- Provide education and highlight stewardship of the environment and ecology of Puget Sound;
- Restore dispersed, clean stormwater discharge to Elliott Bay to promote enhanced aquatic habitat along the seawall;
- Reduce water demand within the urban landscape through stormwater reuse.

Constraints

- Feasibility of infiltration is limited by underlying soils, shallow groundwater, tidal influences, and seawall improvements;
- Drainage infrastructure needs to complement and integrate with many competing needs within the project area;
- Operations and maintenance considerations should be considered in selection and siting of practices;
- The subsurface of the project will require a stable substrate to support surface loads and ample space to avoid conflicts with subsurface utility infrastructure.

This preliminary analysis provides the design team with a framework for the consideration of contextually appropriate sustainable strategies during the early phases of design. Some of the storm water management strategies considered include planting, bioretention facilities, permeable pavement, green roofs and rainwater harvesting, all of which can be integrated into the design. Those strategies can improve water quality and reduce runoff while meeting code requirements related to storm water management, such as the City of Seattle's requirement for implementation of Green Stormwater Infrastructure (GSI) to the "maximum feasible extent".



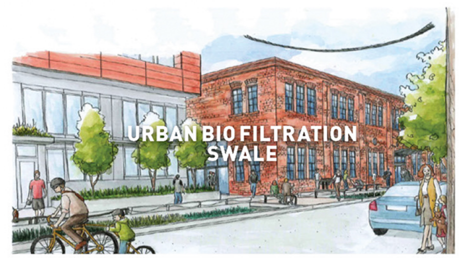



SUSTAINABILITY

STORMWATER INFRASTRUCTURE TYPES

Bioretention planters are flat-bottomed, landscaped basins containing an amended soil mix and native plants within an impervious structure (preventing infiltration into surrounding, native soil). Bioretention planters are used to mimic pre-development conditions where the soils and plants work together to store and treat stormwater runoff.

Permeable pavement is a paving system that contains empty spaces which allow rainfall to percolate into underlying soil. There is a variety of permeable pavement surface options (asphalt, concrete, pavers, etc.). Permeable pavement systems can be designed to provide differing levels of flow control. Permeable pavement surfaces function as a permeable land surface, reducing the amount of runoff generated during a storm.

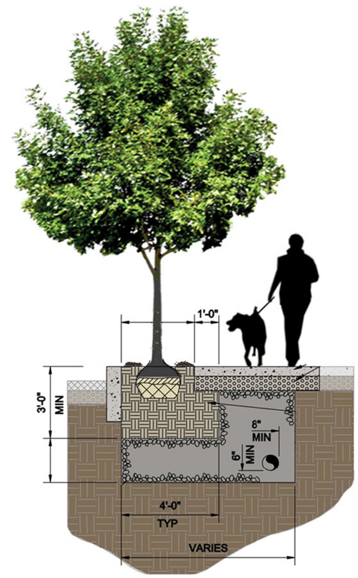


Biofiltration swales are open, gently sloped, vegetated channels designed to treat stormwater. Stormwater enters the head of the swale, percolates through the soil as it travels the swale's length, and conveyed out of the system. Pollutant removal occurs by filtration as stormwater moves through the grass blades, which enhances sedimentation and trapping of pollutants to the grass.

Subsurface wetlands are basins (typically impervious) filled with a porous media (usually gravel or aggregate) that supports plant life. Subsurface wetlands are designed to allow stormwater runoff to flow below the ground surface through the root zone. The facility is designed so that the porous media stays submerged. Wetland plants are rooted in the media to allow for direct uptake of pollutants.

ter harvesting is the capture and of roof runoff for reuse. The primary ents of a rainwater harvesting system the collection system (gutters and outs), storage (cisterns or rain barrels), persion system (pipes or hoses). The ainwater is reused for non-potable uses irrigation. Rainwater harvesting is an e form of green infrastructure where on is not applicable.

Newly planted trees provide flow control in an urban environment by absorbing rain through their leaf system and roots, and allowing space for infiltration. Newly planted trees receive credits toward meeting flow control requirements.



The Silva Cell is a modular suspended pavement system for containing lightly compacted soil underneath paved surfaces for large tree growth and on-site stormwater maintenance. Silva cells and structural soils offer space for tree roots to grow while maintaining sufficient structural support for pedestrian sidewalks.

GSI Location Conditions	Step 1: Slopes	Step 2: Land Use	Applicable Practices
	Mild - Medium (0-6%)	Open Space	Bioretention Planters
			New Trees
			Subsurface Wetlands
			Biofiltration Swales
		Pedestrian and Bike Use	Permeable Pavement Surface
			Enhanced Tree Pits
		Roof	Rainwater Harvesting
			Vegetated Roof
		Parking	Permeable Pavement Surface
			Enhanced Tree Pits
	Steep (>6%)	Open Space	Bioretention Planters
			New Trees
		Pedestrian and Bike Use	N/A
		Roof	Rainwater Harvesting
		Parking	N/A

SUSTAINABILITY

HABITAT AROUND THE BAY RING

Natural ecosystems around the Bay Ring have suffered negative impacts from industrial and commercial development over the last century. An integral part of this project is to adopt strategies for improving the functions of natural ecosystems along the central waterfront. The waterfront is located within an "ecotone", or region of transition between two ecological communities - riparian and intertidal. Those are framed by upland and aquatic ecological communities. Thus the Bay Ring can be described as having four habitat zones: upland, riparian, intertidal, and aquatic. This framework plan focuses on identifying opportunities for enhancing each one of these ecological communities on the waterfront and improving the connections between them.

Upland habitat zone

Riparian habitat zone

Intertidal habitat zone

Aquatic habitat zone


PUGET SOUND
ELLIOTT BAY
LAKE WASHINGTON

SUSTAINABILITY

HABITAT AROUND THE BAY RING

UPLAND HABITAT

The primary component of the urban upland habitat is trees. Trees help mitigate air and water pollution and improve the urban environment for humans and wildlife alike. The City of Seattle Urban Forest Management Plan (2007) is taking steps to preserve and enhance Seattle's urban forest which "has significantly declined over the last few decades." This new commitment to reestablish the urban forest will serve three primary purposes:

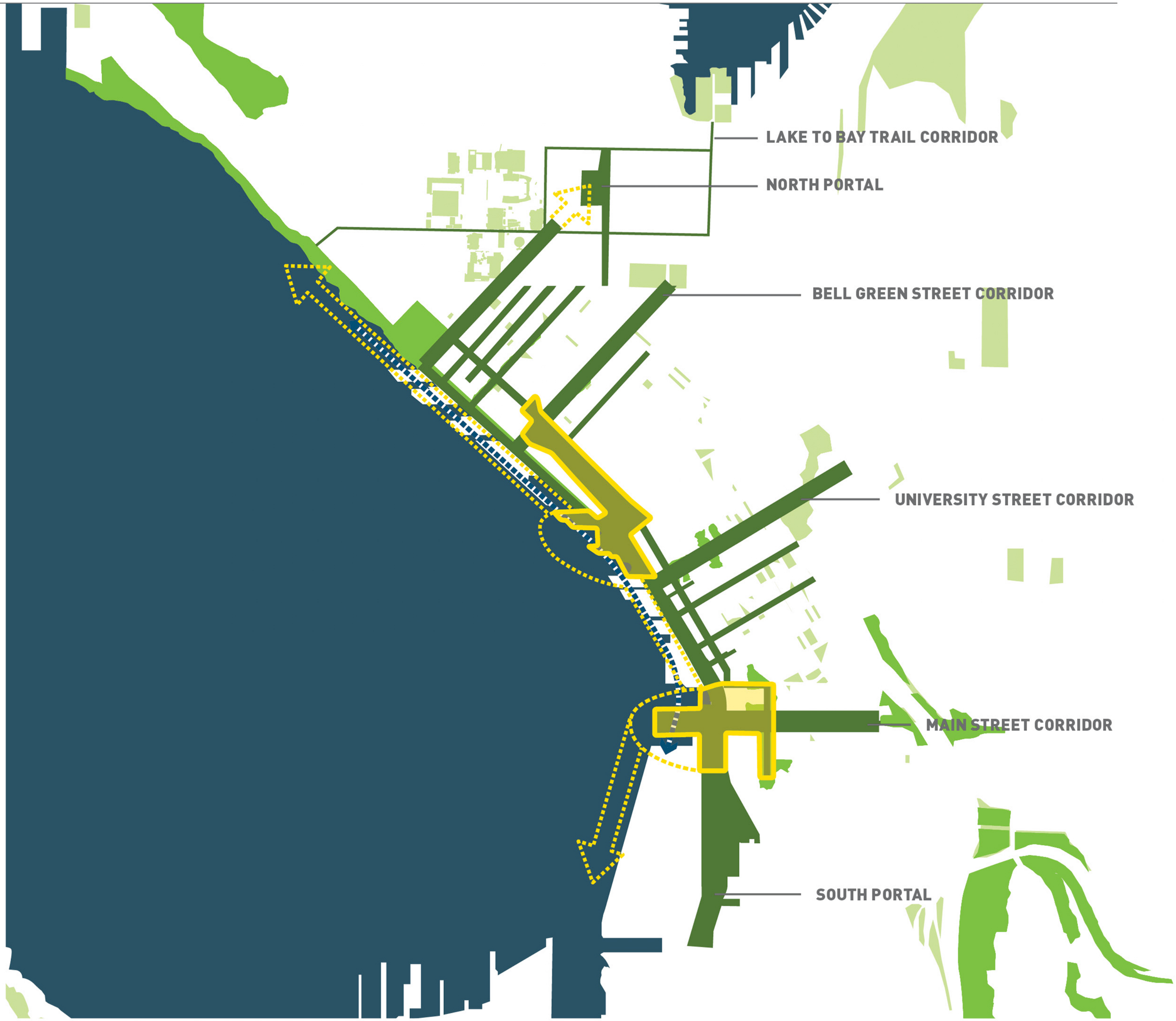
- Create a more connected urban habitat system that pulls the natural realm into the city;
- Establish new and authentic parks, promenades and waterways; and
- Contribute toward a financial investment in mitigating the environmental impacts associated with urbanization, dramatically decreasing the long-term costs.

Seattle's publicly managed parkland totals approximately 6,200 acres. This expanse of open space is dispersed throughout the city and takes on a wide variety of forms, ranging from Interstate Highway Lid parks (Freeway Park + I-90 Lid Parks), to reclaimed military bases (Lake Union Park, Discovery Park and others), to old growth forests (Seward Park). These parks and open spaces range in size from less than an acre to the 534 acres that comprise Discovery Park in Magnolia. Many of the existing parks found throughout Seattle are disconnected from each other, preventing wildlife from moving freely and safely from one area to the other. By strategically inserting vegetal connections between pockets of upland habitat, potential for more biodiversity is increased. The establishment of strategic upland habitat corridors, stretching from the aquatic regions to the upland and connecting existing and proposed habitats, will ensure the integration of the Central Waterfront with the existing urban open space network and its contribution to the creation of a more sustainable upland urban ecosystem. Strategic partnerships can prevent overlap and redundancy, encourage knowledge sharing and ensure a coherent effort to establish beneficial plant communities that will be interconnected to form a larger and healthier environment.

University Street Harbor Steps

Alaskan Way at Pioneer Square

Freeway Park



Existing open space patches & corridors

Potential Upland Corridors

Habitat Enhancement Focus Areas

0' 750' 1500' 3000'

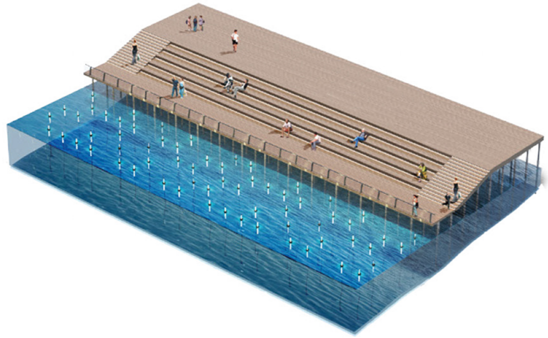
SUSTAINABILITY

HABITAT AROUND THE BAY RING

RIPARIAN AND INTERTIDAL HABITAT

The intertidal region is an important part of the waterfront ecosystem. The rocky, wave-swept shore, native to the Puget Sound region, is a highly diverse and productive habitat. These shores are also inviting to people, making it simple for the public to interact with water and experience its diverse habitats (algae beds, seaweed, salt marshes) and species (barnacles, sea urchins, crabs, starfish, heron, salmon and varieties of sedges). While providing a wealth of educational opportunities the intertidal region also plays an important role in the food web, connecting the upland zone with the aquatic zone.

The central waterfront riparian and intertidal zone has been replaced by the Elliott Bay Seawall. This has eliminated the functions of the riparian and intertidal ecosystems in this part of the Puget Sound and has made it hard for people to interact with the sea. Riparian areas decrease the flow rate of storm water, trap sediments, and reduce the amount of harmful pollutants discharged in water bodies while significantly increasing biodiversity. The introduction of a beach, water terraces, storm water collection devices and get downs can simulate some of the functions of those ecosystems while helping to restore some habitat along the water's edge.



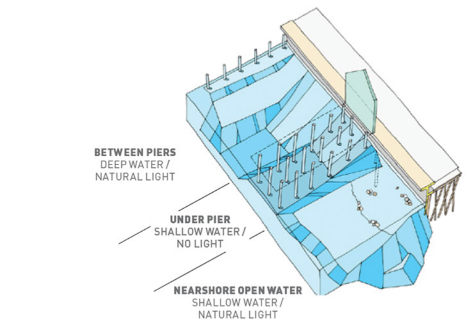
AQUATIC HABITAT

Efforts to restore aquatic habitat along the waterfront are part of the scope of the Elliott Bay Seawall Replacement Project. The Elliott Bay Seawall runs along a natural salmon migration route. Salmon prefers light and shallow water which can no longer be found along the central waterfront, where dredging and overwater coverage have created deep and dark waters. Research conducted by the Elliott Bay Seawall Team has identified three primary existing conditions along the central waterfront:

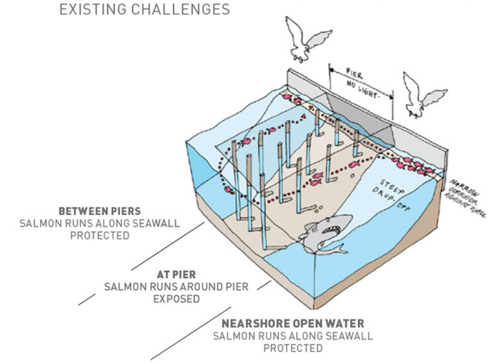
- Near-shore conditions tend to have shallower water and natural light which the salmon favor. They swim along the edge where they are protected.
- The areas between the piers tend to have deeper water and more natural light.
- The areas beneath the piers have relatively shallow water, but very little natural light.
- Because of the lack of natural light beneath the piers, salmon will swim towards the light around the pier perimeter and expose themselves to predators in the deeper waters.

One of the seawall project's goals is to protect and restore marine, riparian, wetland and shoreline buffers where possible. Working with the Seawall Team, the Waterfront Design will incorporate habitat restoration elements such as a light penetrating surface (LPS) in the promenade and an intertidal habitat bench.

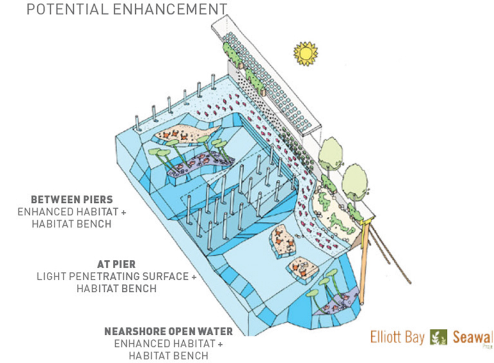
EXISTING CONDITIONS



EXISTING CHALLENGES



POTENTIAL ENHANCEMENT



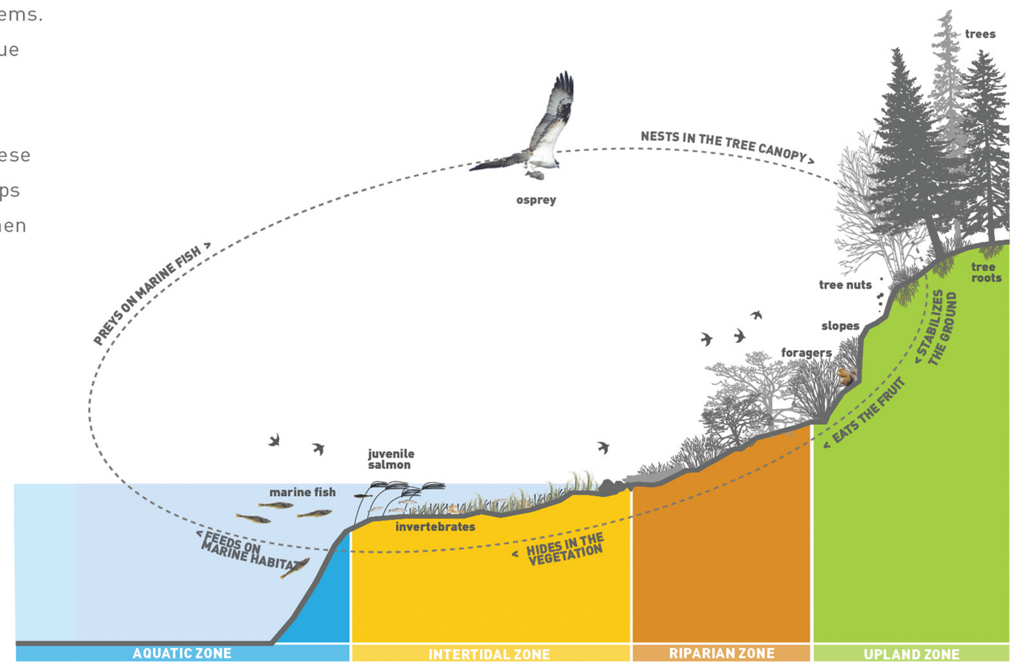
SUSTAINABILITY

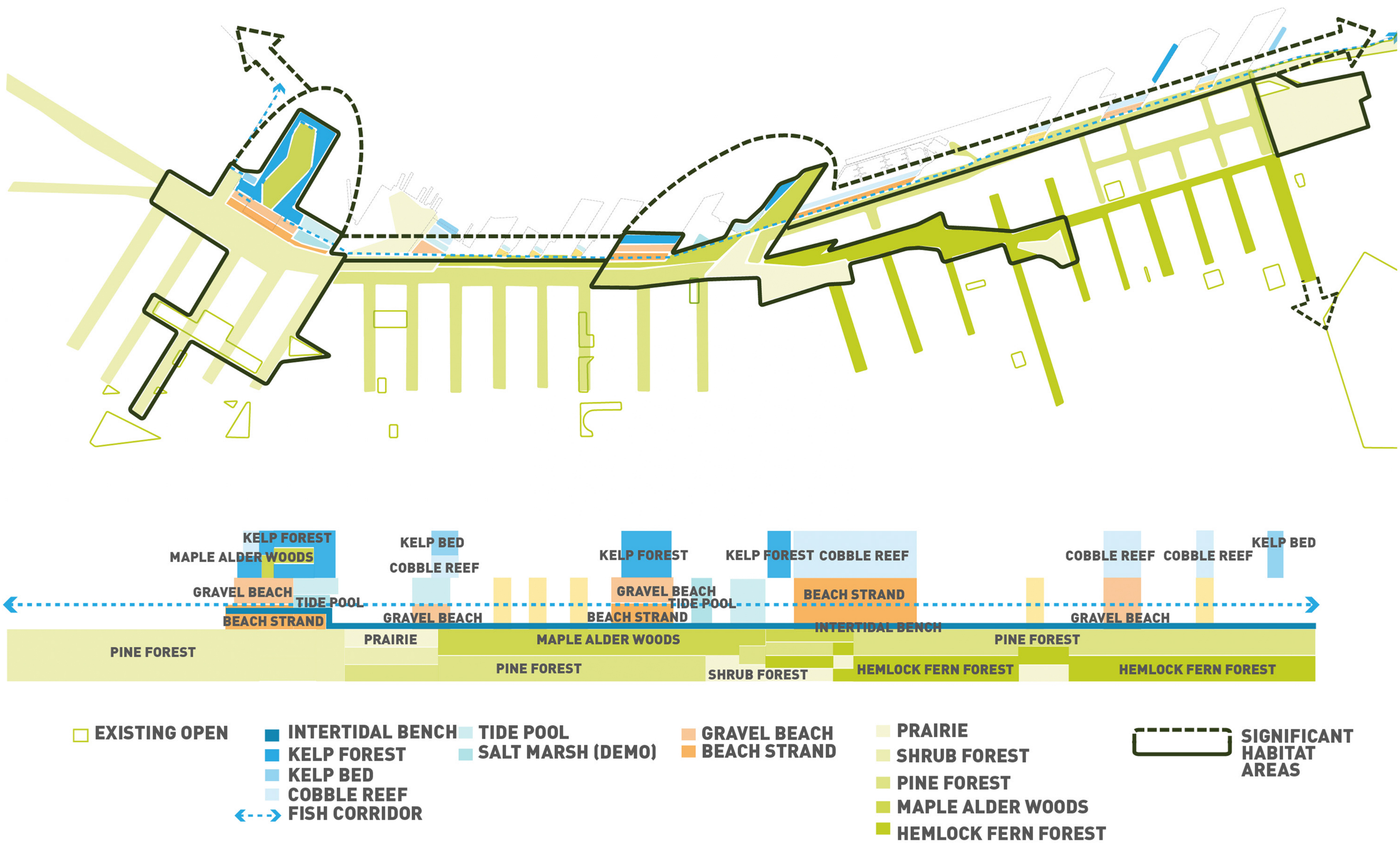
HABITAT AROUND THE BAY RING

SPECIES INTER-RELATIONSHIPS

Each plant and animal species is dependent on a wide array of other species for survival. The diagram to the right illustrates this concept with an example of inter-related species typical to the Puget Sound's native habitat. Ospreys hunt marine fish and juvenile salmon that swim in shallow intertidal waters and feed on the nearby aquatic plants and invertebrates. Further uphill, squirrels feed on nuts, which fall from the mature trees rooted in the steep upland slopes. These trees provide shelter and habitat for the Osprey, and thus the cycle returns on itself.

Inter-species relationships are critical for the establishment of healthy and robust ecosystems. Increased biodiversity in urban areas can emerge through the creation of a connective tissue that links existing pockets of natural habitat with proposed ones. The process of enhancing and connecting habitats around the bay will help plants and animals find opportunities to establish themselves along the waterfront. The integration, maintenance and support of these relationships are critical to the health of natural ecosystems on the waterfront. Partnerships with local and national environmental initiatives will be necessary to augment and strengthen these relationships.




KELP FOREST
MAPLE ALDER WOODS
KELP BED
COBBLE REEF
KELP FOREST
KELP FOREST
COBBLE REEF
COBBLE REEF
COBBLE REEF
KELP BED
GRAVEL BEACH
TIDE POOL
BEACH STRAND
GRAVEL BEACH
GRAVEL BEACH
TIDE POOL
BEACH STRAND
BEACH STRAND
INTERTIDAL BENCH
GRAVEL BEACH
PINE FOREST
PRAIRIE
MAPLE ALDER WOODS
PINE FOREST
PINE FOREST
SHRUB FOREST
HEMLOCK FERN FOREST
HEMLOCK FERN FOREST
EXISTING OPEN
INTERTIDAL BENCH
KELP FOREST
KELP BED
COBBLE REEF
FISH CORRIDOR
TIDE POOL
SALT MARSH (DEMO)
GRAVEL BEACH
BEACH STRAND
PRAIRIE
SHRUB FOREST
PINE FOREST
MAPLE ALDER WOODS
HEMLOCK FERN FOREST
SIGNIFICANT HABITAT AREAS

SUSTAINABILITY

HUMAN HEALTH AND WELLBEING

ENGAGE THE COMMUNITY

An extensive public outreach process described in the Appendix was undertaken to involve the community in building the waterfront environment. Enthusiastic participation was encouraged via community workshops and outreach that engaged the public in thoughtful and interesting ways. Public input was wholly integrated in the design process. Active engagement of the public promotes a sense of ownership and helps in developing stewardship for the long term. Early implementation projects encourage early community participation, ongoing stewardship and showcase the larger ambition and commitment of Seattle to invest in habitat restoration. Potential initiatives could include: Community tree planting, urban agriculture and farmers markets, educational programs and activities, seed exchanges and various art projects related to ecology as described in the waterfront Art Plan.

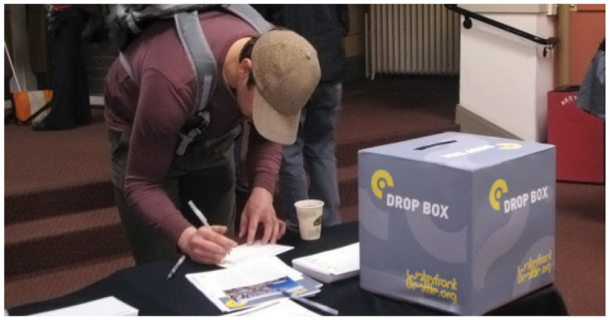
PROTECT AND MAINTAIN EXISTING ASSETS

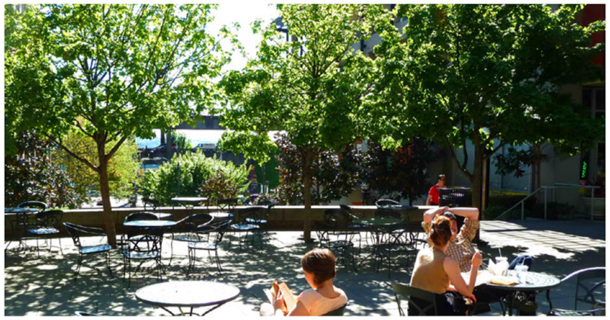
Cultural and historical assets as well as attributes and artifacts that enhance a site's sense of place and meaning will be protected. Public access and understanding of those assets will be promoted.

PROMOTE HEALTHY URBAN LIFESTYLES

The design provides on-site opportunities for outdoor physical activity that improve urban healthy living. Those include extensive pedestrian routes, a bike path, access to public transportation, access to water activities such as kayaking, swimming, and touching the water, roller skating, and play areas.

The design also provides several large and quiet outdoor spaces for mental restoration and social interaction. Most of those outdoor spaces provide a variety of views of large natural and urban landscapes, sunsets and sunrises, as well as closer of views of vegetation, water, art and seasonal changes.





BE AN ECONOMIC CATALYST

The project is designed to provide economic and social benefits to the local community.

In addition to the design of the public realm, the framework plan developed a robust development strategy for the Central Waterfront. The infusion of new residential areas, shops and restaurants, performance venues and entertainment, will strengthen and diversify the waterfront's commercial activity. Vibrant urban development, symbiotically paired with an inviting public realm, will generate private economic growth that could potentially spread to neighboring areas. In addition, the waterfront Art Plan is proposing to support and strengthen the cultural communities, venues and events which will add great sense of place and cultural identity on the waterfront.

SUPPORT LOW IMPACT MEANS OF TRANSPORTATION

The waterfront framework plan has developed an access and mobility strategy which encourages the use of public transit, creates strategic connections and linkages to existing transit routes, improves waterfront transit hubs and adds sustainable alternative modes of transportation such as a waterfront circulator and a bike path. Together these initiatives will improve connectivity, thereby increasing ridership and decreasing carbon emissions in the city.

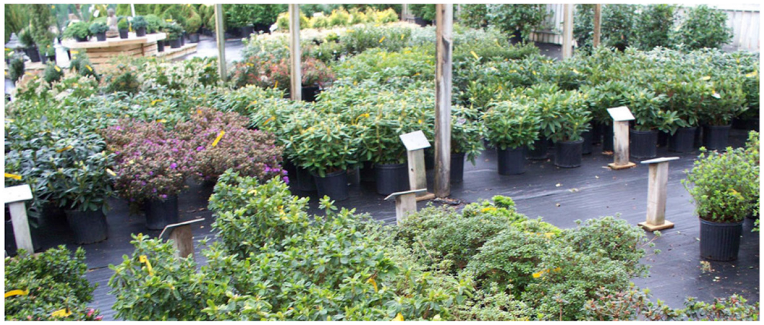
INFORM THE PUBLIC

Both interpretive signage and public outreach will developed to help promote the understanding of sustainability in ways that positively influence user behavior on site and beyond. The public will have access to information about on-site features and processes, the history of the site, its geography, its local ecosystems, its environmental context, and the benefits of physical activities and healthy living. The public will also be informed about opportunities for engaging in healthy living and activities that will improve their environment.

SUSTAINABILITY

MATERIAL SELECTION

The selection of materials for use in the project will take into consideration their impact on the environment as a whole as well as on the local ecosystem in order to support sustainable practices in materials manufacturing and nurseries. Wood products extracted from non-threatened tree species to minimize negative effects on other ecosystems will be favored. Salvaged materials, materials with recycled content and materials with low VOC will be favored whenever possible to reduce the use of virgin materials and avoid sending useful materials to the landfill. Regional materials will be favored to reduce energy use for transportation, support the local economy and promote regional identity. Whenever possible, plants will be purchased from providers who reduce resource consumption and waste. Site lighting will consider the guidelines of the International Dark-Sky Association.



CONSTRUCTION MANAGEMENT

Construction can have significant environmental impacts if not undertaken with care, especially when located near a body of water. Construction can impact air quality, noise levels, water quality, soil erosion and habitat depletion. Construction also generates a very large amount of refuse. The project will prepare a construction management plan to minimize the discharge of construction site pollutants and materials and protect receiving waters, air quality and public safety. Construction and demolition materials will de diverted from disposal whenever possible. For example, the removal of the viaduct, which will create vast amounts of materials bound for the landfill, including concrete, steel, and asphalt, can be considered for materials re-use. The materials generated by demolition could potentially be recycled and reused along the Waterfront for slope stabilization, revetments, riprap, pavement, and public art. In addition, rubble from the Viaduct could be used to fill the Battery Street Tunnel. A site maintenance plan will outline long-term strategies and identify short term actions to achieve sustainable maintenance goals. For example, the storage and collection of recyclables will be provided. Organic matter generated during site operations and maintenance will be composted and used.

OPERATIONS AND MANAGEMENT

Energy efficient outdoor fixtures and equipment will be selected to reduce energy consumption and costs associated with site use and operations.

MONITORING AND INNOVATION

Sustainable design practices can be monitored and documented to evaluate their performance over time and improve the body of knowledge on long term site sustainability. Innovative ideas will be taken into consideration and tested when deemed worth pursuing.

NATIVE VEGETATION COMMUNITIES

The design team also identified the main elements of a vegetation strategy for the waterfront. The development of this strategy will be done in coordination with the seawall team and include aquatic vegetation, riparian vegetation and upland vegetation in an effort to promote the exchange of matter and energy between these systems and provide micro-climatic differences from inland areas, important wildlife habitats and improvements in water quality.

HEMLOCK FERN FOREST

CONIFEROUS TREES

Abies grandis
Grand Fir

Pseudotsuga menziesii
Douglas Fir

Thuja plicata
Western Red Cedar

DECIDUOUS TREES

Acer macrophyllum
Big Leaf Maple

Acer circinatum
Vine Maple

Alnus rubra

FERNS + PERENNIALS

Gaultheria shallon
Salal

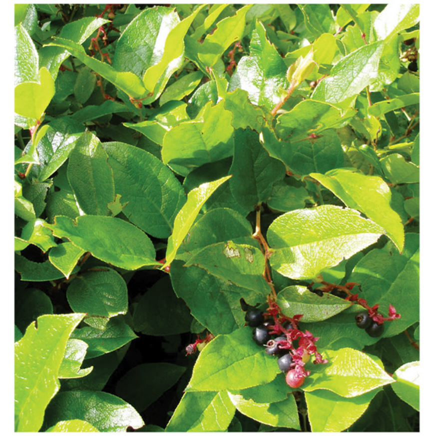
Mahonia aquifolium
Tall Oregan Grape

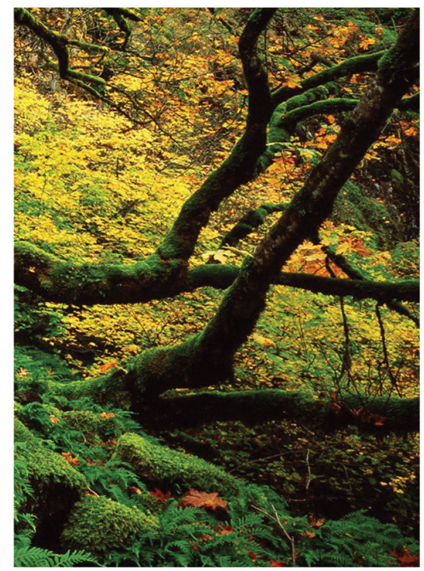
Mahonia nervosa
Low Oregan Grape

Polystichum munitum
Sword Fern

Rubrus ursinus
Trailing Blueberry

Vaccinium parvifolum
Red Huckleberry





GARRY OAK GROVE

TREES

Quercys garryana
Garry Oak
Vaccinium parvifolum
Red Huckleberry
Alnus rubra
Red Alder

GRASSES

Festuca idahoensis
Idaho Fescue

PERENNIALS

Dodecatheon hendersonii
Henderson's Shooting Star
Camassia quamash
Blue Camas
Viola nuttalli
Yellow Prairie Violet
Viola adunca
Western Long-Spurred Violet
Collinsia verna
Blue-eyed Mary
Balsamorhiza sagittata
Showy Yellow Balsam Root

SALTWATER WETLANDS

SALTWATER GRASSES

Triglochin maritimum
Seaside arrowgrass

Grindellia integrifolia
Gumweed

Plantago maritima
Seaside Plantain

Salicornia virginica
Pickleweed

PERENNIALS

Jaumea camosa
Fleshy jaumea

Lathyrus japonicus
Beach Pea

Lupinus littoralis
Shore Lupine

GRAVEL BEACH

TREES

Pinus contorta
Shore Pine

SHRUBS (gravel beach)

Amelanchier alnifolia
Serviceberry; Juneberry

Corylus cornuta var californica
Beaked Hazelnut

Gaultheria shallon
Salal

Holodiscus discolor
Oceanspray

GRASSES

Atriplex patula
Saltweed

Deschampsia cespitosa
Tufted Hairgrass

Distichlis spicata
Saltgrass

Elymus mollis
Dune Wildrye

PERENNIALS

Jaumea camosa
Fleshy jaumea

Lathyrus japonicus
Beach Pea

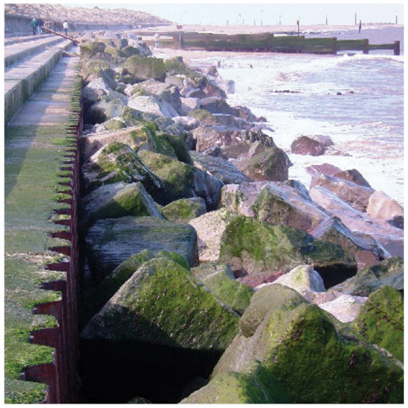
Lupinus littoralis
Shore Lupine

GROUNDCOVERS

Armeria maritima
Thrift; Sea Pink

Aster subspicatus
Douglas Aster

Potentilla anserina var. pacifica
Silver Weed

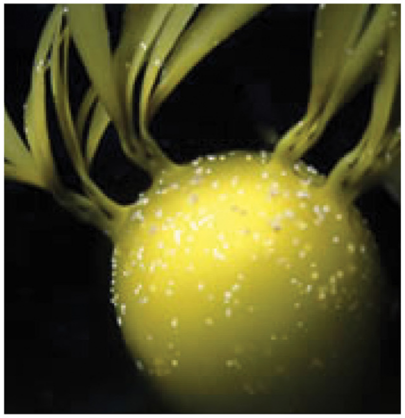


KELP BEDS

GRASS + KELP

Zostera marina
Eelgrass

Nereocystis luetkeana
Bull Kelp



NOTABLE PLANT SPECIES

The greening of the waterfront will require extensive planting. The team has assembled planting lists for species that could be used on the waterfront. The planting will be coordinated with the City of Seattle Urban Forest Management Plan, which aims to restore the declining urban forest in Seattle and develop long term management plans for Seattle's trees. Plantings along the waterfront will favor native species as well as mixtures of species that promote habitat enhancement in the riparian zone and the upland areas. Connectivity between planted areas will be promoted as much as possible so that a system of habitats is created along the waterfront and connects north to the more natural Elliott Bay trail. Parks such as Elliott Bay Park, Olympic Sculpture Park, Denny Park, Bell Street Park, Westlake Park, Yesler Way Triangle, Occidental Park, and Waterfall Garden as well as major Community gardens such as the Belltown P-Patch and the Danny Woo Community Garden on Main Street, will be integrated into the green open space system of the project.

The waterfront will demonstrate its commitment to natural systems, including how we can better manage water and make that visible in the process. The management of stormwater runoff will also be coordinated with the Seattle Public Utilities.

TREES

Pseudotsuga menziesii

Douglas Fir

height: 60' to 80'
spread: 15' to 20'
light: full sun
characteristics: color varies from blue-green to gray-green; evergreen
bloom: no ornamental value
origin: western North America
soil: moist, well drained soil is preferred

Thuja plicata

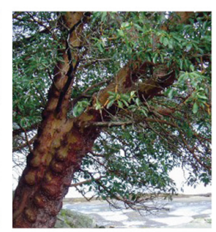
Western Red Cedar

height: 50' to 70'
spread: 15' to 25'
light: full sun
characteristics: glossy dark-green color, older specimens have distinctive red bark; evergreen
bloom: no ornamental value
origin: western North America
soil: somewhat moist soil is preferred

Arbutus menziesii

Pacific Madrone

height: 20' to 12
spread: 15' to 25'
light: full sun
characteristics: glossy dark-green color with white summer blooms and a red, pea-sized fruit; the bark exfoliates with a distinctive red color. a dwarf cultivar, Arubutus 'Marina' is available
bloom: April to June
origin: western North America
soil: well drained, low moisture content is preferred



Quercus garryana

Garry Oak

height: 40' to 80'
spread: 30' to 50'
light: full sun to part shade
characteristics: glossy dark-green color with an acorn fruit; yellow fall color
bloom: no ornamental value
origin: north-western North America
soil: somewhat moist soil is preferred

DRY — MOIST

HEMLOCK FOREST — GARRY OAK GROVE

Alnus rubra

Red Alder

height: 40' to 80'
spread: 30' to 50'
light: full sun to part shade
characteristics: glossy dark-green color with an acorn fruit; yellow fall color
bloom: no ornamental value
origin: western North America
soil: somewhat moist soil is preferred

Fraxinus latifolia

Oregon Ash

height: 30' to 50'
spread: 20' to 40'
light: full sun to part shade
characteristics: green to light-green leaves, turning yellow to brown in the fall
bloom: no ornamental value
origin: western North America
soil: loose, moist soil are preferred

Salix lasiandra

Pacific Willow

height: 20' to 30'
spread: 20' to 30'
light: full sun to part shade
characteristics: green leaves, turning slightly red with sun; the cattails bloom yellow in the spring
bloom: spring
origin: western North America
soil: moist soil are preferred

Salix hookeriana

Coast Willow

height: 10' to 20'
spread: 10' to 15'
light: full sun to part shade
characteristics: green, leathery leave with a hairy to wooly texture and shiney upper surfaces
bloom: spring
origin: western North America
soil: adaptable to moist and dry soils

MOIST — WET

BEACH STRAND/DUNES — SALTWATER WETLANDS

SALT-TOLERANT TREES

Pinus contorta

Shore Pine

height: 30' to 50'
spread: 15' to 20'
light: full sun to part shade
characteristics: dark in color, both in leaf color and bark; does not take pruning as well as other pines, but does serve as a good screen; salt tolerant; evergreen
bloom : no ornamental value
origin: western North America
soil: adaptable to moist and dry soils

Magnolia grandiflora

Southern Magnolia

height: 50' to 70
spread: 15' to 25
light: full sun
characteristics: glossy dark-green color with large, fragrant, white flowers; salt tolerant
bloom: spring
origin: North America
soil: drier soil is preferred

Ilex aquifolium

English Holly

height: 20' to 40'
spread: 10' to 25'
light: full sun to part shade
characteristics: glossy green color with a red, yellow or orange, pea-sized fruit; salt tolerant; evergreen
bloom: no ornamental value from bloom, fruit
to persist through winter
origin: British Isles and Central Europe
soil: well drained soil is preferred

Quercus virginiana

Live Oak

height: 40' to 80'
spread: 30' to 50'
light: full sun to part shade
characteristics: glossy dark-green color; salt tolerant; evergreen
bloom: no ornamental value
origin: North America
soil: somewhat moist soil is preferred

UNDERSTORY

Gaultheria shallon
Salal

Polystichum munitum
Sword Fern

Mahonia nervosa
Tall Oregan Grape

Rubrus ursinus
Trailing Blackberry

Vaccinium parvifolum
Red Huckleberry

Collinsia verna
Blue-eyed Mary

Viola nuttallii
Yellow Prairie Violet

Festuca idahoensis
Idaho fescue

Dodecatheon hendersonii
Henderson's Shooting Star

DRY — MOIST

HEMLOCK FOREST — GARRY OAK GROVE

Distichlis spicata	*Elymus mollis*	*Deschampsia cespitosa*	*Atriplex patula*	*Armeria maritima*	*Aster subspicatus*	*Jaumea carnosa*	*Lathyrus japonicus*	*Lupinus littoralis*
Saltgrass	**Dune Wildrye**	**Tufted Hairgrass**	**Wild Orache**	**Sea Pink**	**Douglas Aster**	**Fleshy jaumea**	**Beach Pea**	**Shore Lupine**

MOIST — WET

BEACH STRAND/DUNES — SALTWATER WETLANDS

COMMON SHORELINE PLANTING

State of Washington Department of Ecology

TREES

COMMON NAME	BOTANICAL NAME	NATIVE/ NON-NATIVE	DECIDUOUS/ EVERGREEN	MATURE HEIGHT (ft)
Oregon White Oak	*Quercus garryana*	Native	Deciduous	60
Grand Fir	*Abies grandis*	Native	Evergreen/ Conifer	200+
Douglas Fir	*Pseudotsuga menziesii*	Native	Evergreen/ Conifer	200+
Bigleaf Maple	*Acer macrophyllum*	Native	Deciduous	60
Red Alder	*Alnus rubra*	Native	Deciduous	50-100
Bitter Cherry	*Prunus emarginata*	Native	Deciduous	50
Western Hemlock	*Tsuga heterophylla*	Native	Evergreen/ Conifer	150
Sitka Spruce	*Picea sitchensis*	Native	Evergreen/ Conifer	100+
Western Red Cedar	*Thuja plicata*	Native	Evergreen/ Conifer	100+
Pacific Madrone	*Arbutus menziesii*	Native	Evergreen/ Broad-leaved	70+
Pacific Yew	*Taxus brevifolia*	Native	Evergreen/ Conifer	30+
Willow	*Salix spp.*	Native	Deciduous	50+

COMMON NAME	BOTANICAL NAME	NATIVE/ NON-NATIVE	DECIDUOUS/ EVERGREEN	MATURE HEIGHT (ft)
Trailing Blackberry	*Rubus ursinus*	Native	Semi-deciduous	Vine
*Himalaya Blackberry	*Rubus discolor*	Non	Semi-Evergreen	Vine-cane
Vine Maple	*Acer circinatum*	Native	Deciduous	10+
Ocean-spray	*Holodiscus discolor*	Native	Deciduous	10+
*Scot's Broom	*Cytisus scoparius*	Non	Deciduous	To 8
Willow	*Salix spp.*	Native	Deciduous	10+
Snowberry	*Symphori-carposalbus*	Native	Deciduous	3+
Rose	*Rosa spp.*	Native	Deciduous	2-10
Elderberry	*Sambucus spp.*	Native	Deciduous	To 15
Salmonberry	*Rubus spectabilis*	Native	Deciduous	To 12
Salal	*Gaultheria shallon*	Native	Evergreen	To 4
Oregon Grape	*Mahonia spp.*	Native	Evergreen	To 6

HERBACEOUS

COMMON NAME	BOTANICAL NAME	NATIVE/ NON-NATIVE	DECIDUOUS/ EVERGREEN
Sword Fern	*Polystichum munitum*	Native	Evergreen
English Ivy	*Hedra helix*	Non	Evergreen
Honeysuckle	*Lonicera spp.*	Native	Deciduous
Nettle	*Urtica spp.*	Native	Deciduous
Foxglove	*igitalis purpurea*	Non	Deciduous
Perennial pea	*Lathyrus spp.*	Non	Deciduous
Bracken Fern	*Pteridium aquilimum*	Native	Deciduous
*Horsetail	*Equisetum spp.*	Mostly non	Deciduous
*Grasses	*Various*	Mostly non	Evergreen

PACIFIC NORTHWEST TREES

Washington State University Master Gardeners

WET WINTER/DRY SUMMER TREES

COMMON NAME	BOTANICAL NAME
Vine Maple	*Acer circinatum*
Chinese Red Birch	*Betula albosinensis var.septentrionalis*
River Birch	*Betula nigra*
Himalayan White Birch	*Betula utilis var. jacquemontii*
English Hawthorn	*Crataegus laevigata*
American Sweet Gum	*Liquidambar styraciflua*
Dawn Redwood	*Metasequoia glyptostroboides*
Shore Pine	*Pinus contorta var. contorta*
Pin Oak	*Quercus palustris*

MOISTURE-LOVING TREES

COMMON NAME	BOTANICAL NAME
Vine Maple	*Amelanchier canadensis*
Chinese Red Birch	*Betula albosinensis var. septentrionalis*
River Birch	*Betula nigra*
Himalayan White Birch	*Betula utilis var. jacquemontii*
American Sweet Gum	*Liquidambar styraciflua*
Dawn Redwood	*Metasequoia glyptostroboides*
Chinese Tupelo	*Nyssa sinensis*
Black Gum	*Nyssa sylvatica*
Bald Cypress	*Taxodium distichum*

FAVORITE PACIFIC NORTHWEST NATIVE TREES

COMMON NAME	BOTANICAL NAME
Grand Fir	*Abies grandis*
Noble Fir	*Abies procera*
Vine Maple	*Acer circinatum*
Incense Cedar	*Calocedrus decurrens*
Weeping Yellow Cedar	*Chamaecyparis nootkatensis*
Pacific Crabapple	*Malus fusca*
Shore Pine	*Pinus contorta var. contorta*
Garry Oak	*Quercus garryana*
Mountain Hemlock	*Tsuga mertensiana*

STORMWATER + GREEN STORMWATER INFRASTRUCTURE

DRAFT

WATERFRONTSEATTLE
STORMWATER BASIS OF DESIGN

SECTION 1.0 - PROJECT OVERVIEW

1.1 PURPOSE

The stormwater scope of work for Phase 1B is limited to the preparation of a stormwater basis of design. The stormwater basis of design will assist in the development of the urban design and provide guidance for the estimate of probable construction cost. The basis of design document will outline the general stormwater management approach for the project.

All flow control and treatment facilities will be designed in accordance with the City of Seattle November 2009 Stormwater Manual, Volume 3 – Stormwater Flow Control and Water Quality Treatment Technical Requirements Manual (hereafter referred to as the Technical Requirements Manual).

1.2 DEFINITIONS

Per Appendix A of the City of Seattle November 2009 Stormwater Manual, Volume 3 – Stormwater Flow Control and Water Quality Treatment Technical Requirements Manual (hereafter referred to as the Technical Requirements Manual), the following definitions apply to this project:

Capacity-Constrained System - A capacity-constrained system is a drainage system that the Director of SPU has determined to have inadequate capacity to carry drainage water.

Designated Receiving Water. This means the Duwamish River, Puget Sound, Lake Washington, Lake Union, Elliott Bay, Portage Bay, Union Bay, the Lake Washington Ship Canal, and other receiving waters determined by the Director of SPU and approved by Ecology as having sufficient capacity to receive discharges of drainage water such that a site discharging to the designated receiving water is not required to implement flow control (SMC 22.801.050). Note also that capacity constraints in any drainage system can modify the flow control requirements for discharges.

Impervious Surface - Any surface exposed to rainwater from which most water runs off. Common impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, formal planters, parking lots or storage areas, concrete or asphalt paving, permeable paving, gravel surfaces subject to vehicular traffic, compact gravel, packed earthen materials, and oiled macadam or other surfaces which similarly impede the natural infiltration of stormwater. Open, uncovered retention/detention facilities shall not be considered as impervious surfaces for the purposes of determining whether the thresholds for application of minimum requirements are exceeded. Open, uncovered retention/detention facilities shall be considered impervious surfaces for purposes of stormwater modeling.

Maximum extent feasible (MEF) - Maximum extent feasible means that the requirement is to be fully implemented, constrained only by the physical limitations of the site, practical considerations of engineering design, and reasonable considerations of financial costs and environmental impacts.

1

Central Waterfront, Phase 1B
April 26, 2012

DRAFT

Pollution-generating Impervious Surface (PGIS) Those impervious surfaces considered to be a significant source of pollutants in drainage water. Such surfaces include those that are subject to: vehicular use; certain industrial activities; or storage of erodible or leachable materials, wastes, or chemicals, and which receive direct rainfall or the run-on or blow-in of rainfall. Erodible or leachable materials, wastes, or chemicals are those substances which, when exposed to rainfall, measurably alter the physical or chemical characteristics of the drainage water. Examples include: erodible soils that are stockpiled; uncovered process wastes; manure; fertilizers; oily substances; ashes; kiln dust; and garbage dumpster leakage. Metal roofs are also considered to be PGIS unless they are coated with an inert, non-leachable material (e.g., baked-on enamel coating).

A surface, whether paved or not, shall be considered subject to vehicular use if it is regularly used by motor vehicles. The following are considered regularly-used surfaces: roads; unvegetated road shoulders; permeable pavement; bike lanes within the traveled land of a roadway; driveways; parking lots; unfenced fire lanes; vehicular equipment storage yards; and airport runways.

The following are not considered regularly-used surfaces: paved bicycle pathways separated from and not subject to drainage from roads for motor vehicles; fenced fire lanes; and infrequently used maintenance access roads.

Pollution-generating Pervious Surface - Any non-impervious surface subject to use of pesticides and fertilizers or loss of soil, and typically includes lawns, landscaped areas, golf courses, parks, cemeteries, and sports fields.

Public Combined Sewer (PS) - A publicly owned and maintained system which carries drainage water and wastewater and flows to a publicly owned treatment works.

Public Storm Drain (PSD) - The part of a public drainage system that is wholly or partially piped, owned or operated by a City agency, and designed to carry only drainage water.

Replaced Impervious Surface - For structures, the removal and replacement of impervious surface down to the foundation. For other impervious surface, the impervious surface that is removed down to earth material and a new impervious surface is installed.

SECTION 2 – MINIMUM REQUIREMENTS DETERMINATION

2.1 EXISTING DRAINAGE SYSTEM

The project lies primarily within PSD basins, but significant portions of the project will also fall within PS basins. Background information, including drainage basin delineations are included in Appendix A.

The existing drainage basin limits are shown on Figures A1 and A2. Also included in the figures are the combined sewer and drainage basin outfalls within the general limits of the project. Table A1 is a spreadsheet listing the various outfalls within the project and existing known information about these outfalls.

2

Central Waterfront, Phase 1B
April 26, 2012

Figure A3 is a schematic of the CSO outfalls in the downtown area. Table A2 taken from the SR 99 CSO and Stormwater Outfall Basis of Design Report indicates additional information regarding the major outfalls within the project limits. The following pages in Appendix A are of photos taken of some of the major outfalls within the project limits.

2.2 DISTURBED AREAS

The project exceeds the following requirement triggers for the PS and PSD systems:

- Greater than 10,000 square feet (SF) of replaced impervious surface
- Greater than 5,000 SF of replaced PGIS

Below are approximate drainage area totals for the project broken out by storm drainage basin type.

	PSD BASINS NEW+REPLACED PGIS	PS Basins NEW+REPLACED IMPERVIOUS
SF	308,489	331,000
Acres	**7.1**	**7.6**

PSD basin areas include first flush areas. These areas will likely be converted over to PSD discharges and require WQ treatment.

2.3 MINIMUM REQUIREMENTS DETERMINATION

The Technical Requirements Manual was used to determine the probable flow control and water quality treatment requirements for the project. Included in Appendix B are flow charts used to determine the likely project flow control and treatment requirements. The following summarizes the requirements in the PSD and PS basins:

PSD Basins

- Flow Control Requirement #1 (FC#1) – Implement Green Stormwater Infrastructure (MEF)
- Water Quality Treatment Requirement #1 (WQ#1) – Basic Treatment

PS Basins

- Flow Control Requirement #1 (FC#1) – Implement Green Stormwater Infrastructure (MEF)
- Flow Control Requirement #5 (FC#5) – Peak Flow Control

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SECTION 3.0 – GREEN STORMWATER INFRASTRUCTURE (GSI)

GSI best management practices (BMPs) include facilities that utilize infiltration, dispersion, and/or detention. Per Table 4.1, the following are GSI categories that meet the FC and WQ requirements. The intent of the project is to provide GSI to the MEF.

Table 4.1 Types of Green Stormwater Infrastructure for Flow Control.

Flow Control	Water Quality Treatment
Trees Planting and Retention	Bio-retention
Bio-retention	Permeable Pavement
Permeable Pavement	
Water Harvesting	
Green Roofs	
Dispersion	

Note that while some of the green stormwater infrastructure BMPs can be used for both flow control and water quality treatment purposes, their most common applications is for flow control

SECTION 4.0 – FLOW CONTROL

FC#1 is required for the entire project with FC#5 required for those portions of the project that fall within the PS system.

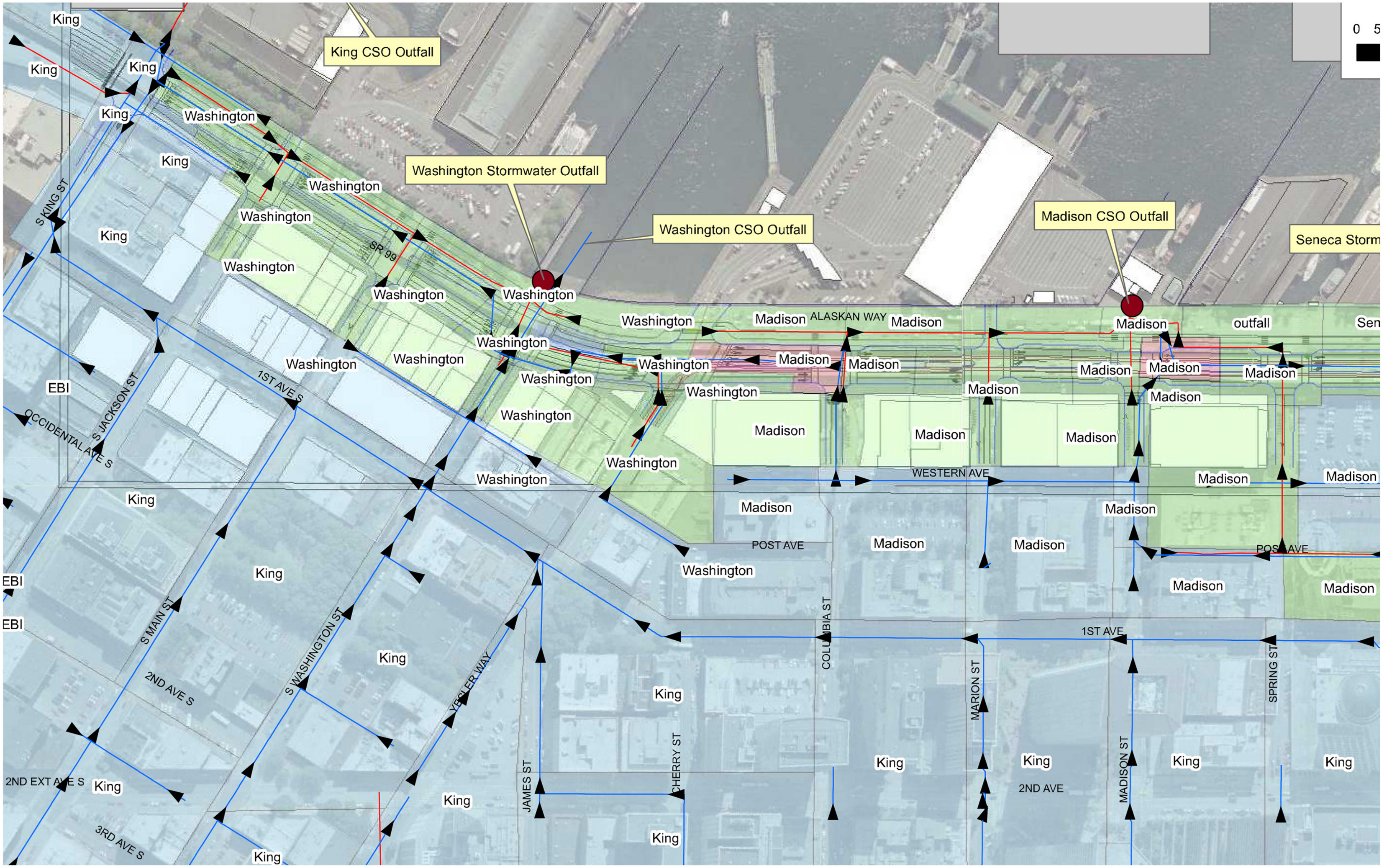
For planning level flow control sizing, approximately 4,500 cubic feet of storage/detention is required per acre of new and replaced impervious surface for projects subject to FC #5. This estimate is based on a recent SDOT drainage design project. Using this sizing estimate and the 7.6 acres of new and replaced surface, the project will require approximately 35,000 cubic feet of detention if all of the flow control requirements were met through detention.

SECTION 5.0 - -WATER QUALITY TREATMENT

WQ#1 – Basic Treatment is required for the project within the PSD basins. The intent is to use GSI to meet this requirement, but due to the urban and high use nature of the project area, it is likely that below grade or proprietary treatment systems will also be required. Some proprietary systems use bioretention as a mechanism for treatment but are not considered a GSI BMP by the City of Seattle.

For planning level water quality treatment sizing, approximate 40 four foot by four foot Filterra units would be required to treat all of the PGIS in the PSD basins. This is based on 10,000 square feet of treatment capacity per unit with another 10 units included because not all of these will be able to be located where they can treat the maximum effective area.

EXISTING DRAINAGE SYSTEM



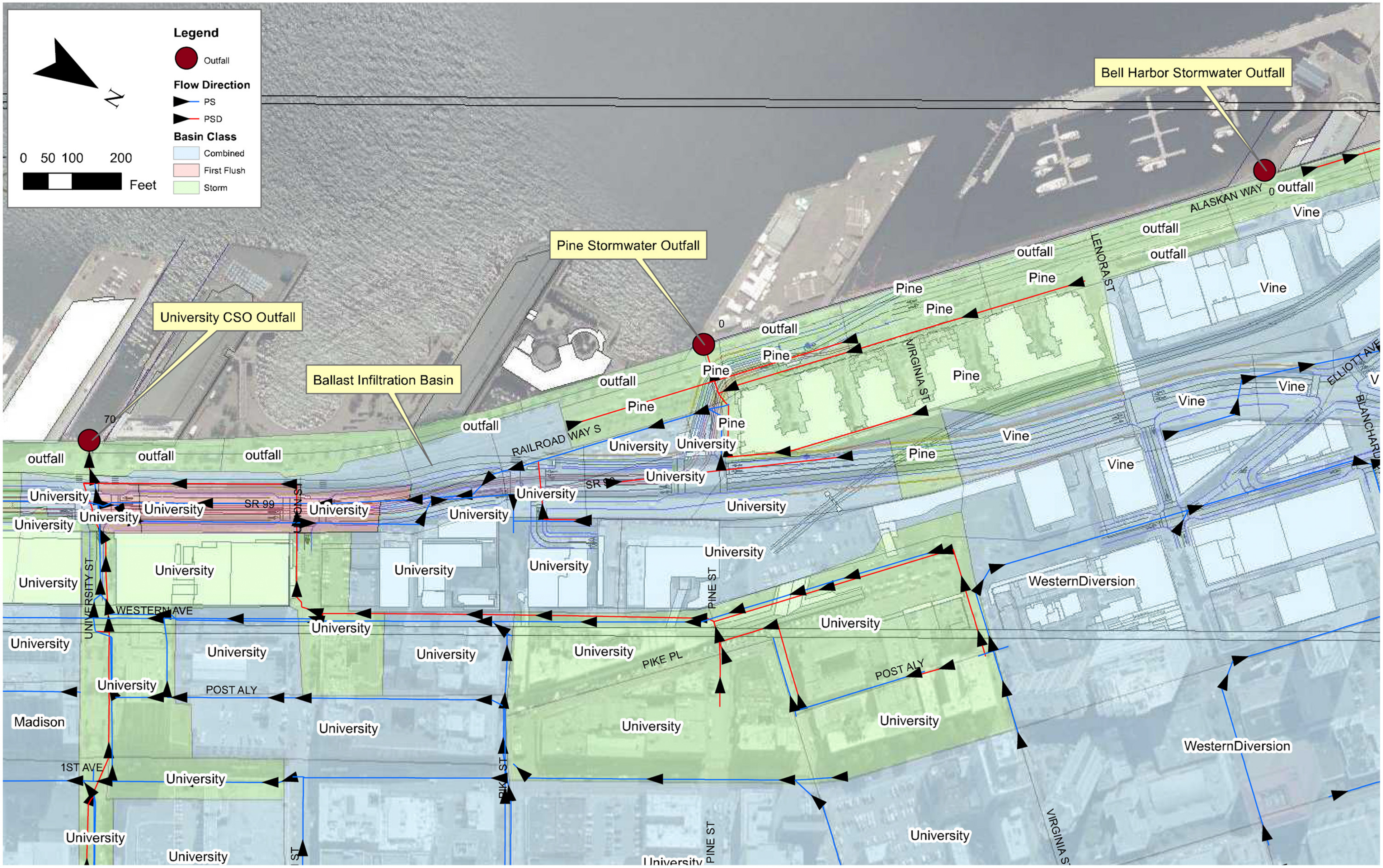
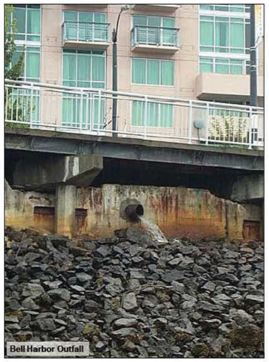

Legend
Outfall
Flow Direction
PS
PSD
Basin Class
Combined
First Flush
Storm
0 50 100 200
Feet
N
University CSO Outfall
Ballast Infiltration Basin
Pine Stormwater Outfall
Bell Harbor Stormwater Outfall
ALASKAN WAY
RAILROAD WAY S
SR 99
WESTERN AVE
POST ALY
PIKE PL
1ST AVE
UNIVERSITY ST
UNION ST
PIKE ST
PINE ST
VIRGINIA ST
LENORA ST
ELLIOTT AVE
BLANCHARD
outfall
University
Pine
Vine
Madison
WesternDiversion

TABLE A1 - EXISTING OUTFALL / PENETRATION RECORD DATA

EBSP Index No.	Existing Ref. No. / Source	EBSP Dwg No.	Survey Number	Identified In GHD Figure	Seawall Station and Offset (New or Old?)	Service(1)	Outfall Diameter	Location – Subbasin/ Outfall	Outfall Pipe Material(2)	Approx. Pipe OD	Slope to Wall	Seawall(3) Penetration IE	Approx. Top of Pipe at Ex. Seawall	Slope of Outfall	Length from Ex. Seawall	Outfall(3) IE	Owner	Habitat Bench Detail	Notes
			111350	x		SW	6" assumed	Broad St											
			111338	x		SW	6" assumed	Broad St											
			111336	x		SW	6" assumed	Broad St											
			111312	x		SW	6" assumed	Clay St											
			111272	x		SW	6" assumed	Clay St											
			111273	x		SW	6" assumed	Clay St											
			111285	x		SW	6" assumed	Cedar St											
			111286	x		SW	6" assumed	Cedar St											
			111426	x		SW?	6" assumed	Cedar St											
	NPDES 69			x		CSO	24"	Vine	CIP		0.20%	4.4		0		-6.8	City		Seawall penetration is 48" before drop structure
			111215	x		SW	6" Assumed	Vine St											
			111221	x		SW	6" Assumed	Vine St											
			111222	x		SW	6" Assumed	Vine St											
			14526	x		SW	6" Assumed	Wall St											
			14527	x		SW	6" Assumed	Wall St											
			14528	x		SW	6" Assumed	Wall St											
			14529	x		SW	6" Assumed	Wall St											
			14533	x		SW	12"	Battery St											
			14533	x		SW	8"	Bell St											
			14398	x		SW		Bell Harbor	DIP								City		
			14381	no		SW	6"	Blanchard St											
			14380	x		SW	8"	Blanchard St											
			110135	no		SW	6"	Blanchard St											
			110134	x		SW	6"	Blanchard St											
			110103	x		SW	6"	Lenora St											
			110102	x		SW	6"	Lenora St											
			110101	x		SW	8"	Lenora St											
			110100	x		SW	6"	Lenora St											
			110099	x		SW	6"	Virginia St											
			110098	x		SW	6"	Virginia St											
			110097	x		SW	6"	Virginia St											
			110096	x		SW	6"	Virginia St											
			110093	x		SW	16"	Pine	DIP		3.60%	7.7		NA		NA	City		Ends at seawall. Not along tunnel construction alignment
			110038	x		SW	6"	Pine St											
			110037	x		SW	6"	Pine St											
			110036	x		SW	6"	Pine St											
			110035	x		SW	6"	Pine St											
			110034	x		SW	6"	Pine St											
			110027	x		SW	6"	Pike St											
			110026	x		SW	6"	Pike St											
			110028	x		SW	8"	Pike St											
			110029	x		SW	6"	Pike St											
			110032	no		SW	6"	Pike St											
			110030	x		SW	6"	Pike St											
			110031	x		SW	6"	Union St											
			29194	x		SW	6"	Union St											
			29189	x		SW	6"	Union St											
			29179	x		SW	6"	Union St											
			?			SW/Water Softening Regenerate	6"	Seattle Steam Company	Carbon Steel								Seattle Steam Company		Located beneath Pier 57
	NPDES 70			x		CSO/SW	24"?	University	CIP		0.15%	4.2		NA		-16.8	City		Seawall penetration is 49"
			29163	no		SW	8"	University St											
			29166	x		SW	8"	University St											
			29148	x															
			29184	no		SW	8"	University St											
			29203	x		SW	10"	Seneca	DIP					NA		5.6	City		Ends at seawall
			29212	x		SW	6"	Seneca St											
			151616	x		SW	6"	Spring St											
			151621	x		SW	6"	Spring St											
	NPDES 71			x		CSO/SW	60"	Madison	Conc		3.50%	-2.3		NA		Not found	City		Ends at seawall
	NPDES 72			x		CSO	24"	Washington 24"	CIP		0.90%	3		10.50%		-18.8	City		Ends 157' beyond seawall
				x		SW	72"	Washington 72"	Conc		2.60%	-2.3		NA		-2.3	City		Ends at seawall
	NPDES 28			x		CSO	48"	King	Conc		0.46%	6.6?		11.70%		-7.4	City(4)		Ends under Terminal 46
				no		CSO/SW	84" (box culvert)	Connecticut	Conc		0.30%	-1.3		2.05%		-11.1	City(4)		Ends under Terminal 37
				no		SW	12"	Massachusetts	CIP		0.39%	5.8		10%		NA	City		South of tunnel and seawall

Bell Harbor Outfall and Vine CSO Outfall Photos



SR 99: Alaskan Way Viaduct & Seawall Replacement Project
CSO and Stormwater Outfall Basis of Design
April 2007

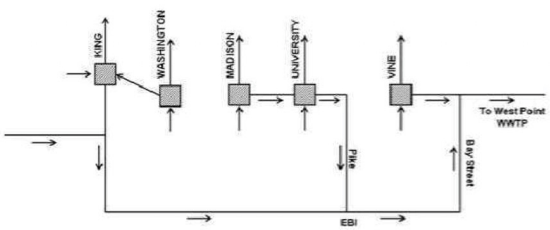
King Street and Washington Street Outfall Photos

SR 99: Alaskan Way Viaduct & Seawall Replacement Project
CSO and Stormwater Outfall Basis of Design
April 2007

Madison, University, and Seneca Streets Outfall Photos

SR 99: Alaskan Way Viaduct & Seawall Replacement Project
CSO and Stormwater Outfall Basis of Design
April 2007

Figure 10 Downtown Seattle Combined Sewer System Flow Schematic



EXISTING SYSTEM

FIGURE A3

SR 99: Alaskan Way Viaduct & Seawall Replacement Project
CSO and Stormwater Outfall Basis of Design
April 2007
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Table 1 Existing Outfall Record Data

Location – Subbasin/ Outfall	Owner	Service(1)	Outfall Pipe Material(2)	Outfall Diameter	Slope to Wall	Seawall(3) Penetration IE	Slope of Outfall	Outfall(3) IE	Notes
Massachusetts	City	SW	CIP	12"	0.39%	5.8	10%	NA	South of tunnel and seawall
Connecticut	City(4)	CSO/SW	Conc	84" (box culvert)	0.30%	-1.3	2.05%	-11.1	Ends under Terminal 37
King	City(4)	CSO	Conc	48"	0.46%	6.6?	11.70%	-7.4	Ends under Terminal 46
Washington 72"	City	SW	Conc	72"	2.60%	-2.3	NA	-2.3	Ends at seawall
Washington 24"	City	CSO	CIP	24"	0.90%	3	10.50%	-18.8	Ends 157' beyond seawall
Madison	City	CSO/SW	Conc	60"	3.50%	-2.3	NA	Not found	Ends at seawall
Seneca	City	SW	DIP	10"		5.6	NA	5.6	Ends at seawall
University	City	CSO/SW	CIP	24"	0.15%	4.2	NA	-16.8	Seawall penetration is 49" before drop structure
Seattle Steam Company	Seattle Steam Company	SW/Water Softening Regenerate	Carbon Steel	6"					Located beneath Pier 57
Pine	City	SW	DIP	16"	3.60%	7.7	NA	NA	Ends at seawall. Not along tunnel construction alignment
Bell Harbor	City	SW	DIP						
Vine	City	CSO	CIP	24"	0.20%	4.4	0	-6.8	Seawall penetration is 48" before drop structure

(1) CSO = Combined Sewer Overflow; SW = Stormwater

(2) CIP = Cast Iron Pipe, Conc = Concrete, DIP = Ductile Iron Pipe

(3) Project Datum = NAVD88; 0.00 NAVD88 = +2.5 feet MLLW

(4) The Connecticut Street Outfall and the King Street Outfall is owned by the City of Seattle according to the Comprehensive Outfall Agreement dated July 27, 1982. CSO flows through these outfalls are permitted by the King County NPDES permit.

MHHW 8.8'
MLLW -2.5'

TABLE A2

SR 99: Alaskan Way Viaduct & Seawall Replacement Project
CSO and Stormwater Outfall Basis of Design
April 2007
4

FLOW CONTROL + TREATMENT REQUIREMENT FLOW CHARTS

Volume 3 — Flow Control and Water Quality Treatment
Technical Requirements Manual
Chapter 2 – Minimum Requirements

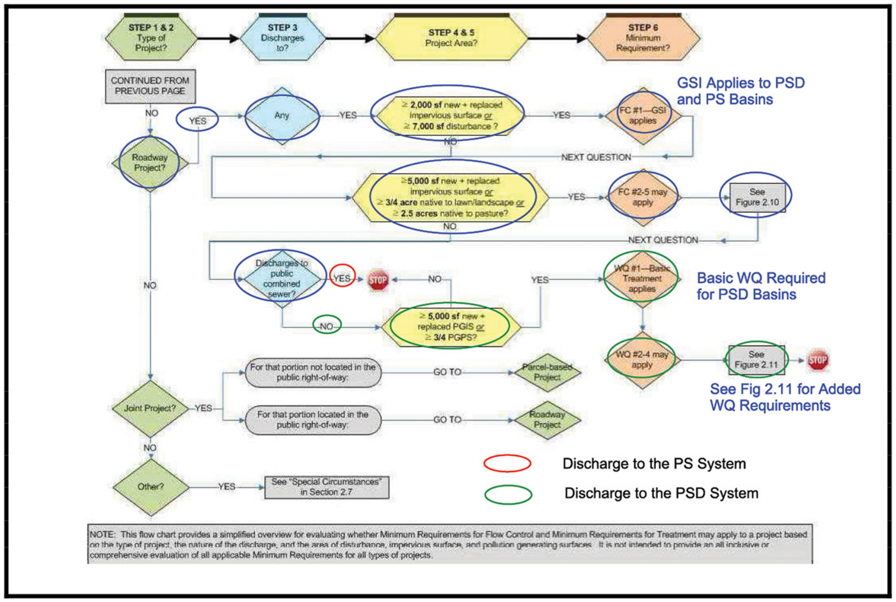


Figure 2.8 (continued). Minimum Requirement Determination Overview Flow Chart.

2-26 *November 2009*

Volume 3 — Flow Control and Water Quality Treatment
Technical Requirements Manual
Chapter 2 – Minimum Requirements

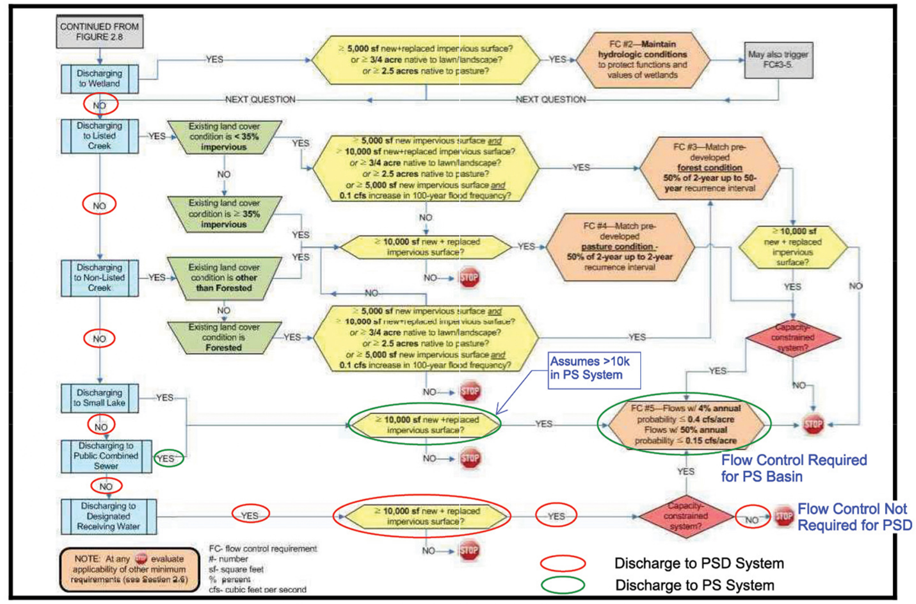


Figure 2.10. Applicability of FC#2-FC#5 to Roadway Projects.

2-28 *November 2009*

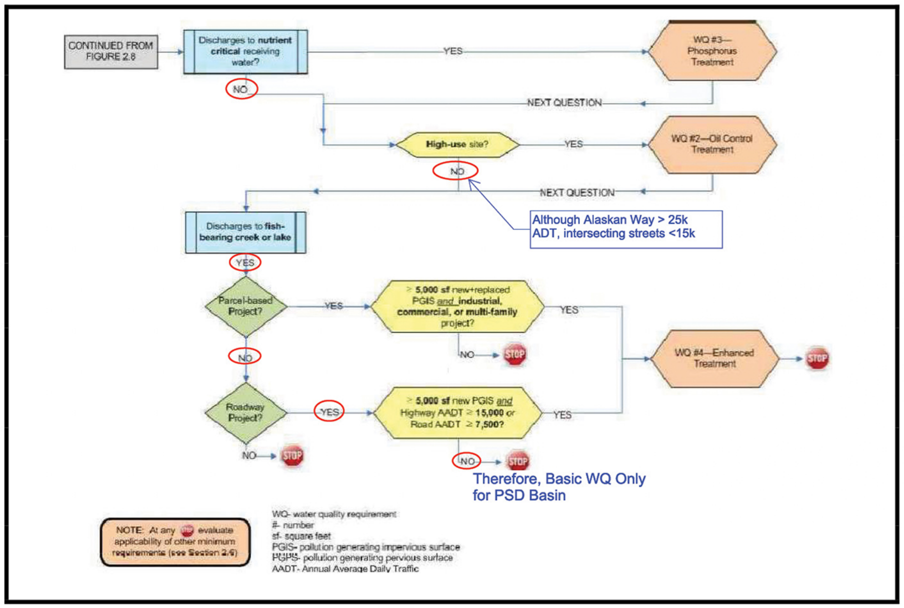


Figure 2.11. Applicability of WQ#2-WQ#4 to Parcel-Based and Roadway Projects.

TECHNICAL MEMORANDUM

waterfront Seattle

Central Waterfront Project –Draft Green Stormwater Infrastructure Framework

Concept Design Phase

PREPARED FOR:	Seattle Department of Transportation (SDOT)
COPY TO:	Central Waterfront Project File
PREPARED BY:	Brittany Hughes/PDX Matt Steiner/PDX Kasey Hurlbutt/PDX Dustin Atchison/SEA
DATE:	April 24, 2012

This memorandum presents the framework established to-date for identifying and communicating opportunities to incorporate Green Stormwater Infrastructure (GSI) into the Seattle Central Waterfront Project stormwater design. This framework is intended to enable the urban design team to consider contextually-appropriate GSI strategies during early planning phases that can be integrated into the fabric of the landscape and architectural design. There are four key, interrelated components to the framework. These tools allow the urban design team to characterize the conditions of the project area, identify types of practices that may be incorporated into the design, and select appropriate GSI practices. These four tools are designed to be used together; they are listed below and described in greater detail in the sections that follow:

- **GSI Maps:** These maps incorporate the urban design and existing conditions to develop classifications for the slopes and types of use within the project area.
- **GSI Matrix:** This tool can be used to determine applicable GSI practices for a given location based on the slope and use of the area and notes constraints that should be considered during design for the selected GSI practice.
- **GSI Descriptions:** These descriptions briefly describe the potential GSI practices with example applications and descriptions of constraints for their use.
- **GSI Cross-Sections:** These cross sections were developed to illustrate the integration of GSI practices into the urban design and to examine design challenges due to limited available grade in the project area.

Background

GSI includes stormwater best management practices (BMPs) designed to mimic natural processes and hydrology. GSI reduces runoff from development through evapotranspiration, dispersion, stormwater reuse, infiltration, and/or detention. Examples of GSI include permeable pavement, bioretention facilities, and green roofs. Successful and effective implementation of GSI BMPs requires close integration of the practices with the site context and urban design elements of a project. In addition, GSI practices present an opportunity to enhance the functionality of the urban design and landscape while providing opportunities for the public to visualize and interact with stormwater management features. The tools described in this memorandum have been designed to aid in identifying the appropriate GSI applications for incorporation into the urban design.

Basis of Design for Green Stormwater Infrastructure

Volume 3 of the City of Seattle's Stormwater Manual titled *Stormwater Flow Control and Water Quality Treatment Technical Requirements Manual* was used to determine GSI requirements for the project. The project lies

primarily within drainage basins that are serviced by storm sewers, but significant portions of the project also fall within drainage basins that drain to the combined sewer system. Generally, combined sewer basins require flow control, while storm sewer basins require both flow control and water quality treatment. GSI can be used to meet both flow control and water quality treatment requirements.

Per City of Seattle Stormwater Code (SMC 22.800-22.808), GSI is required to be used to the "maximum extent feasible (MEF)" to manage runoff from project impervious areas. MEF is defined as "the requirement is to be fully implemented, constrained only by the physical limitations of the site, practical considerations of engineering design, and reasonable considerations of financial costs and environmental impacts." Table 1 below, from the City of Seattle's *Stormwater Flow Control and Water Quality Treatment Technical Requirements Manual,* lists the GSI BMPs that meet flow control and water quality treatment requirements.

TABLE 1
GSI BMPs for Flow Control and Water Quality Treatment

Flow Control	Water Quality Treatment
Tree Planting and Retention	Bioretention
Bioretention	Permeable Pavement (where subsoils meet WQ treatment
Permeable Pavement	
Rainfall Harvesting	
Green Roofs	
Dispersion	

During the conceptual design phase, GSI BMPs that were examined for feasibility included new trees, bioretention planters, permeable pavement, rainwater harvesting, subsurface wetlands, enhanced tree pits, and biofiltration swales. It should be noted that subsurface wetlands and enhanced tree pits are not currently listed as approved GSI BMPs in the *Stormwater Flow Control and Water Quality Treatment Technical Requirements Manual.* However, these two BMPs were examined as they may be approved for use by the time the project begins final design. Silva cells (a primary component of enhanced tree pits) are approved for use by the Washington State Department of Ecology and the design requirements were developed based on conversations with the manufacturer. Design requirements for subsurface wetlands were determined based on published information from the *Georgia Stormwater Management Manual Volume 2 (Technical Handbook).*

GSI Maps

At this stage of design development, it is assumed that two primary factors (slope and urban design use) will drive constraints and applicability of various GSI practices within the Seattle Central Waterfront Project. Thus classifications of project area were created based on the urban design use and slopes. Slope classifications include mild, medium, and steep; urban design uses classifications include open space, parking, roof, and bike and pedestrian use. Two sets of maps that display the classifications of the project area were created to enable designers to quickly characterize locations within the project area (see Attachment 1). The first set of maps highlights the core project elements (elements that will be included in the project) and framework project elements (elements that may be included in the project).Once the location is characterized, the designer can use the additional tools described below to determine an appropriate GSI BMP for the project area.

GSI Matrix

Once the location has been characterized based on slope and land use, the GSI Matrix can be used to determine which GSI practices would be most feasible (see Attachment 2). The matrix identifies appropriate GSI practices for given slope and land use classifications and is designed to be used with the GSI Mpas.

Slope. Slopes are important in defining which GSI practices can be used in the project area. Required slopes vary for GSI practices that rely on vertical filtration through media or horizontal flow through vegetation. For purposes of the GSI mapping and matrix development, slope categories were determined as follows:

- Mild: 0 – 2%
- Medium: 2 – 6%
- Steep: >6%

Land Use. The land use at the location in which a GSI practice will be located also needs to be considered. For example, GSI practices that are applicable for use in open spaces may differ from the GSI practices that are available for use near the roadway (as pollutants and space requirements will vary). Also, it is anticipated that the project location is not suitable for infiltration due to the presence of subsurface structures, low-permeability soils, liquefaction concerns, the extensive amount of underground utilities and additional other conditions which do not favor infiltration.

For ease, areas on the mapping have been categorized by slope and planned urban design use. Once these have been determined, the matrix can be used to screen and identify acceptable GSI practices for the given area in the project. For each of the urban design uses, a brief summary of constraints (such as weight limitations, lining, safety needs, etc.) is included in the matrix.

GSI Descriptions

The GSI practices applicable to the Seattle Central Waterfront Project are briefly summarized along with their benefits, applications, variations, constraints, and design features. The intent of these brief descriptions is to provide the designers with ideas about how a particular GSI BMP can be incorporated into the urban design. Table 2 lists the GSI BMPs that have been identified for the project and includes a brief description of each. For the GSI BMP Descriptions, see Attachment 3.

TABLE 2
GSI BMP Descriptions

GSI BMP	Description
New Trees	Newly planted trees absorb rain through their leaf system and roots, and allow space for infiltration.
Bioretention Planters	Flat-bottomed, landscaped basins containing an amended soil mix and native plants within an impervious structure (preventing infiltration into surrounding, native soil).
Permeable Pavement	Paving system that contains empty spaces which allow rainfall to percolate into underlying soil.
Rainwater Harvesting	The capture and storage of roof runoff (stored in a cistern, rain barrel, etc.) for reuse such as irrigation.
Subsurface Wetlands	Basins (typically impervious) filled with a porous media (usually gravel or aggregate) that allow stormwater runoff to flow below the ground surface through the root zone and support wetland plant life by keeping the porous media submerged.
Enhanced Tree Pits	A modular suspended pavement system for containing lightly compacted soil underneath paved surfaces for large tree growth and on-site stormwater maintenance.
Biofiltration Swales	Open, gently sloped, vegetated channels designed to treat stormwater.

SECTION 3.0 – GREEN STORMWATER INFRASTRUCTURE (GSI)

GSI best management practices (BMPs) include facilities that utilize infiltration, dispersion, and/or detention. Per Table 4.1, the following are GSI categories that meet the FC and WQ requirements. The intent of the project is to provide GSI to the MEF.

Table 4.1 Types of Green Stormwater Infrastructure for Flow Control.

Flow Control	Water Quality Treatment
Trees Planting and Retention	Bio-retention
Bio-retention	Permeable Pavement
Permeable Pavement	
Water Harvesting	
Green Roofs	
Dispersion	

Note that while some of the green stormwater infrastructure BMPs can be used for both flow control and water quality treatment purposes, their most common applications is for flow control

SECTION 4.0 – FLOW CONTROL

FC#1 is required for the entire project with FC#5 required for those portions of the project that fall within the PS system.

For planning level flow control sizing, approximately 4,500 cubic feet of storage/detention is required per acre of new and replaced impervious surface for projects subject to FC #5. This estimate is based on a recent SDOT drainage design project. Using this sizing estimate and the 7.6 acres of new and replaced surface, the project will require approximately 35,000 cubic feet of detention if all of the flow control requirements were met through detention.

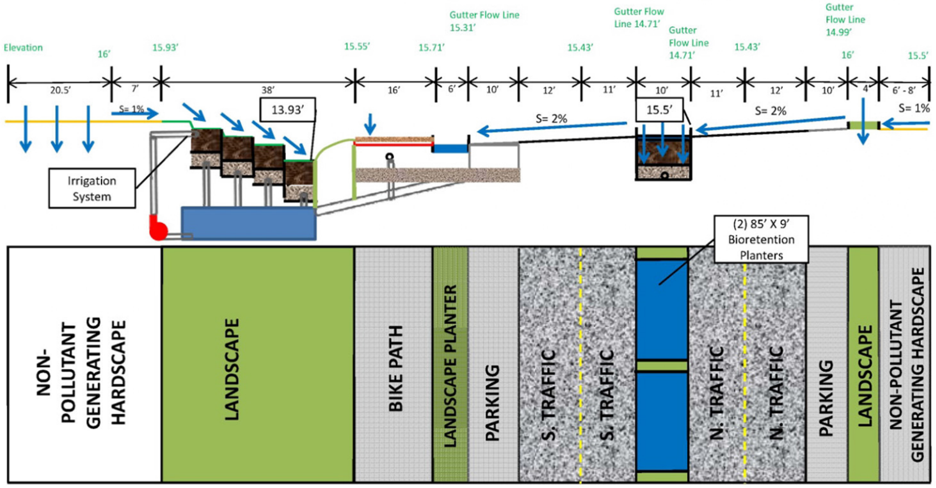
SECTION 5.0 - -WATER QUALITY TREATMENT

WQ#1 – Basic Treatment is required for the project within the PSD basins. The intent is to use GSI to meet this requirement, but due to the urban and high use nature of the project area, it is likely that below grade or proprietary treatment systems will also be required. Some proprietary systems use bioretention as a mechanism for treatment but are not considered a GSI BMP by the City of Seattle.

For planning level water quality treatment sizing, approximate 40 four foot by four foot Filterra units would be required to treat all of the PGIS in the PSD basins. This is based on 10,000 square feet of treatment capacity per unit with another 10 units included because not all of these will be able to be located where they can treat the maximum effective area.

PERMEABLE PAVEMENT WITH STORAGE AND WEST BIORETENTION

Description	Opportunities	Constraints
Runoff from the roadway and/or hardscape surfaces and collected in cisterns located beneath the promenade. Collected runoff is then pumped to raised or at grade bioretention planters for treatment and reuse.	- Potential reduction in water demand while expanding plant palette for the project area. - Seattle Steam re-use could provide significant reduction in winter runoff volumes. - Eliminates surface ponding within pedestrian areas (compared to bioretention)	- Pumping required where subsurface storage is necessary. - Real time controls may be necessary to optimize system for summer vs. winter performance. - Subsurface storage and piping may conflict with utility infrastructure.



PERMEABLE PAVEMENT WITH STORAGE

Description	Opportunities	Constraints
Roadway runoff is infiltrated in porous pavement in parking lanes and treated/stored in the subsurface via a sand treatment layer , silva cells or amended structural soils that are connected to enlarged tree pits with increased soil volume for tree growth.	- Minimized impact on competing uses in furnishing zones - Functional use of pavement and texture to delineate special lanes - Enhanced tree pits to support larger trees and longer life-span within project area.	- Locally untested configuration of Silva Cells beneath permeable pavement. - Maintenance access to subsurface treatment layers may be problematic - Permeable pavements within travel way are currently not allowed by SDOT - Moss reduction may need to be addressed particularly in pedestrian areas

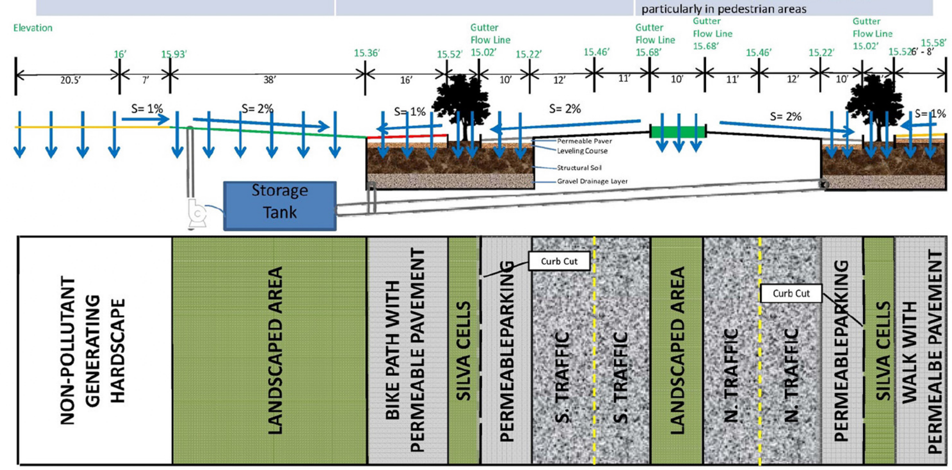


TABLE 3
CONSTRAINTS + OPPORTUNITIES FOR GSI OPTIONS ALONG PROMENADE

Option	Description	Opportunities	Constraints
A: Distributed Bioretention	Roadway runoff is mitigated within stormwater planters distributed within the street section (e.g. furnishing zones and medians).	- Strategy is a more standard and better understood approach - Required footprint and depth for GSI may be reduced due to locating facilities close to runoff source. - May be located to minimize competing space needs	- Furnishing zone on the west side of the roadway will have many competing needs including loading/unloading, pedestrian access, driveways, bike path, etc. - Distributed practices, i.e. within medians, may be more difficult to maintain and access. - Designs need to consider how to provide pre-settling where catchment area exceeds 2,000 sf.
B: Promenade Bioretention	Roadway runoff is conveyed west of the bike path to a more centralized bioretention facility integrated with the promenade	- Design may be integrated with promenade to provide urban amenities - Centralized maintenance - Edge treatments could be incorporated into urban design	- Depth of bioretention relative to surrounding hardscape may be as much as 24" lower - Conveyance system need to be shallow/low slope to minimize drop, e.g. runnels - Uncertain maintenance responsibilities (e.g. Parks, SPU, SDOT, Business assoc.?) - Designs need to consider how to provide pre-settling where catchment area exceeds 2,000 sf.
C: Permeable Pavement with Enhanced Tree Pits	Roadway runoff is infiltrated in porous pavement in parking lanes and treated/stored in the subsurface via a sand treatment layer , silva cells or amended structural soils that are connected to enlarged tree pits with increased soil volume for tree growth.	- Minimized impact on competing uses in furnishing zones - Functional use of pavement and texture to delineate special lanes - Enhanced tree pits to support larger trees and longer life-span within project area.	- Locally untested configuration of Silva Cells beneath permeable pavement. - Maintenance access to subsurface treatment layers may be problematic - Permeable pavements within travel way are currently not allowed by SDOT - Moss reduction may need to be addressed particularly in pedestrian areas
D: Subsurface Wetlands	Runoff is conveyed west of the bike path and treated within a subsurface wetland located within the promenade	- Design may be integrated with promenade to provide urban amenities - Centralized maintenance - Edge treatments could be incorporated into urban design - Eliminates surface ponding within pedestrian areas (compared to bioretention)	- Non-standard practice. - Urban, micro-basins may not support necessary hydrology (supplemental irrigation/storage may be necessary) - Planting palette may not match urban design goals - Sizing factor may require large treatment area
E: Rainfall Harvesting/ Cisterns	Runoff from the roadway and/or hardscape surfaces and collected in cisterns located beneath the promenade. Collected runoff is then pumped to raised or at grade bioretention planters for treatment and reuse.	- Potential reduction in water demand while expanding plant palette for the project area. - Seattle Steam re-use could provide significant reduction in winter runoff volumes. - Eliminates surface ponding within pedestrian areas (compared to bioretention)	- Pumping required where subsurface storage is necessary. - Real time controls may be necessary to optimize system for summer vs. winter performance. - Subsurface storage and piping may conflict with utility infrastructure.
F: Biofiltration Swales	Runoff from the roadway is conveyed west of the bike path and treated via a flow through planter that steps down to the promenade area (similar to the Swale on Yale project).	- Design may be integrated with promenade to provide urban amenities - Centralized maintenance - Swale footprint could be incorporated into urban design	-Would likely require vertical sidewalls in order to provide enough area for treatment. - Emergent vegetation necessary for enhanced treatment and low slopes may be difficult to establish where urban canopy is proposed.

NEWLY PLANTED TREES

Pictured at left is a rendering showing newly planted trees that are used to delineate and shade a walkway.

DESCRIPTION

Newly planted trees provide flow control in an urban environment by absorbing rain through their leaf system and roots, and allowing space for infiltration. Newly planted trees receive credits toward meeting flow control requirements.

Suitability for Structures: Limited. Needs to meet setback requirements, provide enough depth for proper root growth, and weight capacity.

Slope Constraints: None.

Applicable Locations: Adjacent to pedestrian paths and areas, roadways, buildings.

Applicable Runoff Surfaces: Patios, parking lots, sidewalks, and landscaped areas

Drainage Discharge System and Requirements Applicability:

- No discharge required
- Treatment of Offsite Areas: No
- GSI Standard: Meets Tier 1, runoff reduction methods

BENEFITS

- Provides flow control
- Creates habitat and promotes biodiversity in urban areas
- Enhances the landscape aesthetically
- Environmental benefits include improved air quality, reduced temperatures, and pollutant removal

APPLICATIONS

- Utilized in a variety of spaces
- Used to create a safer and more pleasant walking environment by visually providing distinct edges to sidewalks and other public spaces
- Used to soften or screen other urban features such as signs and utility poles

CONSTRAINTS

- Minimum setbacks:
  - 5 feet from structures
  - 5 feet from underground utility lines
  - 2 feet from the edge of any paved surface
- Must select an approved tree species from the City of Seattle's tree list
- For flow control credit, trees must be at least 1.5 inches in diameter and meet height requirements as follows:
  - Deciduous trees must be a minimum of 6 inches tall
  - Evergreen trees must be a minimum of 4 feet tall
- Irrigation is required for the first 3 years to promote establishment of the tree

REFERENCES

-Seattle, City of (2012). Right-of-way Improvements Manual, Chapter 4. http://www.seattle.gov/transportation/rowmanual/manual/4_14.asp

- Seattle, City of (2009). Stormwater Treatment Technical Requirements Manual. Directors' Rules, Vol. 3. Seattle Municipal Code, Chapters 22.800 – 22.808, Stormwater, Flow Control & Water Quality Treatment Technical Requirements Manual. Issued November 2009.

BIORETENTION PLANTERS

DESCRIPTION

Bioretention planters are flat-bottomed, landscaped basins containing an amended soil mix and native plants within an impervious structure (preventing infiltration into surrounding, native soil). Bioretention planters are used to mimic pre-development conditions where the soils and plants work together to store and treat stormwater runoff.

Pictured at left is a bioretention planter that receives runoff from the sidewalk. Pictured at right is a bioretention planter that receives runoff from the street.

BENEFITS

- Removes a wide range of pollutants.
- Creates habitat and promotes biodiversity in urban areas
- Enhances the landscape aesthetically

APPLICATIONS

- Utilized in a variety of spaces regardless of runoff source, native soil infiltration rate, depth to water table, and topography
- Used to filter runoff on confined sites and can be placed close to building or property lines
- Have flexibility in their design, allowing for variations in shape and planting scheme that can be used to fit the nature of the site

VARIATIONS

- Stair-stepped or cascading designs can be utilized on slopes.
- A flow restrictor can be installed on the outlet to further detain flow.
- Impervious liners can be constructed out of concrete, bentonite, or geomembrane liners.

Suitability for Structures: Limited. Requires a minimum structure depth (>36 inches) and weight capacity.

Slope Constraints: Flat facility bottom is required. Stair-stepped or cascading designs can be utilized on slopes.

Applicable Locations: Adjacent to pedestrian paths and areas, roadways, buildings.

Applicable Runoff Surfaces: Building roofs, patios, parking lots, roadways, and landscaped areas

Drainage Discharge System and Requirements Applicability:

- Storm Drainage Systems: Yes, meets water quality requirements
- Combined Sewer Areas: Minimal, requires large footprint to meet flow control requirements
- Treatment of Offsite Areas: Yes
- GSI Standard: Meets Tier 4, non-infiltrating facilities

CONSTRAINTS

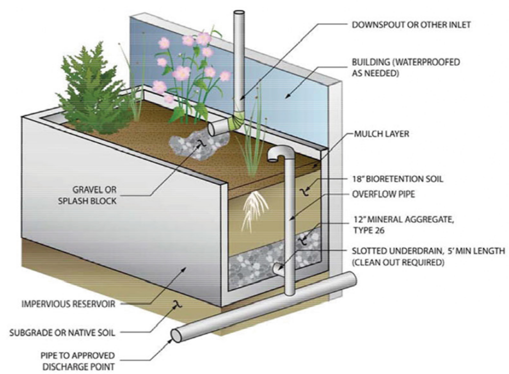
- Maximum size: 800 square feet of bottom area
- Maximum drainage area: 5,000 square feet of impervious area
- The planter must include an underdrain and overflow directed to an approved discharge point
- In many cases, the vertical walls may require a curb and/or railing for pedestrian safety
- If the planter is adjacent to a building, waterproofing on the building structure is often necessary

DESIGN FEATURES

The impervious reservoir disconnects the bioretention planter from the surrounding native soils which allows for **flexibility in the location of the planter** without having to consider existing conditions such as native soil infiltration rate, depth to water table, and topography, as well as runoff source.

The planter ponding area provides a surface storage depth between 6 and 12 inches for stormwater flows prior to infiltration. The ponding area should drain within 24 hours following a storm event.

The main function of the mulch layer is to filter out heavy metals. A mulch layer 2 to 4 inches in depth should be used. The mulch layer also reduces weed establishment, regulates soil temperature and moisture, and adds organic matter to the soil.



Bioretention soil filters out pollutants such as suspended solids and nutrients from stormwater. The soil should be a minimum of 18 inches deep and also provides a growing medium for plants. Plants in bioretention planters are selected based on species native to the area and tolerance to local climate and biological stresses.

A 12-inch layer of gravel and an underdrain pipe are installed in the bottom of the bioretention planter. Stormwater is collected in the underdrain and directed to an approved discharge point. The underdrain can also be connected to a downstream Best Management Practice (BMP) such as another bioretention planter.

The footprint required for a bioretention planter is determined based on the amount impervious area contributing flow to the facility. The footprint of the bioretention planter area can be approximated using the following equation:

Bioretention Planter Area = Contributing Impervious Area x 0.065

REFERENCES

-Roth, Matthew (2009). *Portland's Greenstreets Program a Sterling Best Practice Model* . Retrieved January 27, 2012, http://sf.streetsblog.org/2009/11/13/portlands-greenstreets-program-a-sterling-best-practice-model/

-Seattle, City of (2012). Right-of-way Improvements Manual, Chapter 6. http://www.seattle.gov/transportation/rowmanual/manual/6_1.asp

- Seattle, City of (2009). Stormwater Treatment Technical Requirements Manual. Directors' Rules, Vol. 3. Seattle Municipal Code, Chapters 22.800 – 22.808, Stormwater, Flow Control & Water Quality Treatment Technical Requirements Manual. Issued November 2009.

PERMEABLE PAVEMENT SURFACES

Pictured at top is porous pavement system using pavers. Pictured at right is an open-celled paving grid with vegetation.

DESCRIPTION

Permeable pavement is a paving system that contains empty spaces which allow rainfall to percolate into underlying soil. There are a variety of permeable pavement surface options (asphalt, concrete, pavers, etc.). Permeable pavement systems can be designed to provide differing levels of flow control. This description will focus on **permeable pavement surfaces** which are ideal for soil with limited infiltration capabilities. Permeable pavement surfaces function as a permeable land surface, reducing the amount of runoff generated during a storm.

BENEFITS

- Maintains perviousness of site
- No additional land area is necessary for stormwater treatment and flow control
- Provides rooting space for trees in urban areas

APPLICATIONS

- Can be used to replace conventional pavements including:
  - Sidewalks and pedestrian plazas
  - Pedestrian and bike trails
  - Driveways
  - Most parking lots
  - Low volume private roads
- Should be used in areas with low pollutant and sediment loading

VARIATIONS

- Permeable pavement **facilities** typically have a thicker aggregate subbase and are designed to receive runoff from other areas, but can only be used in areas where infiltration into native soil can be accommodated.

CONSTRAINTS

- Cannot be installed over contaminated sites
- Susceptible to clogging if receiving runoff from off-site areas and if not periodically swept

Suitability for Structures: No.

Slope Constraints: Applicable for slopes up to 5%.

Applicable Locations: sidewalks, pedestrian plazas, driveways, and parking lots

Applicable Runoff Surfaces: Building roofs, patios, parking lots, roadways

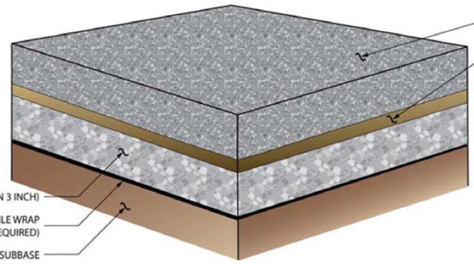
Drainage Discharge System and Requirements Applicability:

- No discharge to storm or combined sanitary sewer is required.
- Treatment of Offsite Areas: Limited to receiving flow from impervious areas no greater than 10% of the permeable pavement area.
- GSI Standard: Meets Tier 3, impervious surface reduction methods.

DESIGN FEATURES

The **Wearing Course** is the top layer of permeable pavement surface. It provides the strength to withstand loads from traffic or other uses while maintaining empty spaces to allow stormwater to infiltrate. There are a variety of permeable pavement wearing course options which include porous asphalt or concrete, modular blocks with sand or gravel infill, or plastic grid systems filled with gravel or soil planted with grass.

The **Leveling Course** is located underneath the wearing course and provides a more uniform surface for laying pavement or pavers. This layer consists of crushed aggregate and also provides some structural support for the permeable pavement.



An **Aggregate Subbase** is the last layer of structural support for the permeable pavement surface. It must also be deep enough to drain the design peak rainfall intensity.

Lastly, a **Separation Layer** (or a geotextile) is provided to prevent fine-grained soils in the native soil from migrating upward into the aggregate subbase.

REFERENCES

-Seattle, City of (2012). Right-of-way Improvements Manual, Chapter 6. http://www.seattle.gov/transportation/rowmanual/manual/6_1.asp

- Seattle, City of (2009). Stormwater Treatment Technical Requirements Manual. Directors' Rules, Vol. 3. Seattle Municipal Code, Chapters 22.800 – 22.808, Stormwater, Flow Control & Water Quality Treatment Technical Requirements Manual. Issued November 2009.

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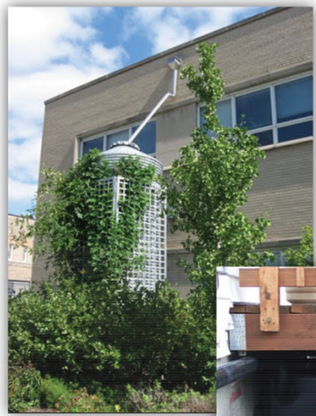
RAINWATER HARVESTING



Pictured at left is a cistern with a planted trellis that receives runoff from the rooftop. Pictured at center is a cistern installed under a deck.

DESCRIPTION

Rainwater harvesting is the capture and storage of roof runoff for reuse. The primary components of a rainwater harvesting system include the collection system (gutters and downspouts), storage (cisterns or rain barrels), and dispersion system (pipes or hoses). The stored rainwater is reused for non-potable uses such as irrigation. Rainwater harvesting is an effective form of green infrastructure where infiltration is not applicable.

BENEFITS

- Conserves water and provides supplemental water supply for uses such as irrigation
- Reduces stormwater runoff volumes by capturing and storing roof runoff
- Improves plant health by providing non-chlorinated water for irrigation
- Harvested rainwater can be used for irrigation in the dry summer months, reducing potable water demand

APPLICATIONS

- Can be used in residential, commercial, or industrial development for new or retrofit projects
- Storage can be installed at grade, below ground, or under a deck
    - Storage can be individual or connected in series to increase storage capacity

VARIATIONS

- Rain Barrels
- Cisterns, both underground and aboveground
- Tanks
- Storage beneath a surface

Suitability for Structures: Moderate. Ensure weight capacity for storage volume as well as a feasible connection to a collection system.

Slope Constraints: None.

Applicable Locations: Near buildings.

Applicable Runoff Surfaces: Roofs.

Drainage Discharge System and Requirements Applicability:

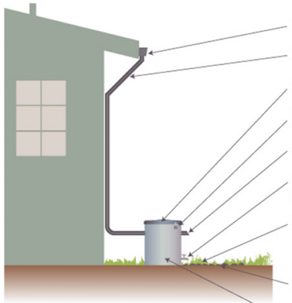
- No discharge to storm or combined sanitary sewer is required.
- Treatment of Offsite Areas: No.
- GSI Standard: Meets Tier 2, infiltrating and reuse facilities.

CONSTRAINTS

- Only runoff from roof surfaces is allowed for collection
  - Avoid runoff from roofing materials such as copper or zinc that may release contaminants into the system
- Must be designed to prevent mosquitoes and other life forms from entering the system
- Opaque storage containers must be used in above ground applications to minimize algae growth
- Could require a pumping system for reuse depending on the design
- System should be designed for asynchronous flows by performing a water balance equation to minimize occurrences of overflows

DESIGN FEATURES

Rainwater harvesting systems begin with the collection of roof runoff. The **Downspout System** collects runoff from the roof through gutters. A screen should be installed at the downspout to keep leaves and other large debris from entering the system. It is also recommended that the screen be capable of excluding insects.



Source: Bay Area Stormwater Management Agencies Association, *Start at the Source (1999)*

The downspout system pipes roof runoff to a storage tank. Storage tanks are either a **Rain Barrel** (approximately 50 to 60 gallons) or a **Cistern** (larger and custom-sized). Rain barrels are typically installed at a single downspout, whereas cisterns may be connected to multiple downspouts.

The stored rainwater is released through an **Outlet Pipe** that can be manually operated (during summer watering periods) or left open to disperse runoff to a landscaped area during a storm. The outlet pipe may be connected to a garden hose or a drip line to disperse water throughout the landscaping area.

Flows in excess of the storage tank volume are released through an **Overflow Pipe**, which can discharge runoff to an energy dissipater, another stormwater BMP, or to an approved discharge point. The energy dissipater can be a rock pad or a downspout splash block.

REFERENCES

- Seattle, City of (2009). Stormwater Treatment Technical Requirements Manual. Directors' Rules, Vol. 3. Seattle Municipal Code, Chapters 22.800 – 22.808, Stormwater, Flow Control & Water Quality Treatment Technical Requirements Manual. Issued November 2009.

BIOFILTRATION SWALES

Pictured at the top is a biofiltration swale that receives runoff from a street. The lower picture shows a biofiltration swale that receives runoff from a sidewalk and office park.

DESCRIPTION

Biofiltration swales are open, gently sloped, vegetated channels designed to treat stormwater. Stormwater enters the head of the swale, percolates through the soil as it travels the swale's length, and conveyed out of the system. Pollutant removal occurs by filtration as stormwater moves through the grass blades, which enhances sedimentation and trapping of pollutants to the grass.

BENEFITS

- Meets basic water quality treatment requirements
- Creates habitat and promotes biodiversity
- Enhances the landscape aesthetically

APPLICATIONS

- Utilized in a variety of spaces regardless of runoff source, native soil infiltration rate, depth to water table, and topography
- Used to filter runoff on confined sites and can be placed close to building or property lines
- Have flexibility in their design, allowing for variations in shape and planting scheme that can be used to fit the nature of the site

VARIATIONS

- A swale with saturated soil conditions, because of influent and/or site conditions, can be accommodated.
- Runoff can enter at multiple locations along the length of the swale instead of solely at the head.
- Swale's berm may be made from compacted earth, timber, concrete, plastic or similar weather-resistant non-erodible material.

Suitability for Structures: Limited. Requires a minimum structure depth (>36 inches) and weight capacity.

Slope Constraints: The longitudinal slope must be between 1.5% and 2.5%.

Applicable Locations: Adjacent to pedestrian paths, roadways, driveways, and parking lots

Applicable Runoff Surfaces: Building roofs, patios, parking lots, roadways, and landscaped areas

Drainage Discharge System and Requirements Applicability:

- Storm Drainage Systems: Yes, meets water quality requirements
- Combined Sewer Areas: Minimal, provides little to no detention or storage
- Treatment of Offsite Areas: Yes
- GSI Standard: Meets Tier 2, infiltrating and reuse facilities

CONSTRAINTS

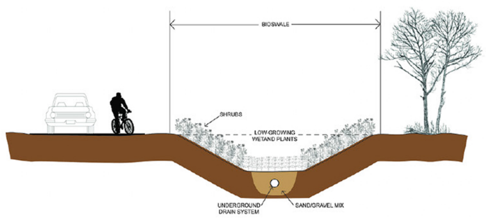
- Minimum length: 100-foot minimum length
- Maximum drainage area: 5 acres of impervious area
- Longitudinal slope should be between 1.5 and 2.5 percent.
- A biofiltration swale should not be located in a shaded area.
- To maintain healthy grass growth, a swale must dry out between rainfall events.
- Stormwater runoff containing high concentrations of oil and grease impairs the treatment capacity.

DESIGN FEATURES

The berm disconnects the biofiltration swale from the surrounding native soils which allows for flexibility in the location of the swale without having to consider existing conditions such as native soil infiltration rate, depth to water table, and topography, as well as runoff source.

The biofiltration swale must be at least 100 feet long and 2 to 10 feet wide. For a swale width between 10 and 16 feet, a divider berm is needed. The maximum horizontal to vertical side slope is 3:1; however, a 4:1 slope is preferred. The longitudinal slope must be between 1.5 and 2.5 percent. In order to maintain a healthy system the velocity of stormwater runoff should not exceed 1.0 ft/sec, as it will flatten the grasses.

Biofiltration swales remove pollutants by filtrating stormwater moves through the grass blades, which enhances sedimentation and trapping of pollutants to the grass, and soil, which filters out pollutants such as suspended solids and nutrients from stormwater. Plants in biofiltration swales are selected based on species native to the area and tolerance to local climate and biological stresses. A newly constructed swale shall be protected from stormwater flows until grass has been established.



Underdrains shall be 6-inch minimum Schedule 40 PVC perforated pipe with 6 inches of clean drain rock above the pipe. The gravel and pipe must be enclosed by geotextible fabric.

REFERENCES

- Seattle, City of (2009). Stormwater Treatment Technical Requirements Manual. Directors' Rules, Vol. 3. Seattle Municipal Code, Chapters 22.800 – 22.808, Stormwater, Flow Control & Water Quality Treatment Technical Requirements Manual. Issued November 2009.

ENHANCED TREE PITS

DESCRIPTION

Enhanced tree pits are expanded tree pits with an improved subsurface structure that offer space for tree roots to grow while maintaining sufficient structural support for adjacent pedestrian sidewalks and pavement surfaces. The Silva Cell, commonly used to create the substructure, is a modular suspended pavement system for containing lightly compacted soil underneath paved surfaces for large tree growth and on-site stormwater mitigation.

Pictured at left is the base of Silva Cells. Pictured at right are the top of the Silva Cells and base for sidewalk.

BENEFITS

- Provides flow control
- Creates habitat and promotes biodiversity in urban areas
- Enhances the landscape aesthetically
- Environmental benefits include: improved air quality, reduced temperatures, and pollutant removal

APPLICATIONS

- Utilized in a variety of spaces
- Used to create a safe and more pleasant walking environment by visually providing distinct edges to sidewalks and other public spaces
- Used to soften or screen other urban features such as signs and utility poles

CONSTRAINTS

- Minimum setbacks (for trees):
  - 5 feet from structures
  - 5 feet from underground utility lines
  - 2 feet from edge of any paved surface
- Must select an approved tree species from the City of Seattle's tree list
- For flow control credit, trees must be at least 1.5 inches in diameter and meet height requirements as follows:
  - Deciduous trees must be at least 6 inches tall

Suitability for Structures: Limited. Needs to meet setback requirements, provide enough depth for proper root growth, and weight capacity.

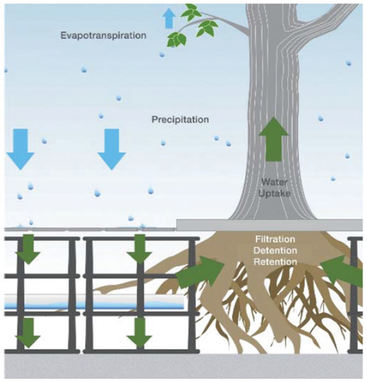
Slope Constraints: Flat facility bottom is required. Stair-stepped or cascading designs can be utilized on slopes

Applicable Locations: Part of pedestrian paths and sidewalks

Applicable Runoff Surfaces: Patios, parking lots, sidewalks, and landscaped areas

Drainage Discharge System and Requirements Applicability:

- Storm Drainage System: Yes
- Treatment of Offsite Areas: Yes
- GSI Standard: Meets Tier 1, runoff reduction methods



- Evergreen trees must be a minimum of 4 feet tall
- Must have at least 16" of depth in order to accommodate one Silva Cell frame
- No more than three Silva Cells can be stack together

DESIGN FEATURES

Each Silva Cell is composed of a frame and deck. The frame measures 48" long, 24" wide, and 16" tall. Frames can be stacked one, two, or three units high. Frames can be placed next to each other as much as needed. Each frame is approximately 92% void space before filling, so utilities can be incorporated into Silva Cell designs. Uncompacted soil is used fill the frames. This soil allows for greater expansion of the tree roots, increases the tree's life, and allows for better infiltration. A deck piece is added to the frame and will serve at the foundation for pedestrian walkways. Openings on the desk allow for air and runoff to penetrate at enclosed soil. A drainage system is placed within the frame system to capture and convey and excess moisture.

REFERENCES

-DeepRoot. Silva Cell Overview. http://www.deeproot.com/products/silva-cell/silva-cell-overview.html

-Seattle, City of (2012). Right-of-way Improvements Manual, Chapter 6. http://www.seattle.gov/transportation/rowmanual/manual/6_1.asp

- Seattle, City of (2009). Stormwater Treatment Technical Requirements Manual. Directors' Rules, Vol. 3. Seattle Municipal Code, Chapters 22.800 – 22.808, Stormwater, Flow Control & Water Quality Treatment Technical Requirements Manual. Issued November 2009.

SUBSURFACE WETLANDS

Pictured above is a subsurface wetland.

DESCRIPTION

Subsurface wetlands are basins (typically impervious) filled with a porous media (usually gravel or aggregate) that support plant life. Subsurface wetlands are designed to allow stormwater runoff to flow below the ground surface through the root zone. The facility is designed so that the porous media stays submerged. Wetland plants are rooted in the media to allow for direct uptake of pollutants.

BENEFITS

- Removes a wide range of pollutants.
- Creates habitat and promotes biodiversity in urban areas
- Enhances the landscape aesthetically
- Attenuates peak flow
- Provide better water quality treatment than constructed wetlands alone

APPLICATIONS

- No minimum drainage area requirement
- Well suited for retrofit applications
- Intended for space-limited applications and used for water quality treatment
- Requires low land consumption and can fit within an area that is typically devoted to landscaping
- Can be located in an area with a high water table and soils that have low-permeability

CONSTRAINTS

- Not recommended for areas with high sediment content in stormwater or clay/silt runoff areas
- Cannot be installed until site construction is complete
- The BMP has high maintenance requirements.

Suitability for Structures: Very limited. Requires grade change, weight capacity, and the ability to collect sufficient flow.

Slope Constraints: Generally there is no slope requirement, but sufficient change in elevation between the inlet and outlet is needed to ensure successful gravity flow. The local slope should be no greater than 2 percent.

Applicable Locations: Relatively flat, open spaces.

Applicable Runoff Surfaces: Building roofs, patios, parking lots, roadways, and landscaped areas

Drainage Discharge System and Requirements Applicability:

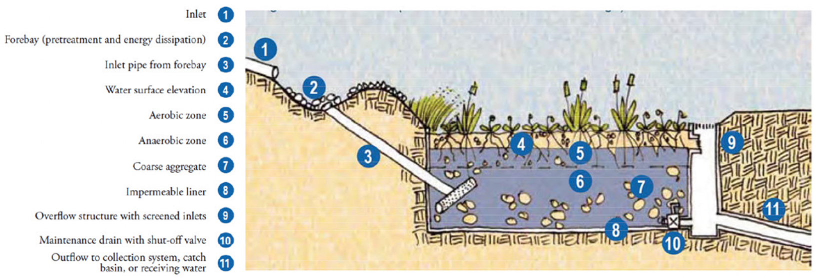
- Storm Drainage Systems: Yes, meets water quality requirements
- Combined Sewer Areas: Attenuates peak flows
- Treatment of Offsite Areas: Yes
- GSI Standard: No standard for subsurface wetlands currently exists.

DESIGN FEATURES

To prevent clogging of the gravel bed, stormwater first passes through a **forebay** to remove litter and sediment. The forebay also slows down stormwater prior to it entering the basin. The stormwater then exits the forebay and flows into the gravel layer of the wetland. The inlet into the basin can be at grade or below grade, depending on the design. Some applications also include an **impermeable liner** to allow for placement in areas with high water tables, or soils that have low permeability.

Stormwater flows by gravity through the **porous media layer** of the subsurface wetland. Typical media used includes gravel, sand, or rocks at a depth ranging between 1 and 3 feet.

Pollutants are removed through a variety of chemical, physical, and biological processes in a subsurface wetland, with the gravel layer (or other porous media) as the primary treatment. Uptake of pollutants also occurs through plant root systems. The key for subsurface wetlands is for the gravel layer to be **submerged** year-round to promote growth of hydrophilic wetland plants and water quality treatment.



The **outlet** for the subsurface wetland is at the surface of the downstream end of the facility to promote submergence of the porous media layer and to also act as an overflow for the facility. A maintenance drain can be inserted at the bottom of the basin, but kept closed unless full drainage of the submerged wetland is needed.

REFERENCES

-Atlanta Regional Commission (2001). Georgia Stormwater Management Manual Volume 2: Technical Handbook First Edition. Issued August 2001.

-San Francisco Public Utilities (2010). San Francisco Stormwater Design Guidelines Appendix A: BMP Fact Sheets. Pgs 66 – 71. June 2010.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