Improving Water Quality with Green Infrastructure and Low Impact Development

Florida Stormwater Association
Winter Conference 2019

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December 4, 2019

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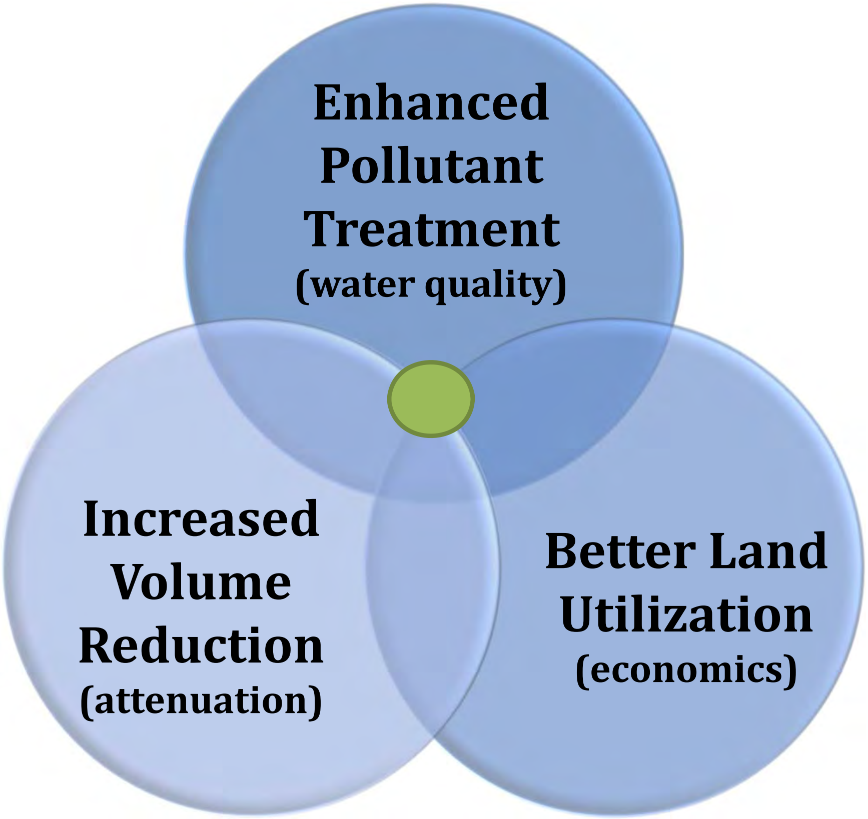
Benefits of GI / LID



Focus on ***stormwater*** *as a resource*

Challenges of GI / LID

- Effective integration with traditional practices
- Lack of familiarity of local contractors
- Lack of familiarity by City / County engineers
- Lack of familiarity by regional permitting authorities
- Lack of experience with maintenance procedures
- Demonstrating benefit
- Incentivizing

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Orange County LID Manual project:

- **LID Manual**
  - 7 LID practices
  - Practices suitable for greenfield type urban development
- **LID concept plans comparison**
  - Traditional vs. LID site design
  - Comparison of costs and maintenance requirements
- **LID maintenance cost projections**
  - Annual maintenance costs for each of the LID practices
  - 10-year maintenance cost projections
- **Stormwater master planning**
  - Mostly closed basins/good soils

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GI / LID Practices:

- Pervious pavement
- Bioretention Areas/ Bioswales
- Rain Gardens
- Planter Box
- Tree Box Filters
- Curb Cuts & Inverted Medians
- Stormwater Harvesting / Cisterns







Cost Impacts:

- **Capital Costs**
  - Reduced infrastructure (↓)
  - Potentially smaller ponds (↓)
  - More vegetation/plantings (↑)
  - Contractor certifications (↑)
- **Maintenance Costs**
  - Training/certifications for personnel (↑)
  - Replace typical landscaping – offset overall BMP maintenance area (↓)
  - Infiltration/media testing (↑)

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Concept Plans Comparison

- **Purpose**
  - Show LID techniques can accommodate equivalent density/intensity development as traditional methods
  - Provide alternatives to structural stormwater facilities
  - Provide additional opportunities for infiltration
  - Illustrate that water quality, water quantity, and nutrient loading criteria can be met or exceeded using LID practices
- **Project Site (29.09 acres): portion of Hamlin PD**
  - Commercial:
    - Grocery store – 54,000 sq. ft.
    - Bank (Outparcel) – 4,500 sq. ft.
    - Retail – 4,500 sq. ft.
  - Residential:
    - 168 MF units (7 buildings at 24 units/building)

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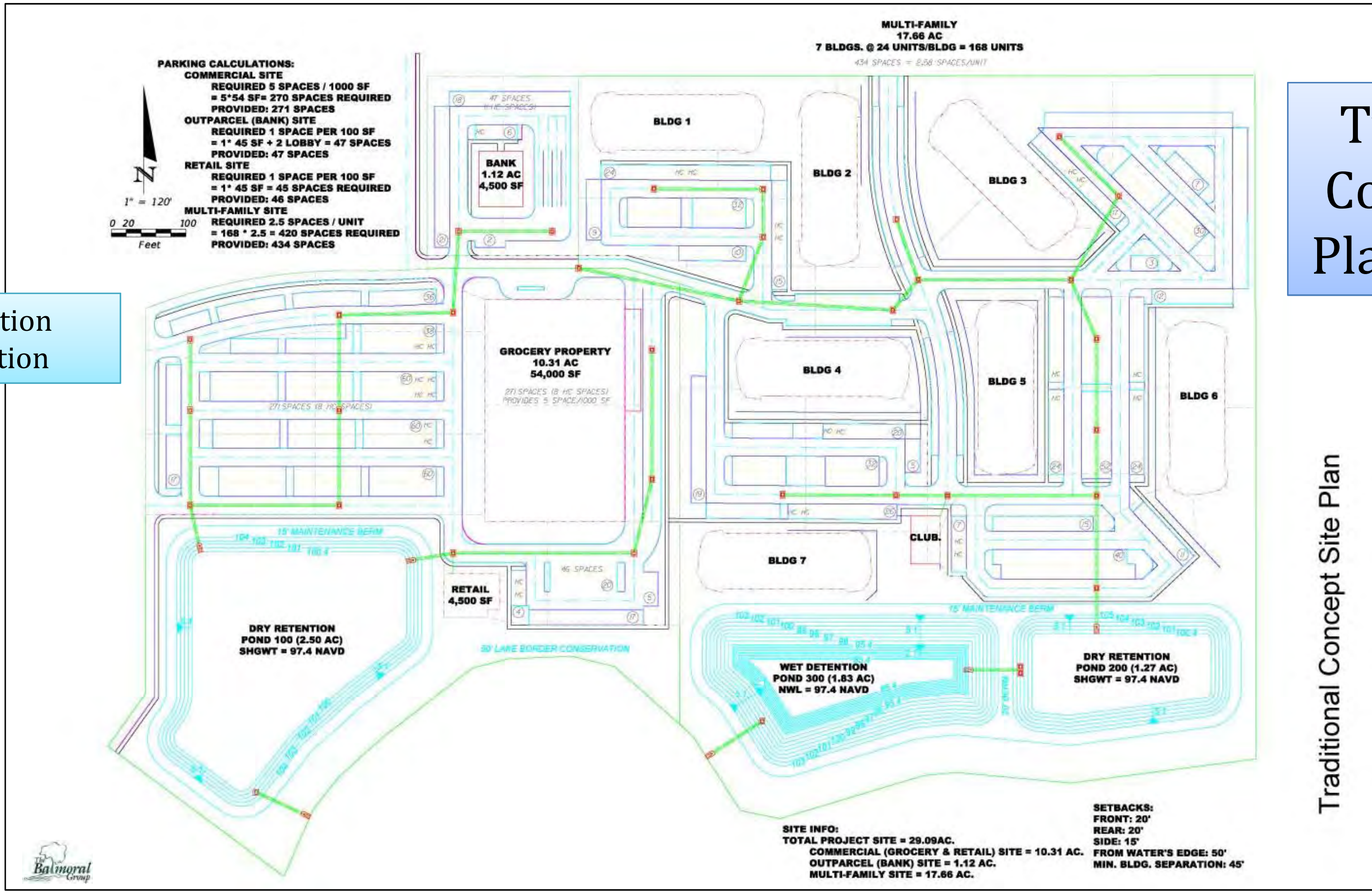
- Wet Detention
- Dry Detention



Traditional Concept Site Plan Example

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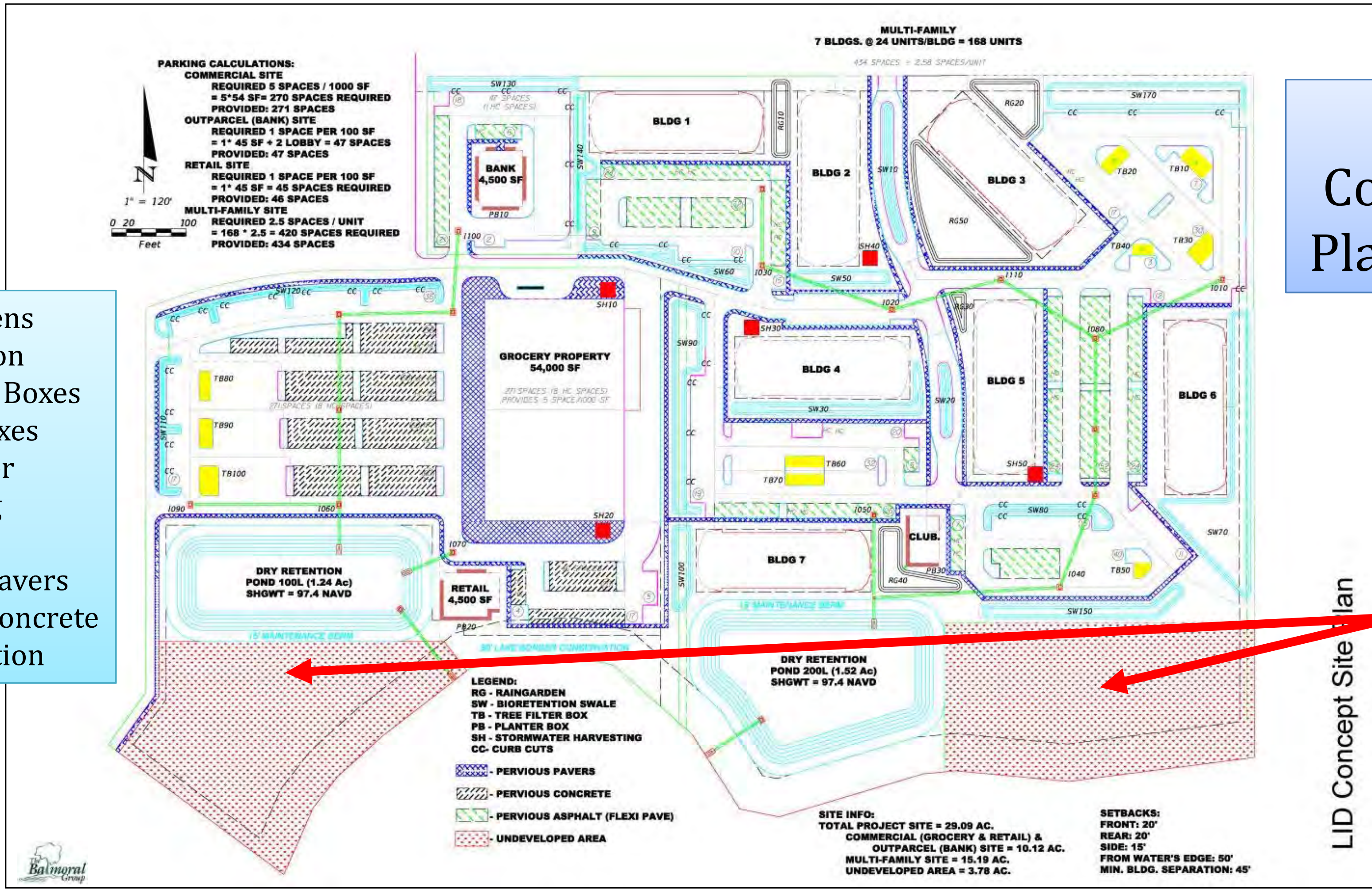

GI / LID Concept Site Plan Example

- Rain Gardens
- Bioretention
- Tree Filter Boxes
- Planter Boxes
- Stormwater Harvesting
- Curb Cuts
- Pervious Pavers
- Pervious Concrete
- Dry Detention

Equivalent developed area but 3.78 acres not needed to achieve same stormwater attention and treatment goals

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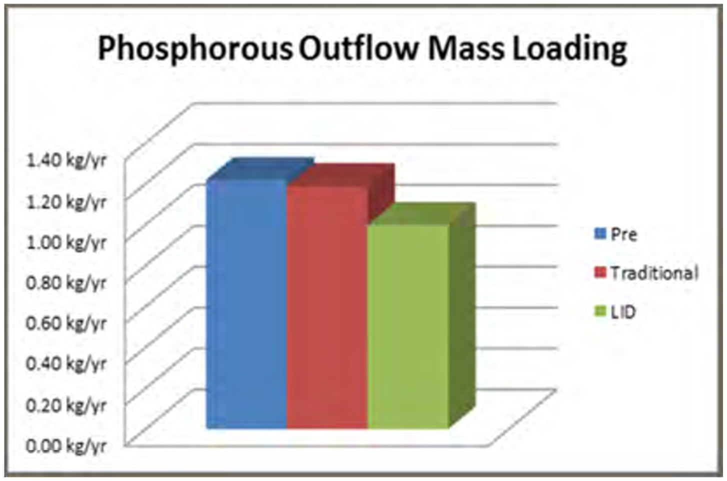
Comparison Results

- The LID Concept provides the same commercial and residential sq. ft. and parking
- LID Utilizes 25.31 acres of the original 29.09 acres – a reduction of 3.78 acres (13%).
- The LID concept plan meets or exceeds the Traditional concept plan in all stormwater management criteria.

Table 1: Comparison of Traditional and LID Results

Criteria	Traditional	LID
Treatment Volume [1]	4.40 ac-ft	5.83 ac-ft
Volume to Ponds [2]	17.7 ac-ft	11.7 ac-ft
Site Discharge Rate [3]	8.46 cfs	8.05 cfs
Pollutant Loading Removal	95.95%	96.69%
Outflow Mass Loading	1.19 kg/yr	0.86 kg/yr

(1): Treatment Volume is controlled by the retention depth needed for nutrient removal
(2): Total Inflow volume for the 25yr/24hr (Orange) storm event to Ponds 100/100L and 200/200L
(3): Peak Discharge to Lk Hancock for the 25yr/24hr (Orange) storm event



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Traditional vs. LID Example - Cost Comparison Results with Land Savings

Pay Item	LID Cost	Traditional Cost	LID Description	Traditional Description
Pavement	$ 741,323.67	$ 586,532.87	Pervious Pavement, Pervious Asphalt, and Pavers	Asphalt and Concrete Sidewalk
Bioretention Swale	$ 645,387.05	$ 290,941.07	Bioretention Swale	Landscaping
Raingarden	$ 408,062.24	$ 104,400.34	Raingarden	Landscaping
Planter Box	$ 47,296.75	$ 9,645.40	Planter Box	Landscaping
Tree Box Filter	$ 128,730.00	$ 6,307.27	Tree Box Filter	Landscaping
Curbing and Medians	$ 86,326.45	$ 86,886.83	Valley Gutter, Type D curb, and Pavement	Type D Curb and Pavement
Stormwater Harvesting	$ 212,621.14	N/A	Stormwater Harvesting	- -
Primary Storm System	$ 398,769.82	$ 818,139.65	Two Dry Retention Ponds	Two Dry Retention Ponds and One Wet Detention Pond
Secondary Storm System	$ 354,529.42	$ 644,946.81	36-inch Pipe, Manhole, DBI C, 36-Inch MES	12-inch & 36-inch Pipe, DBI C, 36-Inch MES
Undeveloped Land	N/A	$ 849,000.00	- -	$200k/acre multi-family; $250k/ acre retail
Totals:	$ 3,023,047	$ 3,396,800		

~12% Costs Savings

Maintenance Costs Projections

- Project maintenance costs for each of the LID practices:
  - frequency
  - inspection activity
  - maintenance activity
  - labor/equipment/materials
  - costs of similar traditional stormwater management activities
- Compare example project data
- Compare to national data

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Annual Cost Projection

Table PP-1 - Pervious Pavement[1] vs Conventional Pavement Projected Annual Maintenance Costs

LID Practice Maintenance Cost Projection

Orange County, Florida

Base Pervious Pavement Area (sf): 20000 Base maintenance costs in table below are for an approximately 20,000 square feet (approximately 100 parking space) pervious pa... Caution: If base area is modified then labor hours and material allowance should be revisited to match the updated base area.

Design Pervious Pavement Area (sf): 20000 Area of the Design pervious pavement practice. The Size Factor in the table below is applied to this area to adjust the annual cost.

Category | Frequency | Inspection Activity | Maintenance Activity | Labor/Equip./ Materials

Maintenance Activity	Projected Frequency[2]	Inspection Activity[2]	Maintenance Activity Description[2]	Labor / Equipment / Materials Required	Notes
Monthly Trash and Debris Removal	Monthly (12 times a year)	Inspect area for trash and debri accumulations	Remove trash and debris from pavement area.	Laborer with brooms, dust pans, and garbage bags.	Considered similar to "Trash / Litter Pickup and Removal" work.
Triannual Minor Inspection, Cleaning, and Restoration	3 times per year (Two times per year with allowance for one additional occurrence after a major storm.)	Inspect pavement for ponding water	Monitor these areas to determine if surface infiltration rates have been compromised. If so, vacuum area wit street sweeper to reduce the risk of clogging.	Inspector to perform visual inspection.	The hours estimated for each task assume that the tasks would occur as part of regular maintenance at multiple pervious / conventional pavement areas.
		Inspect pavement for accumulated sediment	Remove accumulated sediment by vacuuming with street sweeper if necessary. Identify source of sedimen and repair area	Inspector to perform visual inspection.	
		Inspect outlets	Remove accumulated sediment from outlet and repair areas of erosion	Laborer with hand tools. Rubble rip ra or gravel to repair erosion area.	
		Inspect adjacent areas for erosion	Stabilize bare areas	Laborer with hand tools. Cover bare areas with sod or gravel as needed.	
		Inspect for vegetation growth within pervious pavement	Kill vegetation within pervious pavement area	Laborer with herbicide and backpack sprayer.	
Annual Inspection and Maintenance	Once per year (prior to wet season)	Conduct surface vacuuming wit street sweeper	Vacuum with street sweeper pervious pavement and surrounding contributing pavement.	Subcontractor capable of vacuuming the parking lot with street sweeper.[7]	This estimate assumed that rehabilitation of the pervious pavement is not required annually, but would occur as part of a major restoration effort.
		Conduct infiltration testing	Using ERIK procedures, determine th infiltration rate through the pervious pavement is at least 2.0 inches per hour.	Subcontractor or County staff qualified to perform test. Testing supplies. This test is assumed to occur concurrent with the semi-annual inspection for accumulated settlement. Contractor should rehabilitate pavement by vacuuming with street sweeper.[8]	
Annual Compliance Report	Annually	N/A	N/A	Responsible Party to compile annual summary of relevant inspection and maintenance data.[9]	

Pervious Pavement $ | Conventional Pavement $

Maintenance Activity	Pervious: Labor Hours[3]	Pervious: Cost / Hr[4]	Pervious: Material Allowance[4]	Pervious: Total Cost Per Occurrence:	Pervious: Base Annual Cost:	Pervious: Size Factor[5]	Pervious: Adjusted[6] Annual Cost:	Conventional: Labor Hours[3]	Conventional: Cost / Hr[4]	Conventional: Material Allowance[4]	Conventional: Total Cost Per Occurrence:	Conventional: Annual Cost:	Conventional: Size Factor[5]	Conventional: Adjusted[6] Annual Cost:
Monthly Trash and Debris Removal	0.5	$40	$5	$25	$300	0.20	$300	0.5	$40	$5	$25	$300	0.20	$300
Triannual – Inspect pavement for ponding water	0.25	$60	$0	$15	$45	0.05	$45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Triannual – Inspect pavement for accumulated sediment	0.25	$60	$0	$15	$45	0.05	$45	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Triannual – Inspect outlets	0.25	$40	$25	$35	$105	0.05	$105	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Triannual – Inspect adjacent areas for erosion	0.25	$40	$25	$35	$105	0.10	$105	0.25	$40	$25	$35	$105	0.10	$105
Triannual – Inspect for vegetation growth	0.5	$40	$15	$35	$105	0.50	$105	0.5	$40	$15	$35	$105	0.50	$105
Annual – Conduct surface vacuuming	0.5	$95	$0	$48	$48	0.05	$48	0.5	$95	$0	$48	$48	0.05	$48
Annual – Conduct infiltration testing	1	$60	$100	$160	$160	0.05	$160	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Annual Compliance Report	4	$75	$0	$300	$300	0.00	$300	4	$75	$0	$300	$300	0.00	$300
						Total Annual Maintenance Cost:	**$1,213**						**Total Annual Maintenance Cost:**	**$858**

Green shading indicates cell can be manually edited.

Purple shading indicates cell ... d should n...

~41% Costs Increase

Example 10-Year Maintenance Cost Projection

Table PP-2 - Pervious Pavement Projected 10-Year Maintenance Costs*

LID Practice Maintenance Cost Projection

Orange County, Florida

Inflation Rate: 3% *User input inflation rate. The base rate of inflation is 3%.*

Maintenance Activity	Year										Totals
	1	2	3	4	5	6	7	8	9	10	
Monthly Trash and Debris Removal	$300	$309	$318	$328	$338	$348	$358	$369	$380	$391	$3,439
Triannual Minor Inspection, Cleaning, and Restoration	$405	$417	$430	$443	$456	$470	$484	$498	$513	$528	$4,643
Annual Inspection and Maintenance	$208	$214	$220	$227	$234	$241	$248	$255	$263	$271	$2,379
Annual Compliance Report	$300	$309	$318	$328	$338	$348	$358	$369	$380	$391	$3,439
										Total 10 Year Maintenance Cost:	**$13,900**

Green shading indicates cell can be manually edited.

Purple shading indicates cell result of formula calculation and should not be manually edited.

Notes:

*Costs are projected to the specific year from 2013 (year 1) dollars using a base inflation rate of 3%.

**Refer to Table PP-1 for annual maintenance cost assumptions.

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Traditional vs. LID Example - Maintenance Cost Comparison

Maintenance Scenario	Design Practice Size	Estimated Annual Maintenance (2013 Dollars)	Estimated 10-Year Maintenance (3% inflation)
Pervious Pavement	36792 sf	$1,333	$15,278
Bioretention	73846 sf	$11,367	$130,311
Rain Garden	26498 sf	$5,877	$67,377
Planter Box	2448 sf	$1,804	$20,684
Tree Box Filter	10 boxes	$1,586	$18,722
Curb Cuts / Inverted Medians	N/A	N/A	N/A
Stormwater Harvesting (w/ Cisterns)	134528 gal	$9,120	$104,548
Dry Retention Pond	92522 sf	$11,303	$133,462
Totals:		$42,390	$490,382

Maintenance Scenario	Design Practice Size	Estimated Annual Maintenance (2013 Dollars)	Estimated 10-Year Maintenance (3% inflation)
Dry Retention Pond	132,675 sf	$15,880	$187,512
Landscaped Area	30,546 sf	$5,889	$69,542
Swale	73,843 sf	$8,779	$103,663
Wet Detention Pond	63,319 sf	$4,451	$49,095
Totals:		$34,999	$409,812

~20% Costs Increase

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Traditional vs LID Example Take Home Points

- With proper planning, significant cost savings may be achieved when considering land savings in new development scenarios
- LID approach may accommodate more water quality treatment in impaired waters basins
- LID approach may accommodate more infiltration in recharge areas
- Maintenance costs
  - May increase with LID practice applications
  - Focus on offset costs compared to traditional maintenance requirements
  - Enhanced water quality treatment offset may provide additional benefit
  - Long Term maintenance cost can be offset by up front capital savings

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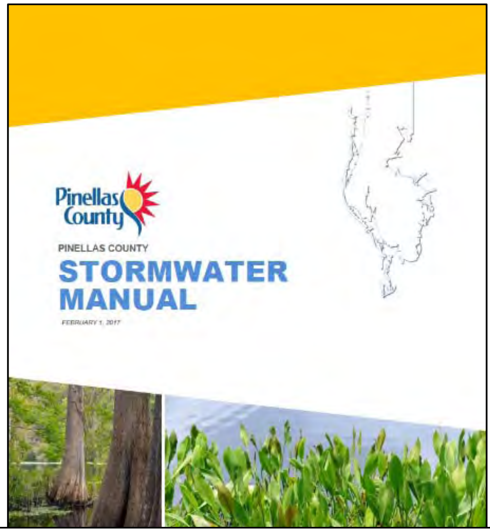
Promoting Green Infrastructure in Code

- Manual was created to promote an advanced stormwater management approach that is integrated with a revised land development code that incorporates a variety of green infrastructure or low impact development options to address stormwater quantity/quality standards as redevelopment occurs.
- The standards, herein, align with the State of Florida Environmental Resource Permit (ERP) and the administrative standards established by the Southwest Florida Water Management District (SWFWMD).
- The County, through its codes and policies, will allow design flexibility while establishing quantity/quality goals to ensure a sustainable future.
- Manual is designed in three distinct parts that each address the stages of the stormwater design process:
  - Introduction and Site Planning
  - Pinellas Stormwater Requirements
  - Best Management Practices Catalog



Land Development Code
Article II: Drainage Requirements

Sec. 154-52. - Pinellas County Stormwater Manual.

The Pinellas County Stormwater Manual is intended to provide detailed drainage requirements and guidelines for the construction of physical improvements in the unincorporated limits of the county and on Pinellas County owned infrastructure in the incorporated limits of Pinellas County. However, to the extent this article conflicts with a municipal ordinance, the more stringent criteria shall be met. The Pinellas County Stormwater Manual shall be adopted by ordinance of the county commission and kept on file in the development review services and public works departments.

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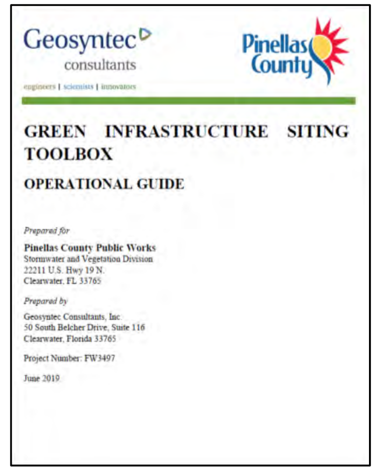
Green Infrastructure Siting Tools

- Develop a rating and suitability framework for siting GI as part of the new GI program
- End result to provide framework and toolset to evaluate water quality benefits and suitability to conceptualize and prioritize future GI projects
- Produce initial list of ranked GI projects
- Top ranked projects are conceptualized as proof of concept
- SOPs developed so COUNTY may easily replicate the results
- Establish standardized water quality benefit evaluation procedures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Pinellas County

GREEN INFRASTRUCTURE SITING TOOLBOX

OPERATIONAL GUIDE

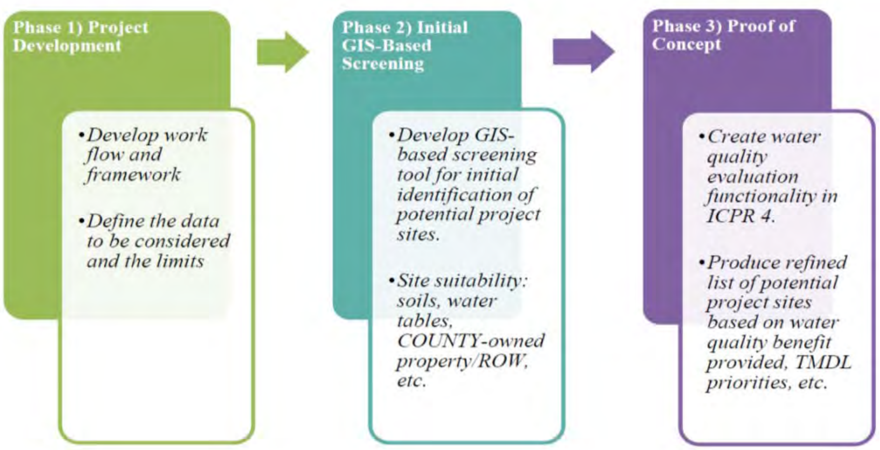
Prepared for
Pinellas County Public Works
Stormwater and Vegetation Division
22211 U.S. Hwy 19 N.
Clearwater, FL 33765

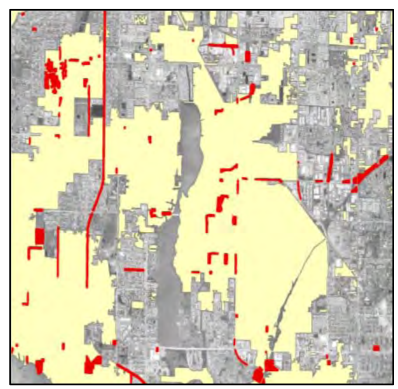
Prepared by
Geosyntec Consultants, Inc
50 South Belcher Drive, Suite 116
Clearwater, Florida 33765

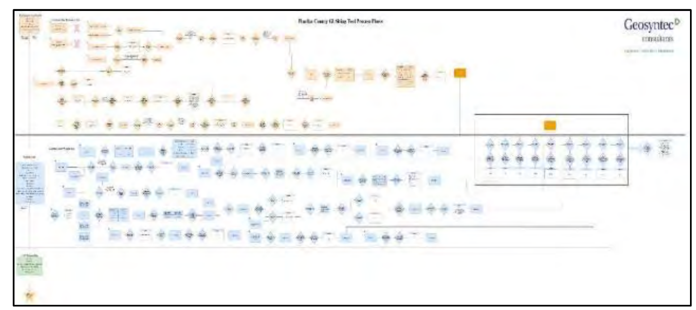
Project Number: FW3497

June 2019

Structural BMPs	Structural Stormwater BMPs	Manual Section	Explicit Load Reduction Credit
SW1	Retention Basin	6.1	√
SW2	Exfiltration Trench	6.2	√
SW3	Underground Storage and Retention	6.3	√
SW4	Treatment Swales	6.4	√
SW5	Vegetate Natural Buffers	6.5	√
SW6	Pervious Pavements	6.6	√
SW7	Green Roofs with Cisterns	6.7	√
SW8	Wet Detention Systems	6.8	√
SW9	Stormwater Harvesting/ Horizontal Wells	6.9	√
SW10	Up-Flow Filter Systems	6.10	√
SW11	Managed Aquatic Plant Systems	6.11	√
SW12	Biofiltration Systems/Tree Box Filters	6.12	√
SW13	Rain gardens	6.13	√
SW14	Rainwater Harvesting/Cisterns	6.14	√
SC15	Rainfall Interceptor Trees	6.15	√







Bay Lake - Water Quality Retrofit

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- Bay Lake Impaired for Nutrients
- Mixed land uses in contributing area
- 319 Grant for LID BMP Demonstration
- Modular Wetland Units with Filtration, Bioactivated Media, and Plant Uptake

Bay Lake - Post-Improvement Stormwater Flow

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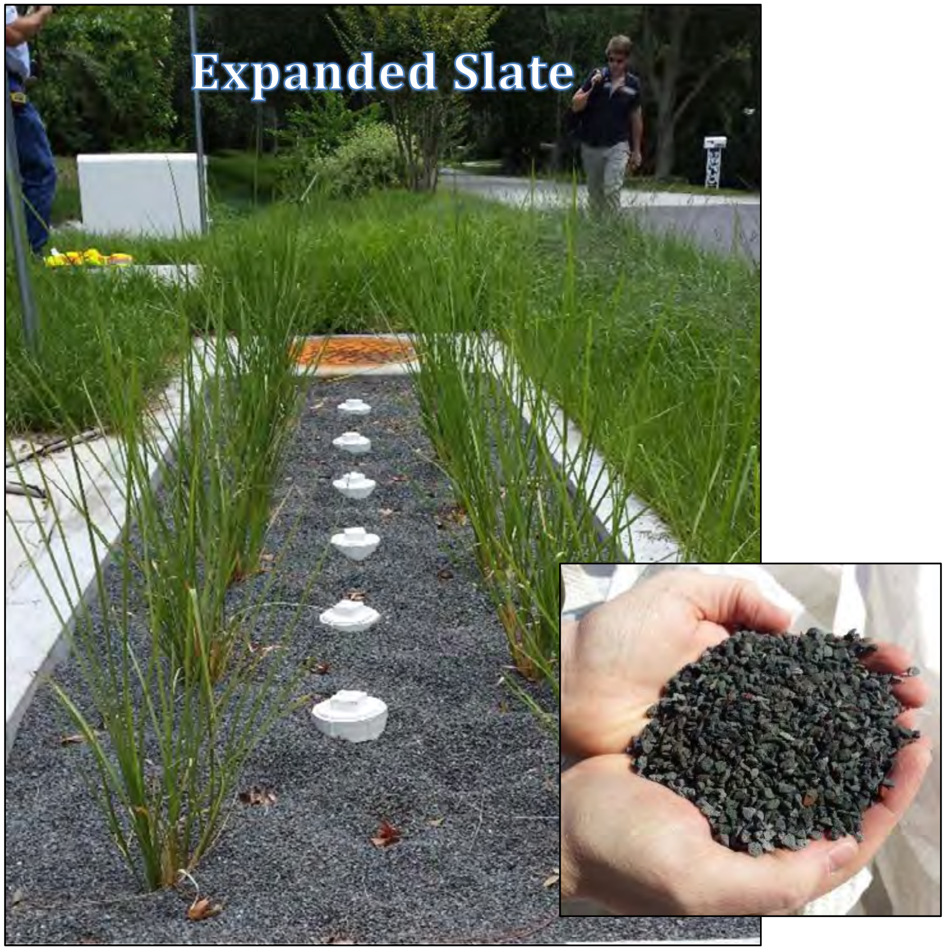
Bay Lake - Modular Wetlands



Bay Lake - Monitoring Equipment

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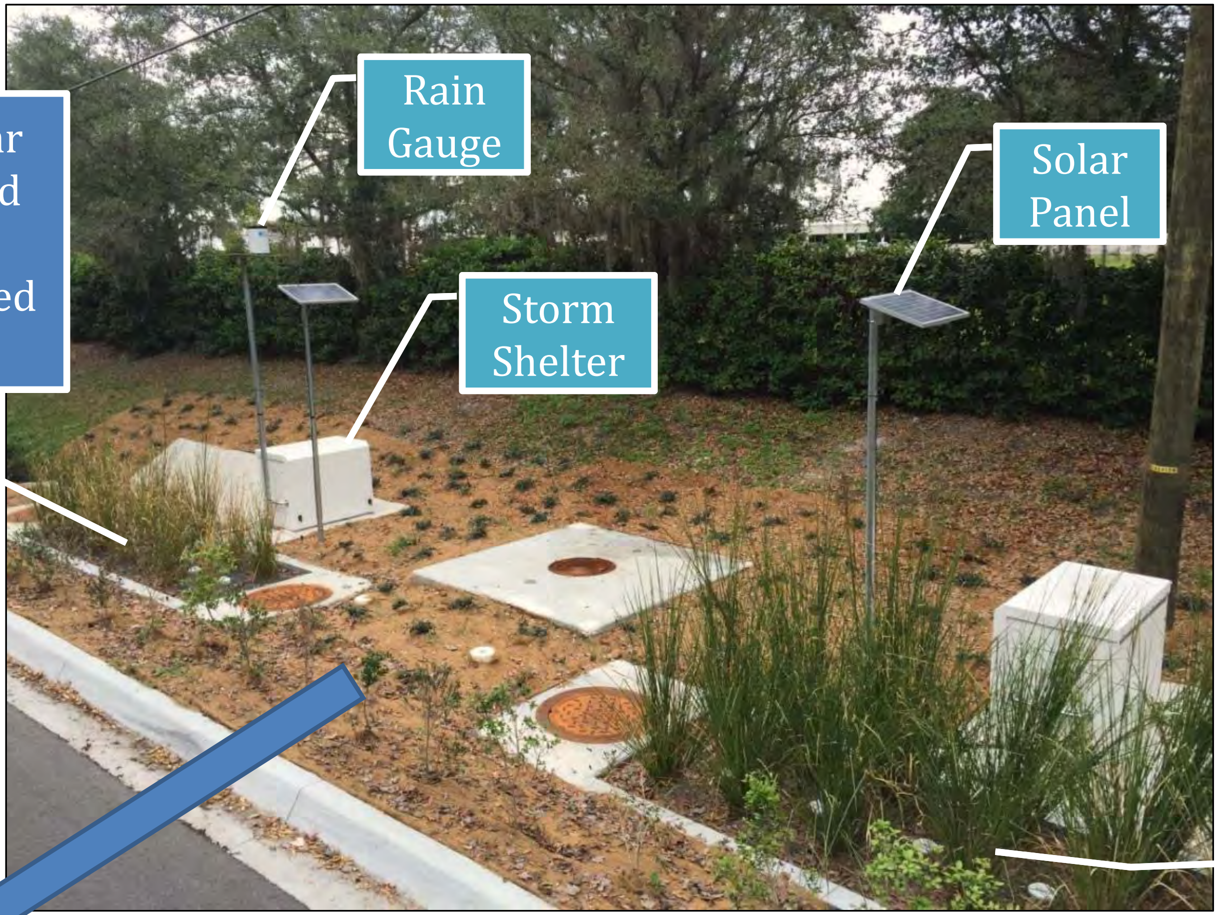

Modular Wetland with Bold and Gold

Bay Lake - Maintenance

- High sediment loading from ditch-inflow caused filter chamber to clog
- Maintenance crews contributed to clogging with grass clippings getting into system
- System undersized for specific application

Bay Lake - Maintenance

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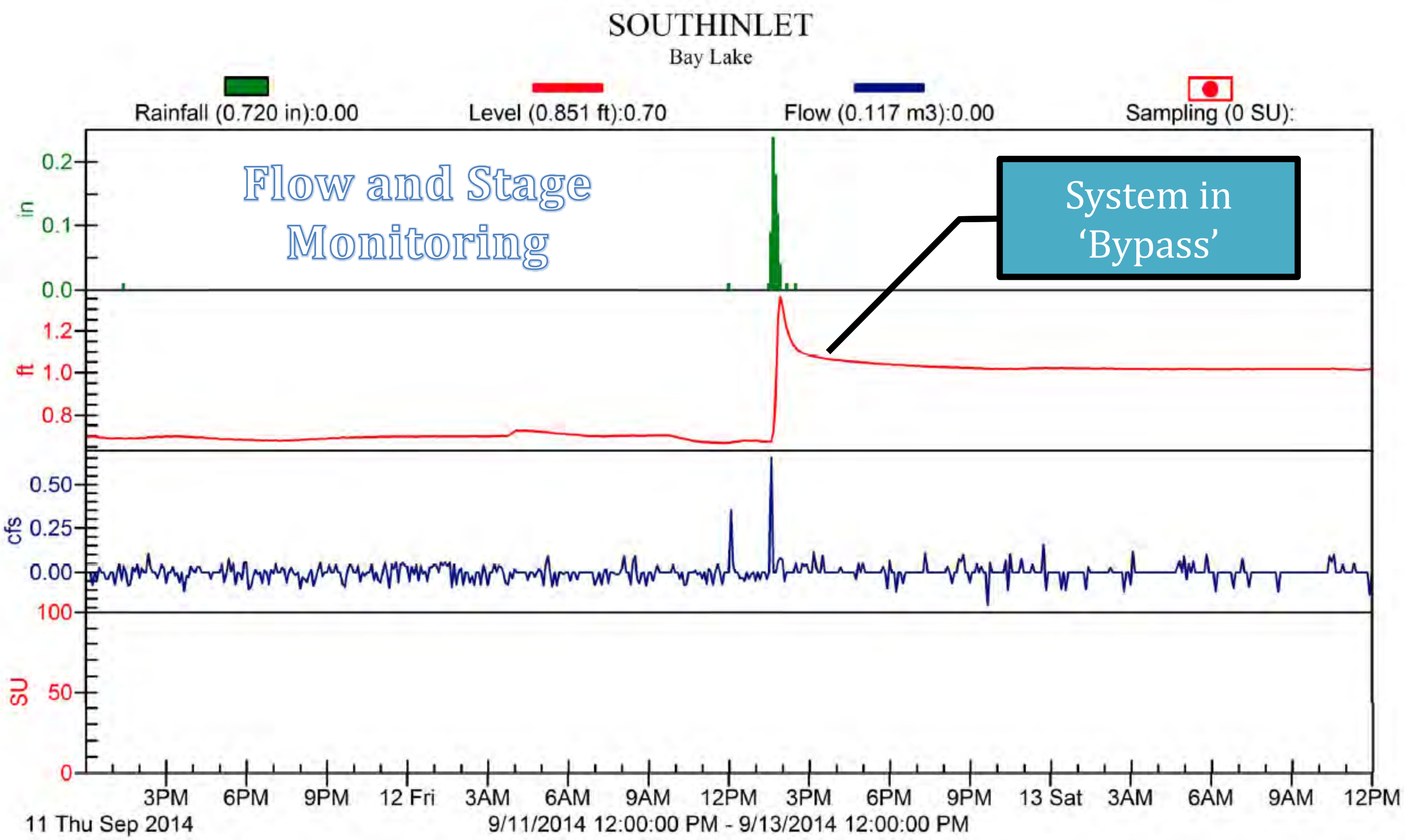

Bay Lake - Results

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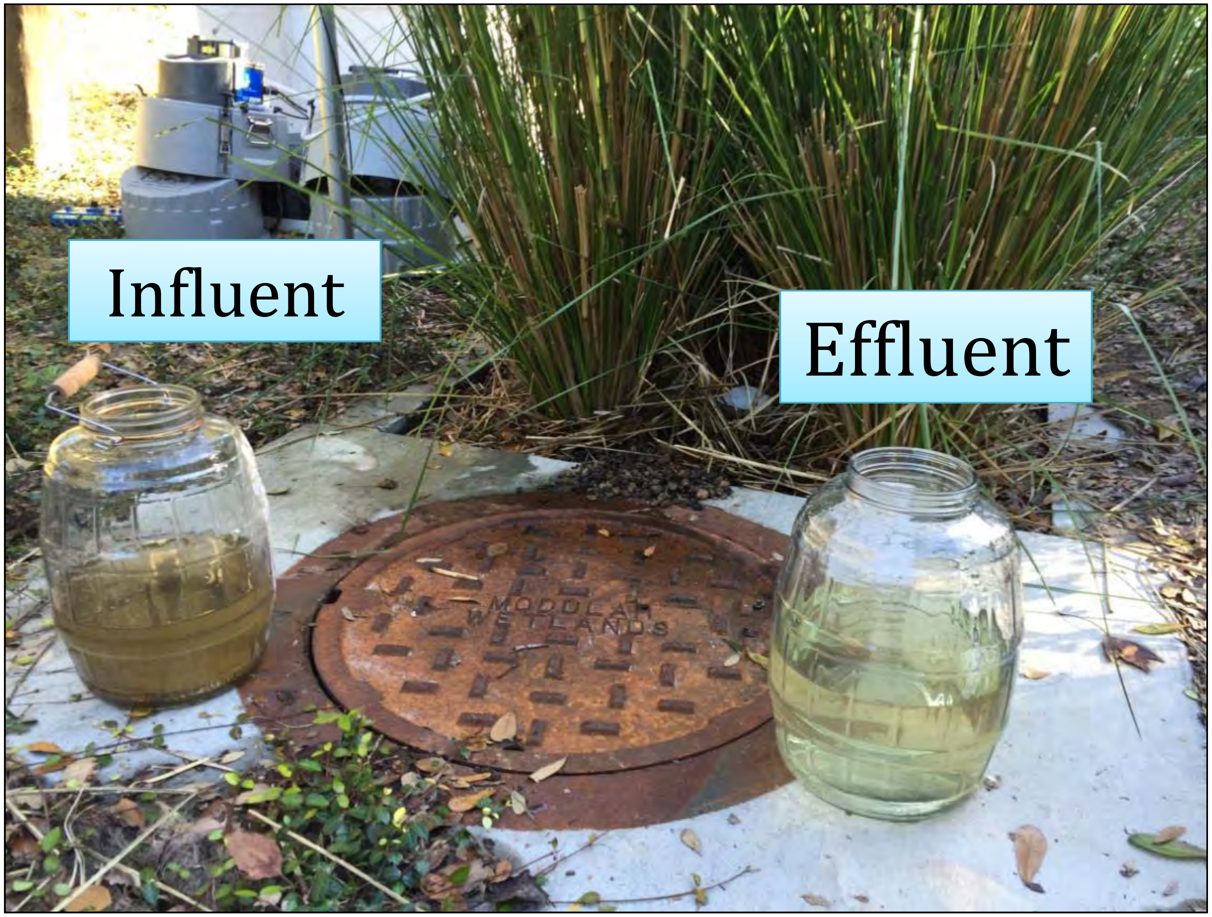

Parameter	Percent Removal	
	Modular Wetland	
	North (Expanded Slate)	South (Bold & Gold)
Orthophosphorus	26.6%	39.1%
Total Phosphorus	38.1%	57.0%
Ammonia	65.5%	73.0%
Total Kjeldahl Nitrogen	44.3%	54.9%
Nitrate / Nitrite	33.3%	-3.1%
Total Nitrogen	38.6%	48.3%
Total Suspended Solids	78.9%	82.8%

GI / LID BMP Resilience

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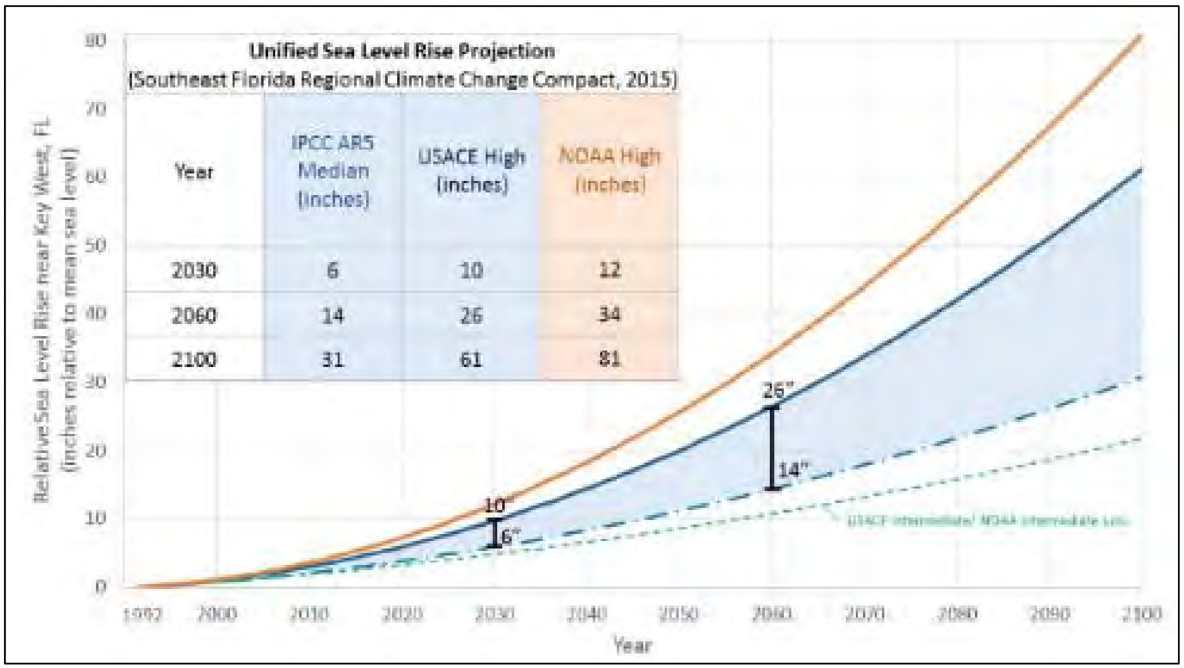
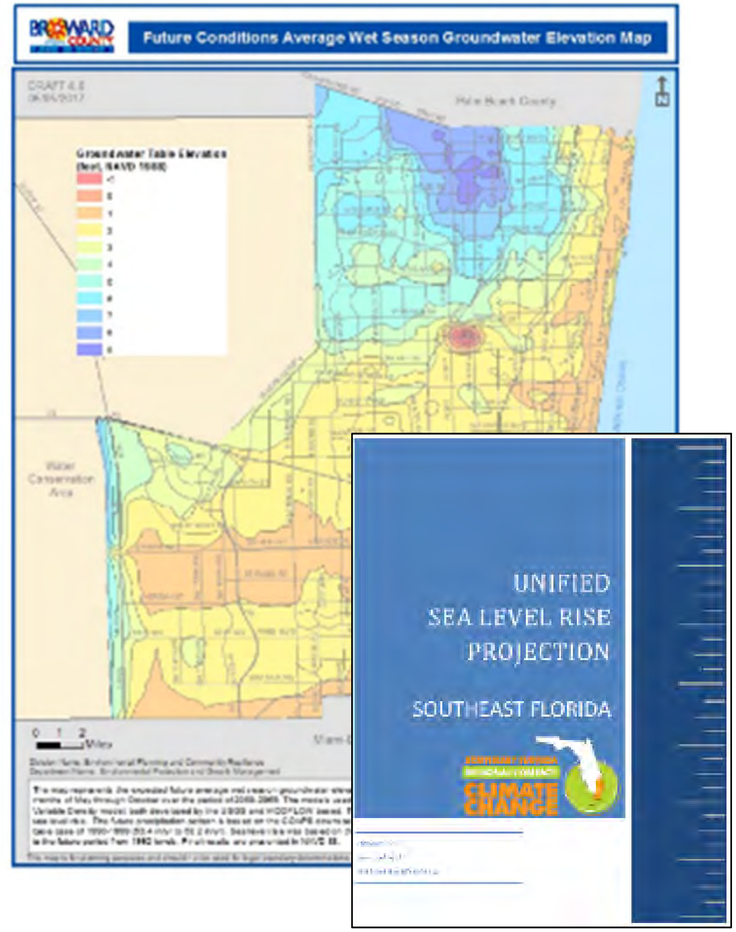
- Impacts of Future Climate Change
  - Sea Level Rise
  - Groundwater Table Rise
  - Changes in Hydrology – More Intense Storms





GI / LID BMP Resilience

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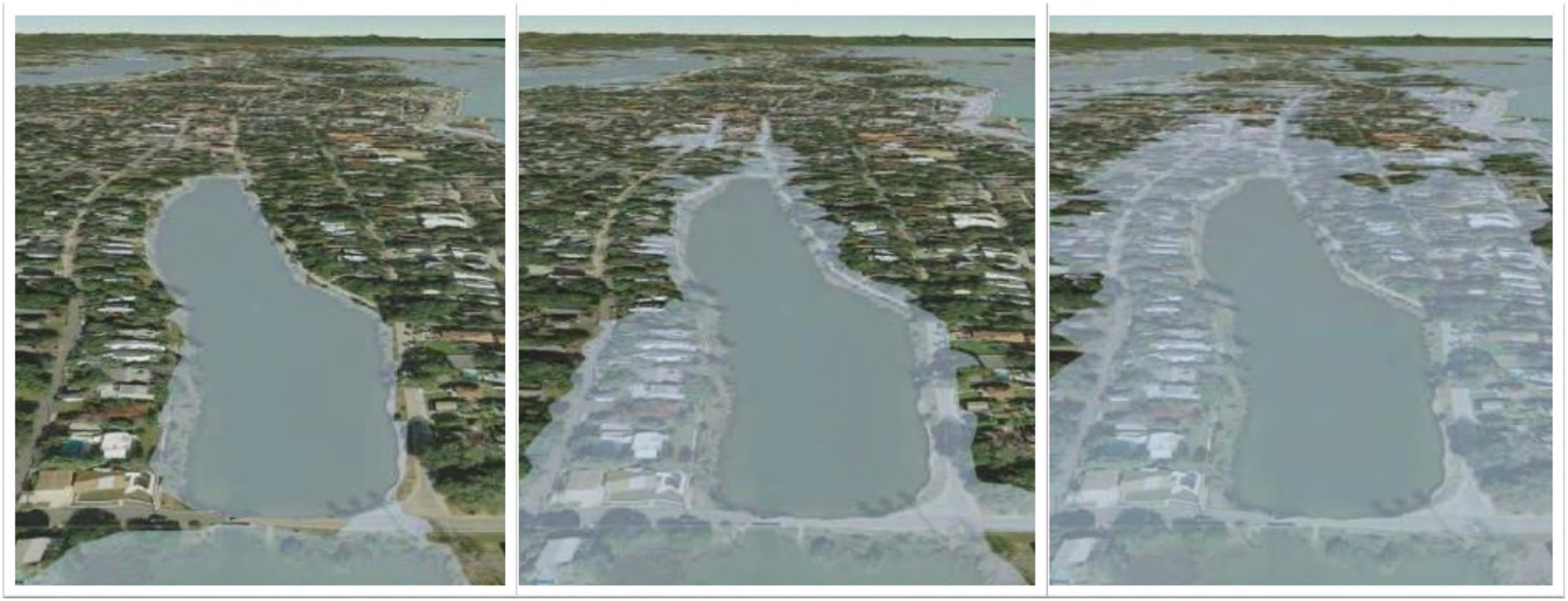
Existing and Forecasted Estimated Nuisance Flooding Conditions at St. Augustine's Maria Sanchez Lake based on FDEO's 2016 *Coastal Vulnerability Assessment*



Existing **12" SLR (2030s)** **24" SLR (2040s)**

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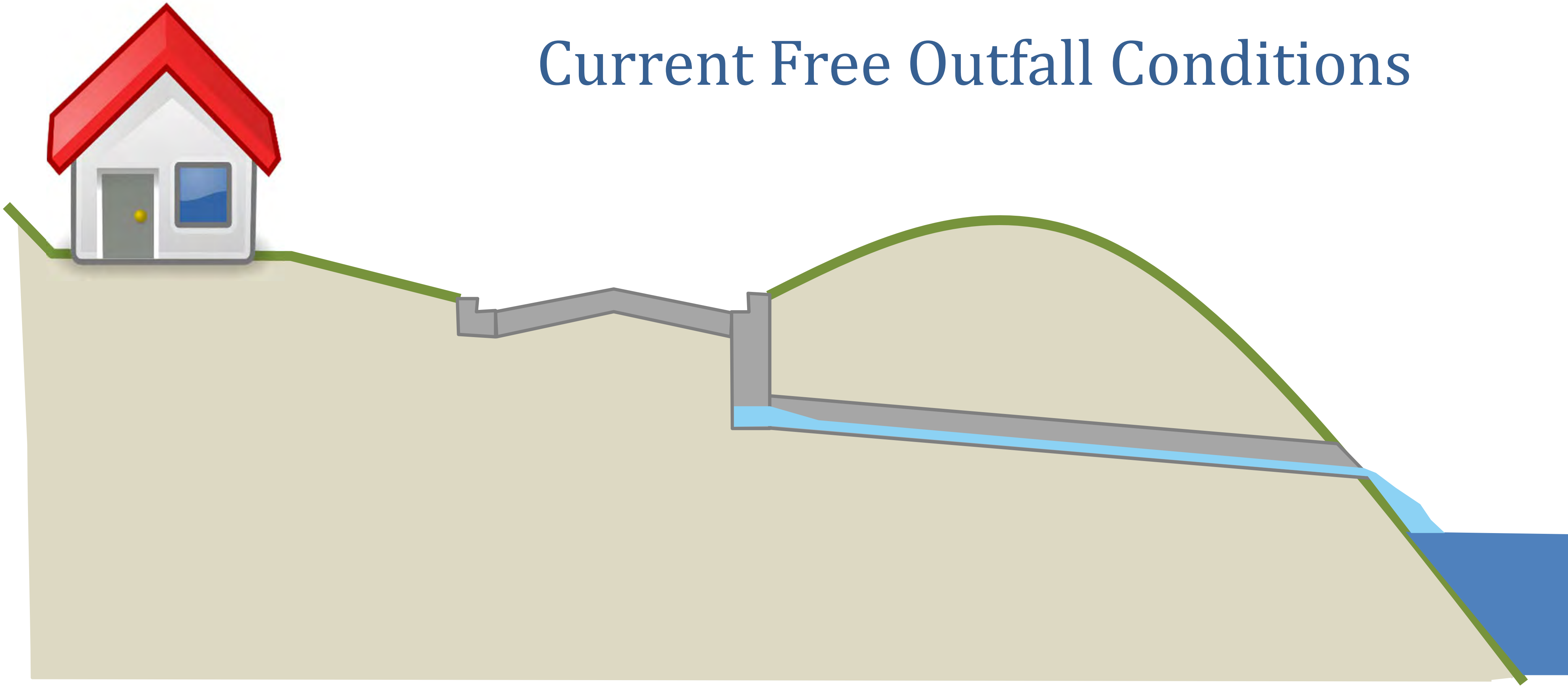
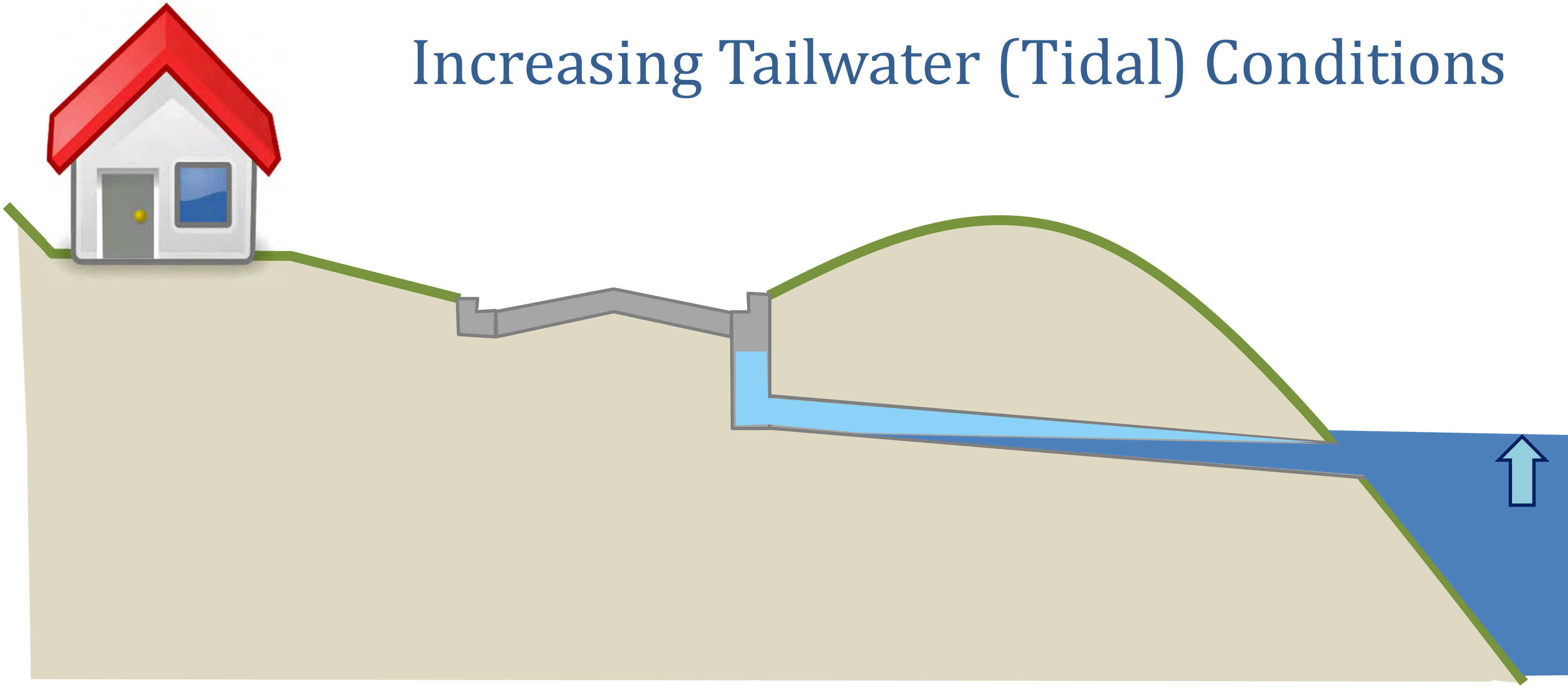
Current Free Outfall Conditions



Increasing Tailwater (Tidal) Conditions



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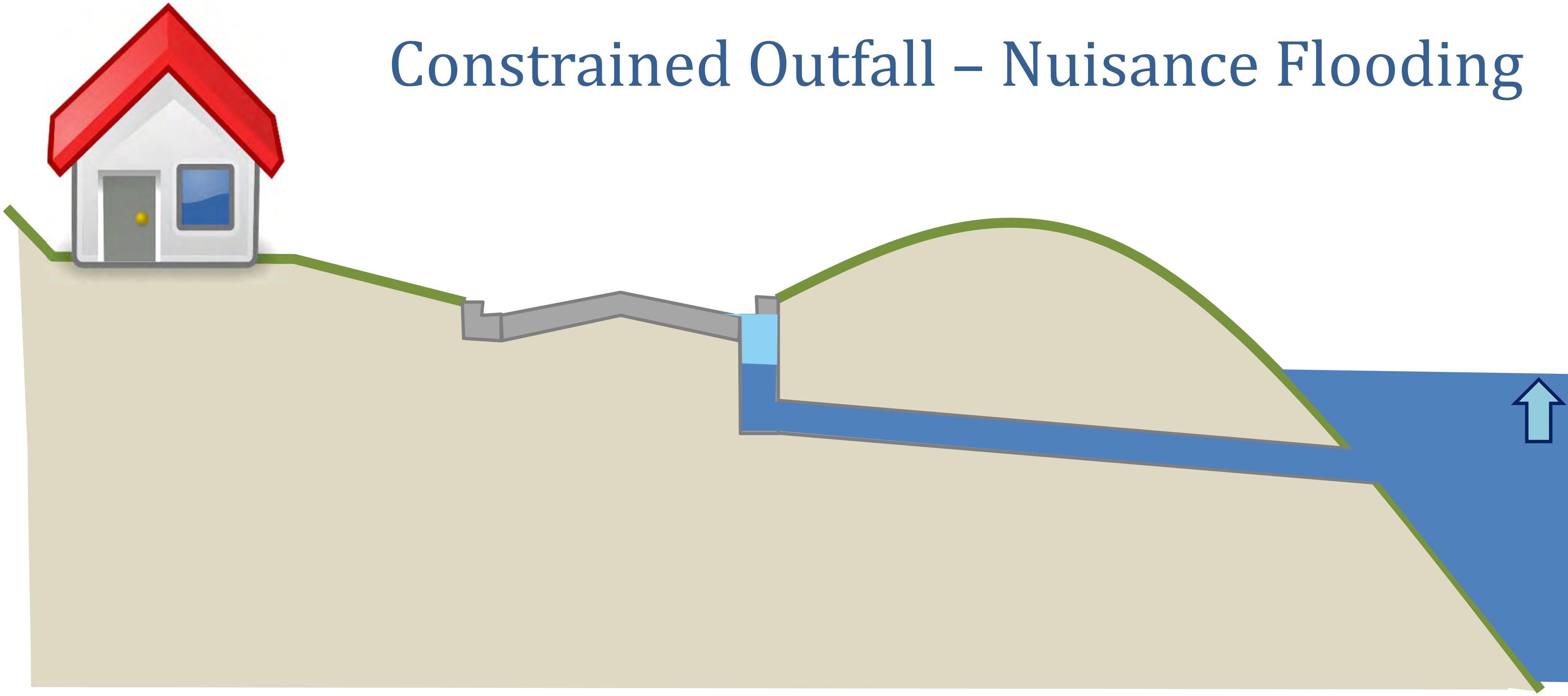
Constrained Outfall – Nuisance Flooding



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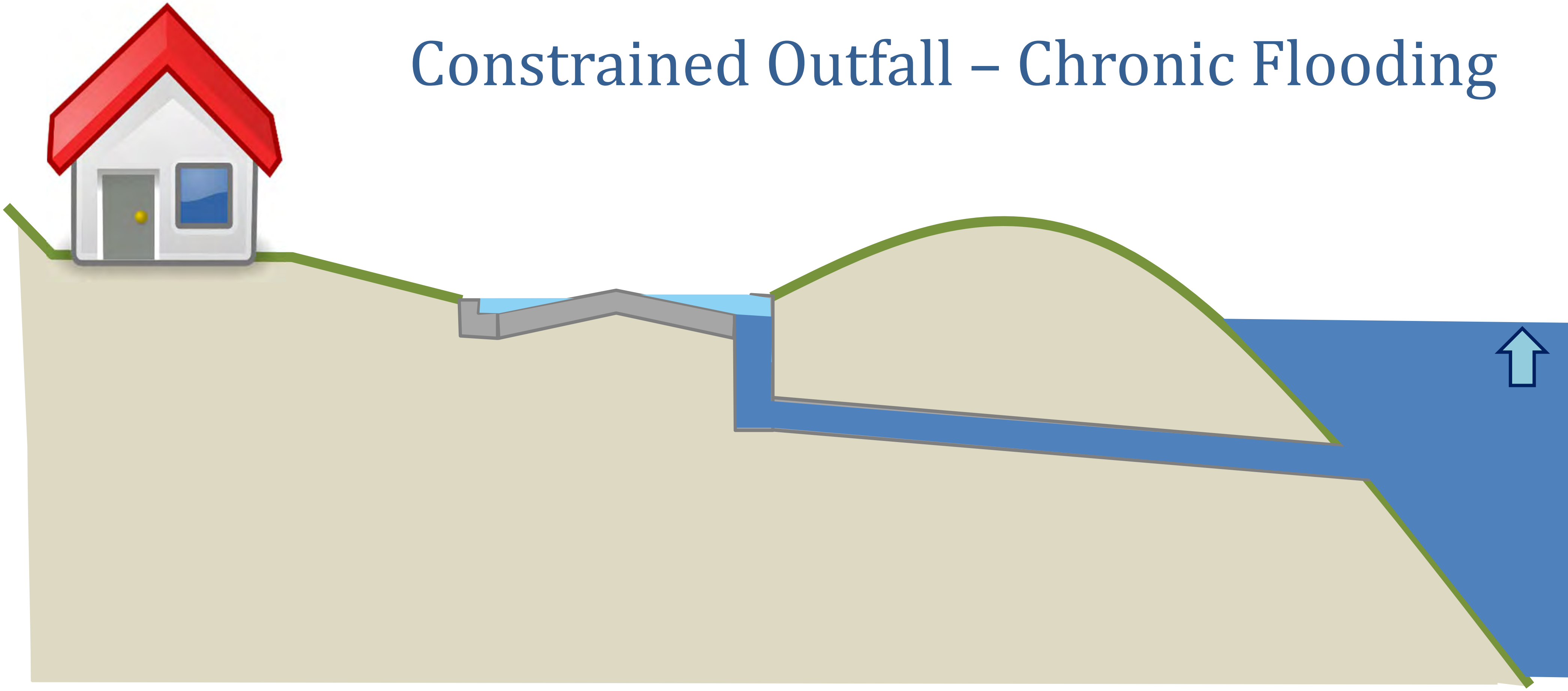
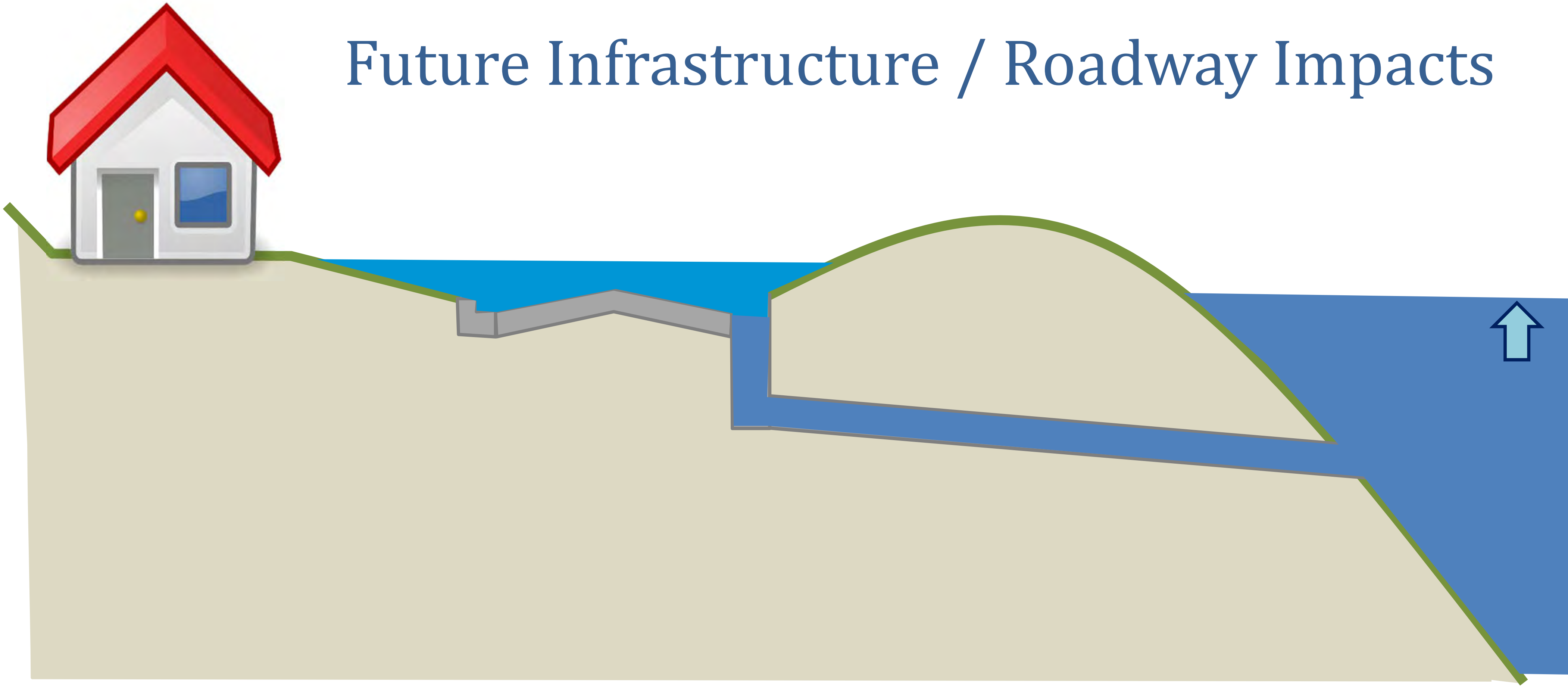
Constrained Outfall – Chronic Flooding



Future Infrastructure / Roadway Impacts



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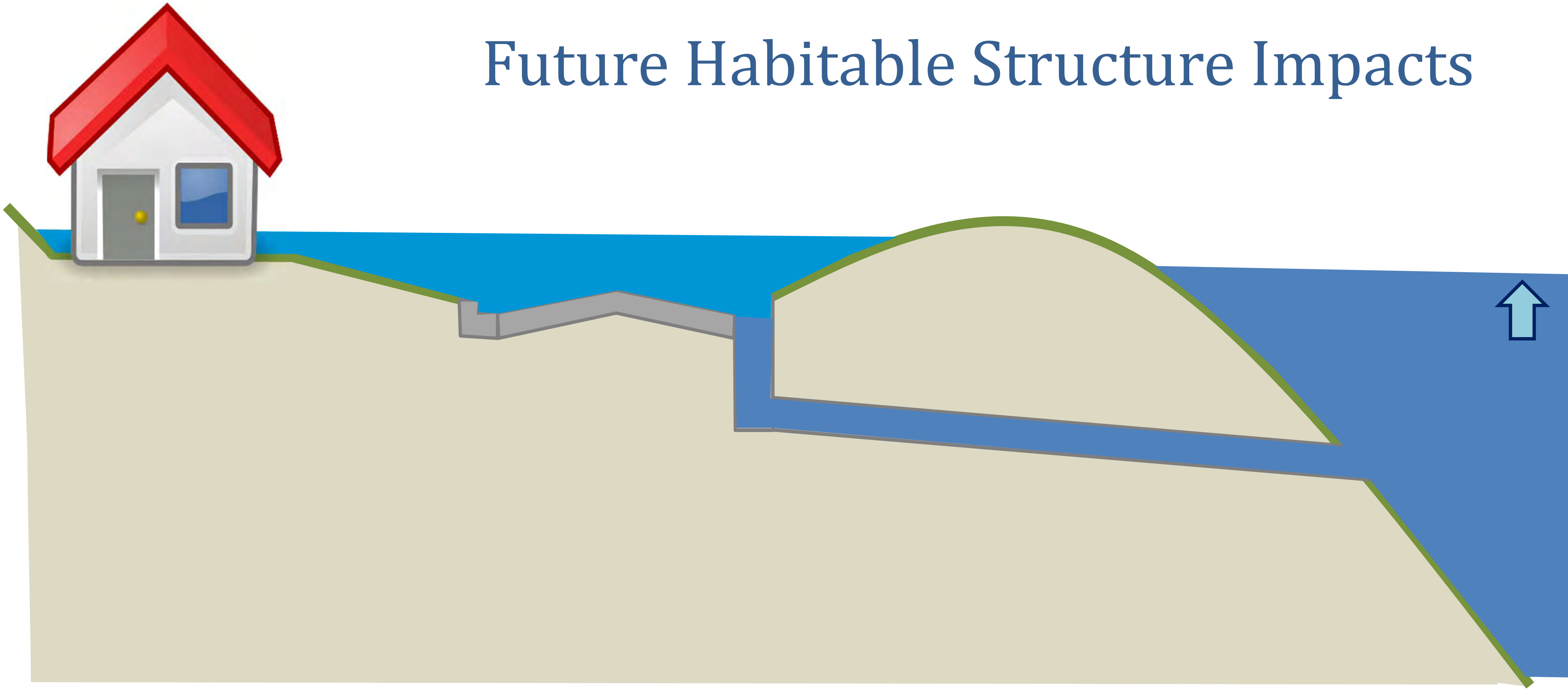
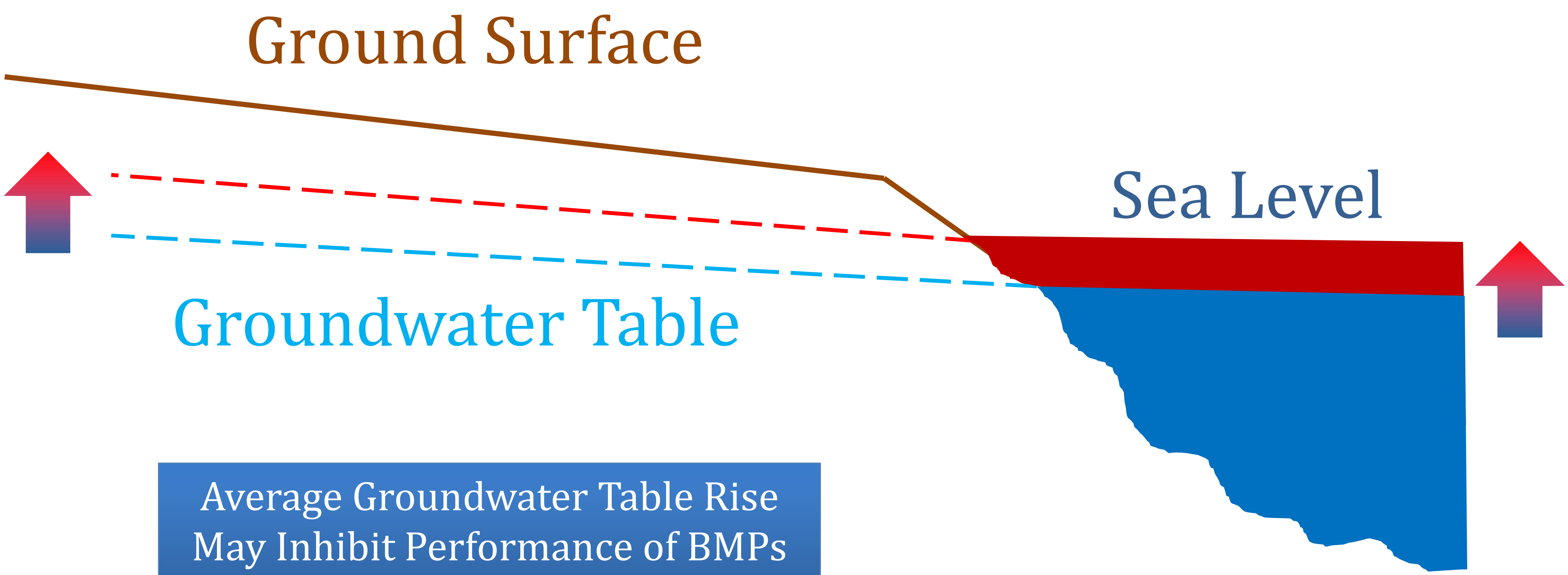
Future Habitable Structure Impacts



GI / LID BMP Resilience



Average Groundwater Table Rise
May Inhibit Performance of BMPs
Relying on Infiltration

GI / LID BMP Resilience

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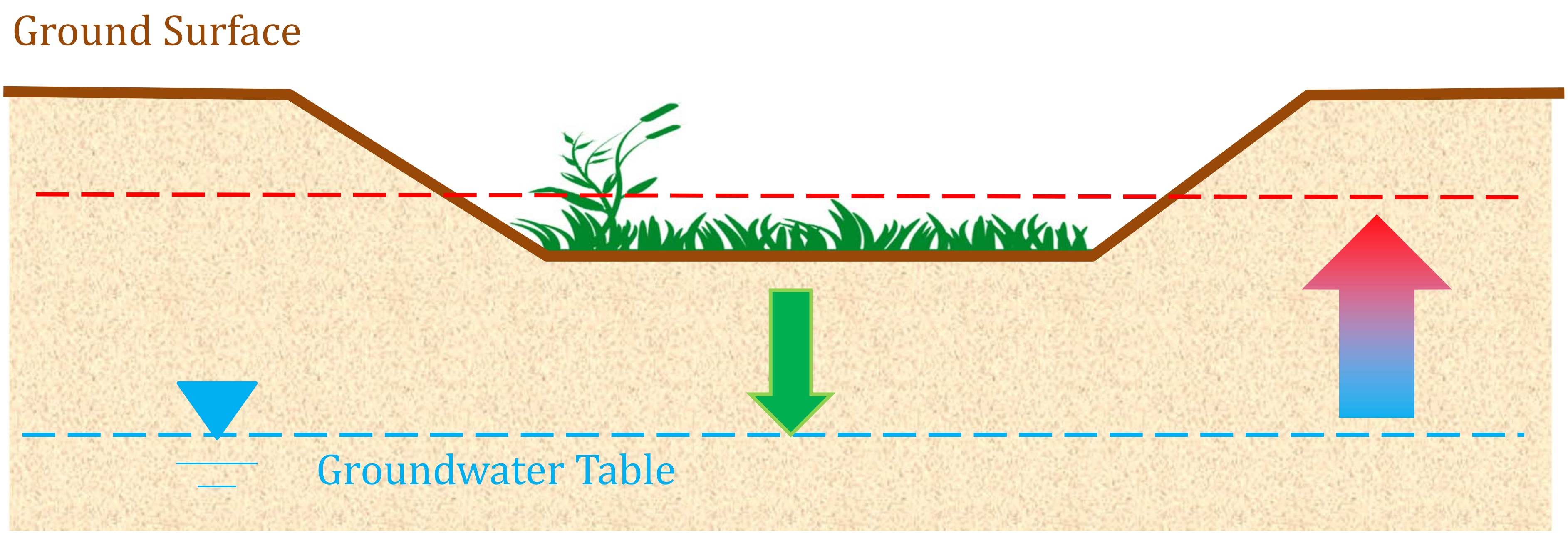
Retention Pond / Bioretention / Rain Garden / Swale



Average Groundwater Table Rise May Inhibit Performance of BMPs Relying on Infiltration

GI / LID BMP Resilience

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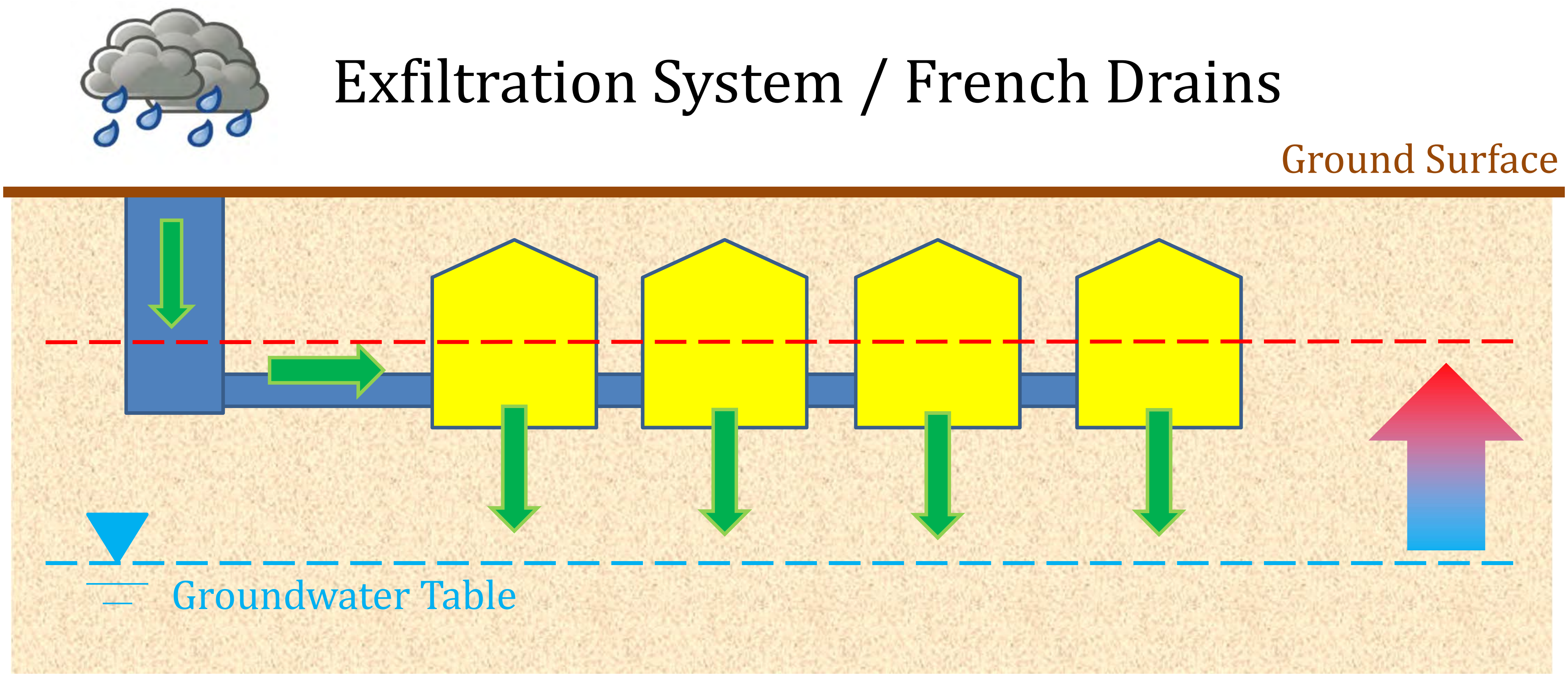
Exfiltration System / French Drains



Average Groundwater Table Rise May Inhibit Performance of BMPs Relying on Infiltration

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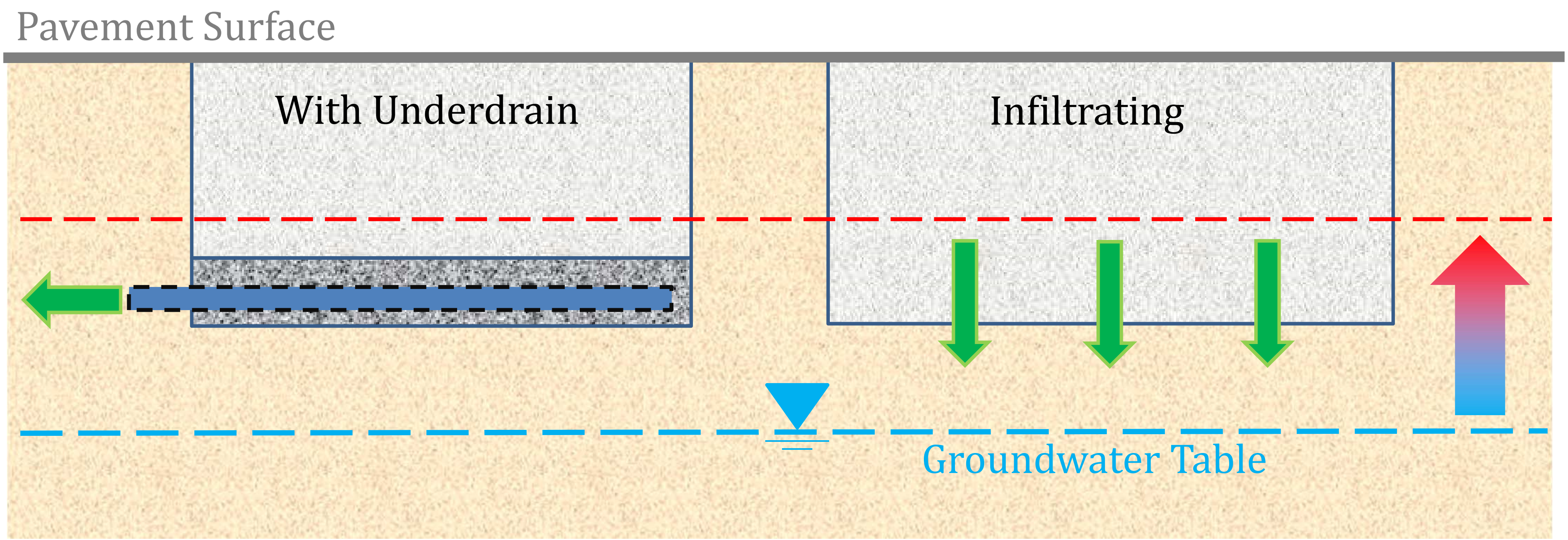
Pervious Pavement Systems



Average Groundwater Table Rise May Inhibit Performance of BMPs Relying on Infiltration

GI / LID BMP Resilience

Traditional Stormwater Strategy

Sensitive to Groundwater Table and Tailwater Elevation

Centralized One Big Stormwater Facility for Attenuation and Treatment

Receiving Water

GI / LID BMP Resilience

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Distributed Hydrology Stormwater Strategy

GI / LID ➔ Treatment Train

Bioretention / Rain Gardens

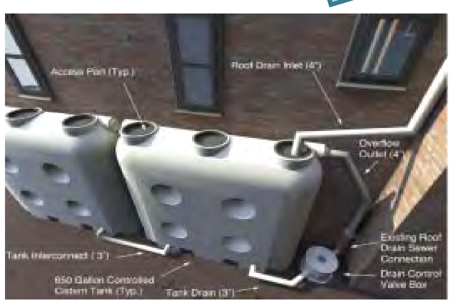
Smaller Footprint Pond

Inlet Filters / Modular Wetlands

Mitigate Constraints of Shallowing Groundwater Table and Increasing Tailwater

Planter Boxes / Tree Boxes

Stormwater Harvesting



Pervious Pavement

Receiving Water

GI/LID Stormwater Management

Source: Geosyntec, 2013,
Aerial: Google, 2013

GI / LID BMP Resilience

- Future GI/LID BMP Strategies
  - Design for Future Conditions
  - Adapt Design Criteria to Changing Hydrologic Conditions
  - Evaluate Current BMP Performance Conditions
  - Retrofit Existing BMPs
  - Consider Active Control
  - Adaptive Management

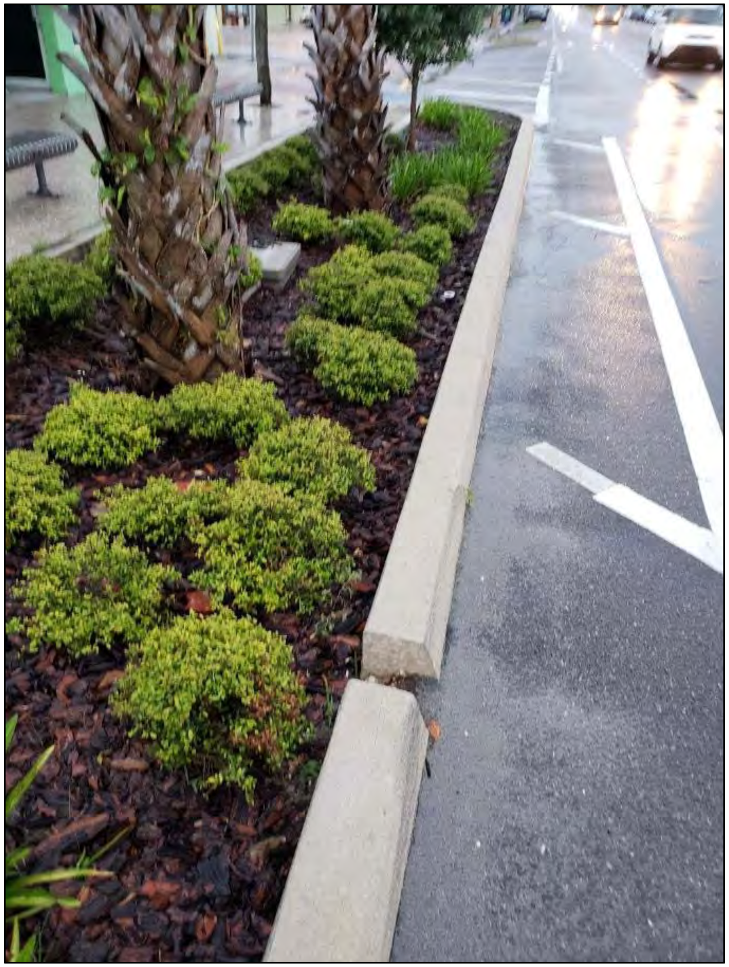
Good Design Intentions……

Geosyntec consultants

Good Design Intentions……

Geosyntec consultants

Good Design Intentions……




?!?@#?
Curb Cut From Nowhere.....

Thank You !

Mark W. Ellard, PE, CFM, D.WRE, ENV SP
Senior Principal, Water Resources

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Geosyntec consultants

engineers | scientists | innovators

Casselton Drive Improvements

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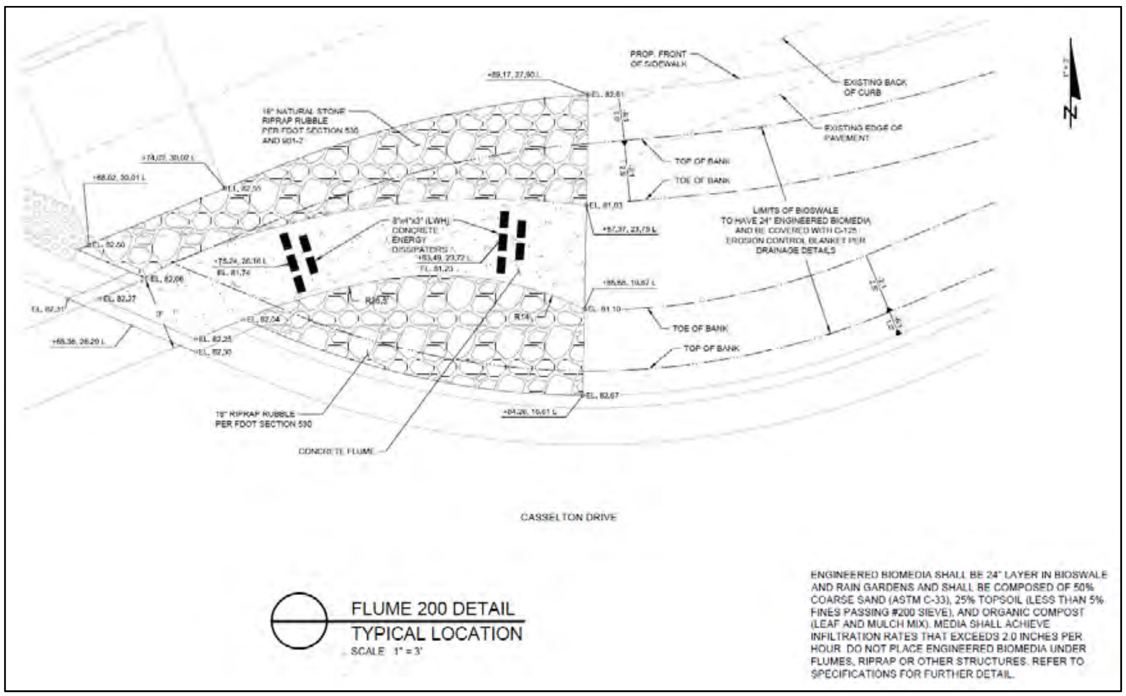
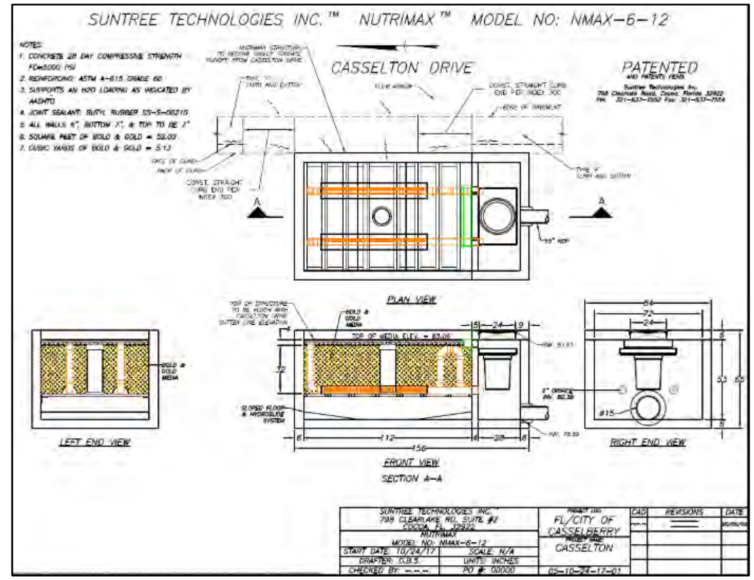
- Multi-Objective Improvement
  - Road Diet
  - Flood reduction
  - Storm sewer rehabilitation
  - Water utility replacement
  - Landscaping
  - Linear Park
- Opportunities !
  - Water Quality Improvement
  - Low Impact Design (LID) Features

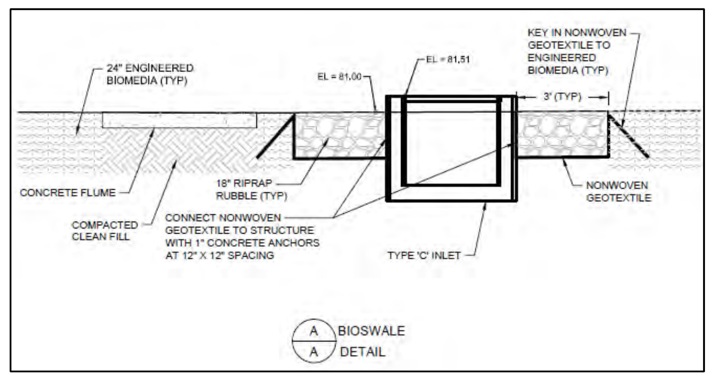
Casselton Drive Improvements

Geosyntec consultants

- Bioswales
- Rain Gardens
- Modular Wetland







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Pre / Post Construction

Casselton Drive Improvements

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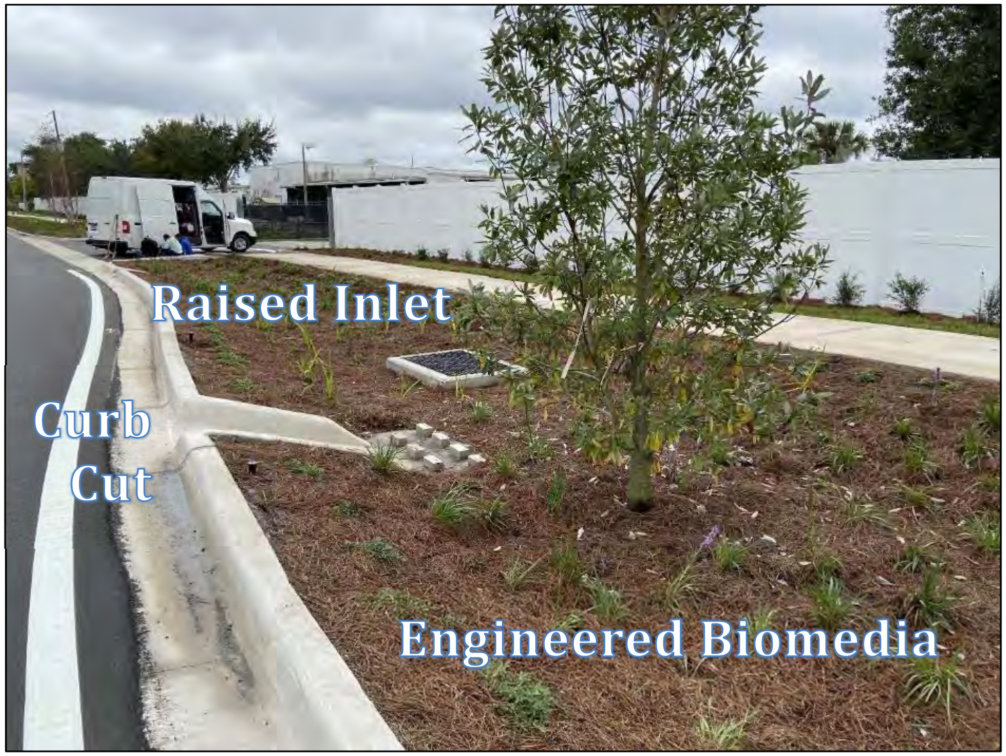
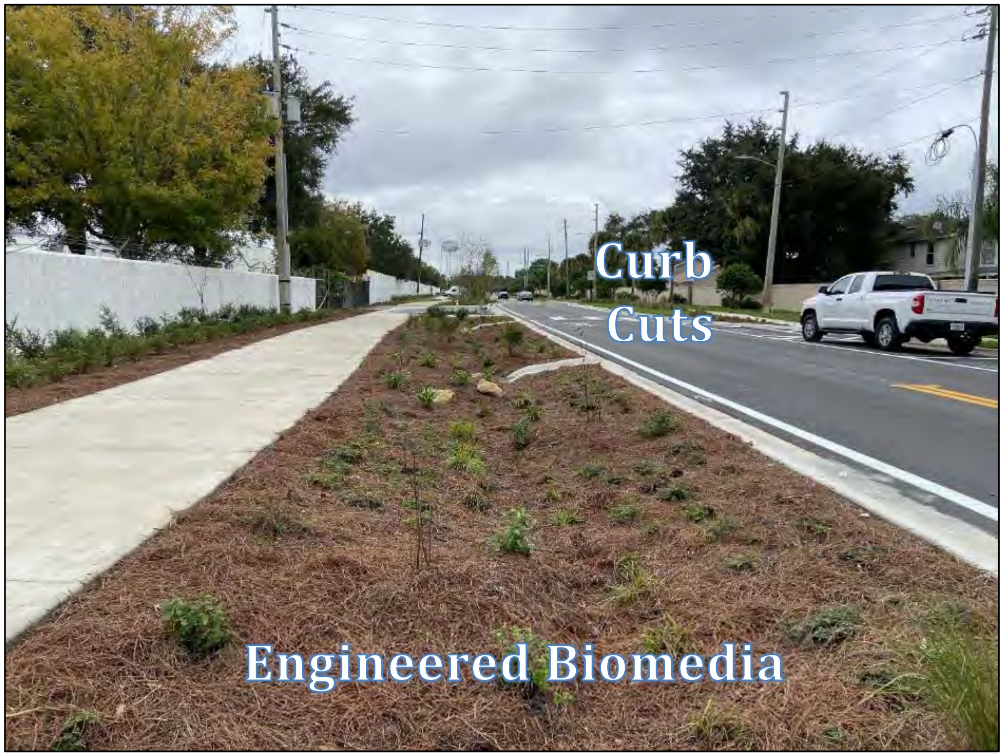
Rain Gardens / Bioswales fed through curb cuts





Casselton Drive Improvements

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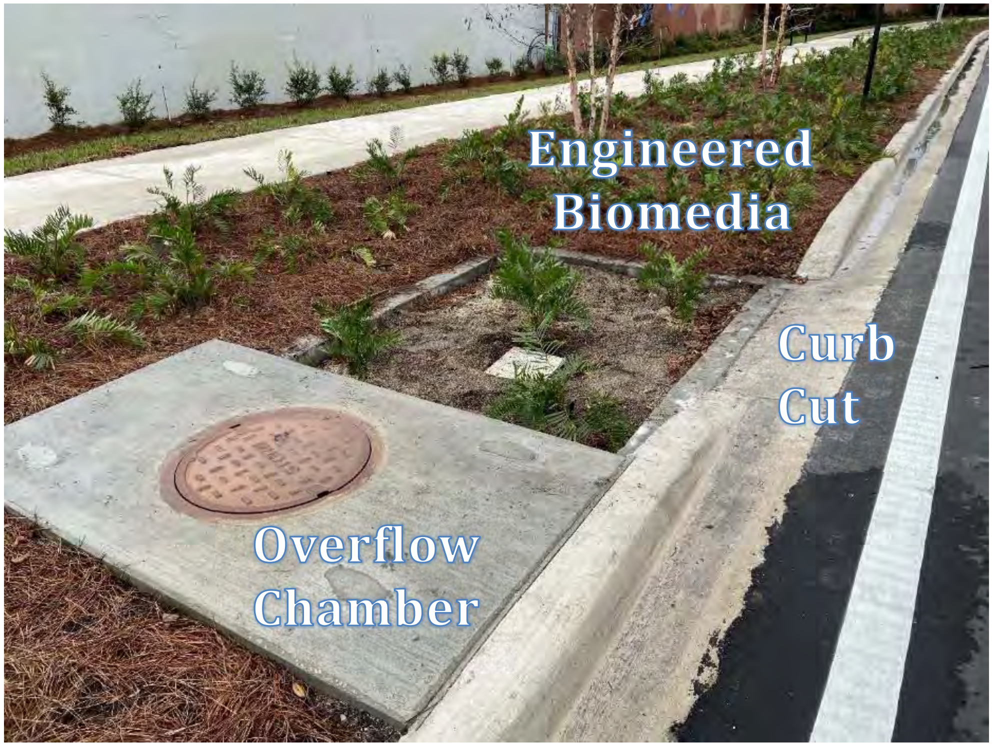
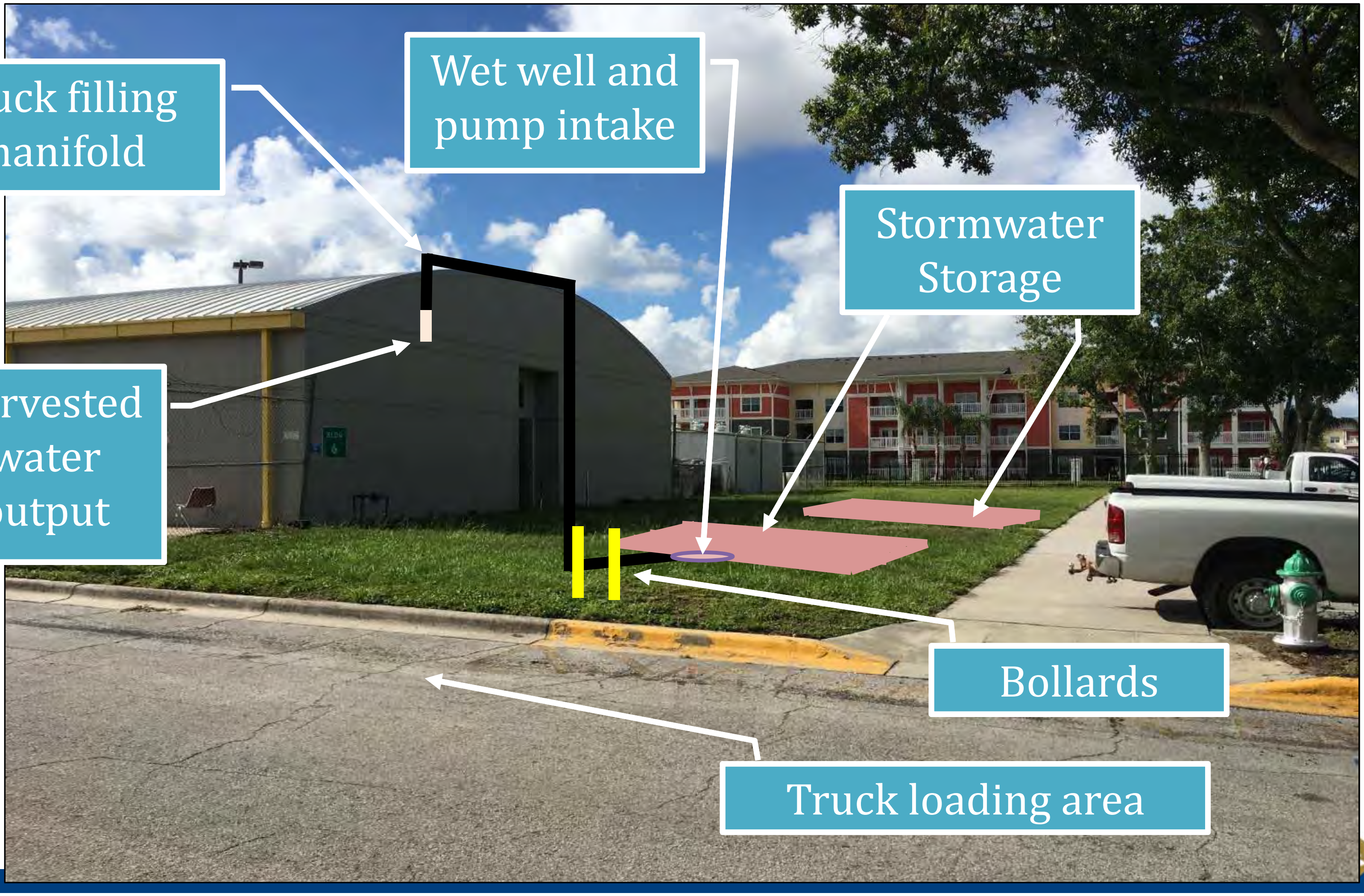
Modular Planter Box



Stormwater Harvesting

- Proposed Project
  - Design, install, and monitor stormwater harvesting demonstration project at Orange County Public Works Maintenance Yard
  - System to collect stormwater from Building 6 roof
  - 10,300 gallon underground reservoir (PIPE-R)
  - Provide water for spray trucks and jetter trucks
  - Real-time control management of storage (OPTI)
  - Monitor system for water quantity and water quality for 1 year

Stormwater Harvesting Site Layout



Stormwater Harvesting System Description

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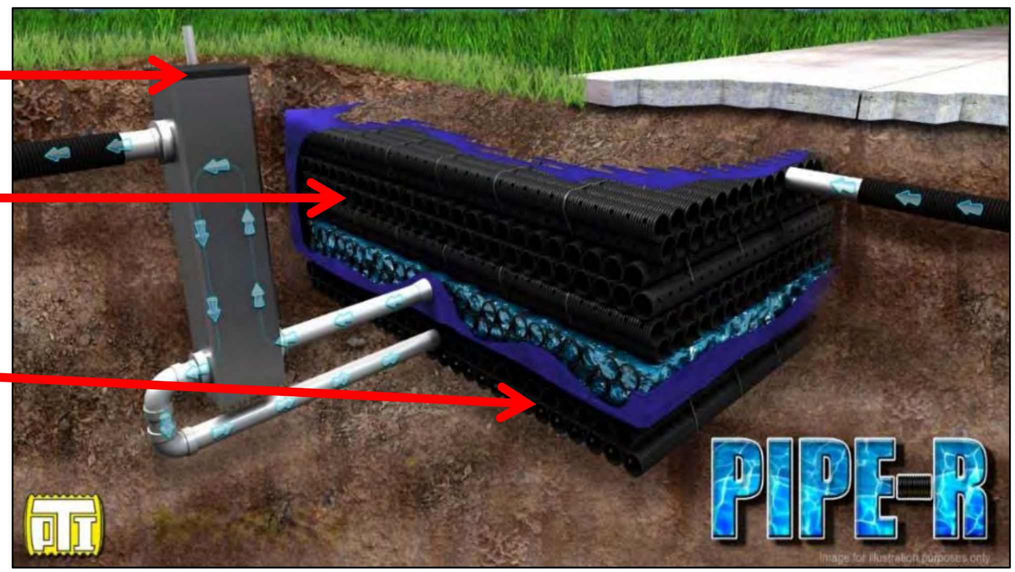
- Main Components
  - Reservoir storage layer
    - Storage of harvested water
    - 10,300 gallons
  - Control box
    - Controls the water level in the reservoir layer
    - Will use real-time control technology (smart controls)
      - Hold on to water when it is needed
      - Release water when it is not needed (before rain event)
    - Location of pump
  - Drainfield overflow
    - Allows water to infiltrate prior to discharge to drainage infrastructure
    - Recharge the groundwater



Stormwater Harvesting Roof Drain Details

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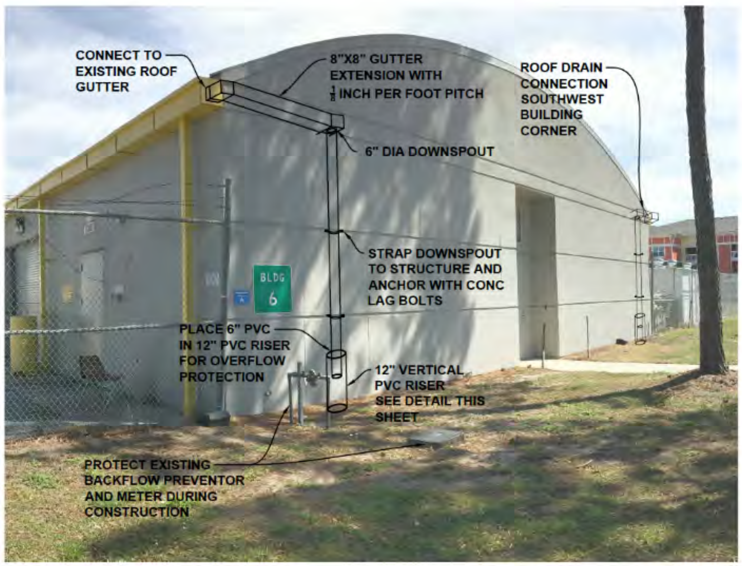
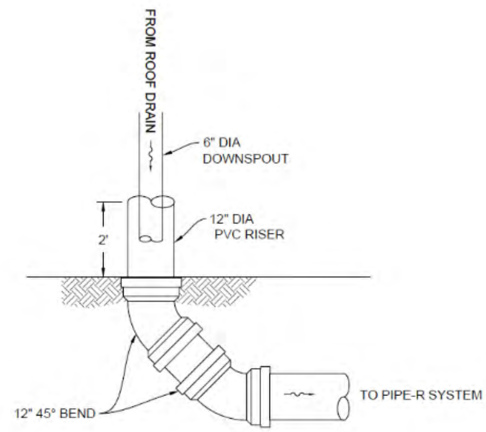


ROOF DRAIN CONNECTION DETAIL

NTS



ROOF DRAIN DOWNSPOUT AND RISER DETAIL

NTS

REVISIONS						
DATE / BY / DESCRIPTION	STORMWATER HARVESTING DEMONSTRATION PROJECT	ORANGE COUNTY GOVERNMENT FLORIDA	Geosyntec consultants 1511 EAST STATE ROAD 434 SUITE 1000 WINTER SPRINGS, FL 32708 Lee G. Mullon, PE FL PE# 72414 AUTHORIZATION NUMBER 4321	ROOF DRAIN DETAILS	SHEET NO.	4

Stormwater Harvesting Plan View of Site Layout

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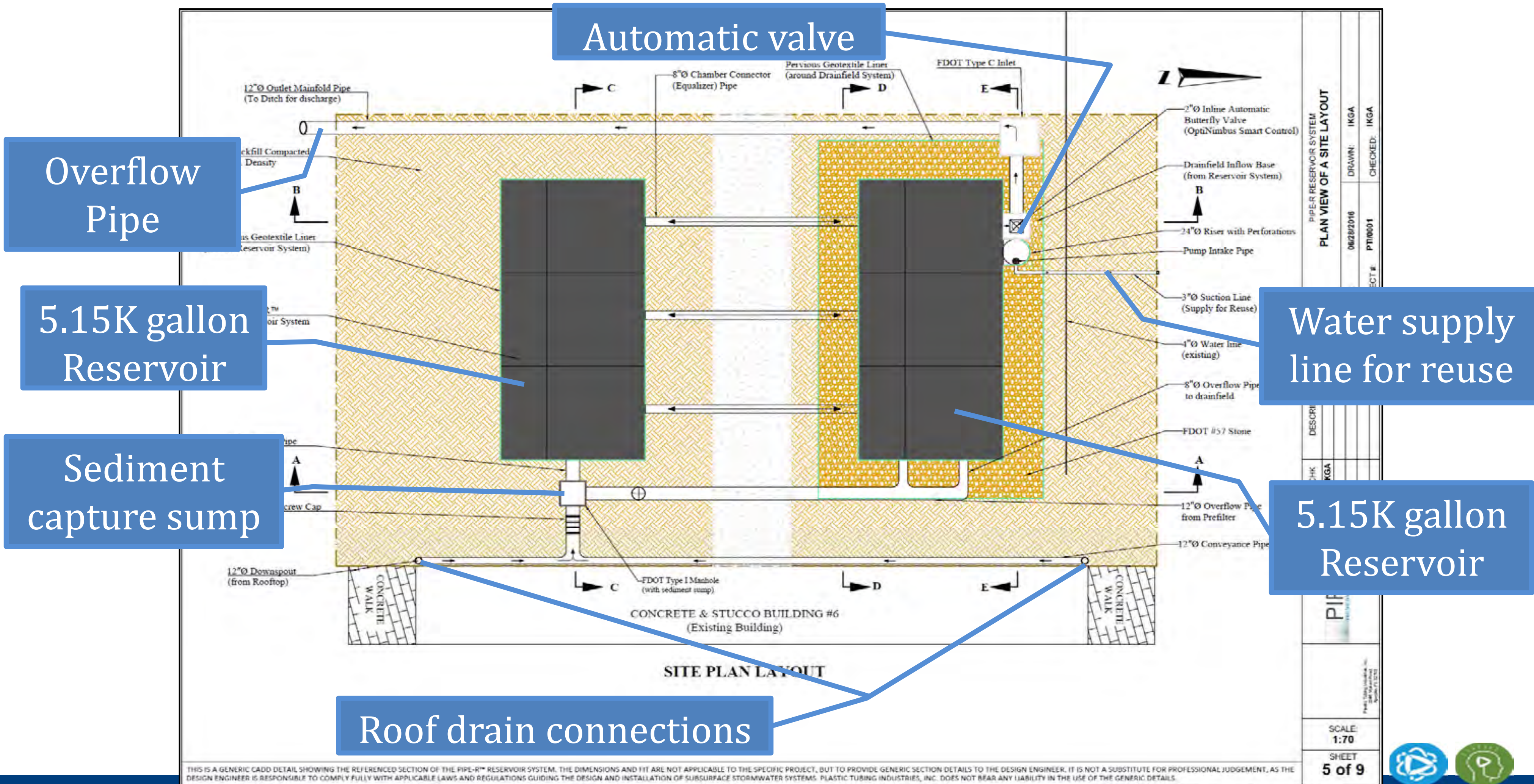

Stormwater Harvesting Installation

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Installation

Water Supply Line

Supply Control

Installation

Bypass Valve

Monitoring Controller

Stormwater Harvesting County Benefits

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- Based on modeling results of this system the following benefits can be expected
  - Reduce potable water use by estimated 70,000 gallons per year
    - Makes the County more sustainable
    - Cost savings
  - Reduce stormwater leaving site by estimated 83% on an average annual basis
    - Reduce pressure on downstream drainage infrastructure
    - Improve water quality by reducing mass of pollutants discharged to surface water bodies
  - Increase groundwater recharge by estimated 46,000 gallons per year
- Gives County experience with new, state-of-the-art technology (real-time controls) and new stormwater practice (harvesting)
- Demonstrate benefits of real-time control stormwater management strategy