Low Impact Development Seminar

- Agenda
  - Opening Remarks – James Rice, DPW Clean Water Act
  - Low Impact Development (LID) Regulatory Compliance – Russell Leong, Honolulu Engineering District
  - LID Overview – Hayley Diamond, DPW Clean Water Act
  - Break (15 minutes)
  - Soil Infiltration Data – Stephen Turnbull, DPW Clean Water Act
  - Bioretention Design – Russell Chung, PBR Hawaii and Associates
  - Native Plant Palette – Rick Barboza, Hui Ku Maoli Ola
  - Draft LID Retrofit Study – Stephen Turnbull, DPW Clean Water Act
  - Room available until 1600 to discuss draft DPW Standard

Low Impact Development Seminar

- Purpose: Discuss island LID approaches and upcoming projects. Share lessons learned
- US Army Garrison, Hawaii (USAG-HI) National Pollutant Discharge Elimination System (NPDES) permit requires post-construction storm water management system (SWMS) program that includes LID
    - Post-construction SWMS Enforcement Policy
- Federal Requirements
    - Section 438 EISA 2007 and EO 13514
    - Department of Defense Memorandum
    - US Army Draft Memorandum

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Low Impact Development Seminar

- SWMS Standard Guidance for USAG-HI new construction and redevelopment projects
    - Requires Operations and Maintenance Plan
    - Native Plants that will work
    - Provide comments and discuss following seminar time permitting
- LID approaches require collaboration
    - Master Planning
    - Engineering
    - Environmental
    - Construction
    - Operations and Maintenance

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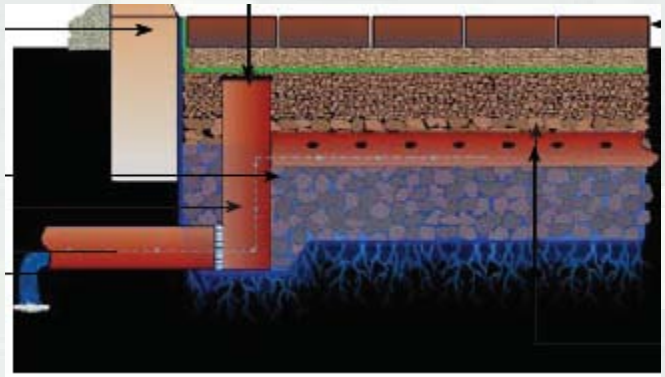
SECTION 438 – EISA2007 BIORETENTION INTRODUCTION

Russell Leong

U.S. Army Corps of Engineers

April 2011

SECTION 438
ENERGY INDEPENDENCE
& SECURITY ACT 2007



SECTION 438

Energy Independence and Security Act of 2007 (EISA 2007) now effectively mandates LID for federal projects

SEC. 438. STORM WATER RUNOFF REQUIREMENTS FOR FEDERAL DEVELOPMENT PROJECTS.

The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow.

DESIGN BUILD RFP

5.1.2.6 Stormwater Management. Employ design and construction strategies (Best Management Practices) that reduce stormwater runoff, reduce discharges of polluted water offsite and maintain or restore predevelopment hydrology with respect to temperature, rate, volume, and duration of flow to the maximum extent practicable. See paragraph 6, Project Specific requirements for additional information.

DEFINITIONS

6.x.1 Definitions.

"Maximum Extent Technically Feasible (METF)". Project site design options shall be evaluated to achieve the design objective to the maximum extent technically feasible. METF criterion requires full employment of accepted and reasonable storm water retention and reuse technologies (e.g., bio-retention areas, permeable pavements, cisterns / recycling, and green roofs), subject to site and regulatory constraints (e.g., site size, soil types, vegetation, demand for recycled water, existing structural limitations, state or local prohibitions on water collection). **All site-specific technical constraints that prohibit the full attainment of the design objective shall be documented**. If the design objective cannot be met within the project footprint, LID measures may be applied on nearby parcels of DoD property (e.g., downstream from the project) within available resources.

DEFINITIONS

6.x.1 Definitions.

“Predevelopment hydrology” is defined as the pre-project hydrologic conditions of temperature, rate, volume, and duration of storm water flow from the project site. The analysis of the predevelopment hydrology must include site-specific factors (such as soil type, ground cover, and ground slope) and use modeling or other recognized tools to establish the design objective for the water volume to be managed from the project site.

“Predevelopment” equals Pre-project equals the vegetative state.

DESIGN TEAM

6.x.3 DESIGN TEAM

- Civil Engineer;
    - Site grading
- Geotechnical Engineer;
    - Exfiltration; methods to maintain or enhance.
    - Geotextiles;
    - Geogrids
- Landscape Architect
    - Plant selection for low areas with longer saturation times;
    - Plant selection for high areas
    - Low P-index soil
    - Upper soil mix (sand, compost, etc.)

DESIGN CRITERIA

6.x.4 Pollutants To Reduce. The post construction Best Management Practices (BMPs) shall reduce Total Suspended Solids; both dissolved and particulate nutrients; suspended petroleum; suspended metals; and temperature.

6.x.4.a Regulated Pollutants for Project in a Watershed with Total Maximum Discharge Loads (TMDL). This project storm drain system does discharge to a watershed with TMDL. The regulated pollutants are total suspended solids, nutrients, etc. This will require additional post construction BMPs to further reduce the pollutant loads.

- TMDLs established for North and South Fork Kaukonahua Stream.
- TMDLs expected late 2010 or 2011 for Waikele Stream.

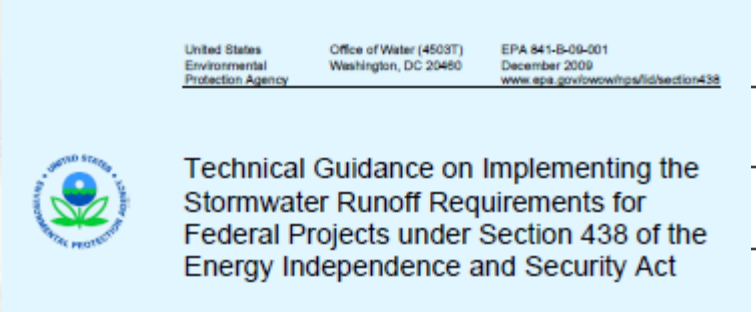
ADDITIONAL CONSIDERATIONS

6.x.5 Operation and Maintenance Manual. Provide and O&M manual for each post construction BMP used. Provide an estimate of the annual maintenance costs in the O&M manual.

6.x.6 Plans and specifications. The plans and specifications shall address protection of the BMP during construction to include preventing damage and sediment accumulation. The plans and specification shall address periodic and final cleaning of the BMPs prior to project turnover.

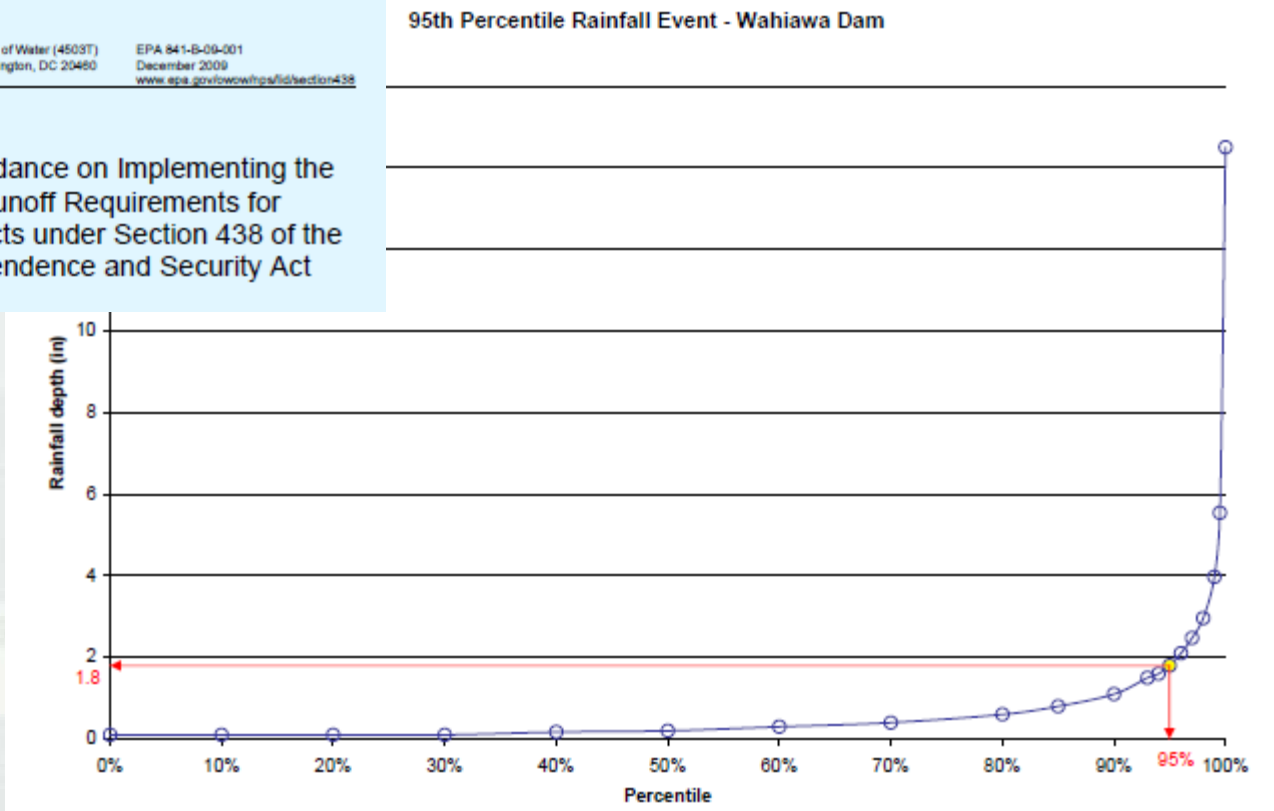
6.x.7 Other Requirements. DOD is required to provide estimated design and construction costs for implementing EISA Section 438. Documented the project cost estimate as a separate line item. Final implementation costs will be documented as part of the project historical file. Post-construction analysis shall also be conducted to demonstrate the effectiveness of as-built storm water features. I.e., apply water to the BMP and measure time to drain, etc.

EPA Technical Guidenance



United States Environmental Protection Agency | Office of Water (4503T) Washington, DC 20460 | EPA 841-B-09-001 December 2009 www.epa.gov/owow/hps/lid/section438

Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act



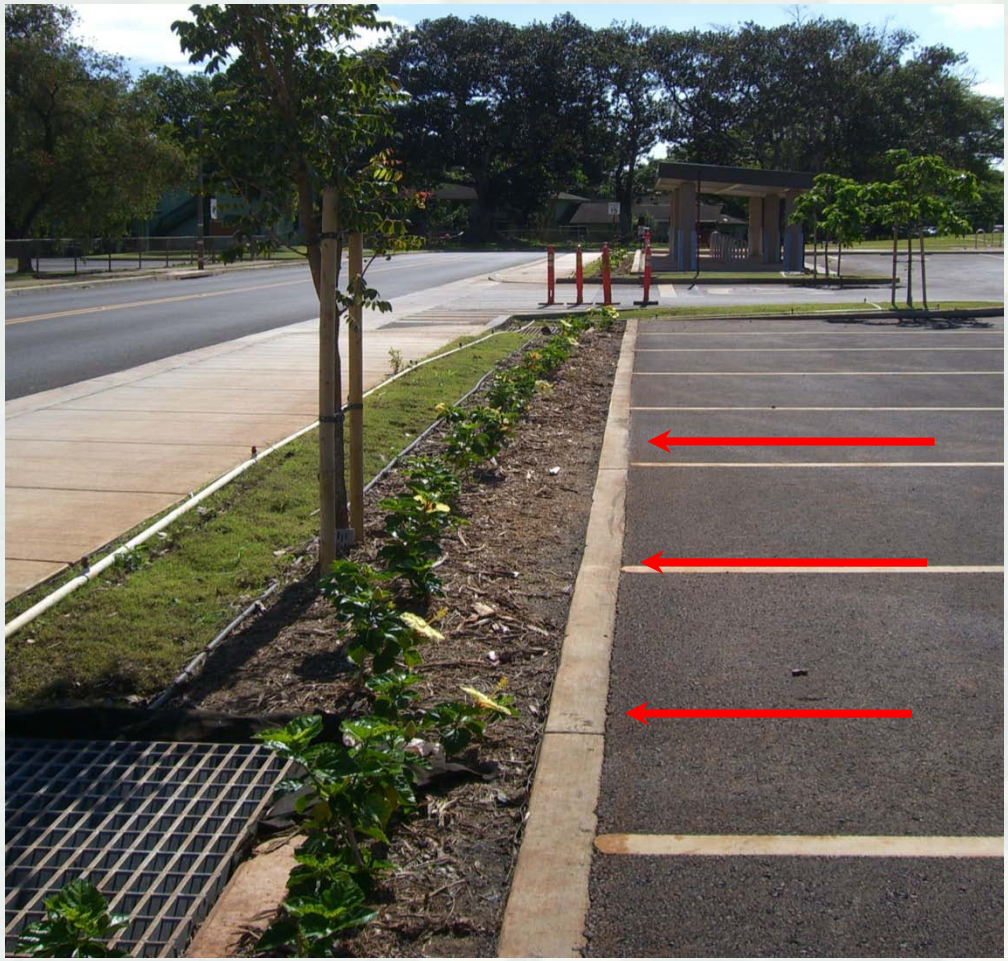
Ref: EPA 841-B-09-001; Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act; December 2009

Comparison Water Volumes

	Section 438 (in)	LEED 6.1 – 1 yr 24 hr (in)	LEED 6.1 – 2 yr 24 hr (in)	CCH Detention (in)	CCH Water Quality (in)
SB	1.8	4	6		1

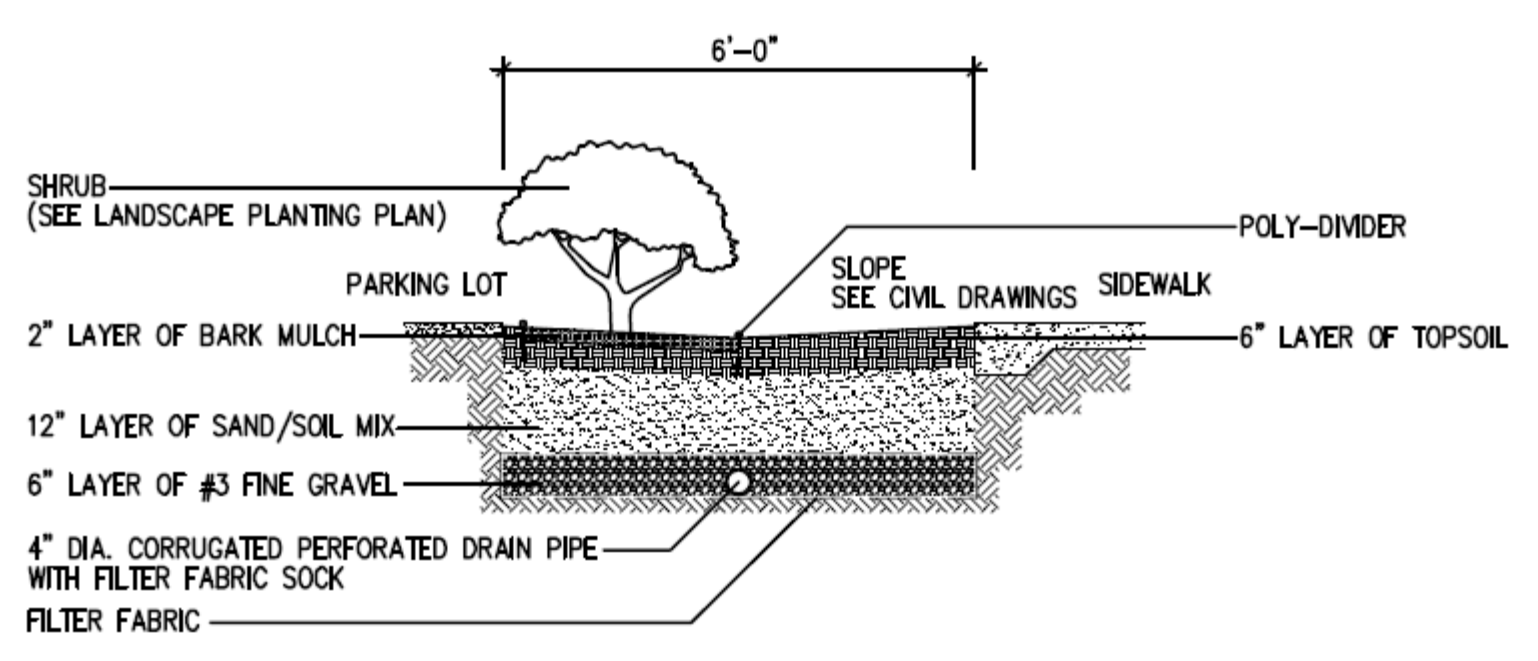
Ref: EPA 841-B-09-001; Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act; December 2009

DOD BIORENTENTION EXAMPLES



WBR 2F2/2G POV PARKING
SCHOFIELD BARRACKS

DOD BIORENTENTION EXAMPLES



WBR 2F2/2G POV PARKING
SCHOFIELD BARRACKS

HI BIORENTENTION EXAMPLES

GCA
HONOLULU

NEXT TO SERVCO
HONOLULU

AK BIORETENTION EXAMPLES

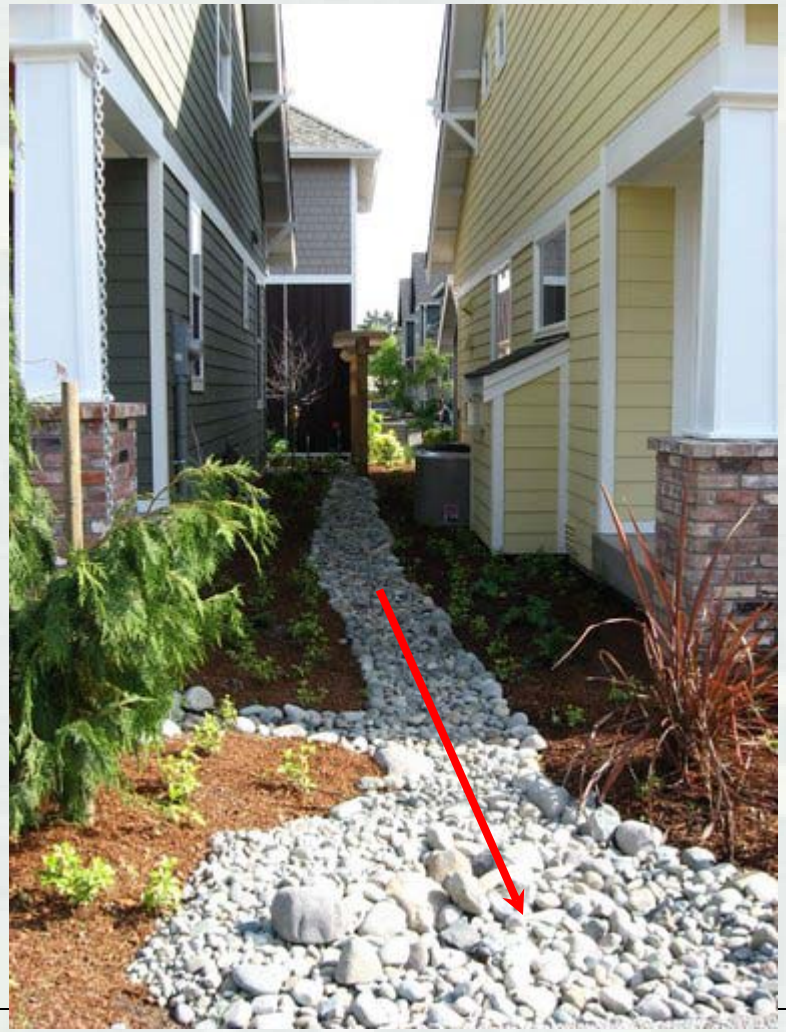
ANCHORAGE, AK

FT RICHARDSON
ANCHORAGE, AK

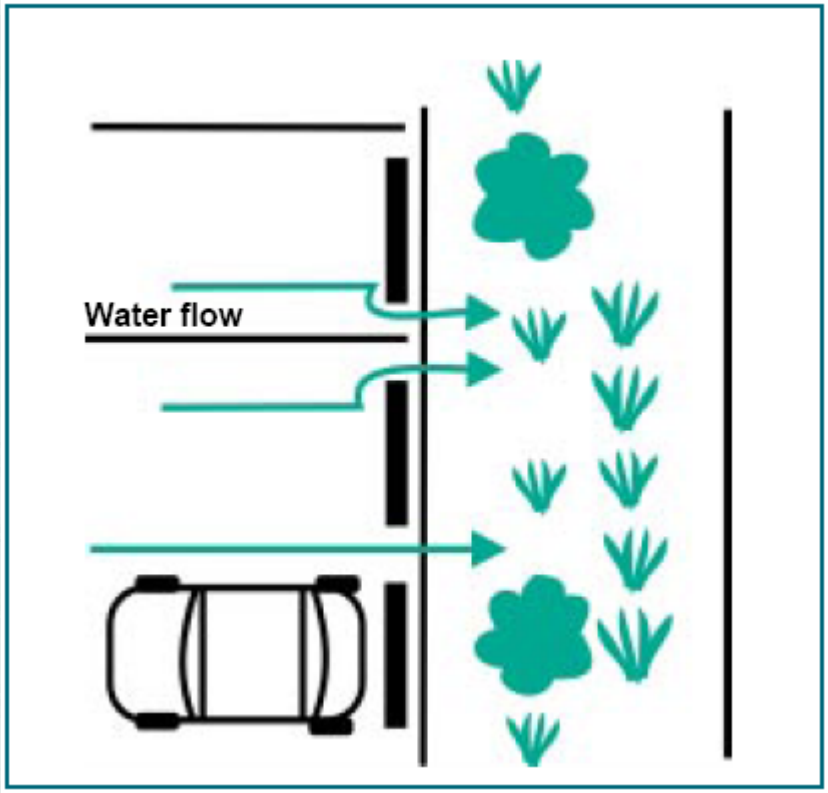
BIORETENTION EXAMPLES

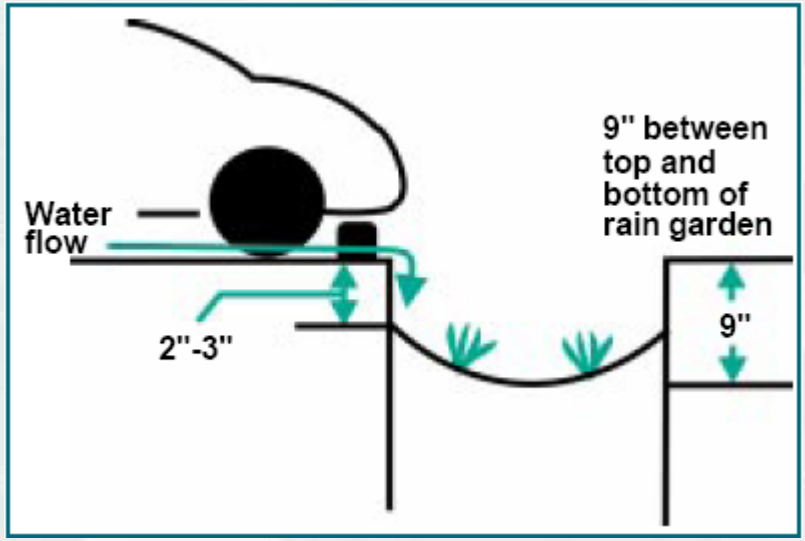
BIORETENTION EXAMPLES

BIORETENTION EXAMPLES



BIOSWALE IN PARKING LOT

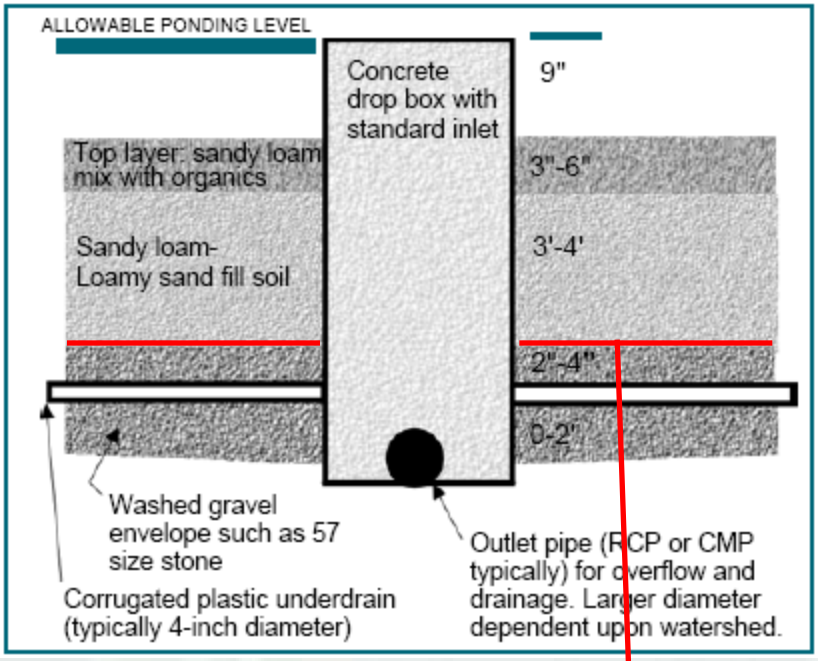




Ref: Nancy White; William F. Hunt, P.E., Ph.D.; Urban Waterways, Designing Rain Gardens (Bio-Retention Areas), NC State University & A&T State University

LOW IMPACT DEVELOPMENT BIOSWALE IN PARKING LOT

Ref1:



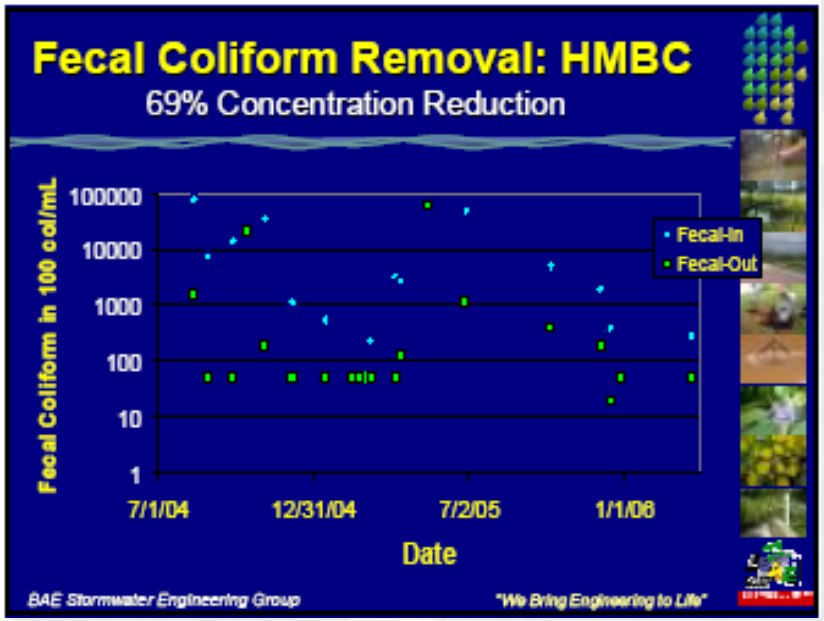
Ref2:

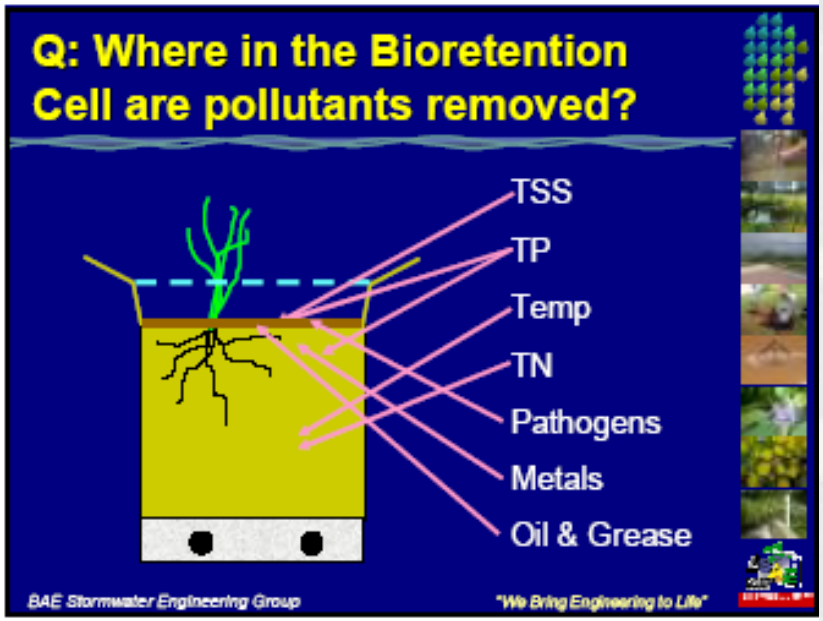
GEOTEXTILE

Ref1: Steve Thibaudeau, P.E, Putting the LID on Site Design, COE Louisville District

Ref2: Nancy White; William F. Hunt, P.E., Ph.D.; Urban Waterways, Designing Rain Gardens (Bio-Retention Areas), NC State University & A&T State University

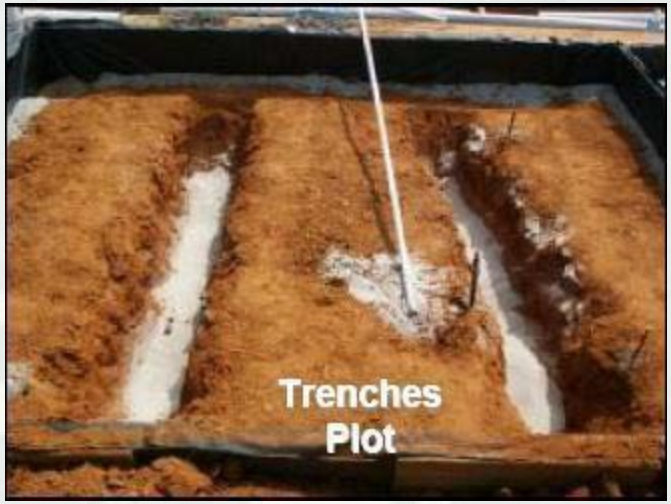
IMPROVEMENTS TO WATER QUALITY





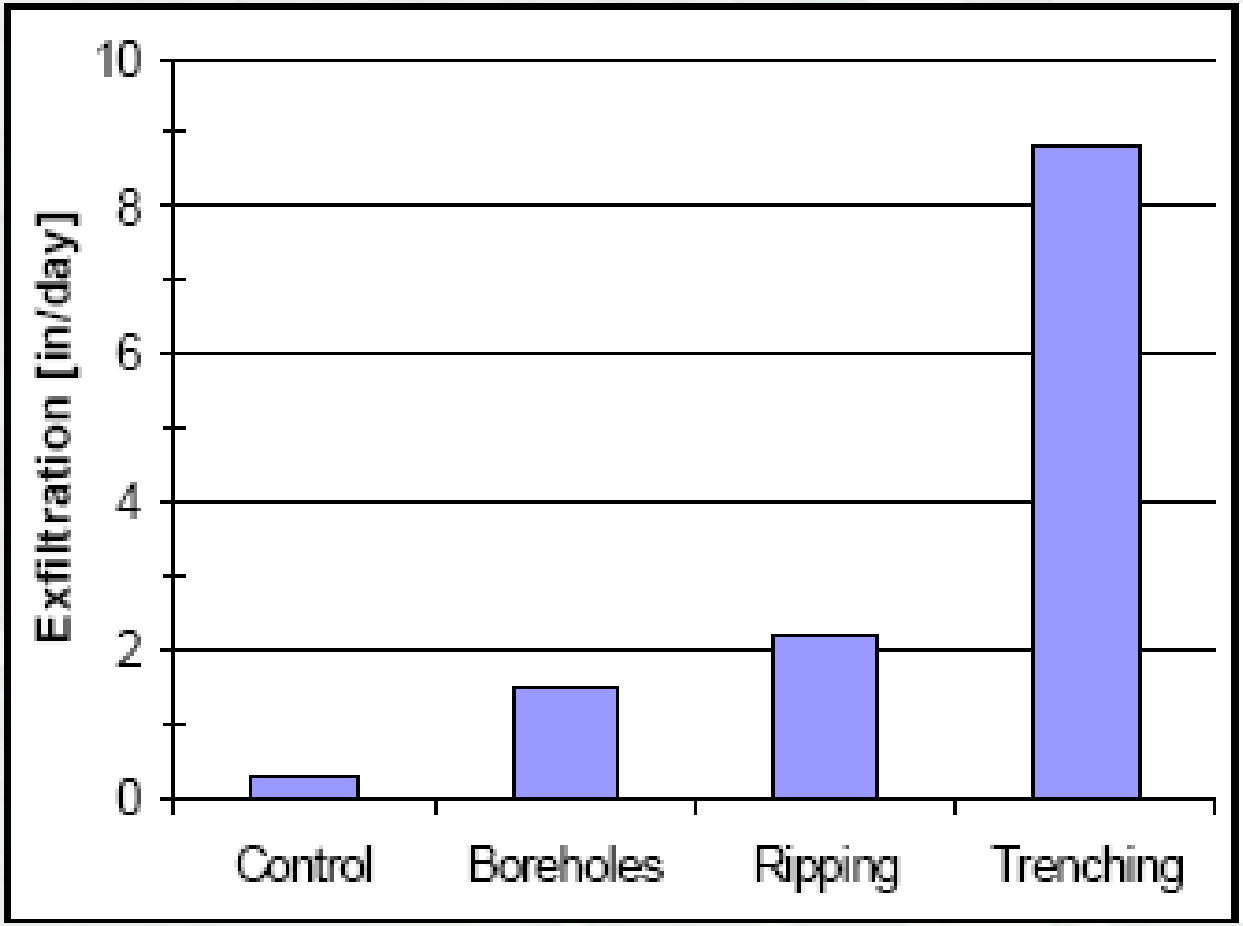
Ref: William F. Hunt, P.E., Ph.D.; Bioretention Research & Impacts on Design, NC State University
www.bae.ncsu.edu/stormwater

MAINTAINING INSITU EXFILTRATION RATES



Ref: Exfiltration from Pervious Concrete into a Compacted Clay Soil, Wesley C. Wright, The University of Tennessee

MAINTAINING INSITU EXFILTRATION RATES



Ref: Exfiltration from Pervious Concrete into a Compacted Clay Soil, Wesley C. Wright, The University of Tennessee

MAINTAINING INSITU EXFILTRATION RATES

Figure 7. The rake method (A) for excavating the bottom of a bioretention cell creates less compaction than the scoop method (B).

Ref: Robert A. Brown, E.I.; William F. Hunt, P.E., Ph.D.; Urban Waterways, Improving Exfiltration from BMPs: Research and Recommendations, NC State University & A&T State University

MIXTURES AFFECTING PERMEABILITY

Table 1: Soil parameters for mixes.

Mixture Label	Mean Permeability (in/hr)	Mean Field Capacity @ 6 hours (%)	% Organic Matter	Dry Bulk Density (kg/m^3)	Porosity
100 c / 0 s / 0 t	7.42	115.3	28.37	442.6	0.594
0 c / 100 s / 0 t	10.23	13.8	0.22	1648.3	0.351
0 c / 0 s / 100 t	0.66	24.7	2.04	1284.2	0.486
80 c / 20 s / 0 t Field	18.35	53.5	13.98	650.3	0.529
80 c / 20 s / 0 t Lab	17.95	63.9	12.92	746.0	0.459
20 c / 50 s / 30 t Field	0.80	28.3	2.69	1029.5	0.540
20 c / 50 s / 30 t Lab	1.84	16.5	2.65	1502.2	0.429
50 c / 50 s / 0 t	2.18	20.8	5.09	950.1	0.476
35 c / 65 s / 0 t	2.77	24.2	5.02	1021.4	0.497

Ref: Donald D. Carpenter and Laura Hallam; An investigation of rain garden planting mixture performance and the implication for design; Low Impact Development 2008.

MIXTURES AFFECTING PERMEABILITY

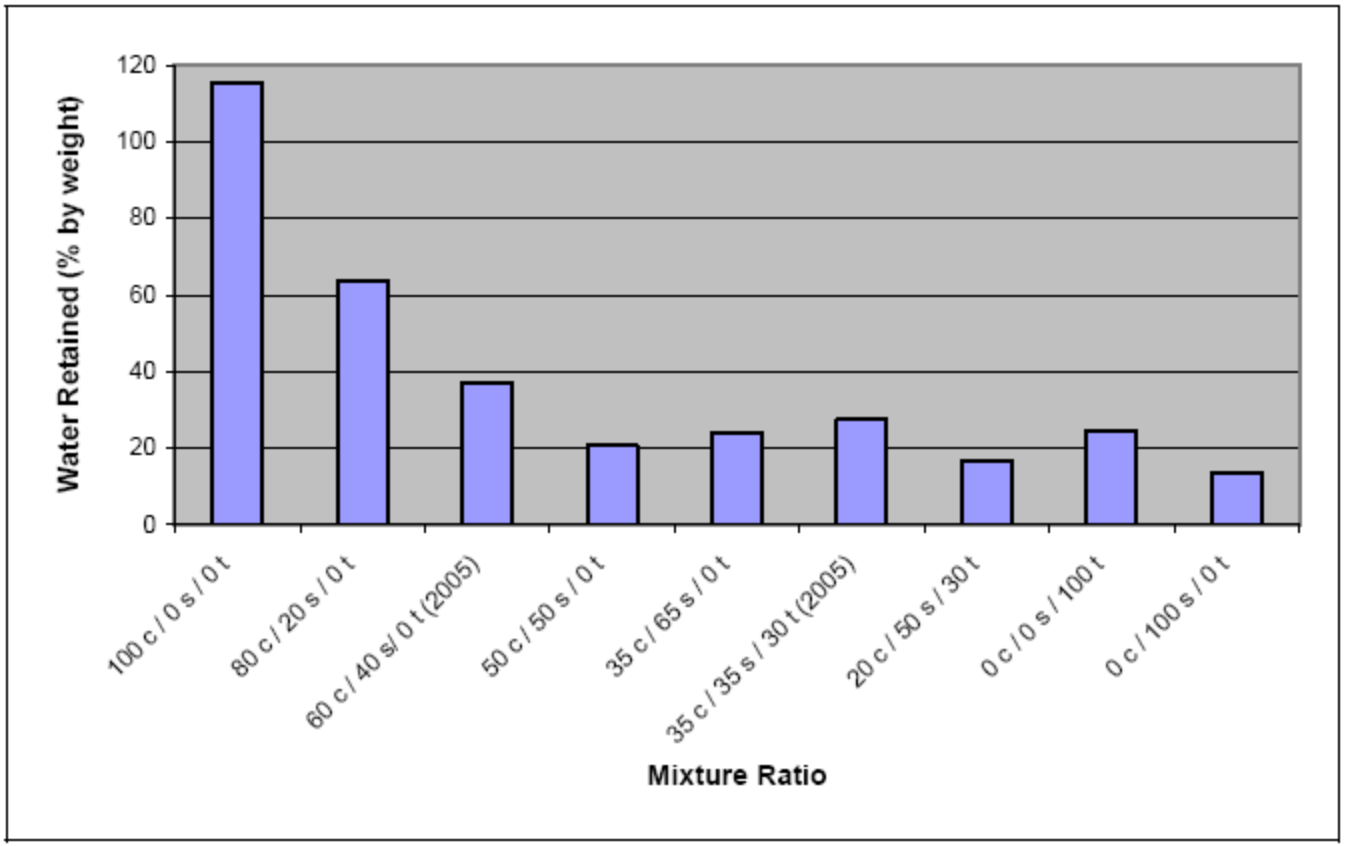


Figure 5: Results of Field Capacity Experiments.

Ref: Donald D. Carpenter and Laura Hallam; An investigation of rain garden planting mixture performance and the implication for design; Low Impact Development 2008.

REFERENCES

- 6.x.2.1 EPA 841-B-09-001; Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act; December 2009.
- 6.x.2.2 EPA memorandum; Clarification on which stormwater infiltration practices/technologies have the potential to be regulated as "Class V" wells by the Underground Injection Control Program, 13 June 2008.
- 6.x.2.3 Memorandum for Assistant Secretary of the Army, DoD Implementation of Storm Water Requirements under Section 438 of the Energy Independence and Security Act (EISA); 13 October 2009.
- 6.x.2.4 UFC 3-230-06A; Subsurface Drainage; 16 January 2004.
- 6.x.2.5 Public Works Technical Bulletin 200-1-62, Low Impact Development for Sustainable Installations: Stormwater Design and Planning Guidance for Development Within Army Training Areas, 1 October 2008.
- 6.x.2.6 UFC 3-210-10, Low Impact Development, 25 October 2004.

REFERENCES

- 6.x.2.7 Donald D. Carpenter and Laura Hallam, An investigation of rain garden planting mixture performance and the implication for design, Low Impact Development 2008.
- 6.x.2.8 Robert A. Brown, William F. Hunt, NC State University and A&T State University Cooperative Extension, Urban Waterways, Improving Exfiltration from BMPs: Research and Recommendations.
- 6.x.2.9 Interlocking Concrete Pavement Institute, Permeable Interlocking Concrete Pavements, 3rd Edition.
- STORMCON (annual)
- LOW IMPACT DEVELOPMENT CONFERENCE (annual)
- http://stormh2o.com/

QUESTIONS?

Low Impact Development Overview

19 April 2011

Ms. Hayley Diamond
Environmental Division, DPW, USAG-HI

Our mission is to provide sustainable installation support and services for Soldiers, Families, and the military community that meets current and future mission requirements, promotes community well-being and enhances the natural environment

Outline

- U.S. Army Garrison, Hawaii (USAG-HI) draft “Storm Water Management Standard”
  - Low Impact Development (LID) Concepts
  - Best Management Practices (BMPs)
- LID versus Conventional Storm Water Management System (SWMS)
  - Cost and Maintenance
  - Energy and Water Efficiency and Security
  - Resources
- Bay Area LID Experience
- LID Design Approach

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USAG-HI Draft Standard

- Provide SWMS in accordance with Federal, State, and Local codes
  - Section 438 of Energy Independence and Security Act (EISA) 2007
  - US Environmental Protection Agency (EPA) "Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act."
  - To download:

    www.epa.gov/owow/nps/lid/section 438

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USAG-HI Draft Standard

- SWMS to retain runoff volume from 95th percentile storm

Installation	95th Percentile Storm – 24 hour (inches)
Schofield Barracks/Wheeler Army Airfield/South Range	1.9
Helemano Military Reservation	2.5
Fort Shafter/Tripler Army Medical Center/Aliamanu Military Reservation	2.1 or 1.5?

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USAG-HI Draft Standard

- Provide operation and maintenance plan
  - Maintenance activity
  - Schedule
- Employ LID to retain runoff volume
  - Small-scale, decentralized treatment facilities to reduce and treat runoff where it originates, mimicking natural hydrology
    - Infiltration
    - Evapotranspiration
    - Reuse
  - Source Control and Treatment Control BMPs

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USAG-HI Draft Standard

- Source Control BMPs
- Minimize runoff associated with development and enhance runoff treatment
  - Minimize and disconnect impervious surfaces
  - Grade site to sheet flow to vegetated areas
  - Minimize development on well-infiltrating soils
  - Phase construction to minimize soil compaction

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USAG-HI Draft Standard

- Treatment Control BMPs
- Treat runoff associated with development
- Sized, engineered facilities
  - Bioretention
  - Vegetated swale
  - Vegetated buffer strip
  - Pocket wetland
  - Infiltration trench
  - Permeable paving
  - Rainwater harvesting
  - Green roof

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USAG-HI Draft Standard

- Bioretention
  - Small-scale facility comprised of vegetation (tolerant to periodic inundation), engineered soil (high organic content) and aggregate storage layer
  - Single facility should not receive runoff from more than 1 acre
  - Recommend 10 foot setback from building foundation, no setback if lined, flow-through system
  - Native soil infiltration rate of 0.5 inch per hour

Source: SFPUC

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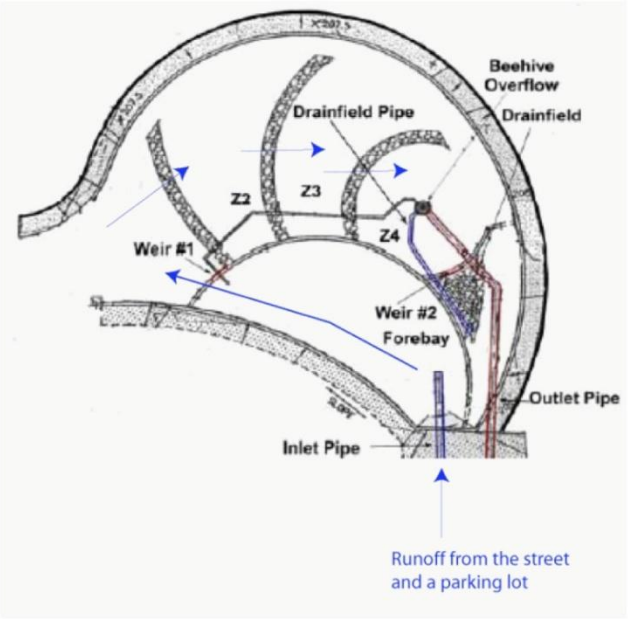
USAG-HI Draft Standard

- Bioretention

Bioretention in Portland, OR
Source: Portland BES



Source: SFPUC

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USAG-HI Draft Standard

- Bioretention

Source: SFPUC

Source: Landscape Architecture Magazine

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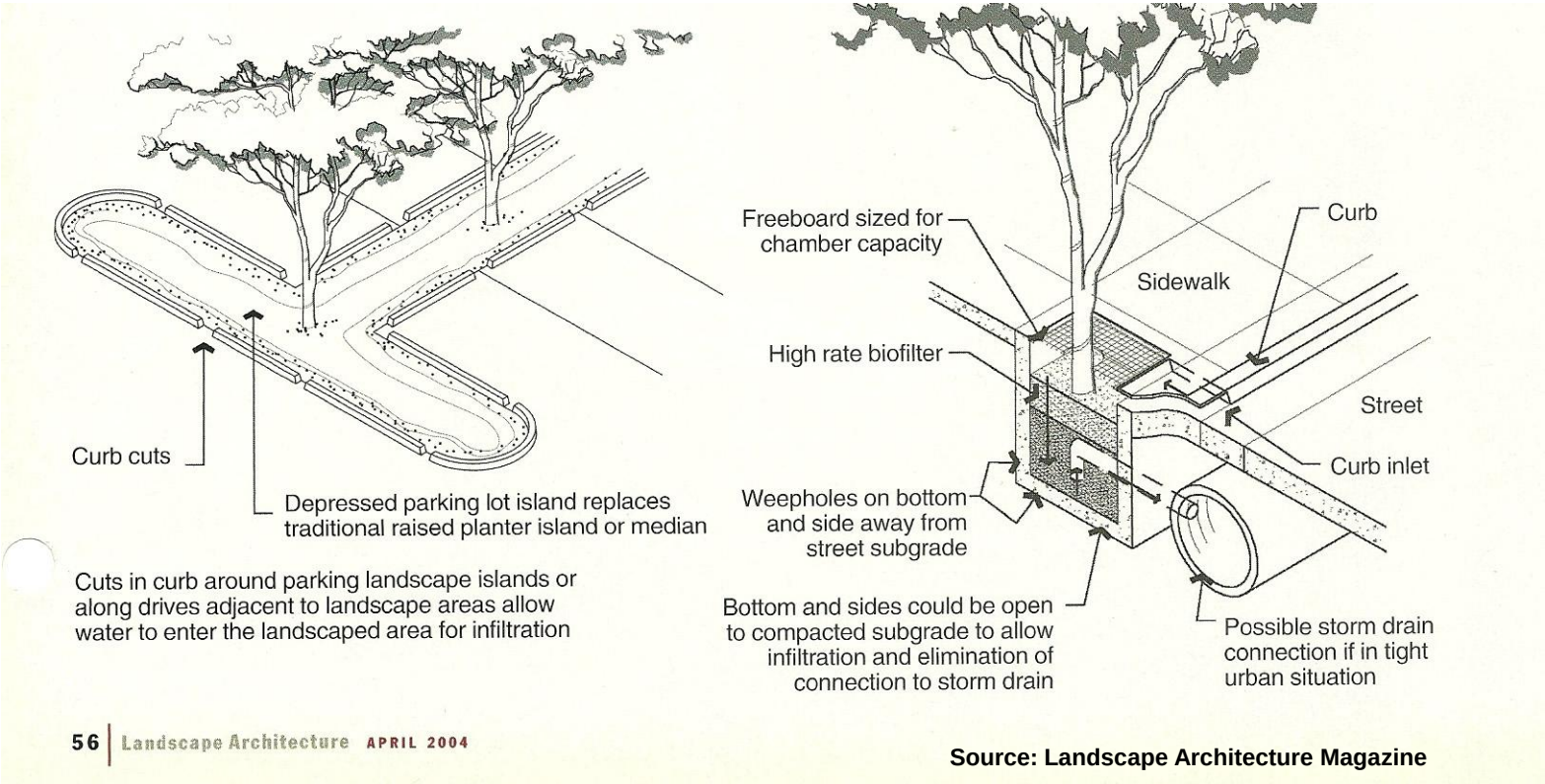
USAG-HI Draft Standard

- Bioretention



Source: Landscape Architecture Magazine

Hayley Diamond/IMPC-HI-PWE/(808) 656-3806 / hayley.diamond@us.army.mil

USAG-HI Draft Standard

- Vegetated swale
  - Broad, shallow trapezoidal channel with dense vegetation covering slopes and bottom
  - Linear, sloped bioretention, 3:1 maximum channel bank slope, check dams for slope exceeding 5%
  - Can eliminate need for curb and gutter
  - Recommend 10 foot setback from building foundation, no setback if lined, flow-through system
  - Native soil infiltration rate of 0.5 inch per hour

Source: SFPUC

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USAG-HI Draft Standard

- Vegetated swale and pervious concrete, no curb/gutter

Source: SFPUC

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USAG-HI Draft Standard

- Sunset Swales parking lot retrofit (2007)
  - Vegetated swales and infiltration basins treating 3.5 acre parking lot adjacent to Lake Merced
    - Native, riparian plant palette
  - Project cost $288,300, approximately $1.87 per square foot of impervious area managed

Photos from Construction

Source: SFPUC

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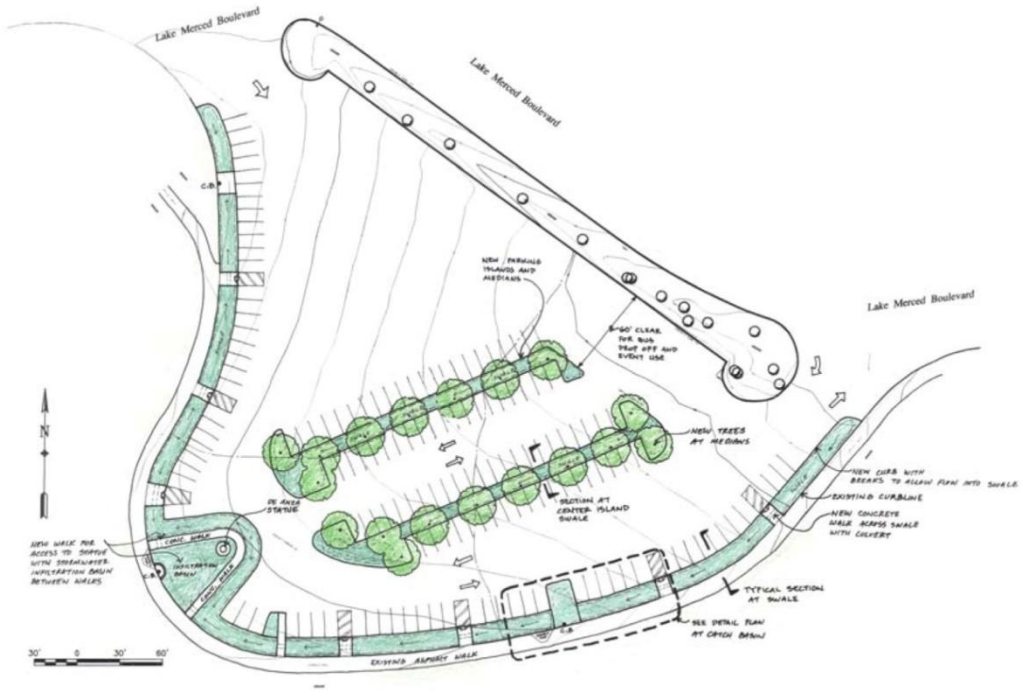
USAG-HI Draft Standard

- Sunset Swales parking lot retrofit (2007)



Source: SFPUC

Bioretention in parking lots
Source: SFPUC

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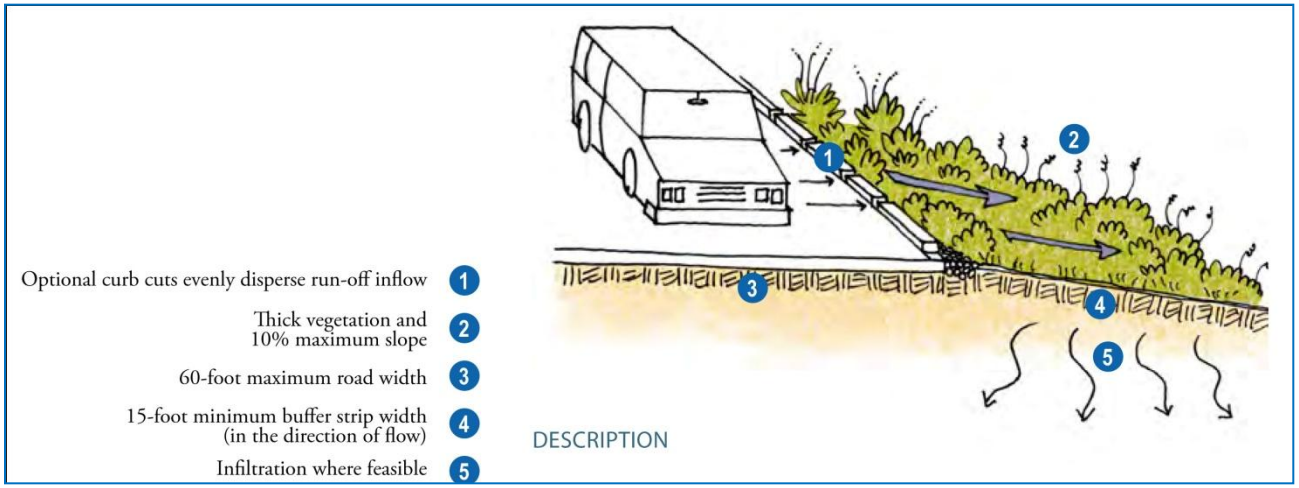
USAG-HI Draft Standard

- Vegetated buffer strip
  - Sloped, vegetated facility to slow runoff, capture pollutants
  - Typical treatment for roads, half-size of contributing road width (minimum 15 feet in width)
  - Recommend to use with other BMPs



Source: SFPUC

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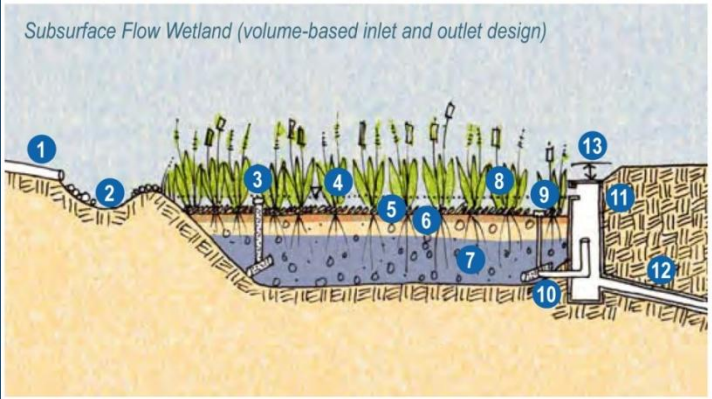
USAG-HI Draft Standard

- Pocket wetland
  - Shallow, vegetated pool
  - Requires pretreatment BMP to remove rubbish and sediment
  - Typically sized 3% to 5% of contributing area
  - Any soil type



1. Inlet
2. Forebay (pretreatment and energy dissipation)
3. Perforated riser and inlet pipe (riser conveys ponded water to gravel layer)
4. Water Quality Volume level
5. Mulch
6. Low permeability wetland soil
7. Medium and coarse gravel
8. Wetland vegetation
9. Observation well and cleanout
10. Primary outlet (perforated pipe with adjustable standpipe to control water level)
11. Overflow structure with screened inlets
12. Outflow to collection system, catch basin, or receiving water
13. Minimum 1 foot freeboard

Source: SFPUC

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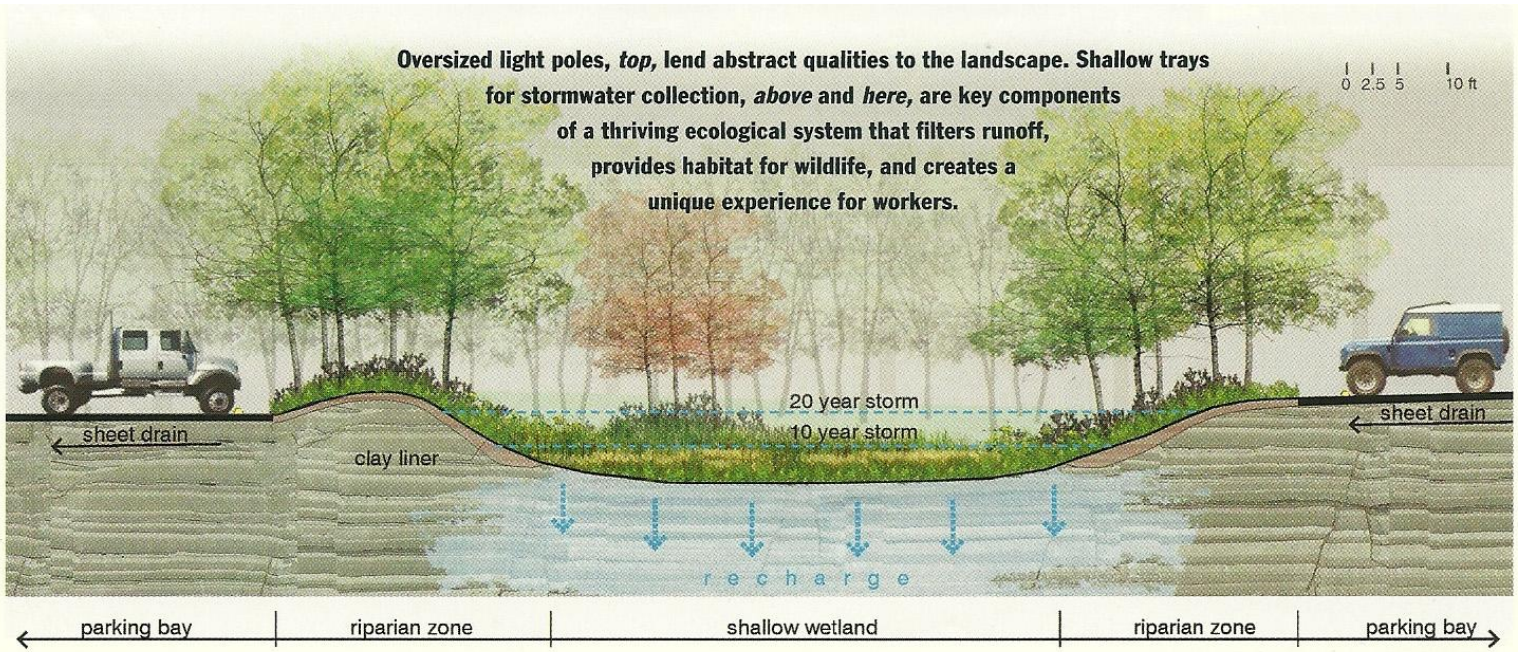
Low Impact Development Overview

USAG-HI Draft Standard

- Pocket wetland



RON ANTON ROCZ, TOP AND MIDDLE; MICHAEL VAN VALKENBURGH ASSOCIATES INC., BOTTO

28 | Landscape Architecture JANUARY 2007

Source: Landscape Architecture Magazine

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USAG-HI Draft Standard

- Infiltration trench
  - Long, narrow, rock-filled trench
  - Requires pretreatment BMP to remove rubbish and sediment
  - Can eliminate need for curb and gutter
  - Suitable for drainage areas 5 acres or less
  - Typically three 3 to 8 feet in depth, not wider than 25 feet
  - Recommend 10 foot setback from building foundation
  - Native soil infiltration rate of 0.5 inch per hour

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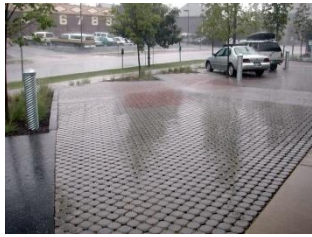
USAG-HI Draft Standard

- Permeable paving
  - Porous, load-bearing surface over aggregate storage layer:
    - Permeable interlocking pavers
    - Porous asphalt
    - Pervious concrete
  - Recommend 10 foot setback from building foundation
  - Native soil infiltration rate of 0.5 inch per hour



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USAG-HI Draft Standard

- Permeable interlocking pavers
  - Cast-in-place or pre-cast concrete blocks with small joints or openings
- Porous asphalt
  - Similar to standard hot-mix but with reduced aggregate fines (typically 2.5” deep)
- Pervious concrete
  - Similar to standard concrete but without fine aggregate (sand and finer) and with optional special admixtures incorporated (typically 4 to 8 inches deep depending on loading)

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USAG-HI Draft Standard

- Permeable paving

Source: Landscape Architecture Magazine

Source: SFPUC

Source: US EPA

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USAG-HI Draft Standard

- Permeable paving

Source: SFPUC

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USAG-HI Draft Standard

Initial Construction Cost Fort Stewart Parking Lot Retrofit (22,042 sq. ft.)	Asphalt Pavement	Concrete Pavement	Interlocking Concrete Pavement
Soil Subbase Preparation	$40,000	$40,000	$40,000
Installation of New Pavement System	$2.84/SF $62,600	$4.88/SF $107,400	$7.70/SF $163,400
Installation of Storm Water Infrastructure	$15,000	$15,000	0
Initial Construction Cost	$117,600	$162,400	$203,000
Life Cycle Cost Analysis (LCCA)	**Asphalt Pavement**	**Concrete Pavement**	**Interlocking Concrete Pavement**
Design Life (years)	25	30	45+
Estimated Annualized Maintenance Cost (50 Yr Service Life)	$6,000 (2)	$3,000 (2)	$1,000
Replacement Interval Factor	2.0	1.67	1.11
Replacement Cost	$125,200	$179,400	$181,400
Avoided Cost	-	-	Land Area Not Required for Dry Detention Basin
Total Cost (LCCA)	$542,800	$491,800	$434,400

Source: Weston Solutions

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USAG-HI Draft Standard

- Disconnect downspout
  - Direct roof downspout to treatment control BMP:
    - Bioretention
    - Vegetated swale
    - Vegetated buffer strip
    - Pocket wetland
    - Infiltration trench
    - Permeable paving

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USAG-HI Draft Standard

- Disconnect downspout
  - Western Harbor, Malmo, Sweden, conveys runoff to vegetation and ponds, which double as amenities throughout neighborhood

Source: SFPUC

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USAG-HI Draft Standard

- Rainwater harvesting
  - Collect and store runoff from roof and pavements
  - Offset potable demand for the following:
    - Irrigation
    - Toilet flushing
    - Car washing
    - Kilauea Military Camp
      - 6.5 acres of catchment area
      - 4 storage tanks
      - Potable and non-potable water supply
      - Collect 11.5 million gallons annually

Source: US EPA

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USAG-HI Draft Standard

- Rainwater harvesting

Rainwater Harvesting at Layfayette Elementary School, located in the Sunset Basin in San Francisco, CA

Source: SFPUC

Source: http://mrgreenbiz.wordpress.com/2008/10/05/

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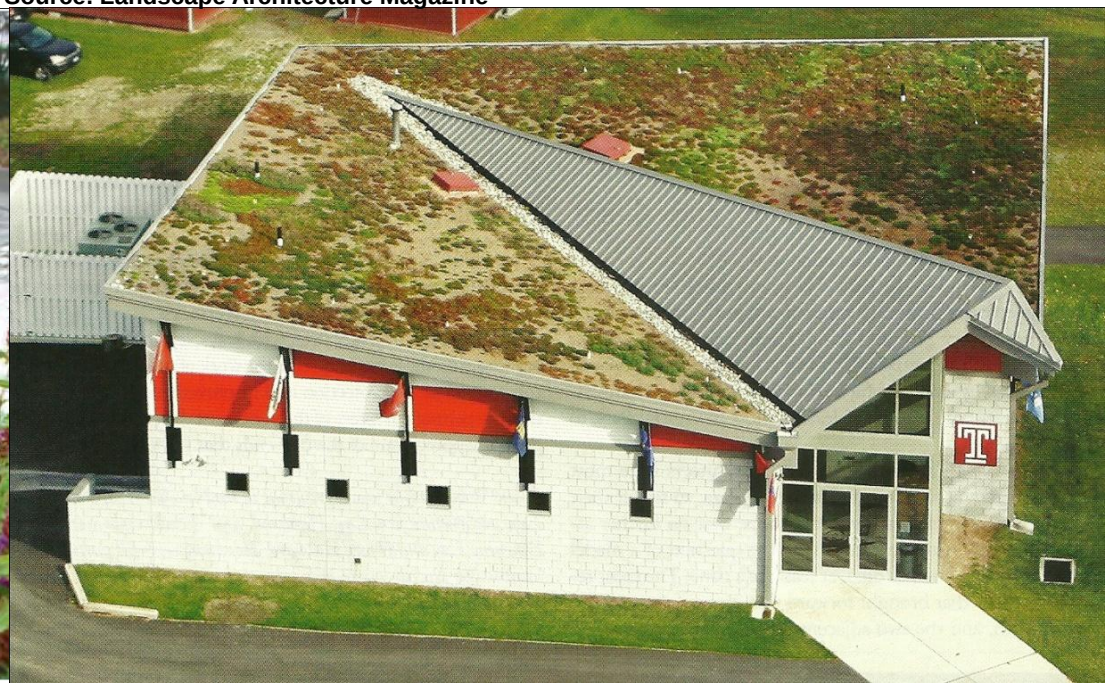
USAG-HI Draft Standard

- Green roof
  - Roofs covered with vegetation
  - Can lower heating and cooling costs for building

Source: SFPUC

Source: Landscape Architecture Magazine



Academy of Sciences building in San Francisco, CA has a nearly 2.5-acre vegetated roof

USAG-HI Draft Standard

Land Use Type

LID Treatment Control BMPs	Building complex	Industrial facility	Road	Parking lot	Sidewalk	Plaza
Bioretention	x	x	x	x	x	x
Vegetated swale	x	x	x	x	x	x
Vegetated buffer strip	x		x	x	x	x
Pocket wetland	x	x		x		x
Infiltration trench	x			x	x	x
Permeable paving	x		x	x	x	x
Disconnect downspout	x	x				
Rainwater harvesting	x	x		x		x
Green roof	x	x				

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USAG-HI Draft Standard

- Specify native or locally adapted vegetation
  - Plant palette and irrigation schedule to be reviewed by Mr. Patrick Ching, DPW Agronomist

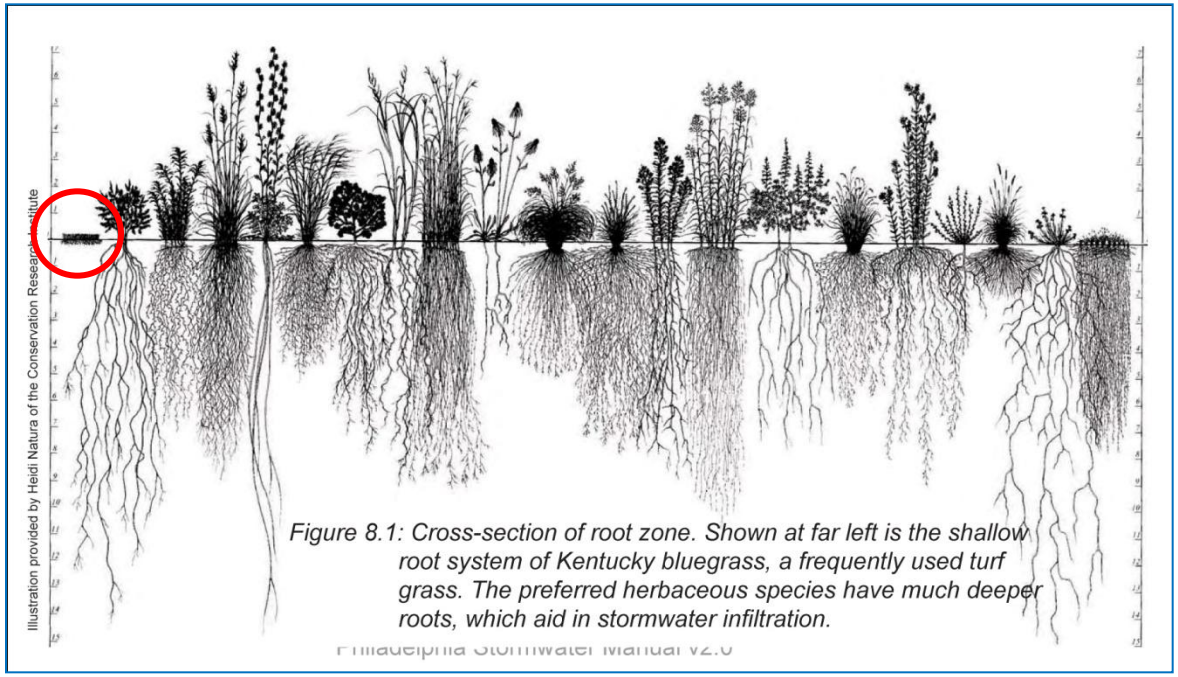

Figure 8.1: Cross-section of root zone. Shown at far left is the shallow root system of Kentucky bluegrass, a frequently used turf grass. The preferred herbaceous species have much deeper roots, which aid in stormwater infiltration.

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LID Versus Conventional SWMS

- Traditional development practices replace pervious surfaces with impervious surfaces
- Increase in storm water runoff
  - Flooding
  - Erodes stream banks and scours stream beds
  - Large quantities of sediment and other mobilized pollutants enter streams and ocean
- Engineer conveyance system to remove runoff from site and construct detention ponds to mitigate impacts of increased runoff rates

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LID Versus Conventional SWMS

- Detention ponds
  - Require space
  - Fail to provide peak control for small, frequently occurring storms
  - Increased duration of peak flow
  - Negligible runoff volume reduction
  - More costly to construct and maintain versus LID

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LID Versus Conventional SWMS

- LID
  - Can reduce downstream flooding through reduction of runoff volume and peak flows
  - Does not require large, contiguous areas of land
  - Increased duration of peak flow
  - Energy and water sustainability
    - Reuse
    - Lower heat island effect/passive cooling
  - Achieves regulatory compliance
  - Aesthetic value/quality of life

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LID Versus Conventional SWMS

LID Technology	Cost; Annual Maintenance Cost (% of Construction Cost)
Bioretention	$3 - $15 per square foot to construct; 5% -7% or $3,012.10 per acre per year
Vegetated Swale	$5 - $9 per linear foot for 15 foot wide swale; 5% -7%
Vegetated Buffer Strip	$0.30 - $0.70 per square foot; $320 per acre
Pocket Wetland	$2.62 per square foot for half-acre two foot wetland; 3% - 5%
Infiltration Trench	$5 - $50 per cubic foot of storage; 5% - 20%
Permeable Paving	Porous asphalt: $3, pervious concrete: $7, permeable pavers: $5 -$15 (all per square foot); lasts 25 - 45 years
Rainwater Harvesting	Varies, typically $1 - $2 per gallon
Green Roof	$18 per square foot; $5.50 per square foot

Source: US EPA,SFPUC, and Wilson, Stephen and Greg Kent (2009). "Real-Life BMP Maintenance Experiences."

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LID Versus Conventional SWMS

SWMS Technology	Cost; Annual Maintenance Cost (% of Construction Cost)
Detention Pond	$160,000 for 0.3 acre-foot; 3% - 5%
Swirl Separator*	Pre-cast units range from $10,000 - $60,000; $1,000 annual maintenance cost
Drain insert*	$100 - $2,000; $534 per acre per year, last 1 - 3 years
Water quality inlet*	$5,000 - $16,000 for pre-cast catch basin

*Does not constitute treatment to the Maximum Extent Practicable by the State of California Regional Water Board. Best used as part of treatment train.

Source: US EPA,SFPUC, and Wilson, Stephen and Greg Kent (2009). "Real-Life BMP Maintenance Experiences."

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LID Versus Conventional SWMS

LID Technology	Maintenance Level of Effort	Frequency
Bioretention	Minimum to moderate: Vegetation management	Moderate
Vegetated Swale	Low to moderate: Occasional removal of captured pollutants, vegetation management	Moderate
Vegetated Buffer Strip	Moderate: Occasional removal of captured pollutants, vegetation management	Moderate
Pocket Wetland	Moderate to high: Occasional removal of debris, vegetation management	Low
Infiltration Trench	Moderate: Replacement of aggregate when clog	Moderate
Permeable Paving	Moderate: Twice annual vacuuming	Low

Source: Water Environment Research Foundation

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LID Versus Conventional SWMS

LID Technology	Maintenance Level of Effort	Frequency
Disconnect Downspout	Minimal	Low
Rainwater Harvesting	Minimal	Low
Green Roof	Minimum to moderate: Vegetation management	Moderate

Source: Water Environment Research Foundation

- Sediment and gross solid build-up are main causes of BMP deterioration (Kang, Joo-Hyan, 2008)

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LID Versus Conventional SWMS

- Wilson, Stephen and Greg Kent. (2009). “Real-Life BMP Maintenance Experiences.”
  - Curb inlet filter – Waikiki Case Study
    - Cleaning time analysis among top four brands (assumes 2 person crew, 8-hour work day)
      - Hydrocompliance – 4 catch basins cleaned per day
      - AbTech – 21 catch basins cleaned per day
      - KriStar – 14 catch basins cleaned per day
      - Bio Clean – 42 catch basins cleaned per day

LID Versus Conventional SWMS

- Wilson, Stephen and Greg Kent. (2009). “Real-Life BMP Maintenance Experiences.”
  - Detention Basin – San Marcos, CA
    - Treating residential and open lots
    - Water Quality Volume: 25,600 cubic feet
    - Annual maintenance cost: $8,320
  - Hydrodynamic Separator and Media Filter – Santa Monica, CA
    - Treating wet weather flows of 33 cubic feet per second
    - Treating dry weather flows of 2 cubic feet per second
    - Annual maintenance cost: $24,900

LID Versus Conventional SWMS

- Wilson, Stephen and Greg Kent. (2009). “Real-Life BMP Maintenance Experiences.”
  - Vegetated swale with pretreatment – City of Ontario, CA
    - .25 acre parking lot
    - Two swales and trench drain with Bio Clean filters as pretreatment
    - Annual maintenance cost: $350

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LID Versus Conventional SWMS

- US EPA. (2007). “Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices.”
  - 17 case studies conclude that applying LID techniques reduce project costs and improve environmental performance
  - Total capital cost savings ranged from 15 to 80 percent for LID strategies versus conventional, with a few exceptions of higher LID cost

LID Versus Conventional SWMS

- US EPA. (2007). “Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices.”
  - 2nd Avenue SEA Street, Seattle, Washington
    - Vegetated swales reduced flooding, eliminated curb and gutter for 660 foot block, costing $651,548 (29% cost saving compared to conventional approach)
  - Parking Lot Retrofits, Bellingham, Washington
    - Bioretention in lieu of underground storage vaults
    - Saved $22,000 on construction (80% savings compared to underground storage vault)

LID Versus Conventional SWMS

- Energy and Water Efficiency and Security, Installation Management Campaign Plan 2010-2017
  - Reduced energy and water consumption
    - Rainwater harvesting
    - Permeable paving: “Cool Paving, lower temperatures when wet” – US EPA
    - Green roofs reduce building energy consumption by 20% - 30%
    - Strategically placed trees can reduce cooling costs by 10% - 20%
    - Vegetation reduces heat island effect, can lead to reduction in cooling cost

Source: Water Environment Research Foundation

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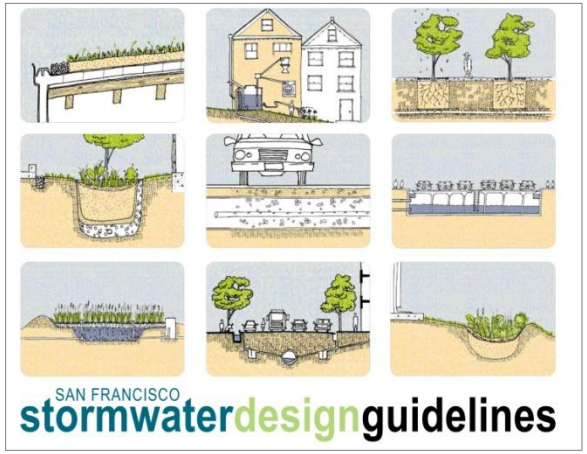
LID Versus Conventional SWMS

- Resources
  - Department of Defense. (2010). “Unified Facilities Criteria: Low Impact Development.” UFC 3-210-10.
  - Horsley Witten Group, Inc. (2006). “CNMI and Guam Stormwater Management Manual.”
  - Horsley Witten Group, Inc. (2006). “Low Impact Development: A Practitioner's Guide Hawaii.”
  - San Francisco Public Utility Commission. (2009). “Stormwater Design Guidelines.”
  - State of Hawaii Commission on Water Resource Management. (2008). “A Handbook for Stormwater Reclamation and Reuse Best Management Practices in Hawaii.”
  - State of Hawaii Department of Transportation Highways Division. (2007). “Storm Water Permanent Best Management Practices Manual.”
  - US Army Corps of Engineers. (2005). “Sustainable Stormwater Storage Alternatives for Army Installations.”
  - http://www.garrison.hawaii.army.mil/sustainability/CleanWater.aspx

Bay Area LID Experience

- San Francisco Public Utility Commission (SFPUC) "Stormwater Design Guidelines"
  - Vegetation Palette
  - Stormwater Control Plan
  - Available at:
    - http://sfwater.org/mto_main.cfm/MC_ID/14/MSC_ID/361/MTO_ID/543
  - Rainwater harvesting subsidy program



Source: SFPUC

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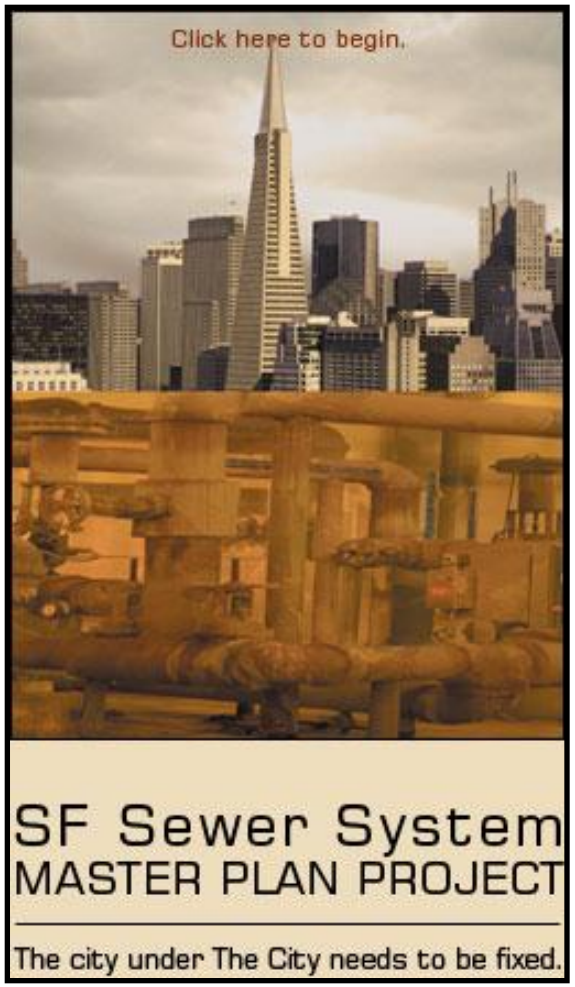
Bay Area LID Experience

- Combined Sewer
  - Flood control
  - Sewer System Master Plan Project Draft Report (2010)
    - 30 year plan for critical infrastructure investments
    - LID projects constitute12% of $6,785 million in sewer system improvement construction projects over 30 years



Source: SFPUC

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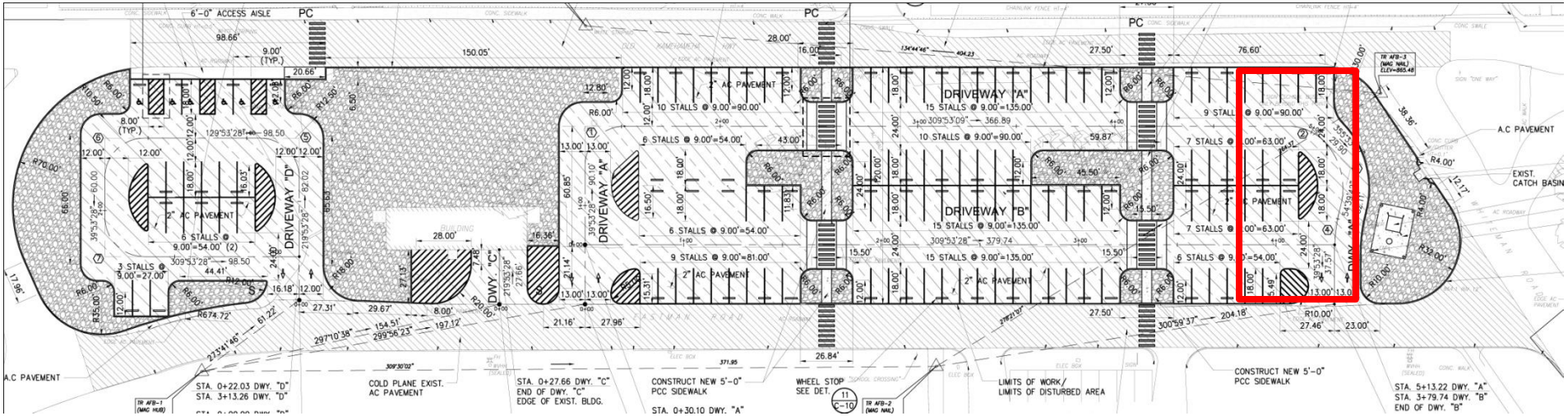
Bay Area LID Experience

- Emeryville Stormwater Management Design
  - Brownfield: former industrial land along SF Bay between Berkeley and Oakland
  - Dense, urban redevelopment
  - Bioretention and permeable paving systems lined to prevent infiltration
  - "Stormwater Guidelines for Dense, Green Redevelopment available at:
    - http://www.epa.gov/dced/pdf/Stormwater_Guidelines.pdf

Source: SFPUC

Low Impact Development Overview

LID Design Approach



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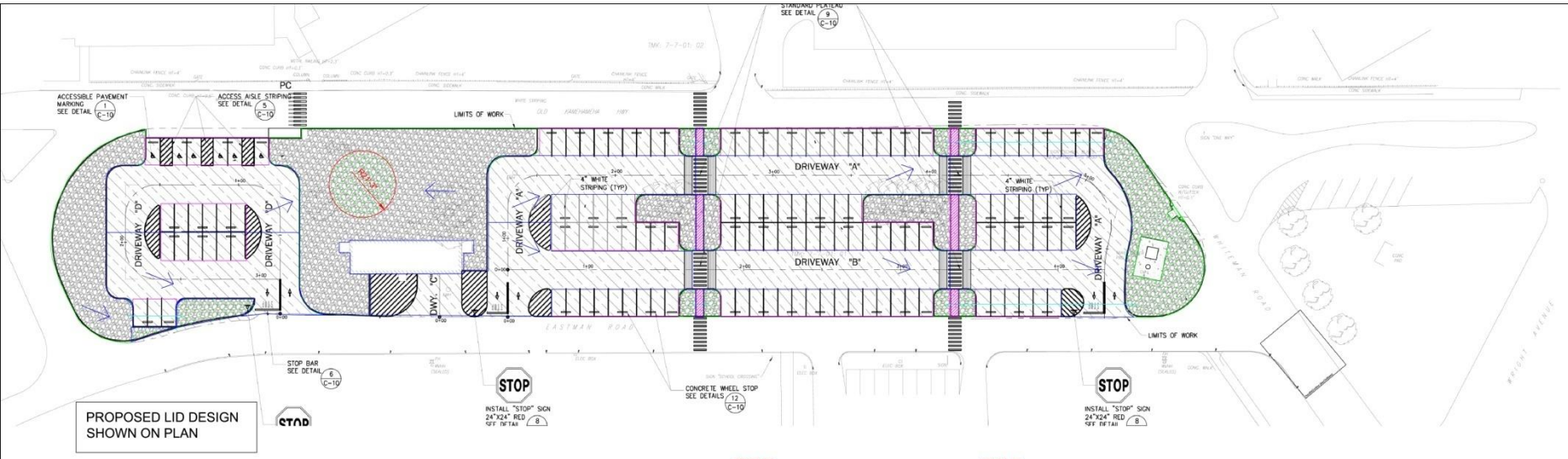
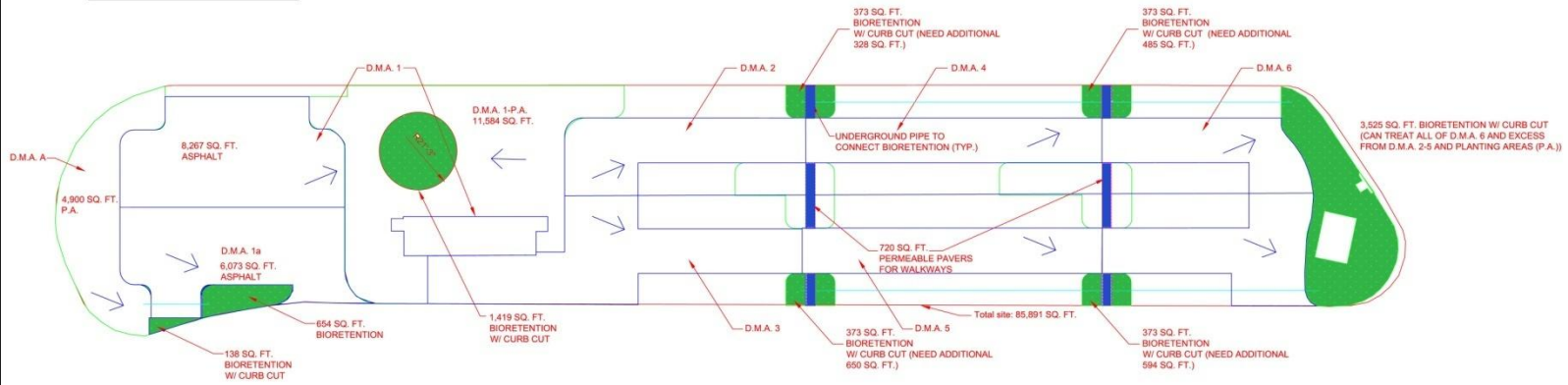
Low Impact Development Overview

LID Design Approach



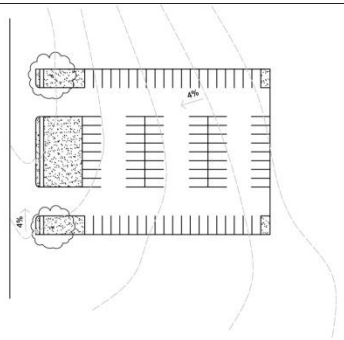


NOTE:
WQV=CARd, where WQV is volume of water in cubic feet, A is area in square feet, Rd is rainfall depth in feet
To retain the 95th percentile storm, use 1.9" for Wheeler Army Airfield (based on at least 30 years of record from National Climatic Data Center)

D.M.A. #	D.M.A. (SQ. FT.)	C (ASPHALT)	Rd (1.9"/12)	WQV (CU. FT.)	BIORETENTION* (SQ. FT.)
A	4900	0.2	0.158333333	155	133
1	9905	0.8	0.158333333	1255	1076
1-P.A.	11584	0.2	0.158333333	367	315
1a	6073	0.8	0.158333333	769	659
2	6461	0.8	0.158333333	818	701

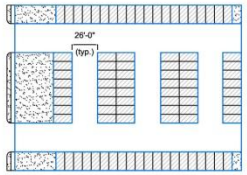
LID Design Approach

1.



Conceptual Parking Lot Layout on Existing Site Plan

2.



Calculate Land Use Areas: Pervious (i.e. landscape, permeable pavers) and Impervious (i.e. asphalt)

- 18,269 sq. ft. asphalt
- 4,791 sq. ft. turf
- 15,048 sq. ft. permeable paving in stalls

3. Calculate Treatment Volume

1. Eliminate permeable paving since it will be designed to infiltrate the 95th percentile storm (1.9" for Schofield Barracks and Wheeler Army Airfield)

2. Calculate treatment volume with the equation WQv = CARd, where C is the runoff coefficient (0.2 for turf and 0.8 for asphalt), A is area in square feet, and Rd is the 95th percentile storm, divided by 12 to convert inches to feet

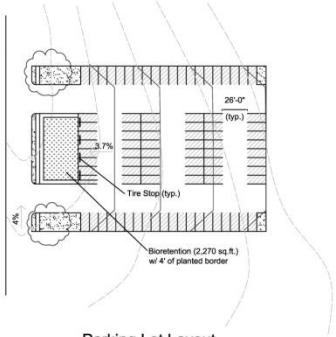
WQv (asphalt) = 0.8 x 18,269 x (1.9/12) = 2,314 cu. ft.
WQv (turf) = 0.2 x 4,791 x (1.9/12) = 152 cu. ft.
WQv (total) = 2,466 cu. ft.

3. Enter treatment volume into bioretention calculator (see provided calculator from the San Francisco Public Utiltiies Commission) or similar to determine area of bioretention required

Size of bioretention required = 2,114 sq. ft.

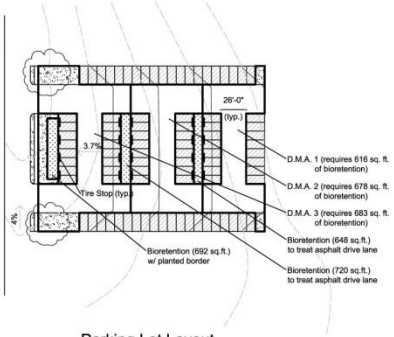
4. Modify layout to include bioretention areas, may require several alternatives and site grading

4a.



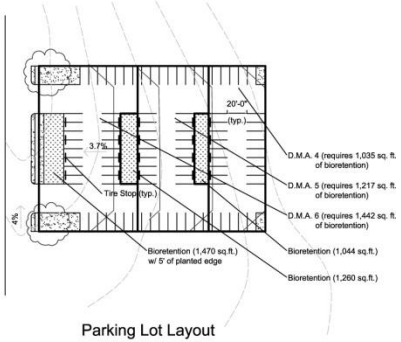
Parking Lot Layout
Alternative #1
(least preferred)

4b.



Parking Lot Layout
Alternative #2
(bioretention islands)

4c.



Parking Lot Layout
Alternative #3
(no permeable paving / bioretention islands)

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LID Design Approach

- Section 438 of EISA 2007 requirement to retain 95th percentile storm on-site
  - To calculate: WQv = CARd, where:
    - WQv = Water Quality Treatment Volume
    - C = Composite Runoff Coefficient
    - A = Area (square feet)
    - Rd = Rainfall Depth (feet)

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LID Design Approach

- Achieves Leadership in Energy and Environmental Design (LEED) Storm Water Quality SS Credit 6.2
  - Implement a storm water management plan that reduces impervious cover, promotes infiltration, and captures and treats the storm water runoff from 90% of the average annual rainfall using acceptable BMPs (best management practices)
  - Rd = 1.0”, which is less than 95th percentile storm

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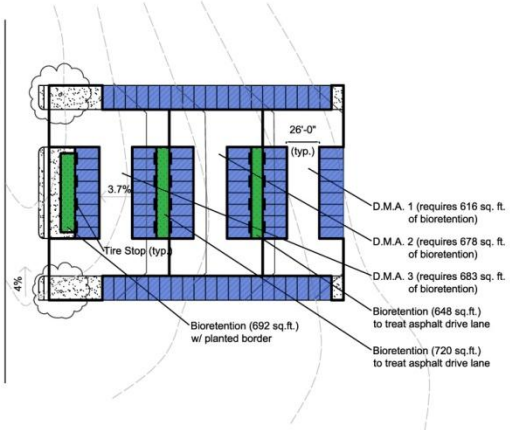
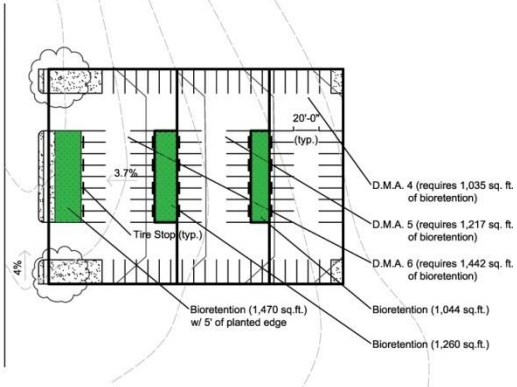
LID Design Approach

4b.



Parking Lot Layout
Alternative #2
(bioretention islands)

4c.



Parking Lot Layout
Alternative #3
(no permeable paving / bioretention islands)

D.M.A.	A (sq. ft.)	Rd (ft.)	C	WQv (cu.ft.)	Bioretention (sq. ft.)*
1	361	0.1583	0.2	11.4	10
1	5582.5	0.1583	0.8	707.1	606
2	6244.5	0.1583	0.8	791.0	678
3	3011	0.1583	0.2	95.3	81
3	5547.7	0.1583	0.8	702.7	602
4	361	0.1583	0.2	11.4	10
4	9441	0.1583	0.8	1195.9	1025
5	11208.5	0.1583	0.8	1419.7	1217
6	3350	0.1583	0.2	106.1	91
6	12444.7	0.1583	0.8	1576.3	1351

Abbreviations

D.M.A.	Drainage Management Area
A	Area
Rd	Rainfall depth (1.9" for SB and WAAF)
C	Runoff Coefficient
WQv	Water Quality Treatment Volume

Note:

* Bioretention size calculated by using San Francisco Public Utility Commission's BMP sizing calculator)

Low Impact Development Overview

LID Design Approach

BIORETENTION CALCULATOR

These calculators size the area of rain garden or flow-through planter to treat the Water Quality Volume (WQv), or calculate the volume of water treated given user entered available dimensions. For sloped systems, use the volume-based Swale calculator.

Input cell =		User enters value
Default value =		User should only change value if able to provide explanation for adjustment
Calculation cell =		User should not change cell

CALCULATOR

Bioretention Calculator - by Water Quality Volume

1	Water Quality Volume - WQv	1419.7	cubic feet
2	Site Meets Infiltration Constraints?	Yes	
3	Underlying Infiltration Rate - f	0.5	inches/hour (generally require f ≥ 0.5"/hr)
4	**Underdrains Required?**	**No**	
5	Depth of Bioretention Soil Mix - d	1.5	feet (recommend >1.5 ft)
6	Porosity of Bioretention Soil Mix - n	0.35	recommend 0.35
	Hydraulic Conductivity of Bioretention Soil Mix - k	4	in/hr (recommend 4)
7	Max Ponding Depth above Filter - Pd	0.75	feet (recommend 0.5 to 1 ft)
8	Fill Time - T	1	hours (0-2 hours, recommend 1)
9	**Area Calculator**	**1,217**	square feet
10	Area Draining to Bioretention	21,650	square feet
11	Sizing Ratio (Bioretention Area/Drainage Area)	5.6%	typically between 4 to 7% of the impervious drainage area
12	Time Needed to Infiltrate WQv (no underdrain)	56	hours (if greater than 48 hours, install underdrains)

Bioretention Calculator - by Available Area

13	Available Area	1217	square feet
14	Site Meets Infiltration Constraints?	Yes	
15	Underlying Infiltration rate - f	0.5	inches/hour (generally require f ≥0.5"/hr)
16	**Underdrains Required?**	**No**	
17	Depth of Bioretention Soil Mix - d	1.5	feet (generally 0.5 to 1)
18	Porosity of Bioretention Soil Mix - n	0.35	recommend 0.35
	Hydraulic Conductivity of Bioretention Soil Mix - k	4	in/hr (recommend 5)
	Factor of Safety	2	recommend 2
19	Max Ponding Depth above Filter - Pd	0.75	feet (recommend 0.5 to 1 ft)
20	Fill Time - T	1	hours (0-2 hours, recommend 1)
21	**Treated Volume**	**1420**	cubic feet
22	Area Draining to Bioretention	21,650	square feet
23	Sizing Ratio (Bioretention Area/Drainage Area)	5.6%	typically between 4 to 7% of the impervious drainage area
24	Time Needed to Drain WQv	56	hours (if greater than 48 hours, install underdrains)

Source: SFPUC

End Of Brief

INSTALLATION MANAGEMENT COMMAND

IMCOM
SOLDIERS • FAMILIES • CIVILIANS

"Sustain, Support and Defend"

Hayley Diamond/IMPC-HI-PWE/(808) 656-3806 / hayley.diamond@us.army.mil

Infiltration Parameters for Central Oahu
19 April 2011

Steve Turnbull
Environmental Division, DPW, USAG-HI

Our mission is to provide sustainable installation support and services for Soldiers, Families, and the military community that meets current and future mission requirements, promotes community well-being and enhances the natural environment

Purpose

- Provide Summary of Infiltration and Soils Data for Central Oahu.
  - Soil Survey Data from Public Sources (USDA).
  - Surface Double Ring Infiltrometer Tests at Kunia Field Station, Schofield Barracks.
  - Saprolite Infiltration Test for SB Landfill (IRP – Installation Restoration Program).
  - Makua Military Reservation Infiltration Testing.
  - Pending – U of Hawaii.

Soil Summary Central Oahu

- Wahiawa Silty Clay (loam) (WaA,WaB,WaC,WaD2)
  - The parent material for these soils is the basalt formations of the Waianae and Koolau Mountains
  - The soils are often described as Oxisols that are very friable and have high infiltration rates (USDA, 2011)
  - The available water capacity is about 0.11 (1.3 to 1.4 in ft_{-1}) in both the surface and subsoil (available to plants)
  - In places root penetrate 30 cm or more (USDA, 2010)

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Wahiawa Silty Clay

- Top layer highly weathered silty clay 50 cm (12-20 inches)
  - The surface soils are highly weathered and have high vertical hydraulic conductivities comparable with sandy soils (~ 2 cm hr-1)
- 2nd layer low permeability layer 108 cm (12-40 inches)
  - Weathered products are trapped below the surface soil, which has lower hydraulic conductivities (0.01 – 0.1 cm hr-1)
- 3rd layer high permeability Saprolite below 158 cm +(62 inches +)
  - This relatively impervious layer is underlain by Saprolite, with extremely high conductivities (10-50 cm hr-1)
- In addition to the soil texture, the soil structure affects soil hydraulic properties – Secondary Permeability (roots, bug and worm holes, cracks, fractures)
- If a soil is disturbed, the structure may break down, decreasing infiltration

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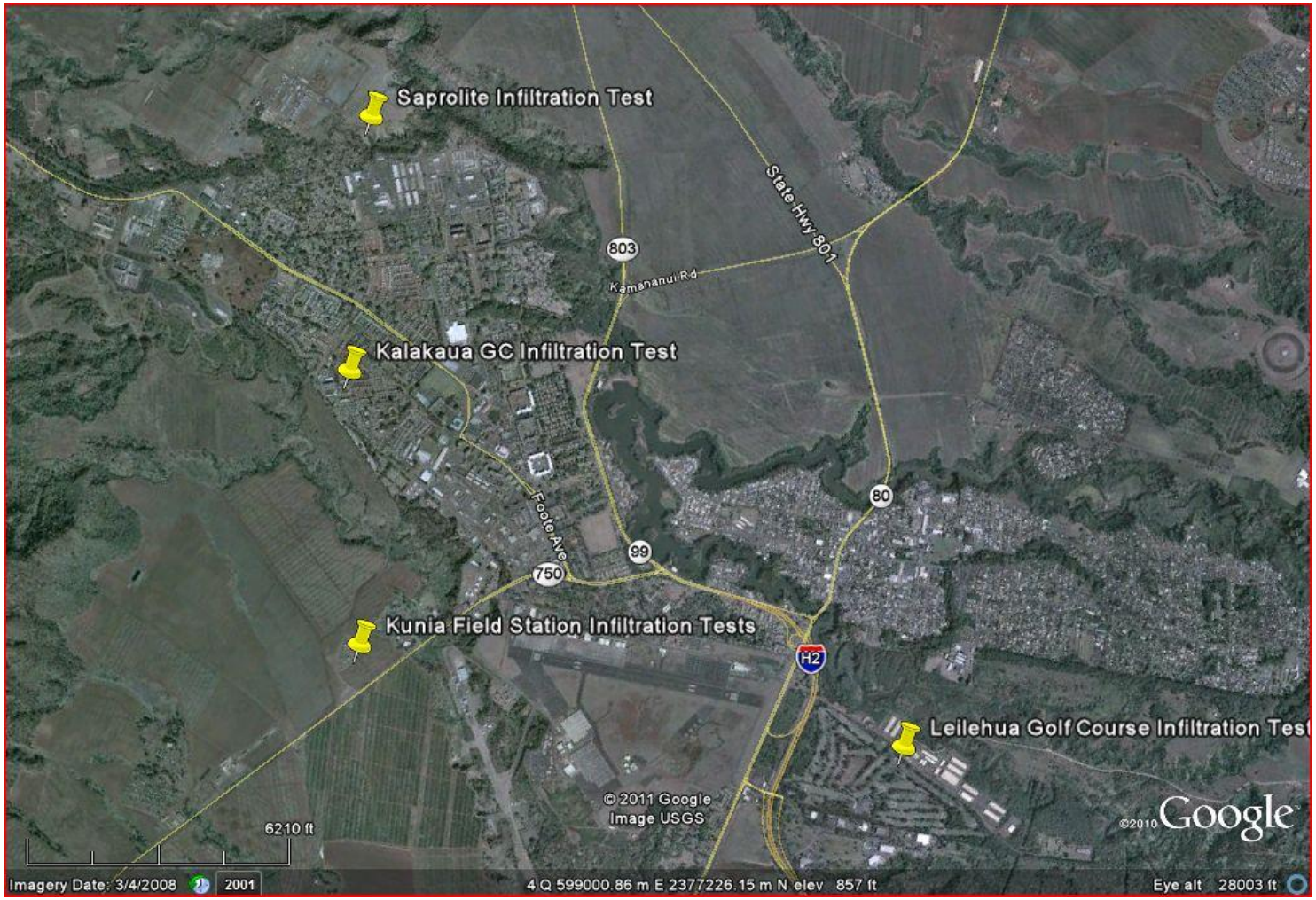
Location of Infiltration Tests



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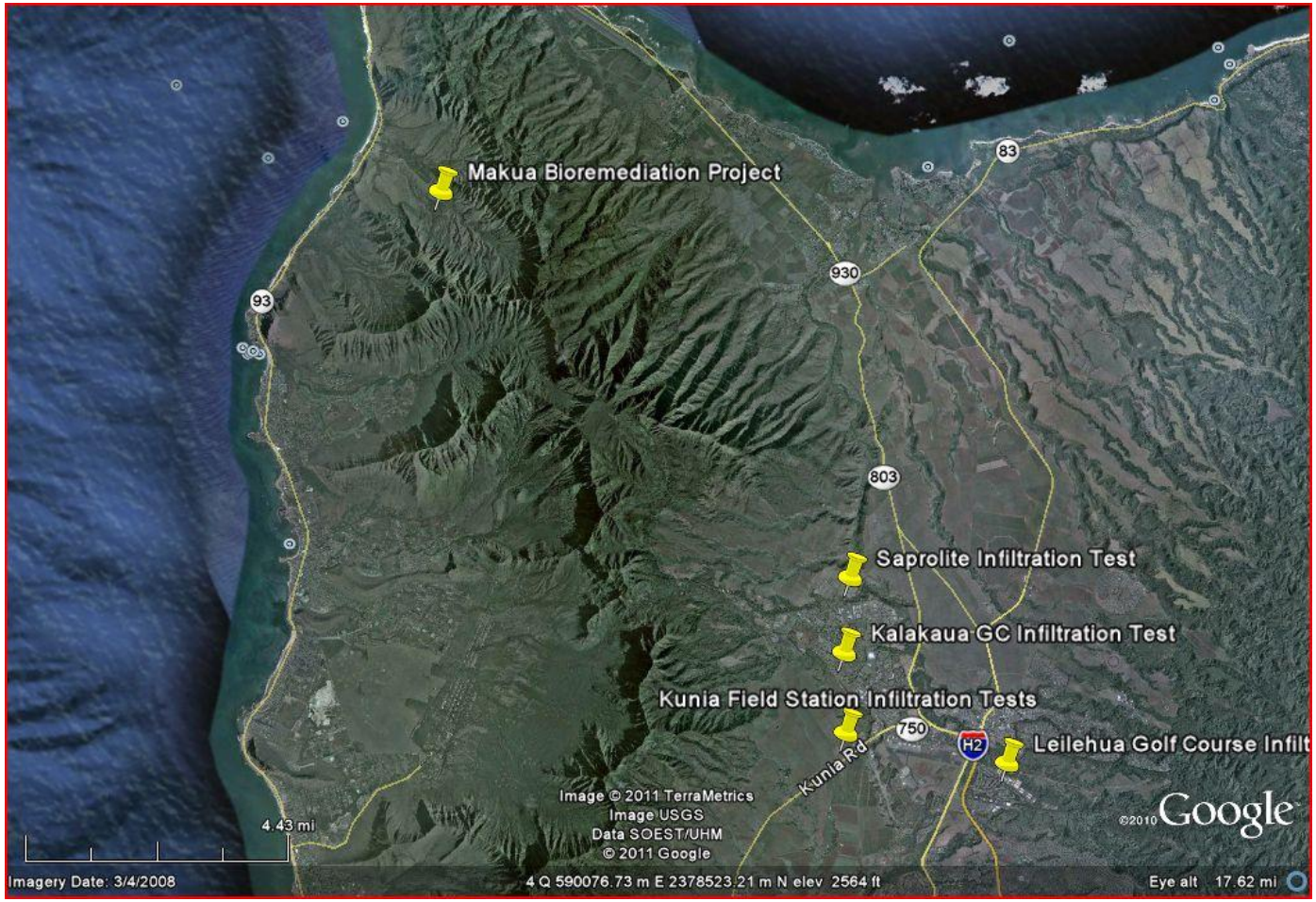
Location of Makua Military Reservation Infiltration Tests



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Double Ring Infiltrometer Tests

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Kunia Field Station Infiltration Tests

- ASTM Standard Method D3385-03, which is an USEPA approved method.
- Infiltration rates 2 to 10 times greater at beginning than end of the test. Tests were run for approximately 1 to 3 days. Grass at surface.

A. Data from Surface Double Ring Infiltrometer Tests at Kunia Field Station							
Test No.	Est. Hyd. Cond.*		Infiltration				
	cm/sec	cm/hr	cm/sec	cm/hr	in/day	in/hr	
1	3.5E-03	12.600	1.4E-03	5.040	48	2	
2	1.8E-03	6.390	7.1E-04	2.556	24	1	
3	1.8E-03	6.390	7.1E-04	2.556	24	1	
4	2.5E-03	9.000	1.0E-03	3.600	33.6	1.4	
5	3.0E-04	1.080	1.2E-04	0.432	4.08	0.17	
6	5.8E-04	2.070	2.3E-04	0.828	7.8	0.325	
Average	**1.7E-03**	**6.255**	**7.0E-04**	**2.502**	**23.58**	**0.9825**	
* Gradient Estimated at 0.4 (literature value)							

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Kalakaua and Leilehua Infiltration Tests

- Run as part of Effluent Reuse Application with State DOH.

D. Effluent Reuse Shallow Infiltration Tests						
			cm/sec	cm/hr	in/day	in/hr
Former Kalakaua Golf Course:			3.73E-03	13.4	126.9	5.3
Leilehua Golf Course:			6.31E-03	22.7	214.6	8.9

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Makua Military Reservation

C. Makua Military Reservation - Bioremediation Project								
				Event Date				
	3/2/2010	4/20/2010	6/1/2010	7/9/2010	8/17/2010	9/21/2010	Winter Rains	Average
Effective Porosity	0.05	0.08	0.04	0.04	0.03	0.03	0.11	**0.05**
Infiltration Rate (cm/hr)	5.49	10.01	5.09	3.29	6.57	5.13	0.83	**5.23**
Infiltration Rate (in/day)	51.84	94.56	48.12	31.08	62.04	48.48	7.8	**49.44**
Infiltration Rate (in/hr)	2.16	3.94	2.005	1.295	2.585	2.02	0.325	2.06

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Saprolite Infiltration Test

B. Saprolite Infiltration Test Infiltration Rates at Schofield Barracks Landfill							
Deep Infiltration Test Measurements (Per Borehole)							
Gradient	Hyd. Cond.		Infiltration Rate				
dimensionless	cm/sec	cm/hr	cm/sec	cm/hr	in/day	in/hr	
1.045	1.04E-02	37.4	1.00E-02	36.0	340	14.2	
1.143	1.03E-02	37.1	9.00E-03	32.4	306	12.8	
1.047	1.06E-02	38.2	1.00E-02	36.0	340	14.2	
1.385	8.20E-03	29.5	5.90E-03	21.2	201	8.4	
1.218	8.90E-03	32.0	7.30E-03	26.3	248	10.3	
1.203	7.80E-03	28.1	6.50E-03	23.4	221	9.2	
Infiltration from Pond Elevation Drop Beginning				15.24	144	6.0	
Infiltration from Pond Elevation Drop End				68.58	648	27.0	

Infiltration Summary

- Infiltration of shallow soils (50 cm or 12 to 20 inches) high enough to absorb rain from 95% Storm (1.9 inches) in many cases with application of LID methods.
- Shallow soils are in many areas a 3 layers system typical of tropical soils (such as Panama):
  - Layer 1: moderate to high permeability
  - Layer 2: lower permeability
  - Layer 3: very high permeability
- Shallow infiltration rates of surface soils were measured at 1.0, 2.0 and 5.0 in/hr at 3 areas of Central Oahu.
- Saprolite infiltration rates were 6.0 to 27.0 in/hr, with an average of 13 in/hr.

LID and Stormwater Management Design Strategies

April 18, 2011

Russell Y. J. Chung, FASLA, LEED AP

PBR HAWAII
& ASSOCIATES, INC.

Presentation Overview

1. Who is PBR HAWAII & Associates, Inc.
2. LID and Stormwater Management Concepts
3. Sample Projects

Our Services

Land Planning

Environmental Studies

Landscape Architecture

Graphic Design

PBR HAWAII & Associates, Inc.

dba PBR HAWAII
Locally / Minority Owned
Started in 1969 - Maui
40 Years of Experience
Staff of +35

Offices in Honolulu, Kapolei, and Hilo

PBR HAWAII

Pacific Basin:

- *Hawaii*
- *Tahiti*
- *Micronesia*
- *Japan*
- *Korea*

PBR HAWAII

PBR CALIFORNIA

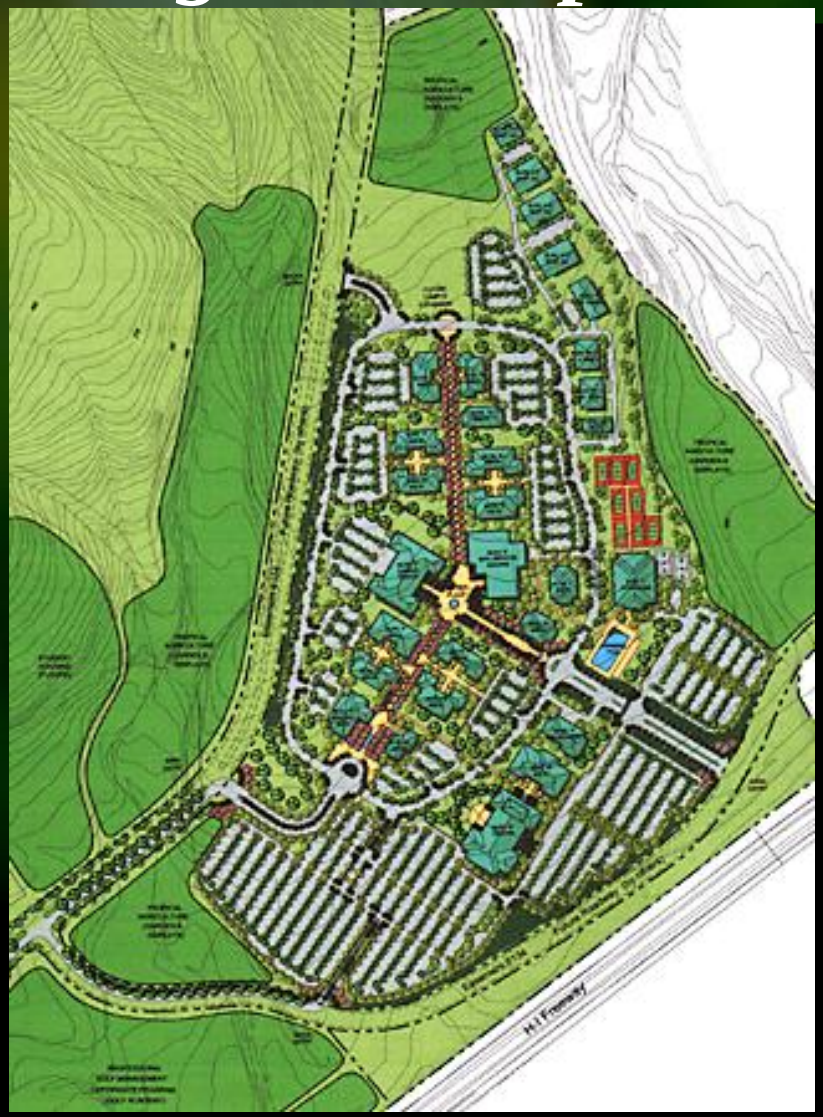
- *United States*
- *Mexico*
- *Canada*
- *France*
- *Spain*

Planning Services

- Regional and Community Planning
- Urban Planning and Design
- Resort Planning
- Park and Recreational Planning
- Residential Master Planning
- Commercial Master Planning
- Housing Studies
- Highway Studies
- Industrial Parks
- Environmental Planning
- State and County Land Use Regulatory Procedures

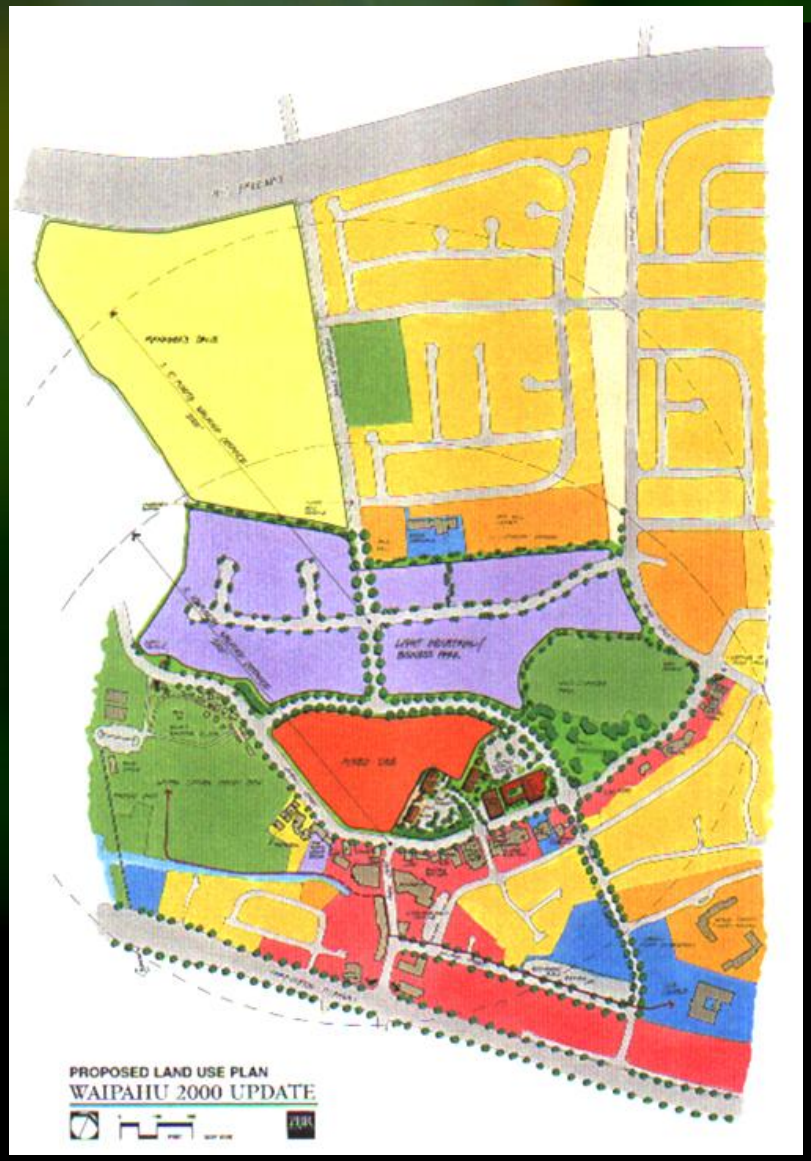
University of Hawai`i West Oahu Long Range Development Plan

2000 ASLA Merit Award

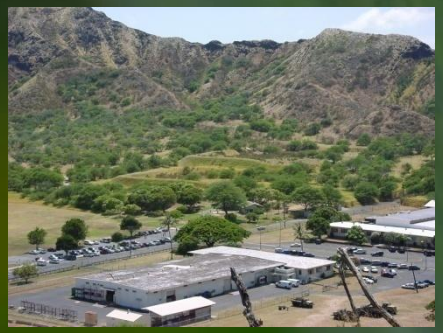


Waipahu 2000 Update

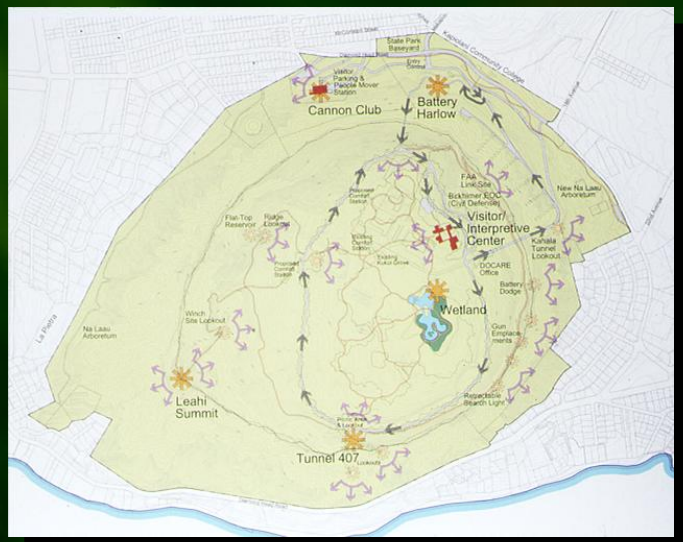
1995 ASLA Award of Excellence – Community Planning



Diamond Head State Monument Master Plan

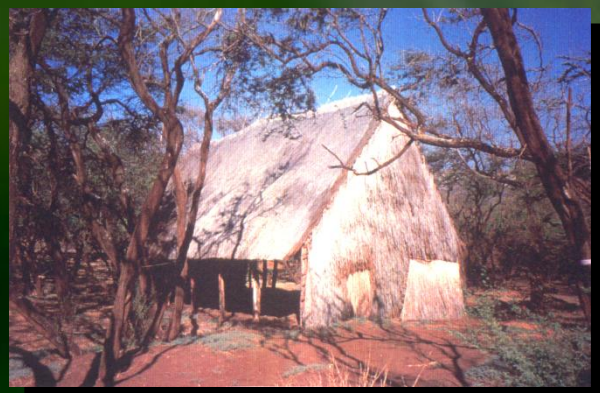


2000 ASLA Merit Award – Planning & Analysis



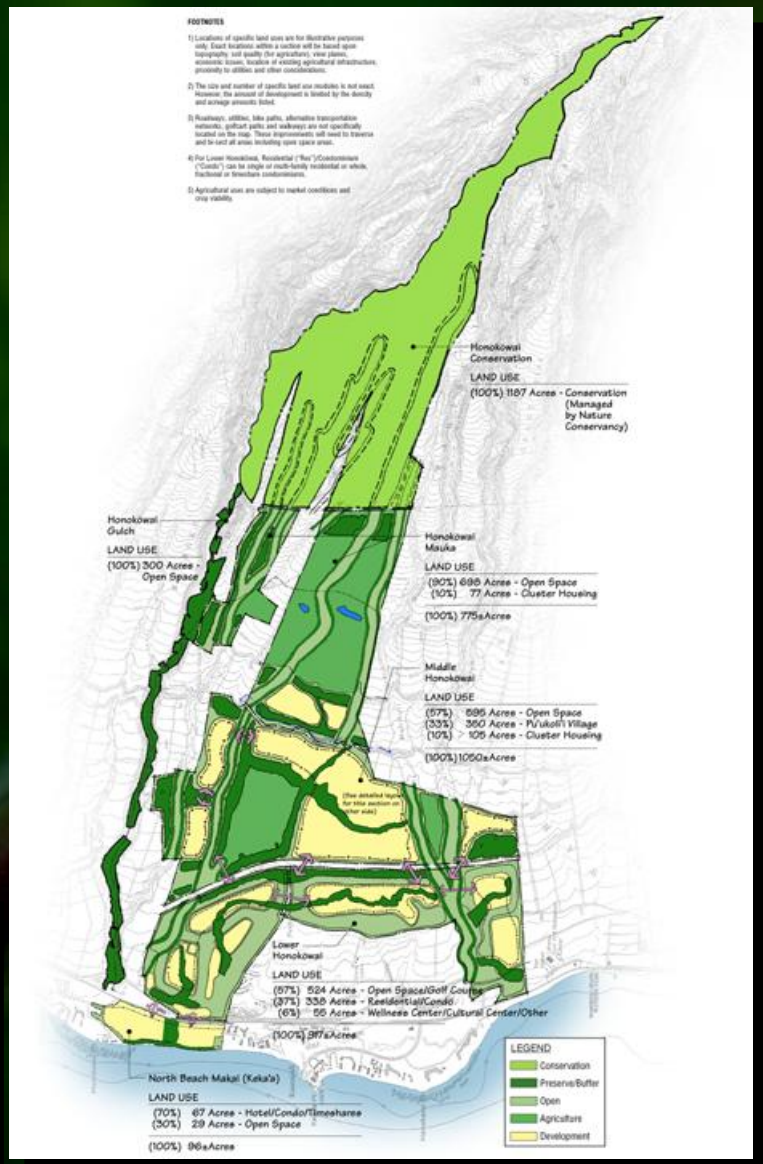
Kaho`olawe Use Plan

2000 ASLA Honor Award – Planning & Analysis



Ka`anapali 2020

2003 APA Community-Based Planning Award



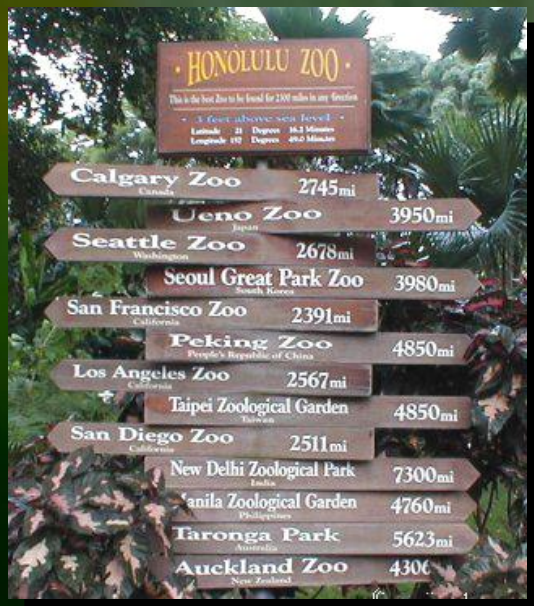
Landscape Design Services

- Landscape Master Planning
- Resort and Golf Course Development
- Park and Recreational Development
- Commercial Development
- Residential Development
- Industrial and Institutional Development
- Transportation Facilities Development
- Military Development
- Historic Preservation/Restoration
- Landscape Renovation
- Landscape Design Guidelines

Honolulu Zoo

Landscape Master Plan

1985 ASLA Merit Award



Kapolei Regional Park

Lanikuhonua *1995 ASLA Award of Excellence – Cultural Park Design*

Residential Development

Medical Institutions

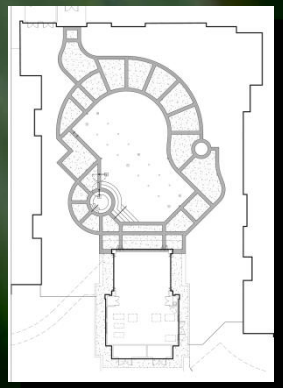
Castle Hospital

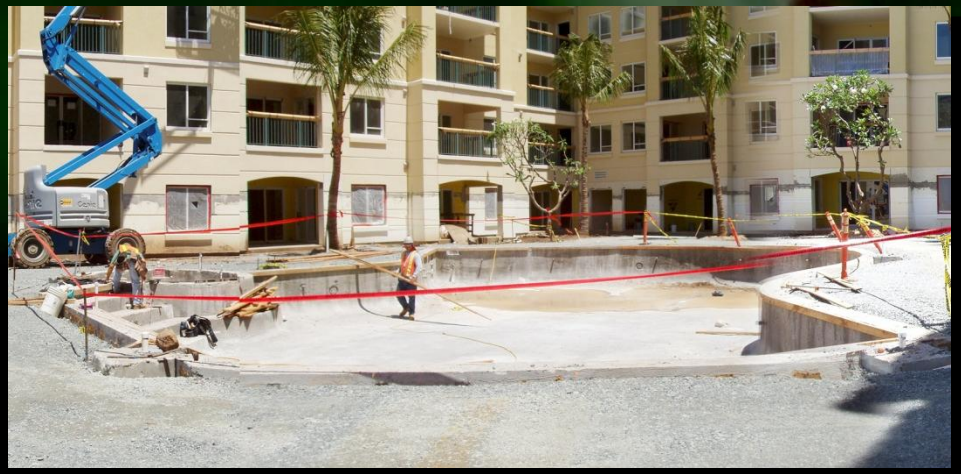
Kaiser Permanente

Kapi‘olani Medical

Pali Momi

Kahala Nui Senior Living



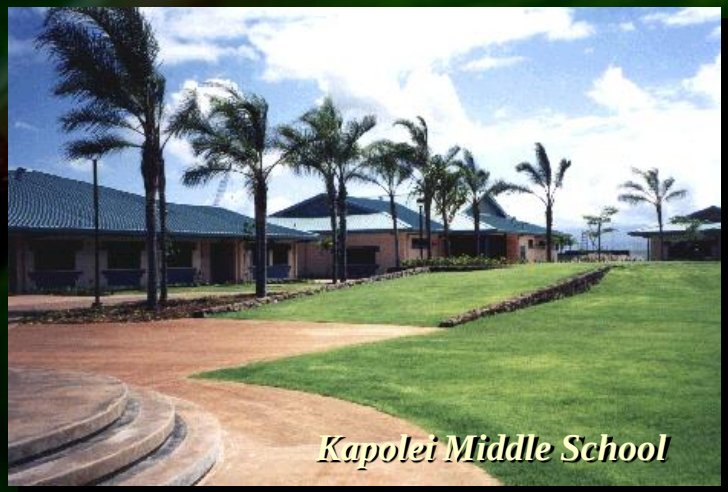


Campus Design

Kamehameha Schools-Maui Campus

2003 ASLA Merit Award-Design
2003 APA Outstanding Planning Award

Kamakahelei Middle School



Kapolei Middle School

Allure Condominium

`Iolani Palace Grounds

Restoration

1995 ASLA Award of Excellence -Urban Design

Fort Street Mall Renovation

Ala Moana Shopping Center

Mall Renovation

2003 Merit Award-Design

The Orchid at Mauna Lani

1998 Merit Winner – BIA Hawaii Renaissance Remodeling Competition
2000 ASLA Merit Award – Design

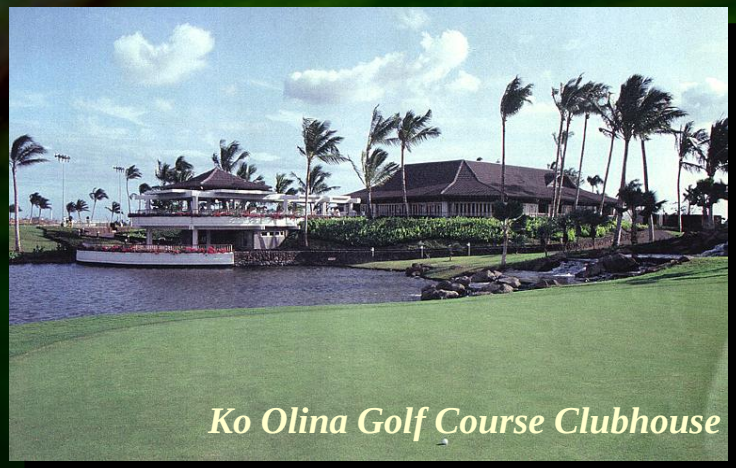
Outrigger Wailea

2003 ASLA Merit Award

Maui Prince Hotel

Ko Olina Resort

1986 Golden Nugget Grand Award – Best Mixed Use Site Plan
1990 ASLA Landscape Excellence Award
1993 ASLA Design Excellence Award



Ko Olina Golf Course Clubhouse

Kuki`o

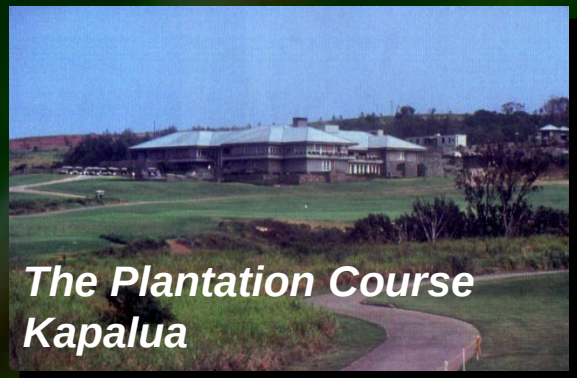
Hawaii

Keauhou Outrigger Resort

Golf Courses

- *Bay View links*
- *Hokukano Golf Course*
- *Kaloko Golf Club*
- *Kamakoa Golf Course*
- *Kapalua Bay Golf Course*
- *Kapalua Mauka Golf Course*
- *Kapolei Golf Course*
- *Ko Olina Golf Course*
- *Kuki‘o Golf Course*
- *Kukui Moloka‘i Golf Course*
- *Kukui`ula Golf Course*
- *Lands of Ka‘u*
- *Makalei Hawai‘i Golf Course*
- *Punalu‘u Resort*
- *Royal Hawaiian (Luana Hills)*
- *Royal Kunia Golf Course*
- *Waikoloa Highlands*
- *Waikoloa Resort North Course*

Ko Olina


The Plantation Course
Kapalua

Kukui`ula

Royal Kunia

Graphic Design

- Report Design
- Color Renderings
- Digital Photo Manipulation
- Scanning Services
- Plotting Services
- Web Design
- Geographic Information System (GIS)

2. LID and Stormwater Management Design Concepts

Topics:

- Parking Mitigation
- Rain Garden
- Vegetated Swale (Bioswales)
- Roof Garden

LID Design Application

- Nearly 70% of the pollution in our surface waters gets there through storm water runoff

- About 50% of that pollution is chemical pollution from products we use for our yard care and household activities and from our yard waste.

LID Design Application

- Reduce erosion and flooding
- Maintain warmer water discharge into streams or water bodies
- Reduce pollutants from reaching streams or water bodies
- Reduce the need for irrigation
- Reduce burden to the public storm water systems
- Improve air quality and reduce air temperatures
- Naturally replenish/recharge groundwater
- Further support wildlife habitat

Landscape Support for Additional LEED Points

LEED 2.2 NC Water Efficiency Points:

- **Water Efficient Landscaping: Reduce by 50%**
- **Water Efficient Landscaping: No Potable Water**

LEED 2.2 NC Sustainable Sites Points:

- **Site Development – Protect or Restore Habitat**
- **Site Development – Maximize Open Space**
- **Stormwater Design – Quantity Control**
- **Stormwater Design – Quality Control**
- **Heat Island Effect – Non-Roof**

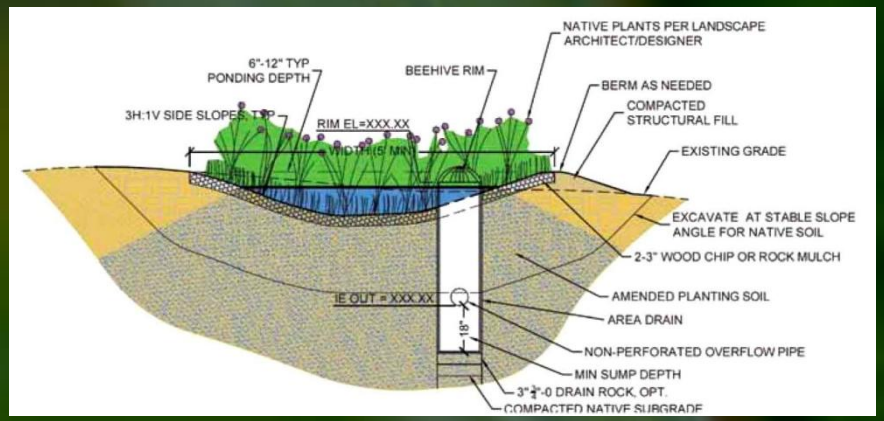
Parking Mitigation

Parking mitigation considers replacing non-permeable surfaces (asphalt, concrete) with permeable surfaces such as porous grass pavers, porous pavement. Use of permeable materials will help to reduce the heat island effect, encourage infiltration and increase the attractiveness of a site.

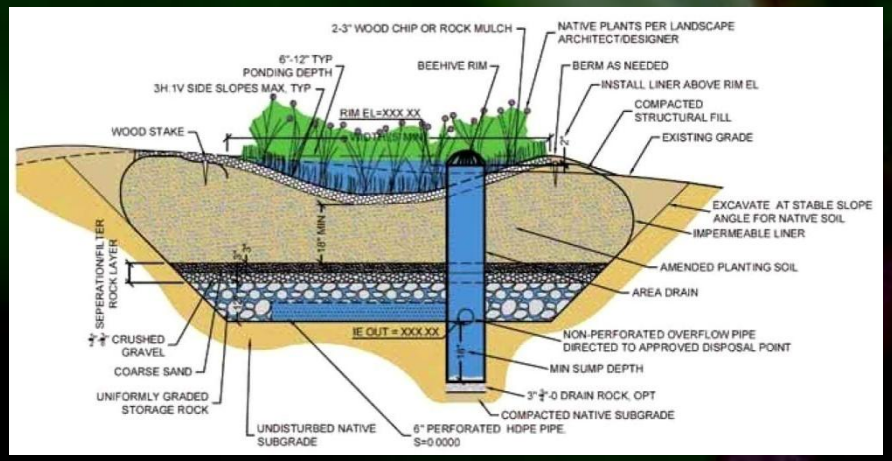
Rain Gardens

A rain garden is a “sunken garden bed” that collects and allows quick percolation treating and reducing storm-water runoff from hardscaped areas .

Types of Rain Gardens



Typical Infiltration Rain Garden



Typical Filtration Rain Garden

Infiltration Rain Garden

Cleanse, detain and reduce runoff volumes allowing water to seep into the surrounding soil

Filtration Rain Garden

Specifically LINED not allow infiltration of runoff. Cleanse and detain runoff but does not significantly reduce storm water volumes.

Use an impermeable liner along the bottom of the facility to prevent infiltration to soils
beneath the garden. (These liners are typically 60-mil PVC, but
bentonite clay mats can be just as effective.)

Elements of Design

Site Assessment

1. Test infiltration rate of native soil at the location.
2. Total the impervious surface of drainage area to calculate the general size/depth of the rain garden
3. Conveyance assessment – How will runoff be moving into the rain garden?
4. Setbacks – Verify distances from easements, buildings, neighboring properties, etc.
5. Site overflow – Where will it go in a heavy prolonged storm?
6. Utilities Assessment – Any conflicts in the rain garden area?

Sizing

Rule of Thumb

1. Design to drain within 24 to 36 hours.
2. Footprint of rain garden typically ranges from 6% to 15% of all impervious surface draining into it.
3. Ponding depth ranges between 6 and 12 inches.
4. Side slopes not to exceed 3’ run to 1’ rise.

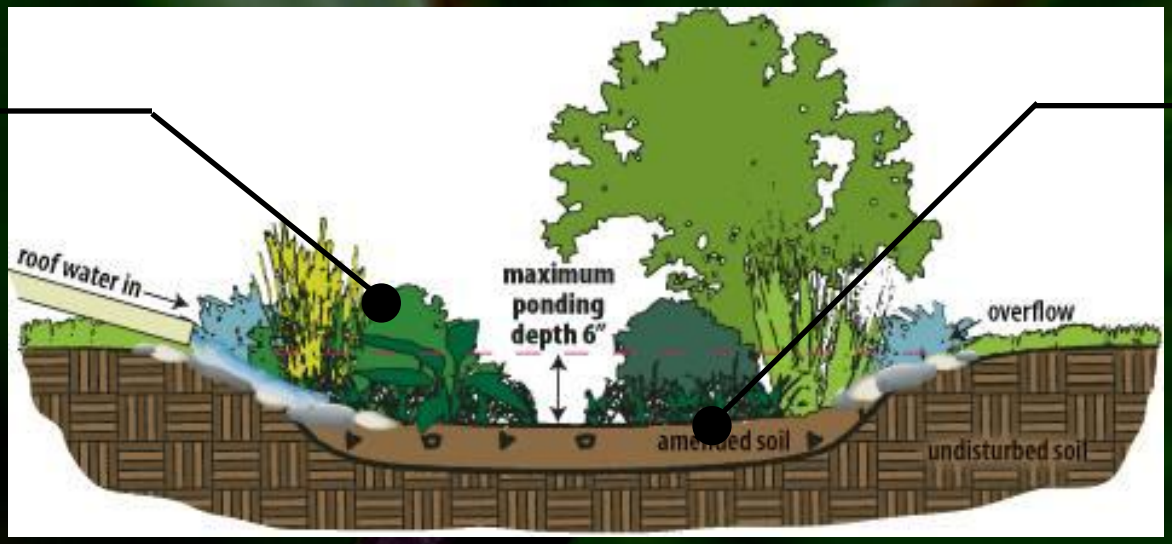
Soil and Medium

1. Rain gardens often have mulch on top and amended planting soils in the middle. Infiltration rain gardens also use the native un-compacted soils at the bottom.

2. Use a heavier mulch in areas with high runoff volume.

3. The minimum infiltration rate should be at least ½ " per hour .

Dense vegetation can also prevent runoff in high flow conditions



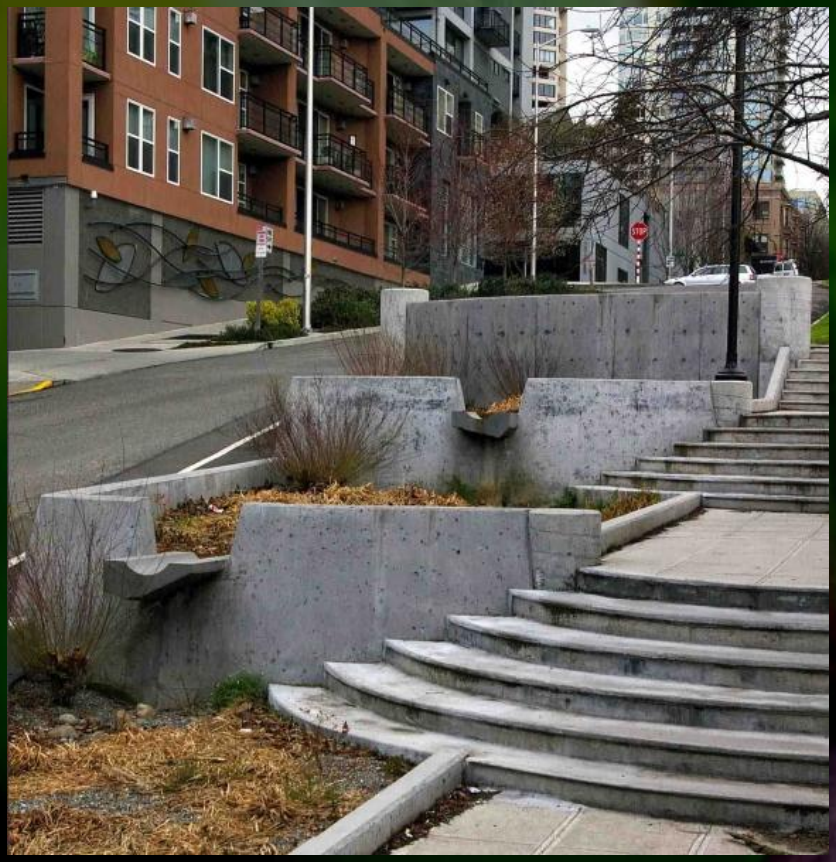
Top layer of mulch and amended soil

Source: Oregon Environmental Council

Vegetation

1. Plant palette must be appropriate to the local climate zone.
2. More planting = more treatment of the runoff.
3. Use of native plant material is always first priority for rain gardens.
4. Plant material should have the ability to survive in the local climate with minimal fertilizers, herbicides, and watering after established.
5. Use appropriate plant types within the rain garden zones based on drought tolerance. Plants on the edge and top of berms will tolerate drier conditions while planting in the basin area must tolerate wetter conditions.

Routing Methods



1. Inlet pipes, downspouts, channels, trench drains, etc. – reinforce point of entry into the rain garden with riprap or vegetation to prevent erosion. Disperse water if possible to prevent erosive pitting.
2. Sheet flow in – Provide a 4' wide (min.) strip of turf grass if possible to pre-treat substantial sediment loads.
3. Incase of overflow:
   - Overflow pipe or catch basin
   - Channel
4. To avoid permit costs, designers should strive to route runoff from the rain garden to a public stormwater conveyance system or surface water
5. Redundancy incase one outflow fails.

Pollution Removal

1. Rain gardens filter and settle sediment and pollutants

2. Pollutants are removed through nutrient cycling or by sequestering pollutants in the soil or in the plants themselves.

3. Other possible pollutants absorbed by rain gardens include phosphorus, nitrogen, and vehicular byproducts such as grease and oils.

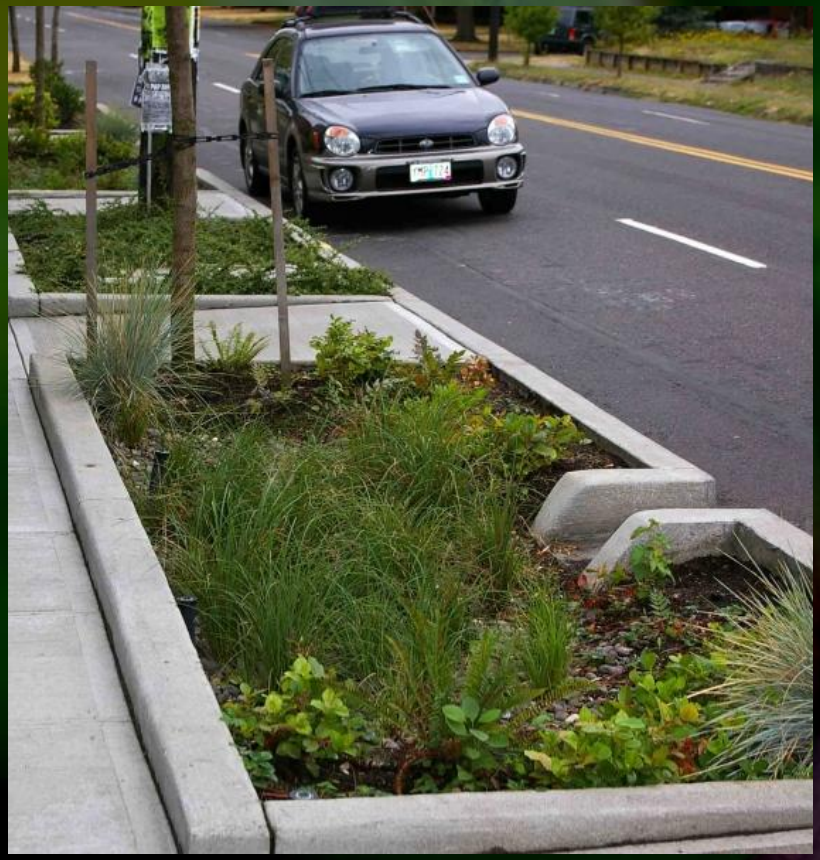
4. Rain gardens are designed to completely drain after 24 hours to prevent the spread of mosquitoes.

Maintenance

Source: Glencoe Elementary, Ratio Architects

- Typical of landscaped areas.
- Frequent watering and weeding in the first 1 to 3 years until established.
- Do not use pesticides, herbicides or fungicides.
- Inspect and tend to the rain garden after a major storm.
- Remove sediment and debris. Replace mulch as required.
- Clean and repair inlets, outlets, embankments, berms and dams.
- Control erosion.
- Ensure proper drainage.
- Replace planting as needed.
- Hand weed if possible.

Cost



- Rain gardens are cost-effective when compared to conventional stormwater management for flow rate, volume control, and water quality treatment, but they vary with size, site conditions, vegetation, and materials required for drainage and routing.

- If the rain garden has no pretreatment, maintenance costs can vary with the choice of long-term erosion control—compost mulch, rock mulch, or dense vegetation—because the mulch option will probably be removed with the sediment and have to be replaced. Rock mulch has a more expensive up-front cost than compost mulch.

Vegetated Swale
(Bioswales)

A vegetated swale is a broad shallow channel covered in dense vegetation. Swales are both natural and manmade, and are designed to trap pollutants and promote infiltration.

It's difference from a Rain Garden is that Bioswales slope to a destination, while Rain Gardens do not. However, a Bioswale may end in a Rain Garden (or series of).

Examples of manmade vegetated swales located near right-of-ways and within park-like settings.

Swales located near a street help to control the spread of stormwater pollutants.

Swales located in park-like settings reduce the velocity of water flow and promote infiltration.

Roof Gardens

A roof garden is a garden located on the roof of a building. Commonly found in urban settings, roof top plantings have the ability to reduce overall heat absorption of a building which then may reduce energy consumption costs.

Roof Gardens

Extensive

Minimum soil depth and designed to be virtually self-sustaining and should require only a minimum of maintenance

Semi-Extensive

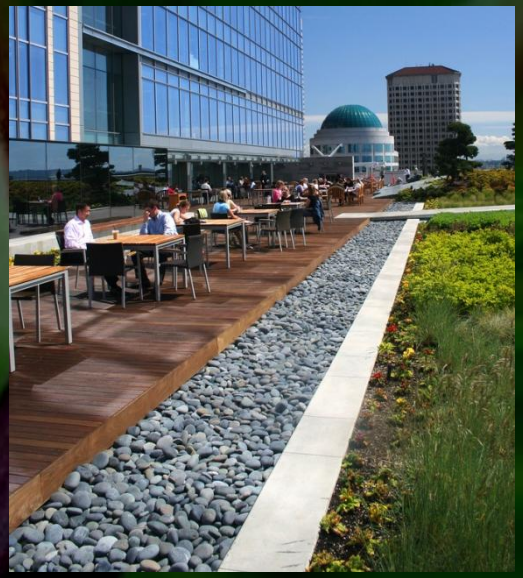
Deeper soil column; supports a wider variety of plants

Intensive

Common roof garden; supports trees and elaborate arrangements. Intensive roof gardens require large, strong structures to support them.

Intensive Roof Garden

Semi-Extensive Roof Garden



Extensive Roof Garden

Creative Roof Gardens

Project Illustrations

PBR Hawaii

Our Approach to Design

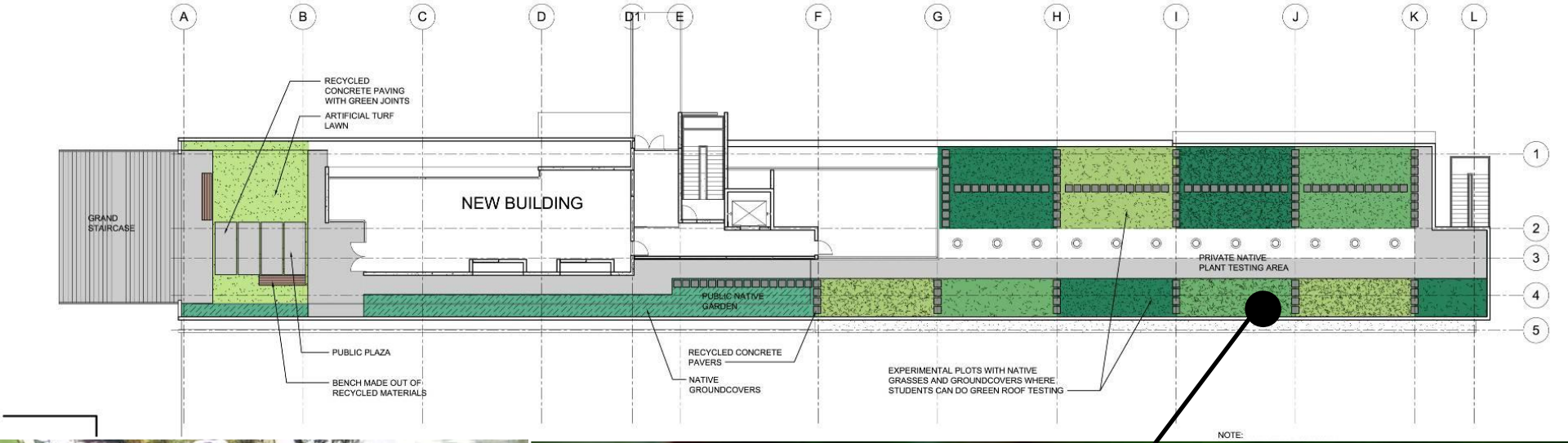
Sustainability in the practice of Landscape Architecture is not new.

Integration of the Culture unique to the locale.

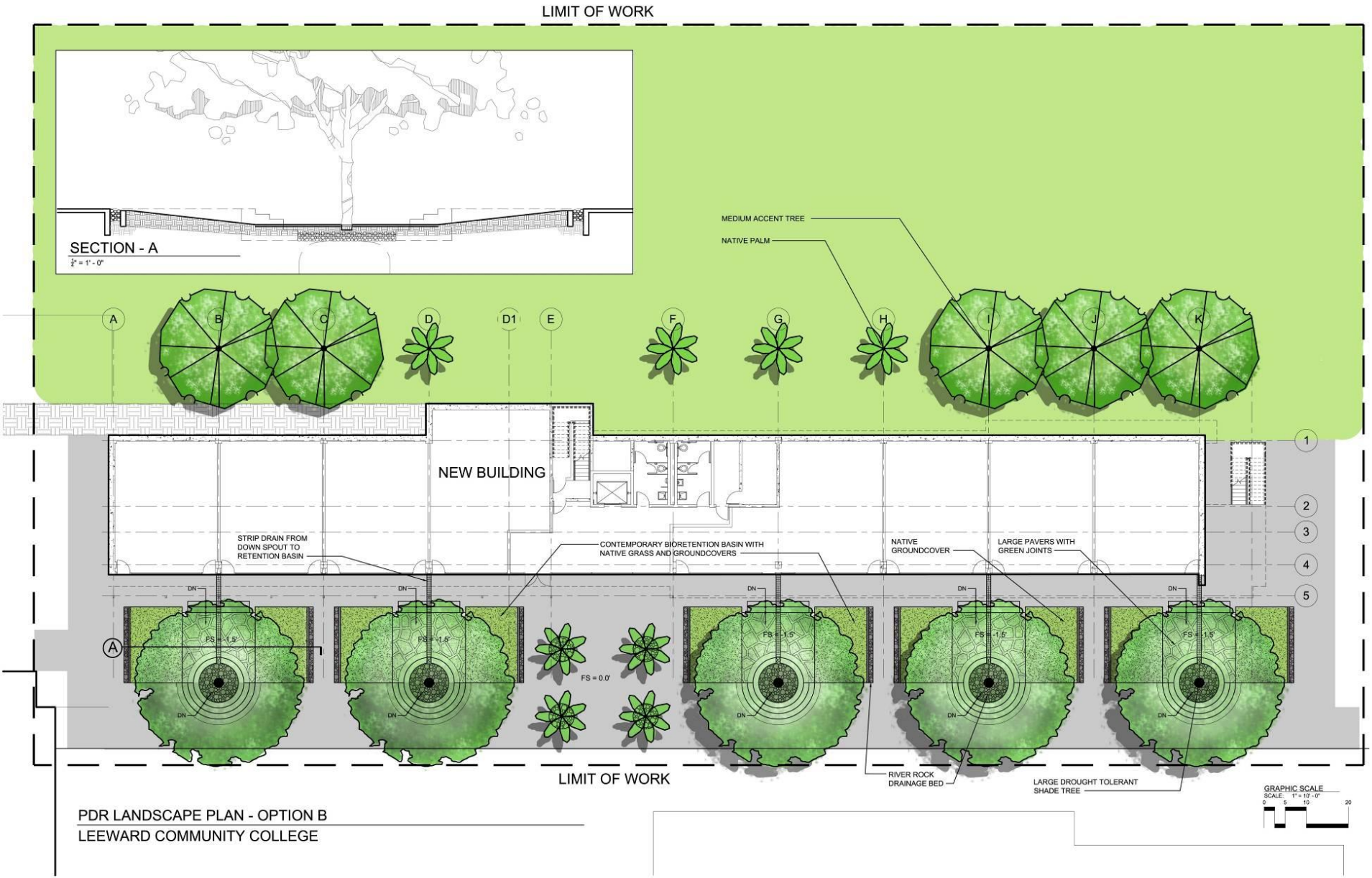
Today's approach is to use our design solutions (as in art) to educate and profess sustainability and responsibility (kuleana).

Leeward Community College Social Science Facility

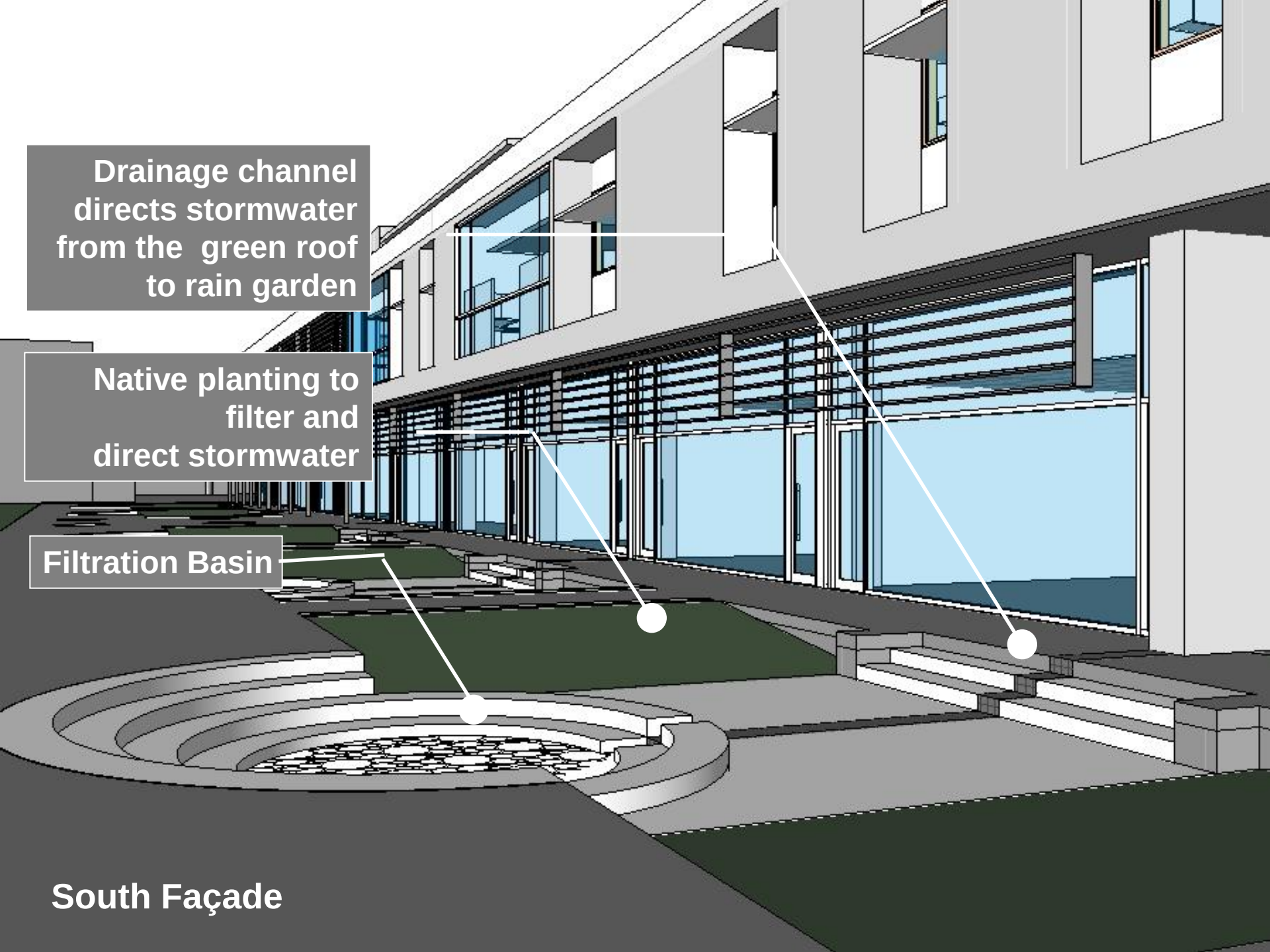
Pearl City, Hawaii



Leeward Community College
Social Science Facility

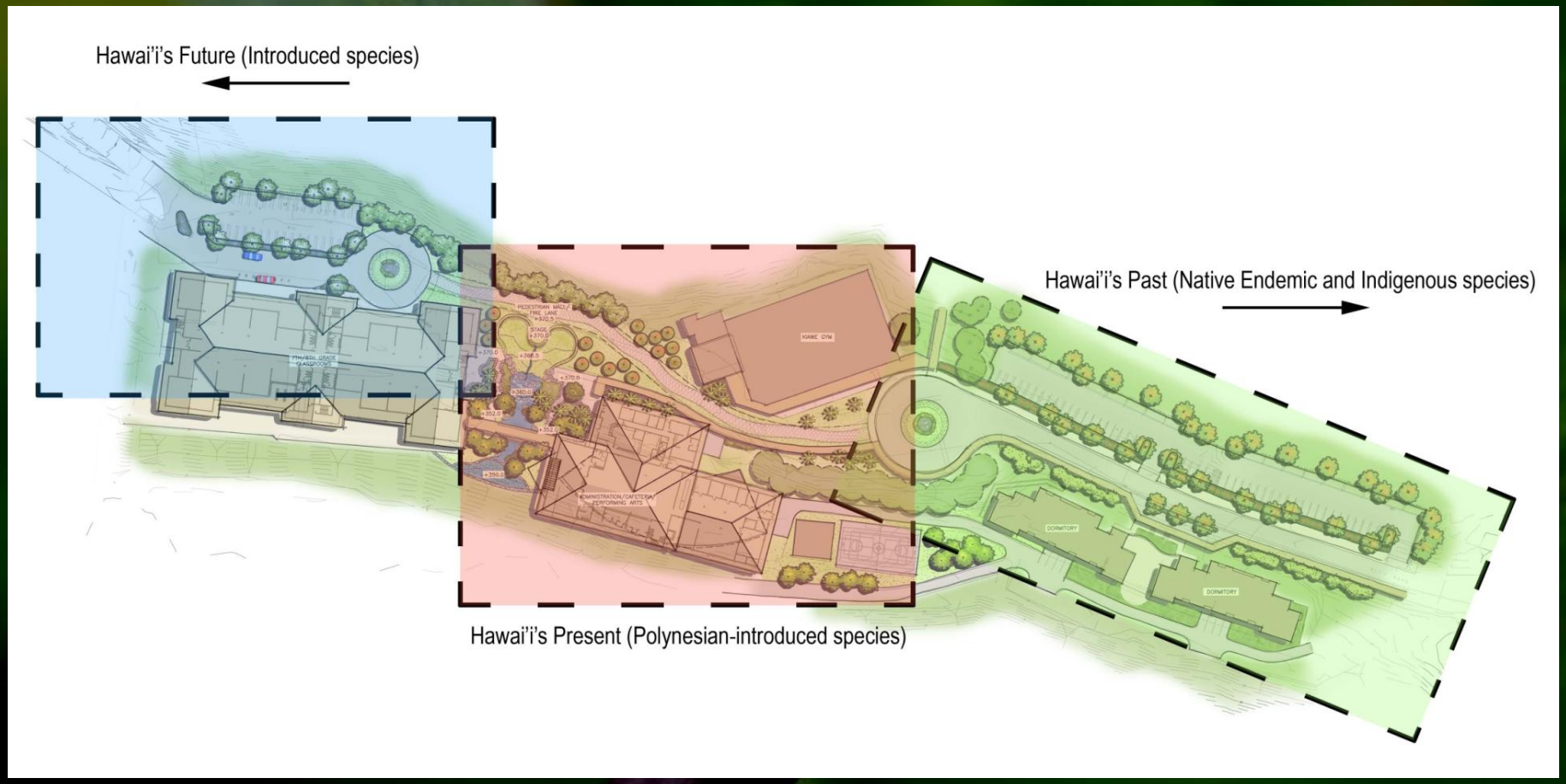


PDR LANDSCAPE PLAN - OPTION B
LEEWARD COMMUNITY COLLEGE


Drainage channel directs stormwater from the green roof to rain garden
Native planting to filter and direct stormwater
Filtration Basin
South Façade

Kamehameha Schools Middle School

Kapälama Campus, Honolulu, Hawaii



Kamehameha Middle School Illustrative Plan

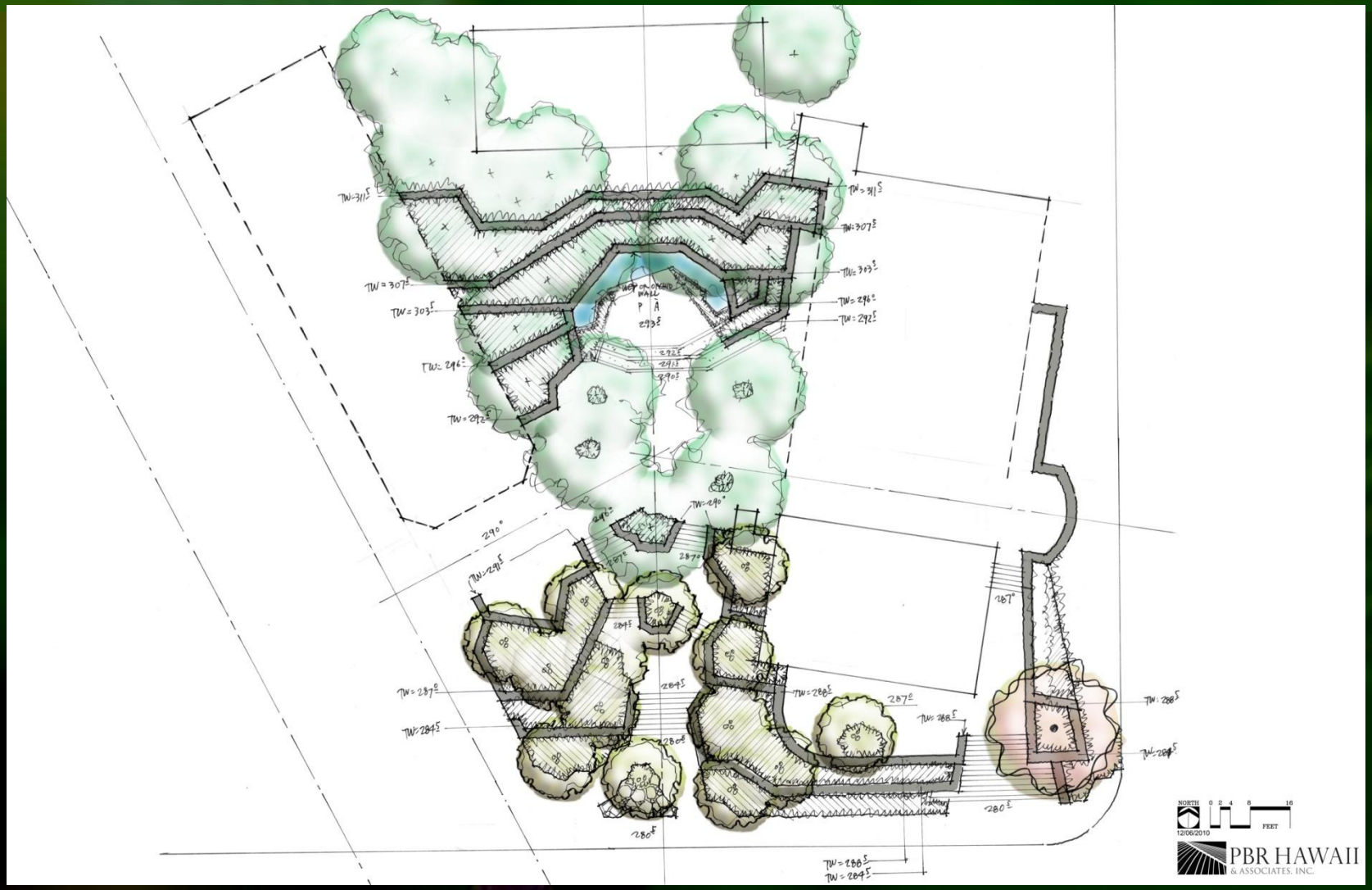
The Piko - Pahu

University of Hawaii Hilo School of Pharmacy

Hilo, Hawaii

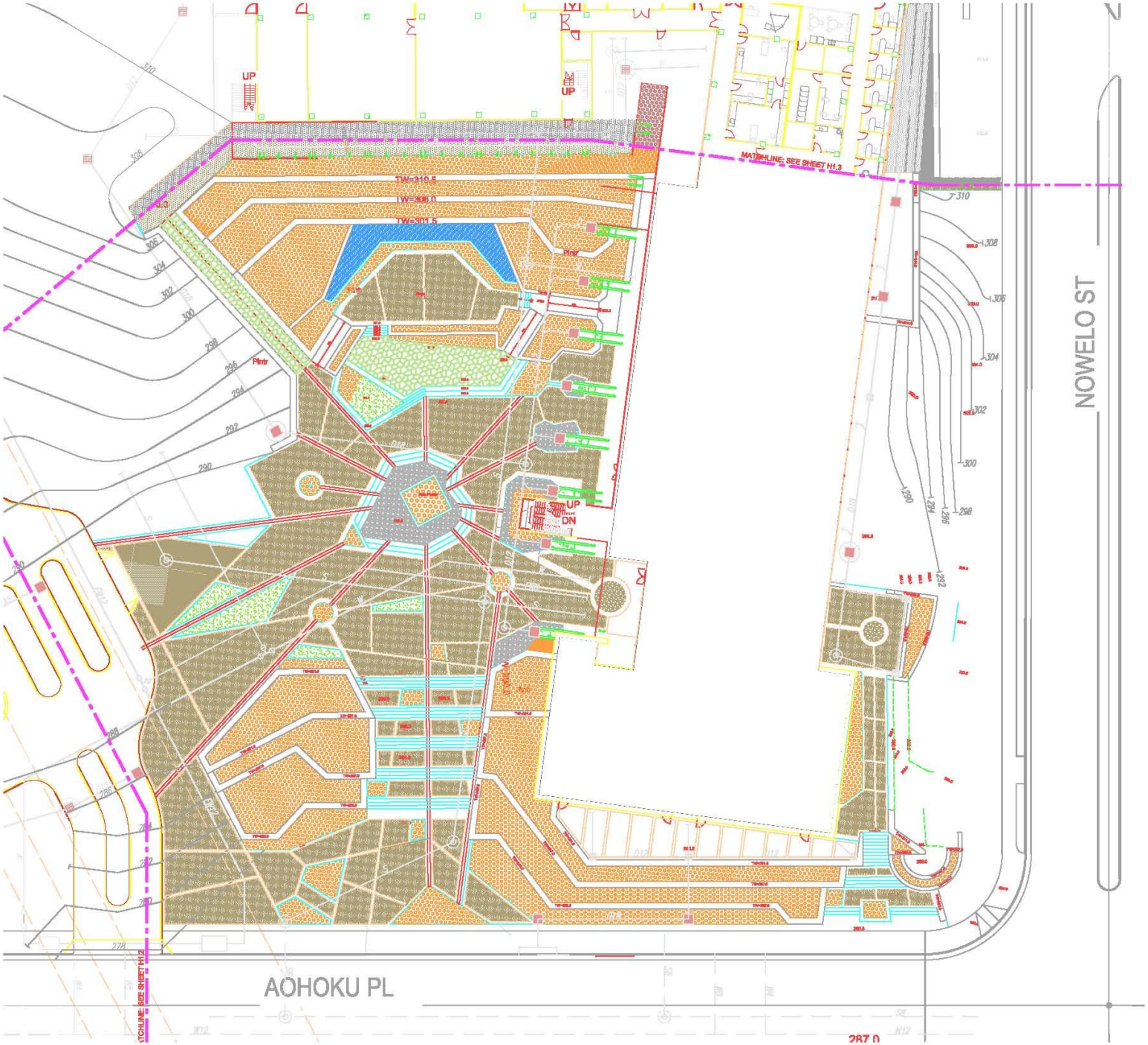
University of Hawaii Hilo School of Pharmacy

Hilo, Hawaii



UHH School of Pharmacy

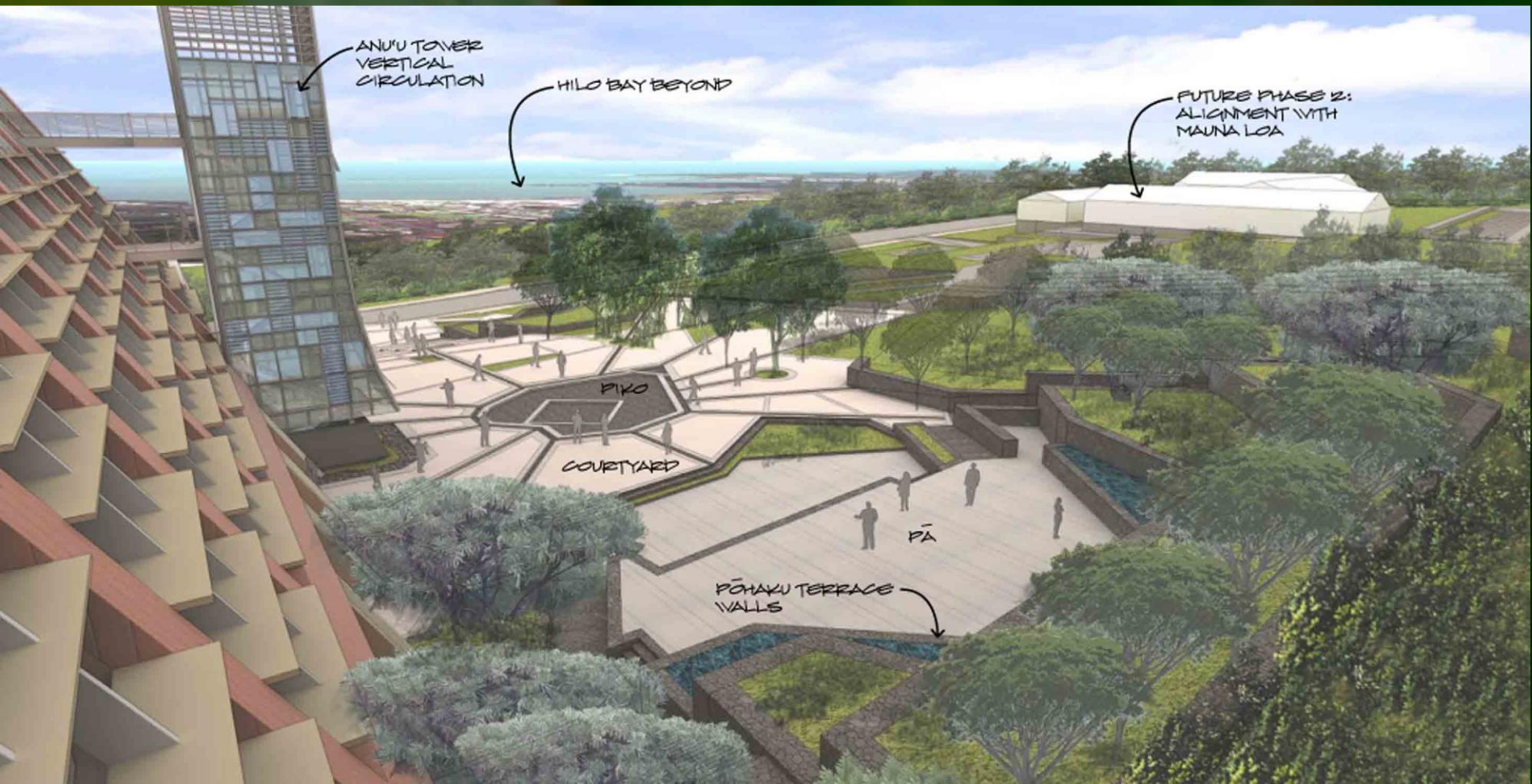
Hilo, Hawaii


NOWELO ST
AOHOKU PL
MATCHLINE: SEE SHEET H1.3
MATCHLINE: SEE SHEET H1.2
TW=310.5
TW=306.0
TW=301.5
UP
DN
Plntr
287.0

UHH SCHOOL OF PHARMACY

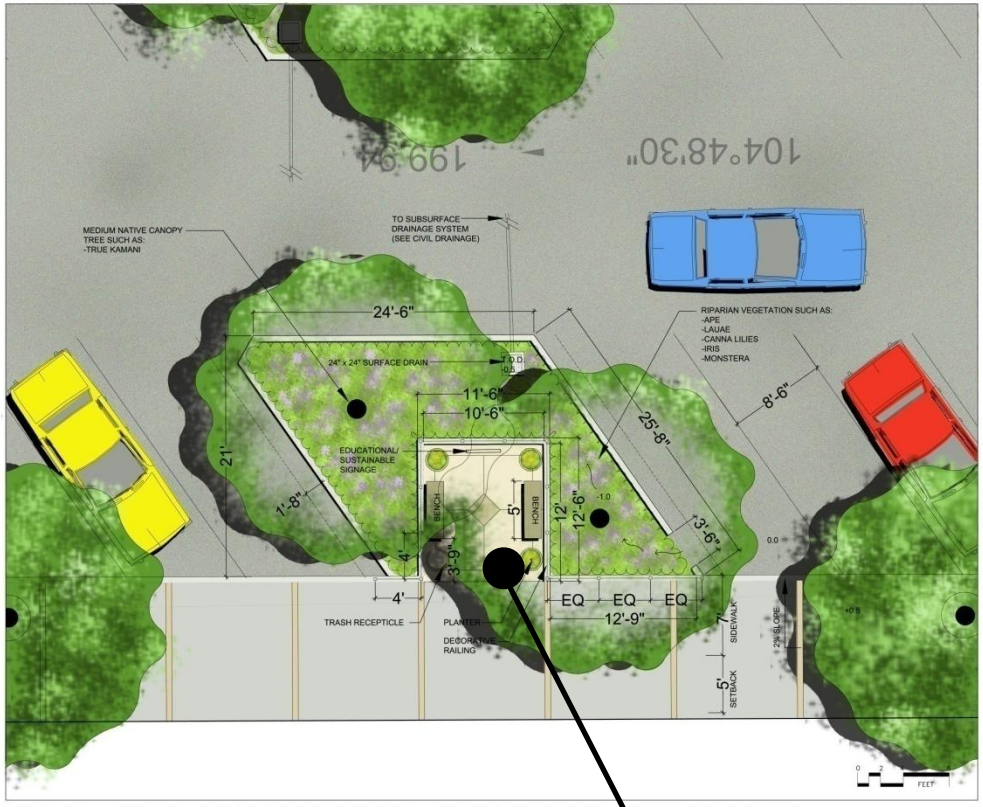
The Central Plaza (Piko)

MAKAI VIEW OF PIKO



Green Street

Puhi, Kauaÿi, Hawaii

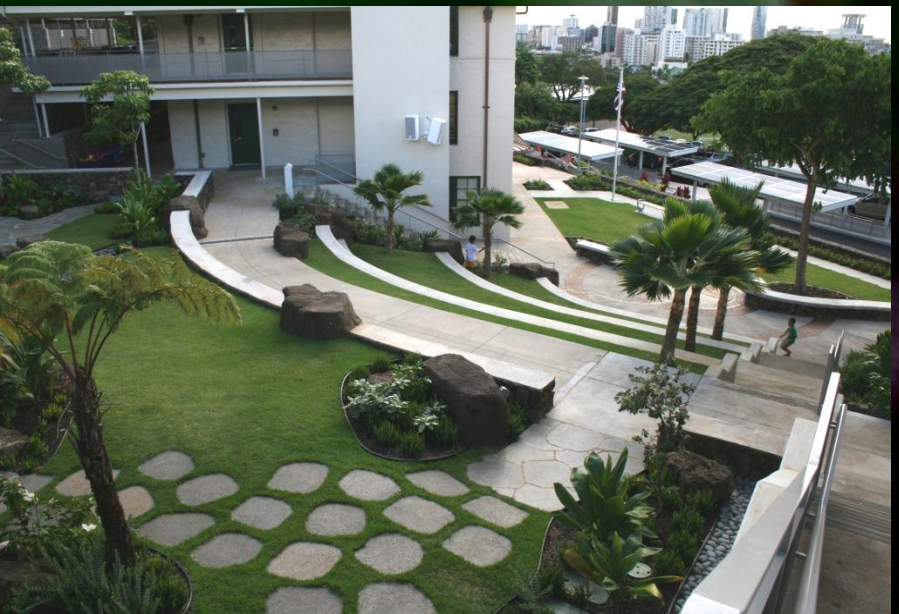


Shaded pedestrian walkways

Education Signage

Design Philosophy

- Provide opportunities for children to learn (at a very early age) the importance of taking care of their natural environment and to be good stewards;
- To create a variety of outdoor play areas where both the athletic and quiet contemplative child could feel comfortable;



Design Philosophy

- Utilize the “outdoor” space as a the second classroom by integrating sustainable concepts and Hawaiian gardens into the landscape; and
- Encourage curiosity and adventure by creating tactile and practical “living” environments.

Hawaiian Petroglyphs

Project Characteristics

- 5 new Campus Facilities and 12 new classrooms to accommodate 300 young learners
- Amphitheater garden
- Various outdoor gathering spaces

Sustainable Features

- Water efficient landscaping comprised of both Adaptive and Native Hawaiian trees, shrubs, and groundcovers
- Rain catchment cisterns located at each campus building

Sustainable Features

- Bio-swales demonstrates as an active play area and to allow rainwater to replenish the earth
- Windmill feature demonstrates the power of wind to produce energy and to pump water

UNITED STATES ARMY PACIFIC COMMAND HEADQUARTERS

Mahalo!

PBR HAWAII
& ASSOCIATES, INC.

Hui Ku Maoli Ola

Ha'iku, Kane'ohe, O'ahu, Hawai'i
Ph. 295-7777

- **Native Hawaiian Plant Nursery**
- **Habitat Restoration Specialists**
- **Landscape Consultation and Contracting**
- **Cultural Education Advocates**

What is a Native Hawaiian Plant ????

- It's a plant that arrived to Hawaii without the aid of man, i.e. it got here on it's own.

- Usually by the three W's
  - Wind: seeds float over on wind currents
  - Wave: seeds float over on ocean currents
  - Wing: seeds become stuck on the feathers and feet or ingested by birds

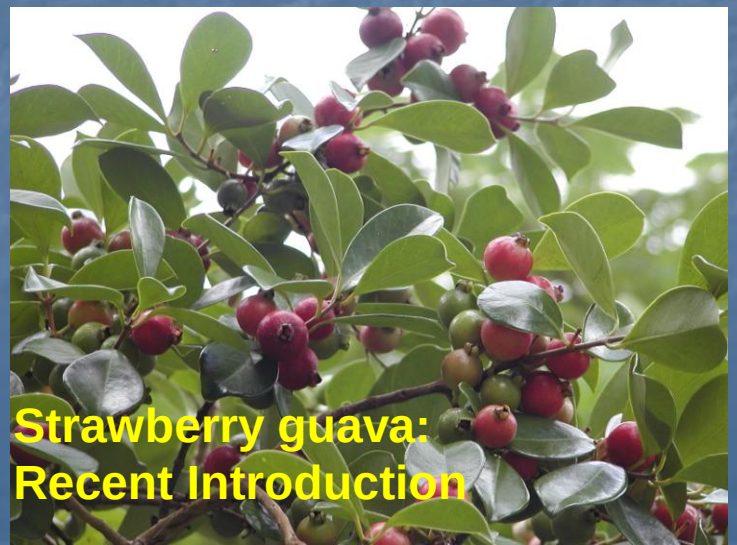
Indigenous vs. Endemic

- Indigenous: A plant or animal that is native to Hawaii as well as other parts of the world
- Endemic: A plant or animal that is found only in Hawaii and no where else in the world.
- Of the 1,400 or so plants that are native to Hawaii, 90% are endemic.

Polynesian vs. Recent Introduction (A.K.A Alien Plants)

- Polynesian Introduction: a plant or animal that was brought to Hawaii by Polynesian settlers
  - Ex. Kalo, Kukui, Coconut,

- Recent Introduction: Plants brought to Hawaii since the discovery by Europeans in 1778.
  - Ex. Red Gingers, Octopus tree, all guavas



Which plant is **native**?

- A. Ohai Ali’i
- B. Beach Heliotrope
- C. Lawa’e Fern
- D. Kiawe

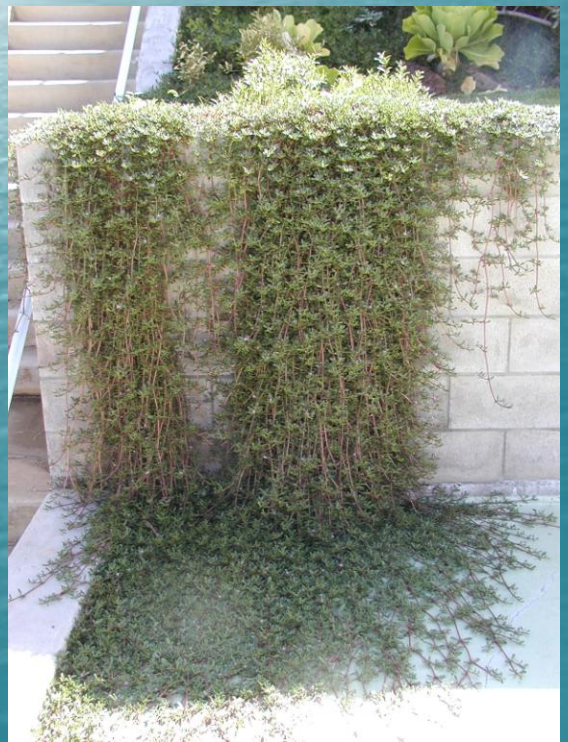
More Plants You May Have Thought Were Hawaiian… But Aren't

- Rose Apples
- All Gingers
- All Heleconias (even bird of paradise)
- Koa Haole (Haole Koa)
- Maunaloa Vine
- Kuhio Vine
- Liliko'i and other passion fruit
- Guavas
- Hula Girl Hibiscus
- Ka'u Orange
- Mangos
- Pineapples
- Proteas
- Anthiriums
- Tiare Gardenia
- Crown Flower
- Bamboo
- Ti Leaves
- Woodrose
- Monkeypod Tree
- Royal Palms

Native Plants For: Retention Basins and or Rain Gardens

- In both cases plants must be able to handle dual living conditions
  - Periods of saturation and dryness
  - Full Sun/Part Shade
  - Attractive (Landscapes)
  - Provide micro habitat?

ʻAkulikuli



- *Sesuvium portulacastrum*
- Indigenous
- Hardy
  - Sun
  - Dry or Wet
  - Wind ok
- Very colorful
- Water cleaner – used in Alawai canal phytoremediation
- Better for pond bottom and toe of slope
- Green roofs

Pohuehue

- ***Ipomea pes-caprae***
- **Indigenous**
- **Hardy**
  - **Sun**
  - **Heat**
  - **Dry**
- **Fast growing**
- **Colorful**
- **Better for mid slope or veg buffer and green roofs**

‘Uki’uki

- *Dianella sandwicense*
- **Indigenous**
- **Hardy**
- **Makes blue dye**
- **Clumper, not a spreader**
- **2 ft tall**
- **Better for smaller veg buffers in both full sun and partial shade as well as green roofs**

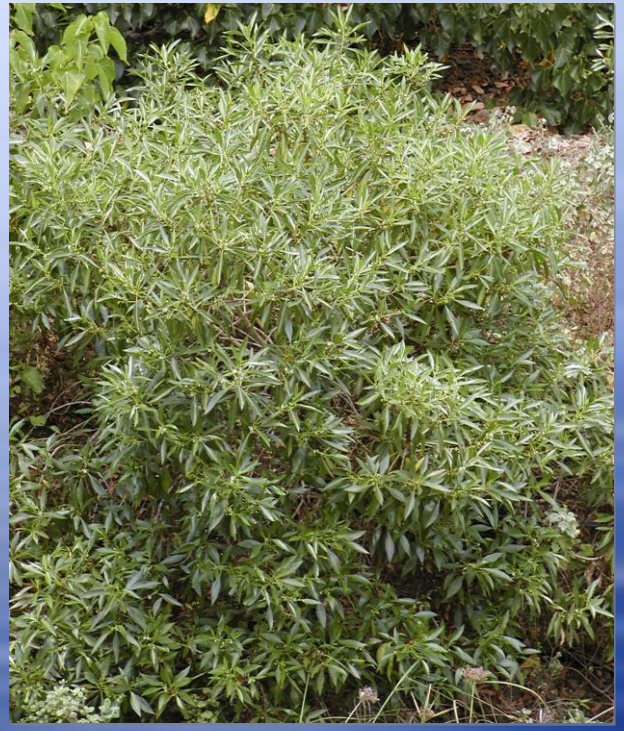
‘Ae’ae

- *Bacopa monnieri*
- Indigenous
- Really nice
- Fast grower
- Needs more watering during establishment period
- Full sun to filtered sun
- Up to 8 inches in height
- Few bugs
- Bottom of ponds, veg. swale veg buffers

Mamaki

- *Pipterus albidus*
- Nice large shrub or small tree
- Does great in partial sun or in shade
- Used for tea and kapa
- Better near top for veg buffer in shadier locations

Naio



- Myoporum sandwicense and M. stellatum
- Great for veg buffer
- Phytoremediation
- Hardy

‘Ihi’ihilauakea

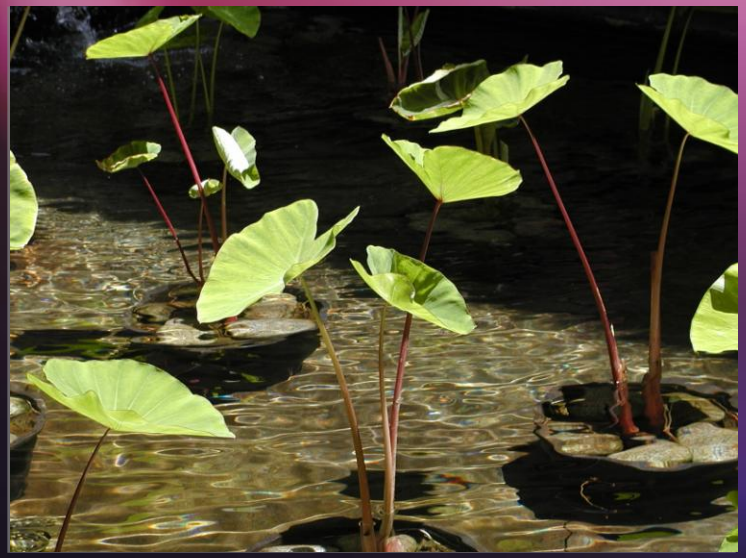
- Marsilea villosa
- Endemic
- Endangered
- From ‘Ihi’ihilauakea crater
- Great in water features or moist soil
- Full sun
- Best for bottom of swales or pocket wetland

‘Akiohala

- Hibiscus furcellatus
- Great color
- Easy to grow
- Best in veg buffer or pocket wetland since they can naturally occur in wetlands

Neke

- *Cyclosorus interruptus*
- Beautiful fern, thrives in full sun and wet conditions
- Naturally occurs in mashes
- Gets about 2ft. tall
- Spreads by rhizomes
- Great for water features or continually wet soil
- Bottom of pocket wetland



Kalo

- Colocasia esculenta
- Tons of different varieties
- Can be grown in landscape or in water feature
- Must be harvested yearly to keep looking good
- Best in pocket wetland

Uala Sweet Potato

- Ipomea batatas
- Great top, mid or bottom of slope, veg buffer, swale, green roofs
- Fast filler
- Edible

Ko Sugar Cane

- Plant individual plants along top, mid or bottom veg buffer
- Lay out stalks across slope to slow down surface runoff
- Edible

‘Aki’aki

- *Sporobolus virginicus*
- Thick growth
- 6-8 inches tall max.
- Full Sun, Drought, Wind, and Salt resistant
- Good soil retainer
- Great for any LID and green roofs

‘Ahu’awa

- *Cyperus javanicus*
- Nice accent around rocks
- Can be grown submerged in water but is also drought resistant
- Full sun
- 2-3 ft. tall
- Best at bottom of slopes

Carex

- Carex wahuense
- Long, graceful blades
- 2 ft. tall
- Able to tolerate full sun to heavy shade
- Good for any type of LID and green roof

Kamanomano

- Cenchrus agrominioides
- Endangered species
- Great cover/Outcompetes weeds
- Full sun
- Perfect for top or midslope and green roofs

‘Ilie’e

- Plumbago zeylanica
- Full sun to part shade
- Great for mid slope use
- Veg buffer and green roofs

ʻUki

- *Cladium jamaicense*
- Nice tall accent grass. 3-5ft. tall
- Short rhizomes keep the grass bunch-like
- Does well in moist soil or with the pot submerged in water for water features
- Great for bottom of pocket wetland

‘Aka’akai

- *Schenoplectis lacustris*
- Great Bullrush
- 4-6 ft. tall
- Great for pocket wetland
- Not to be confused with Schenoplectis californicus which is not native.

Pu'uka'a

- Cyperus trachysanthos
- Endangered
- 3 ft tall
- Very graceful looking
- Great for water features or moist soil
- Pocke wetlands

What other benefits do they provide?

Forest & Kim Starr

nimals

MGF's Slide Bank of Hawai'i's Native Biota

The Nature Conservancy

MGF's Slide Bank of Hawai'i's Native Biota

Marian Leong

Papahana Kuaola

Papahana Kuaola

Allen Borsky

Allen Borsky

Koloa maoli

Phillip Brunner

How are wetland ecosystems valuable to the Hawaiian culture?

Papahana Kuaola

LID Retrofit Survey for Schofield Barracks and Wheeler Army Airfield
19 April 2011

Steve Turnbull
Environmental Division, DPW, USAG-HI

Our mission is to provide sustainable installation support and services for Soldiers, Families, and the military community that meets current and future mission requirements, promotes community well-being and enhances the natural environment

Purpose

- Evaluate the potential for Low Impact Development (LID) Retrofit Projects for Schofield Barracks and Wheeler Army Airfield
- Assist in meeting the post-construction storm water management requirement under NPDES Permit.
  - The permit requires the Army to develop, implement, and enforce a program to reduce pollutants in storm water runoff from new development and redevelopment projects.
  - Establishment of installation-wide instructions or directives that address post-construction runoff.
  - Implementation of best management practices (BMPs) to minimize water quality impacts and attempt to maintain pre-development surface water runoff conditions.
- Waikele and Kaukonahua Streams drain into Pearl Harbor and Kaiaka Bay which are both 303d listed waters. Total Maximum Daily Loads (TMDL) performed show urban areas provide most TSS, N, and P

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LID Survey Methods

- Identify potential LID project locations through analysis of available data, such as satellite imagery, drainage maps, and digital elevations maps.
- Conduct a series of field visits on Wheeler Army Airfield and Schofield Barracks to evaluate, photograph, and document potential BMPs.
- Refine preliminary list of projects based on field visits, including elimination of infeasible projects from approximately 50 to 41 final sites for analysis.
- Prepare a table with information on each remaining potential project, including: project description, Low Impact Development Reference Storm water Treatment Option, area of impervious, disturbed, and natural surface.
- Rank each project for hydrologic and water quality benefits, construction cost, constructability, maintenance costs, education benefits, aesthetic benefits, and recreational benefits.

LID Survey Methods (Con't)

- Prepare spreadsheets for each potential project to calculate runoff, sediment (total suspended solids or TSS) load, nitrogen and phosphorus loads.
- For the proposed 31 BMPs calculate the reductions in flow due to infiltration and retention, as well as the reductions in TSS, nitrogen, and phosphorus as a result of the BMP.
- Prepared an aerial view figure of each potential BMP location, along with a photograph of the location and a summary of the benefit load reductions and calculations for each site.
- Prepare a summary and cost analysis of the BMPs.

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Types of LID Retrofit Projects

- Bioretention:
  - Reduce surface runoff often from around large impervious areas.
  - Can be at installed at grade making them plausible to implement in high use areas.
- Pocket wetlands:
  - Reduce surface runoff and sediment and nutrient loading.
  - Targeted in areas where space and use allow (such as storm drains).
- Lining drainage ditches and swales with geotextile fabric or other material.
  - Reduces erosion and sediment load.
  - Targeted at larger conveyances that have visible signs of erosion.
- Increasing vegetation within drainage ditches and swales.
  - Reduces surface runoff and slows runoff.
  - Reduces erosion and sediment load.
  - Targeted at smaller conveyance systems.

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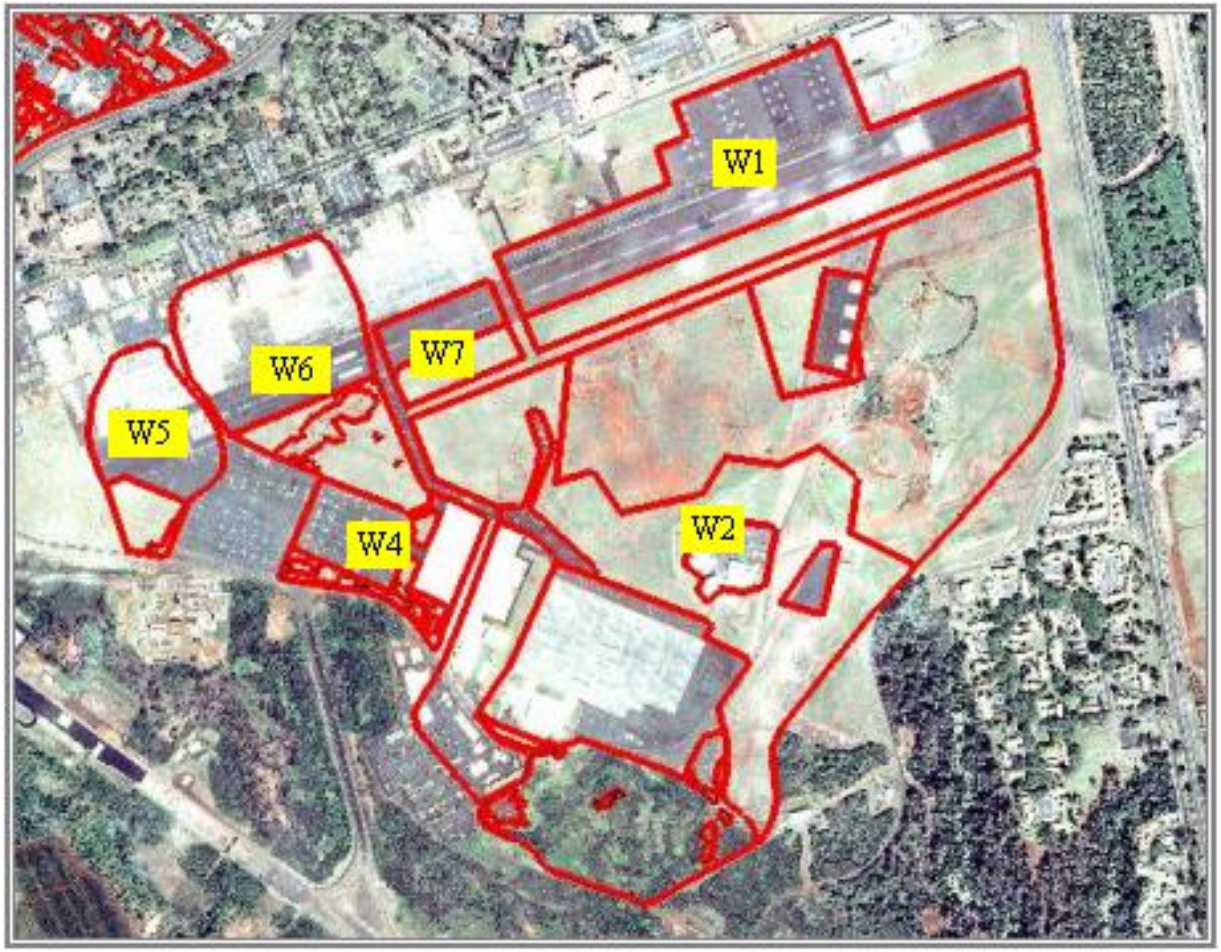
Types of LID Retrofit Projects

- Installing permeable (porous) pavers.
  - Reduces surface runoff.
  - Reduces sediment and nutrient load.
  - Targeted at areas being used as unpaved or impromptu parking lots.
- Vegetation strips.
  - Reduce surface runoff and increase infiltration.
  - Slows runoff.
  - Reduces erosion and sediment load.

Low Impact Development Overview

Wheeler Army Airfield Potential LID Retrofit Projects



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Low Impact Development Overview

Schofield Barracks Potential Retrofit Projects

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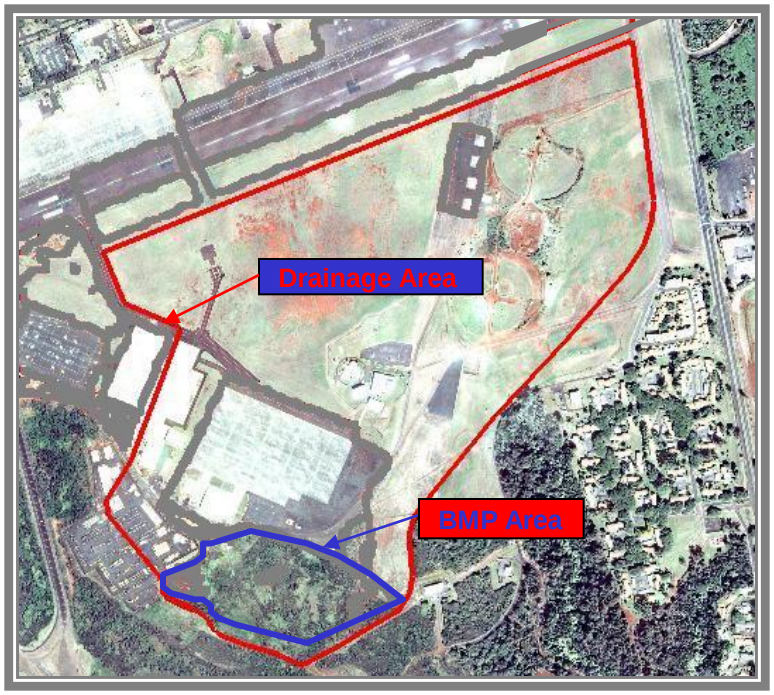
Low Impact Development Overview

W2

W2 retrofit will consider subsurface infiltration and constructed wetland to catch storm runoff from runway and large parking lot before it enters the storm drains that enter Waikele Stream.

Retrofit Name	W2
Description	runway and large parking lot
BMP	Infiltration & Large Wetland
Evaluated Score	29
Total Cost	$77,234.98
Flow Reduction (m^3)	27,176.27
TSS Reduction (kg)	4,281.98
TP Reduction (kg)	10.75
TN Reduction (kg)	60.39



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Low Impact Development Overview

S1A

S1A retrofit was separated from S1 retrofit due to its unique construction requirement. S1A is a small commercial carwash parking lot. The runoff from S1A may contain oil and carwash detergent, so a bio-retention area will be built next to it to remove these compounds.

Retrofit Name	S1A
Description	a small commercial carwash parking lot
BMP	Bioretention & Wetland
Evaluated Score	35
Total Cost	$12,610.49
Flow Reduction (m^3)	8.95
TSS Reduction (kg)	2.63
TP Reduction (kg)	0.01
TN Reduction (kg)	0.07

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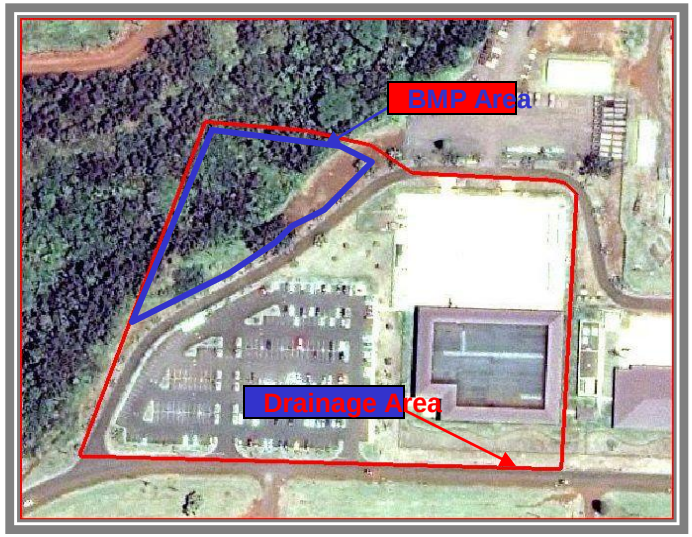
Low Impact Development Overview

S10

S10 retrofit is the Bldg 1503 area. An infiltration system and constructed wetland will be considered to catch and treat the storm runoff from Bldg 1503 and its parking lot.

Retrofit Name	S10
Description	the Bldg 1503 area
BMP	Infiltration & Wetland
Evaluated Score	22
Total Cost	$33,795.95
Flow Reduction (m^3)	1,215.63
TSS Reduction (kg)	106.88
TP Reduction (kg)	0.29
TN Reduction (kg)	2.44



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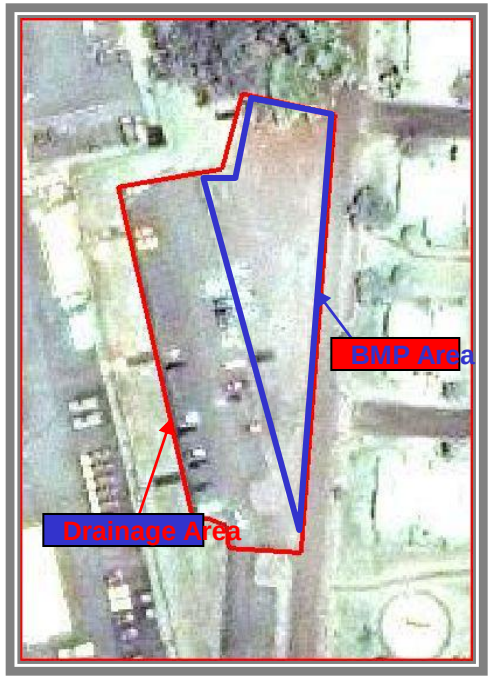
Low Impact Development Overview

S11

S11 retrofit is the eroded parking lot on Maili Road. Permeable pavers will be a solution for better infiltration and erosion control.

Retrofit Name	S 11
Description	the eroded parking lot on Maili Road
BMP	Permeable Pavers
Evaluated Score	27
Total Cost	$427,347.22
Flow Reduction (m^3)	171.04
TSS Reduction (kg)	24.53
TP Reduction (kg)	0.06
TN Reduction (kg)	0.37



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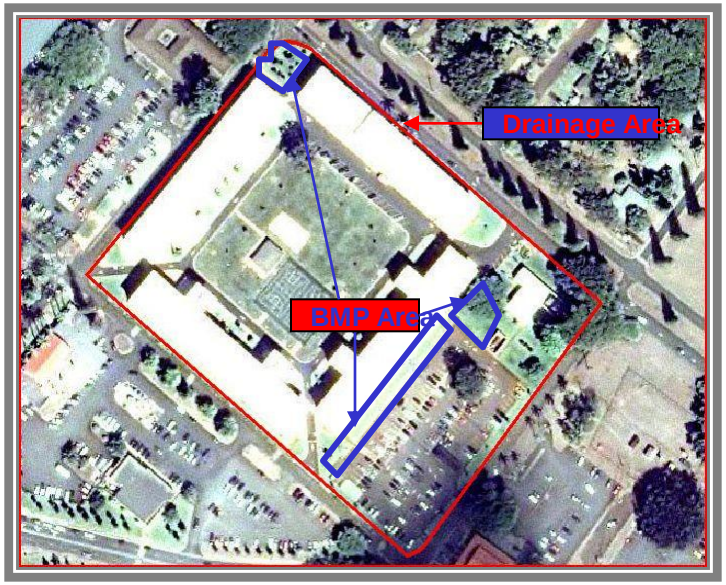
Low Impact Development Overview

S17-Quad C

Retrofit Name	S17-Quad C
Description	Quad C
BMP	Infiltration & Filtration
Evaluated Score	18
Total Cost	$756,539.19
Flow Reduction (m^3)	1,350.57
TSS Reduction (kg)	104.84
TP Reduction (kg)	0.3
TN Reduction (kg)	2.64



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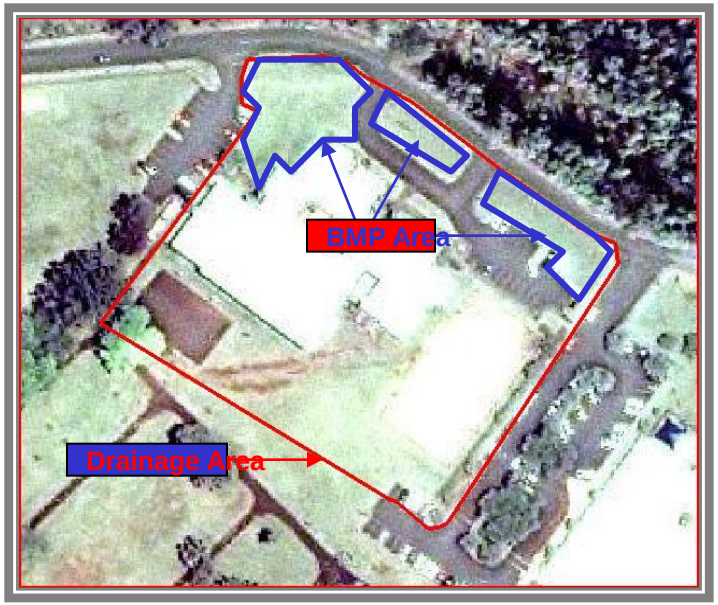
Low Impact Development Overview

S23

S23 retrofit is Bldg 9090 area. Infiltration system and wetland area will be considered to catch the runoff from the parking lot low spot.

Retrofit Name	S23
Description	Bldg 9090 area
BMP	Infiltration & Wetland
Evaluated Score	26
Total Cost	$17,625.77
Flow Reduction (m^3)	350.4
TSS Reduction (kg)	35.68
TP Reduction (kg)	0.1
TN Reduction (kg)	0.73



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LID Retrofit Conclusions

- There are many LID Retrofit possibilities at SB and WAAF.
- Best retrofit projects reduced runoff and treat pollutants on-site before the storm-water channels.
- Flow and Load reductions are calculated for the 95th Percentile Storm.
- Since the largest flow and pollutants loads are from the developed areas, LID can contribute significantly to reducing loads, and meeting regulatory requirements.