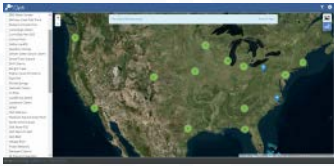
Real-Time Continuous Monitoring and Adaptive Control (CMAC)

Improving Stormwater Systems Performance

April 18, 2016

STORMS
STORM WATER STRATEGY
CALIFORNIA WATER BOARDS



Geosyntec consultants

Opti

TETRA TECH

Speakers

Eric Strecker

Judd Goodman

Geosyntec consultants

Chad Helmle

TETRA TECH

Owen Cadwalader

Opti

CA Stormwater Strategy

To lead the evolution of storm water management in California by

- advancing the perspective that storm water is a valuable resource
- supporting policies for collaborative watershed-level storm water management
- addressing obstacles, developing resources, and integrating regulatory and non-regulatory interests

Continuous Monitoring and Adaptive Control is a tool to help achieve these goals

Audience

Regulators

Stormwater Permittees

Other interested parties – research institutions,
non-profit organizations,
consultants

Outline

1. Background
2. Case Studies
   - Continuous Monitoring
   - Adaptive Control
3. CMAC in California
4. Challenges for Technology Adoption
5. Discussion

Background

And what is CMAC?

How do we improve the performance of BMPs?

- Better, more timely information on maintenance and/or operational adjustment needs (adaptive management)
- More information on BMP performance to improve BMP selection and design for the future
- Improving the hydraulic operations and resulting performance of BMPs using active control
  - Water quality
  - Hydromodification
  - Flood control, and/or
  - Water supply augmentation

Stormwater Monitoring

Low	Number of Observations	High
Slow	Turn Around Time	Fast
High	Ongoing Effort	Low

Manual Measurements
Manual Sample Collection

Continuous Flow Measurements
Auto Sampling
On-site Data Logging

Continuous Monitoring
with Telemetry

Stormwater Control

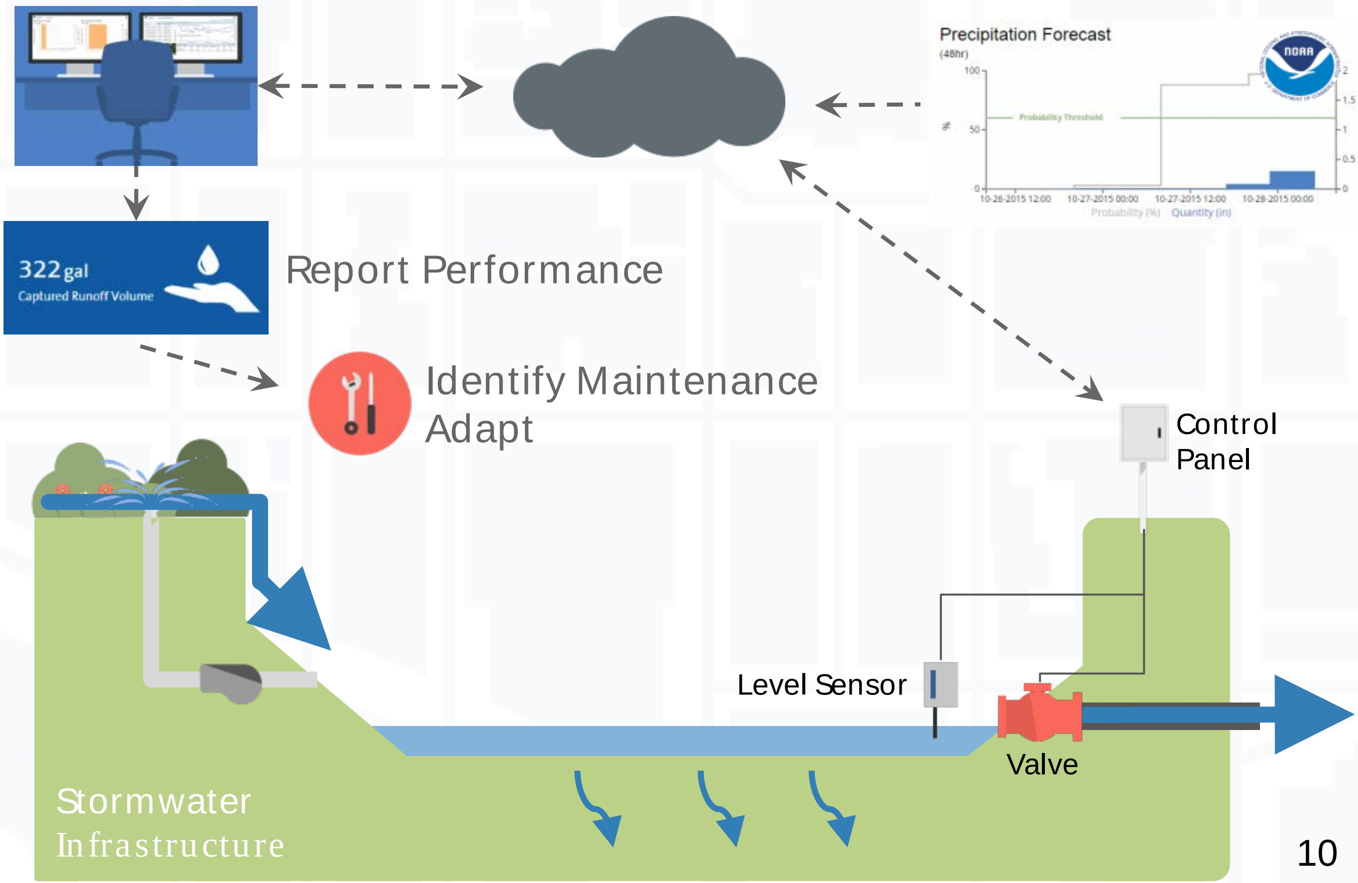
Passive | Adaptive | Active + Adaptive

BMP is designed and set for modeled conditions

BMP can be adapted over time

BMP can react to current conditions

Continuous Monitoring and Adaptive Control



Example BMP Types Where CMAC can be applied

Detention and Infiltration

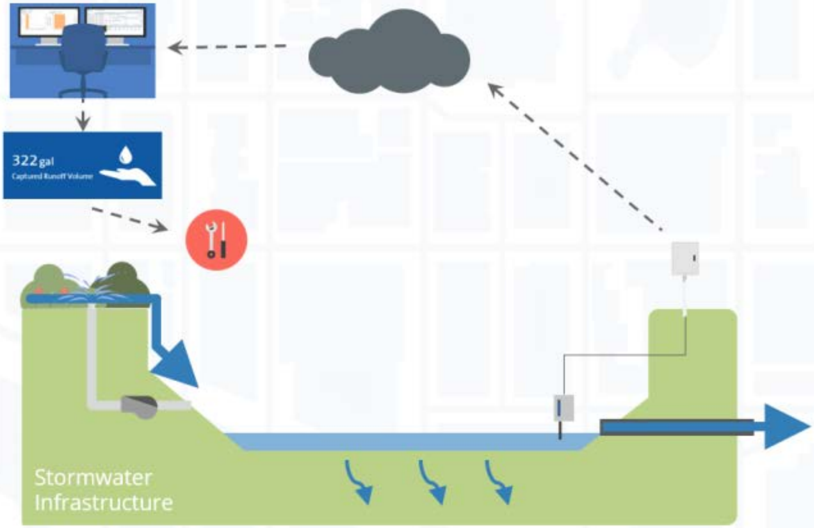
Water Quality and Flow Control

Rainwater Harvesting

Bioretention

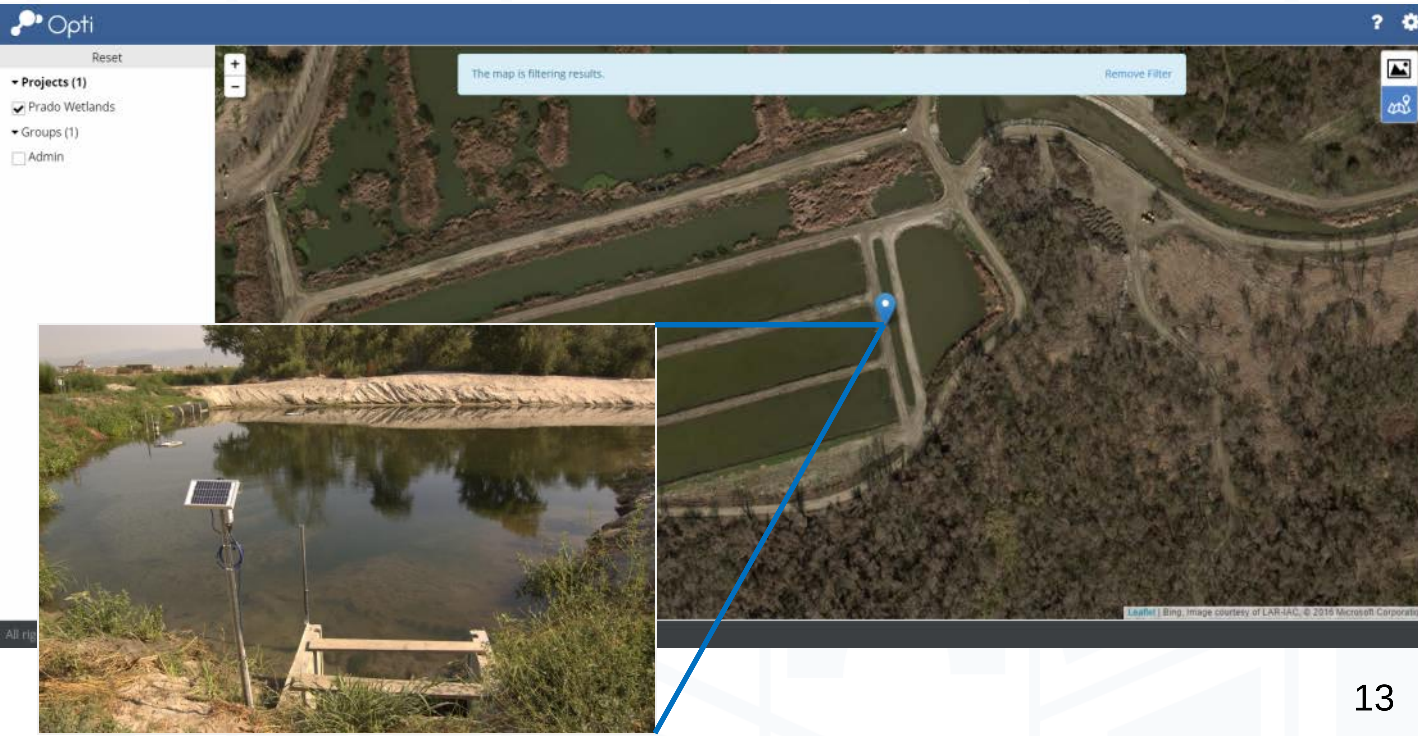
Case Studies

Continuous Monitoring

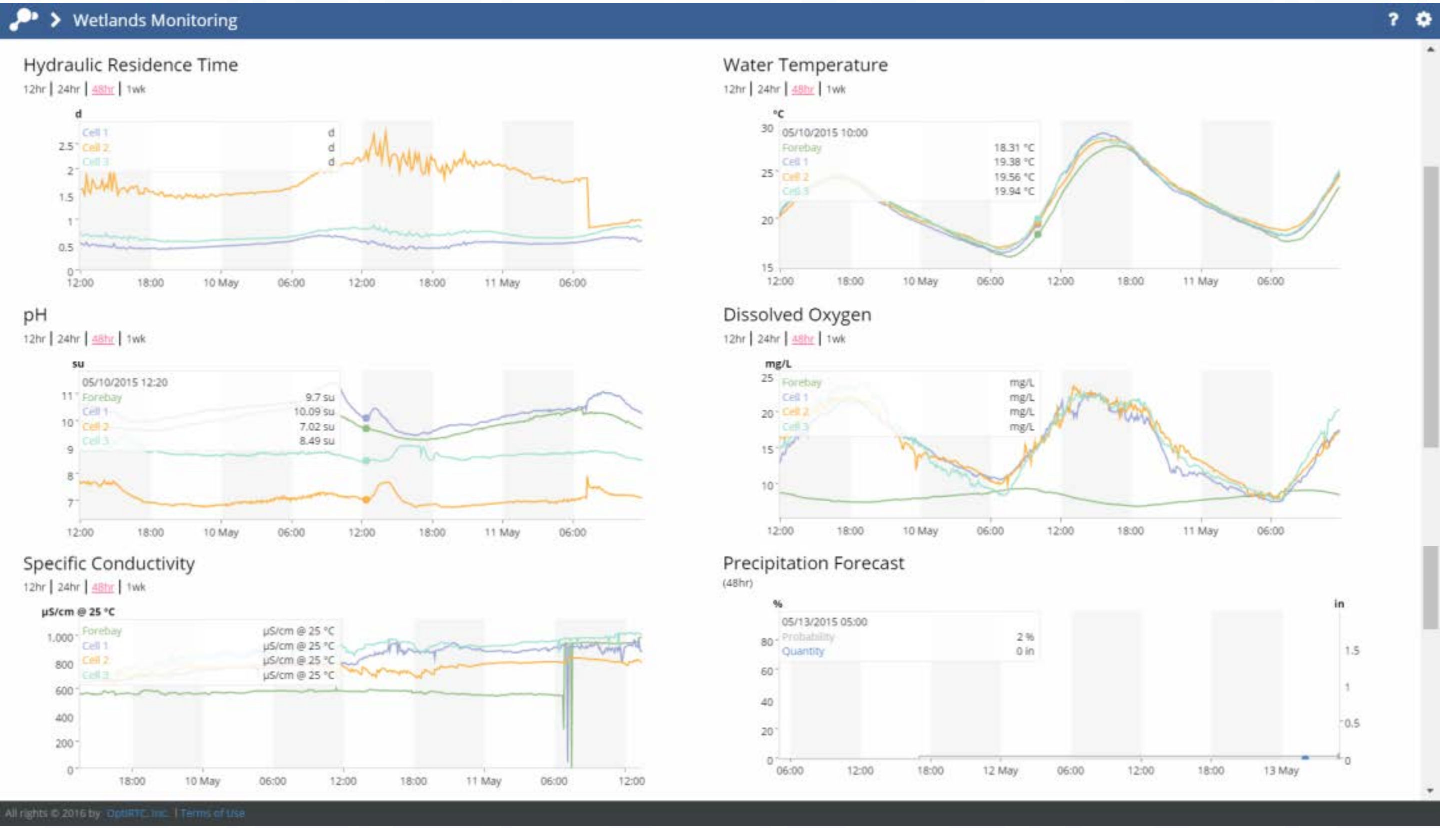


Orange County – Water Quality Monitoring

ReNUWIt
Re-Inventing the Nation's Urban Water Infrastructure



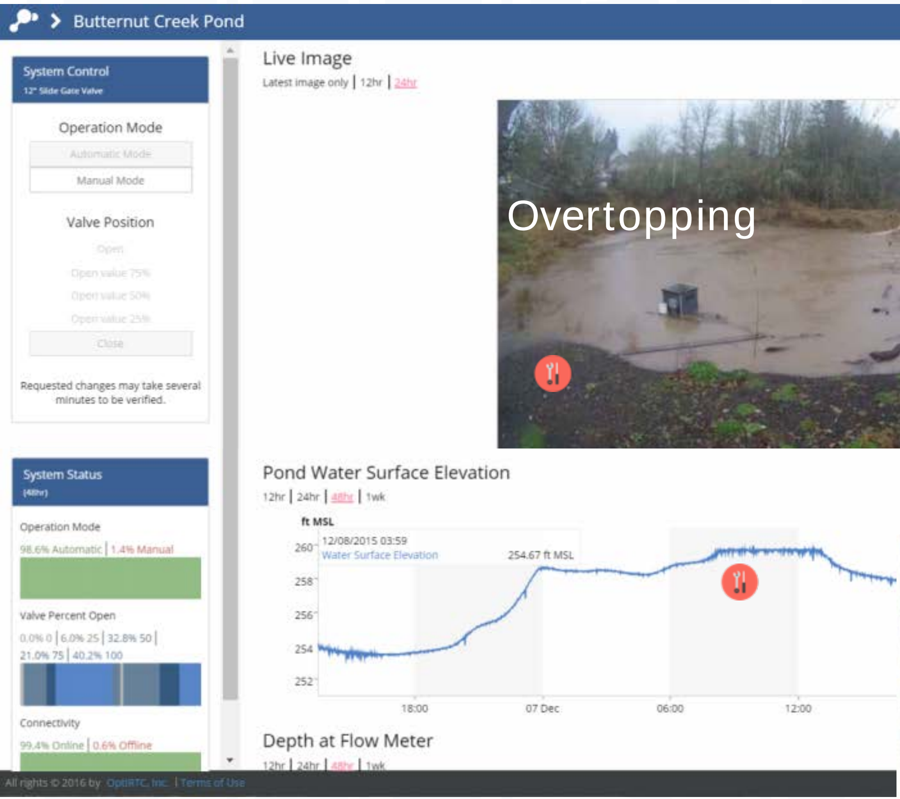
Real-time Water Quality Monitoring Prado Wetlands



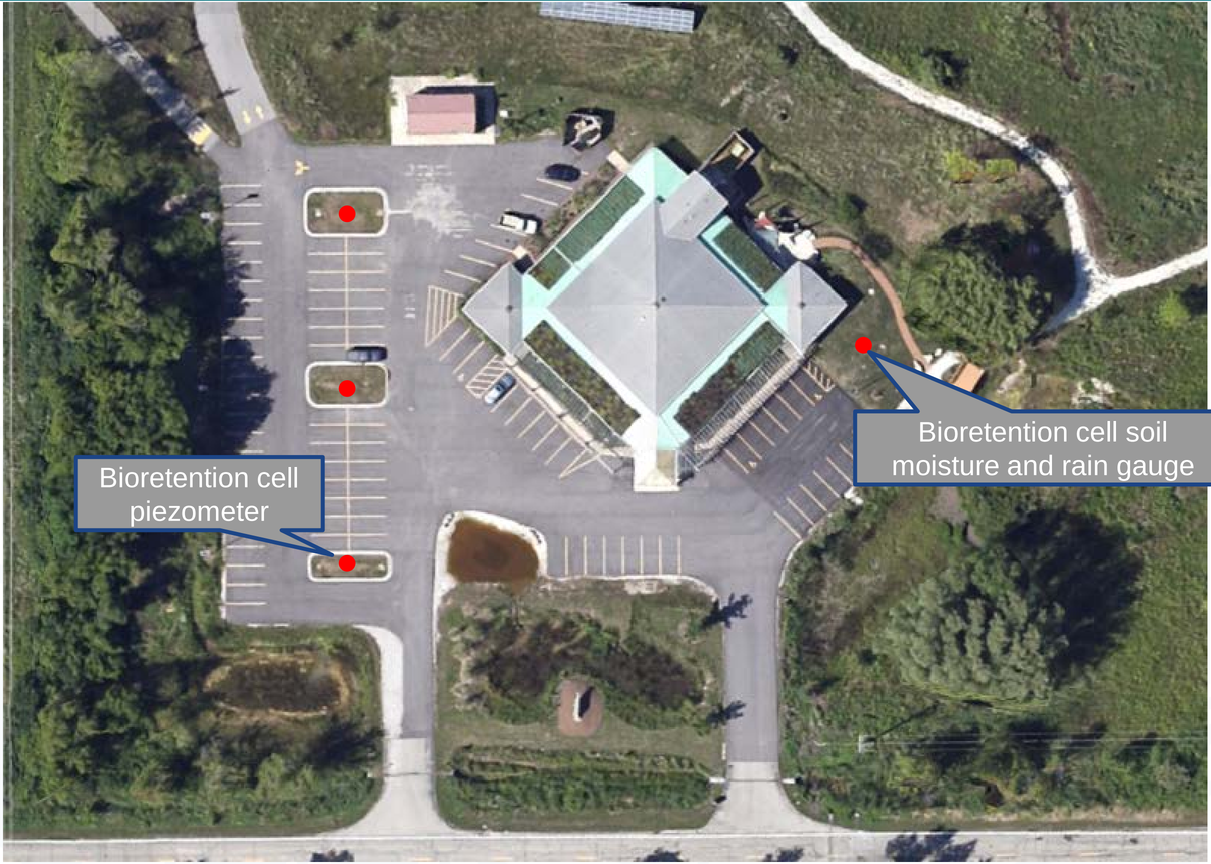
Provide understanding about wetland dynamics

Inform operation

Camera Maintenance Monitoring

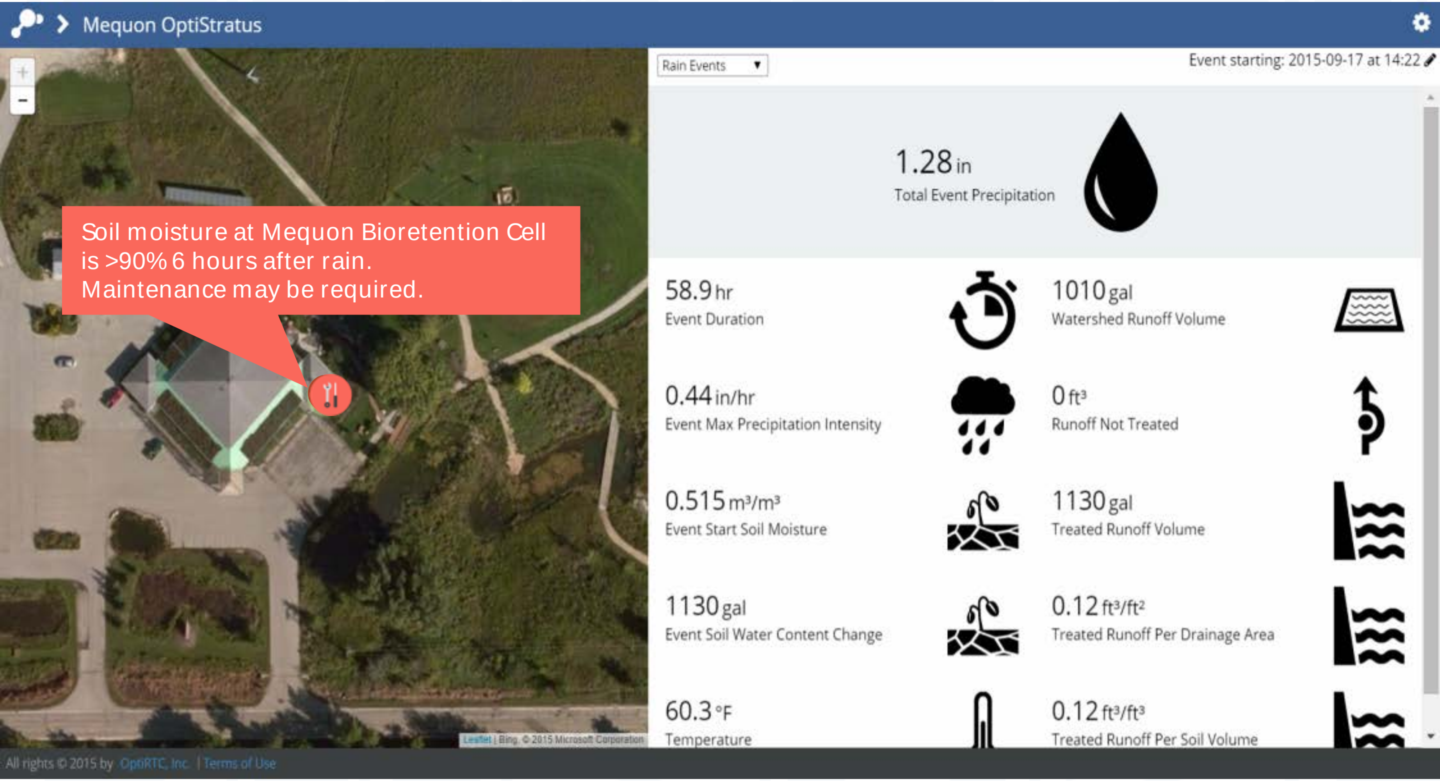


Milwaukee, WI
Green Infrastructure Performance Monitoring

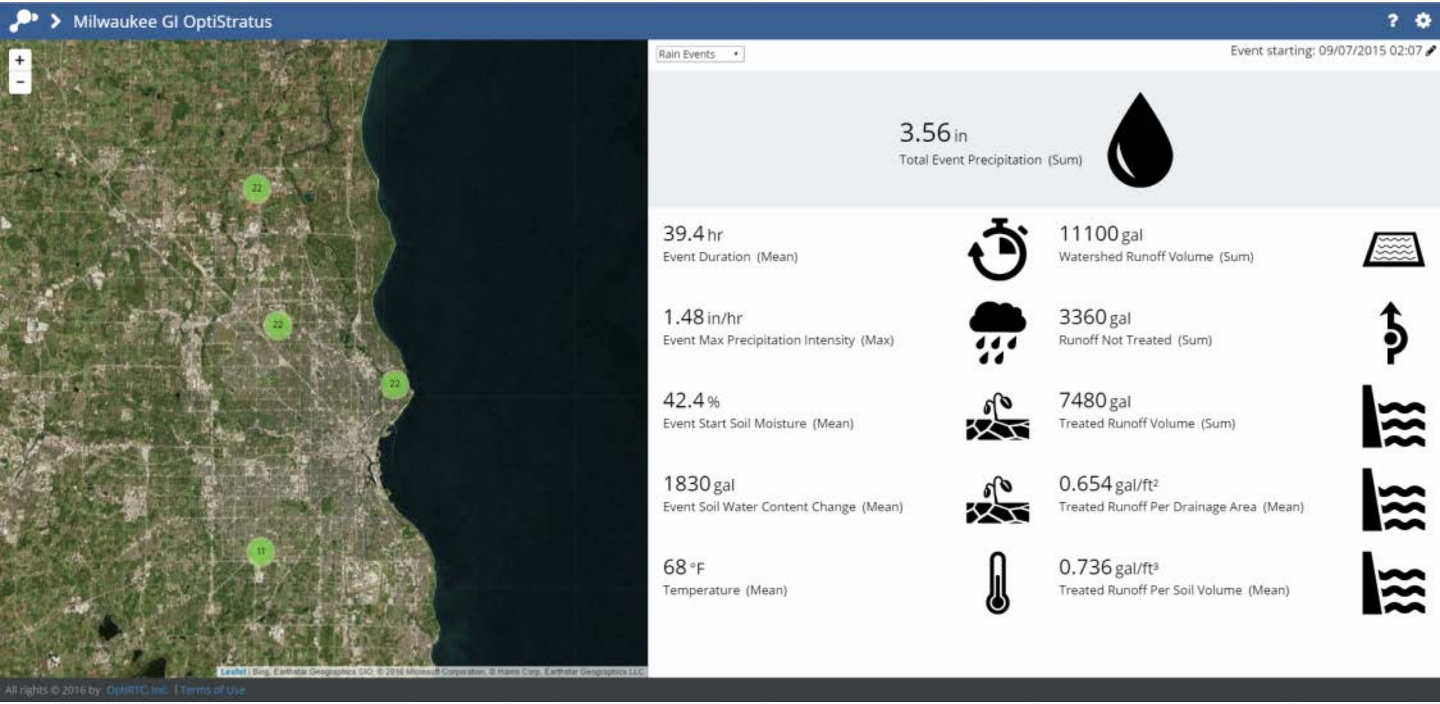


*Project completed in partnership with MMSD and Veolia

Performance Reporting & Maintenance Alerts



Performance Reporting – Multi Site



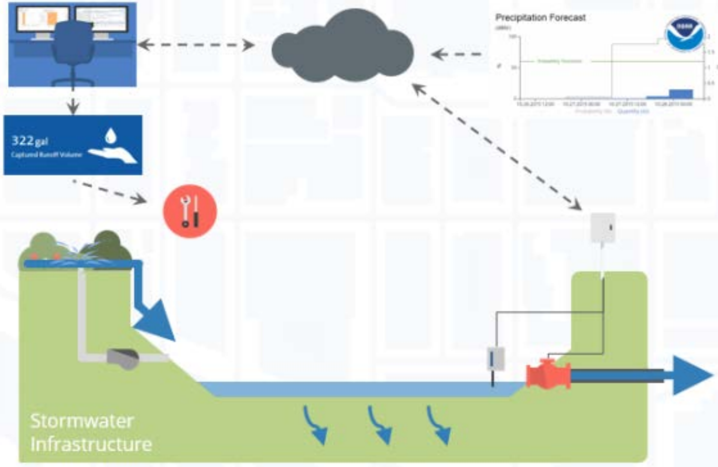
Over 84 million data points collected

Over 440 unique rain events

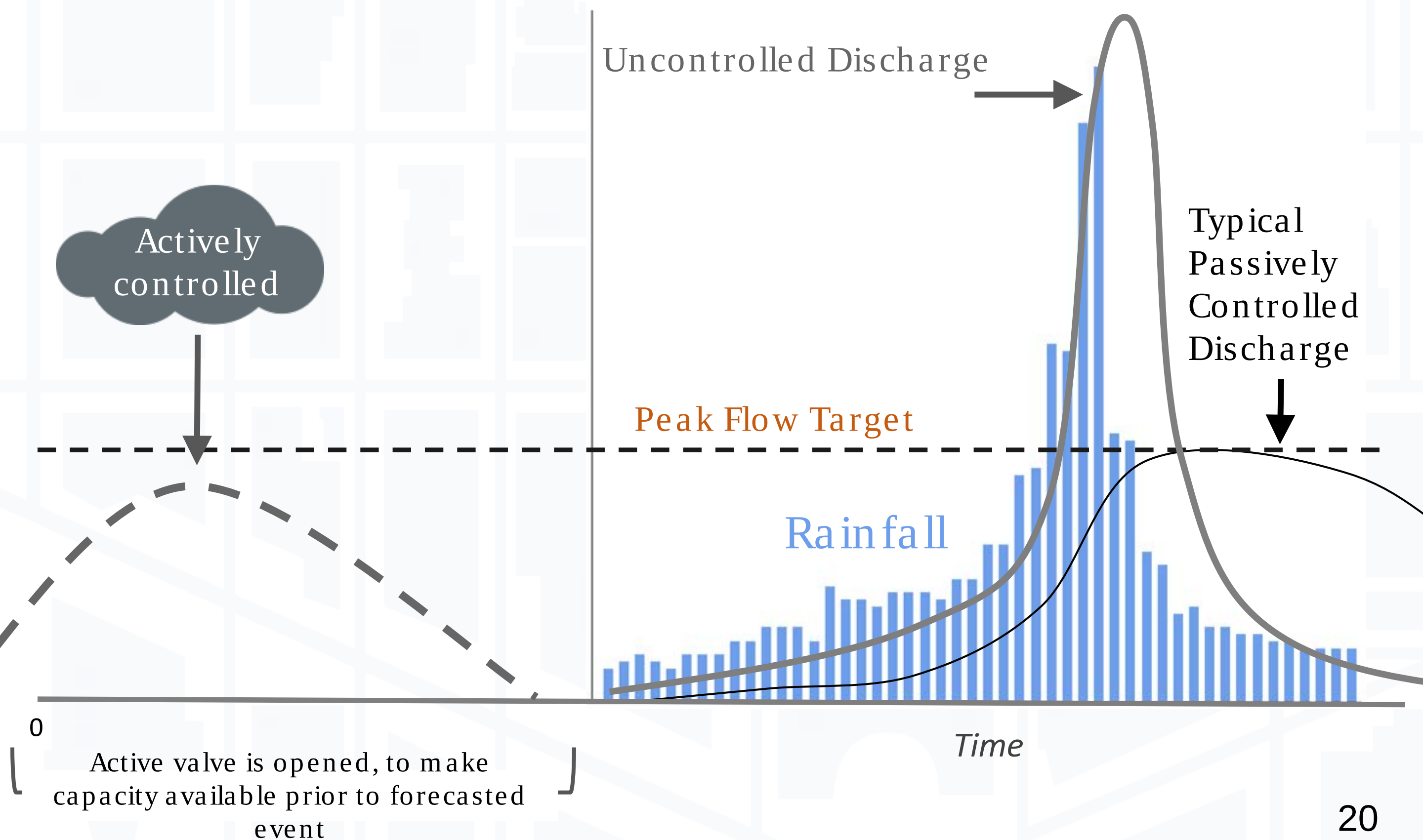
Over 420,000 gallons captured

Case Studies

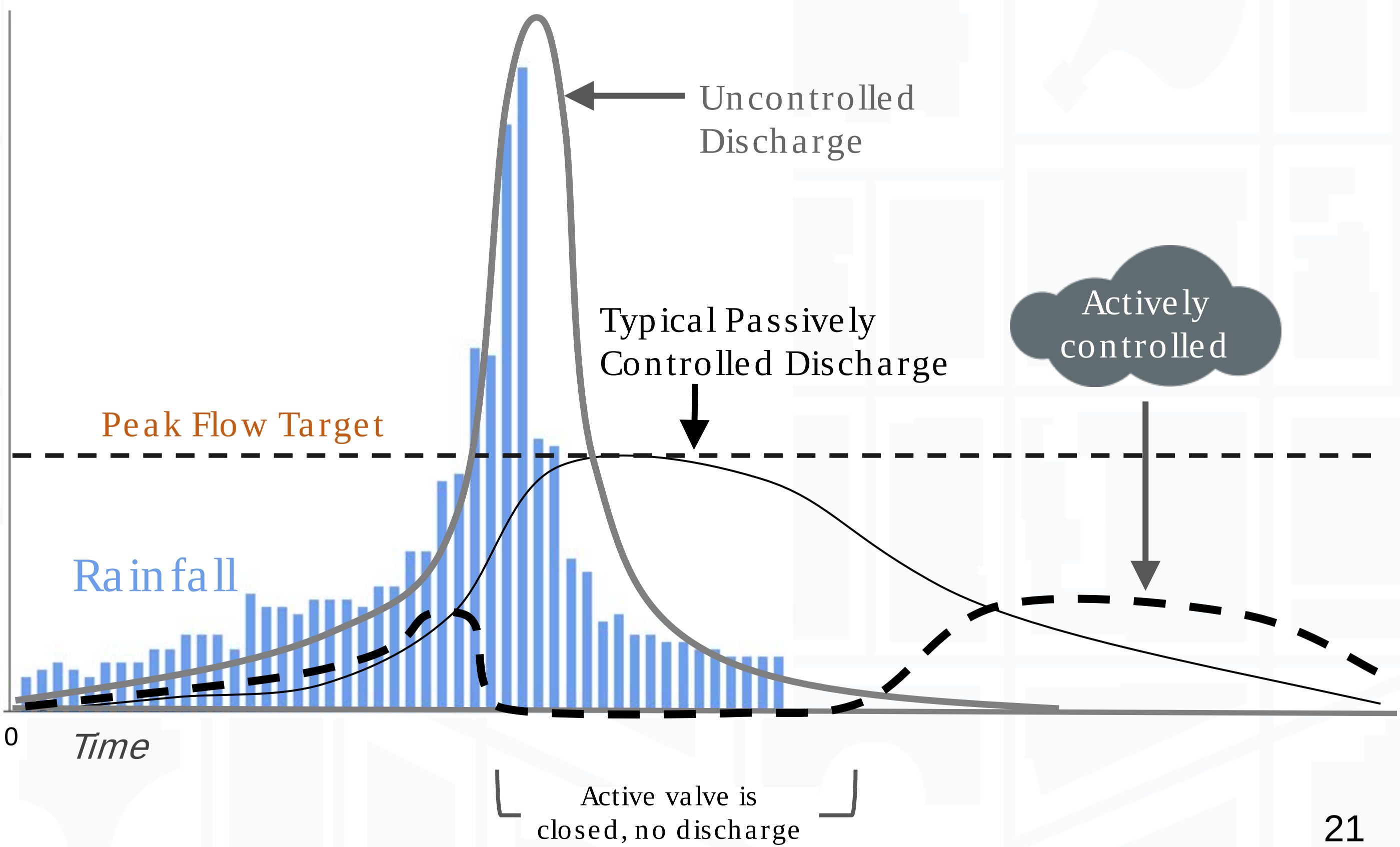
Continuous Monitoring & Adaptive Control



Controlling the Hydrograph – Wet Systems



Controlling the Hydrograph – Dry Systems



Designed for the Watershed Scale

Hydromodification – Wet Pond Oregon

120 acres at 50% impervious

Before

After

General Operation and Control Logic

Inspect and prepare in advance of forecasted event

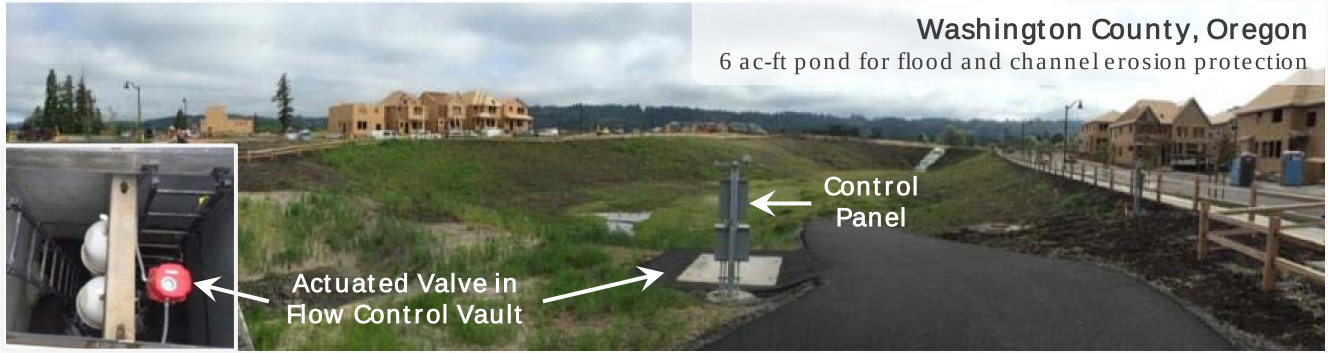
Release at minimum rate during event, if needed, to make capacity available

Return to target dry weather state within allowable timeframe

Continually adapt to current conditions and forecast

Example Storm in Oregon

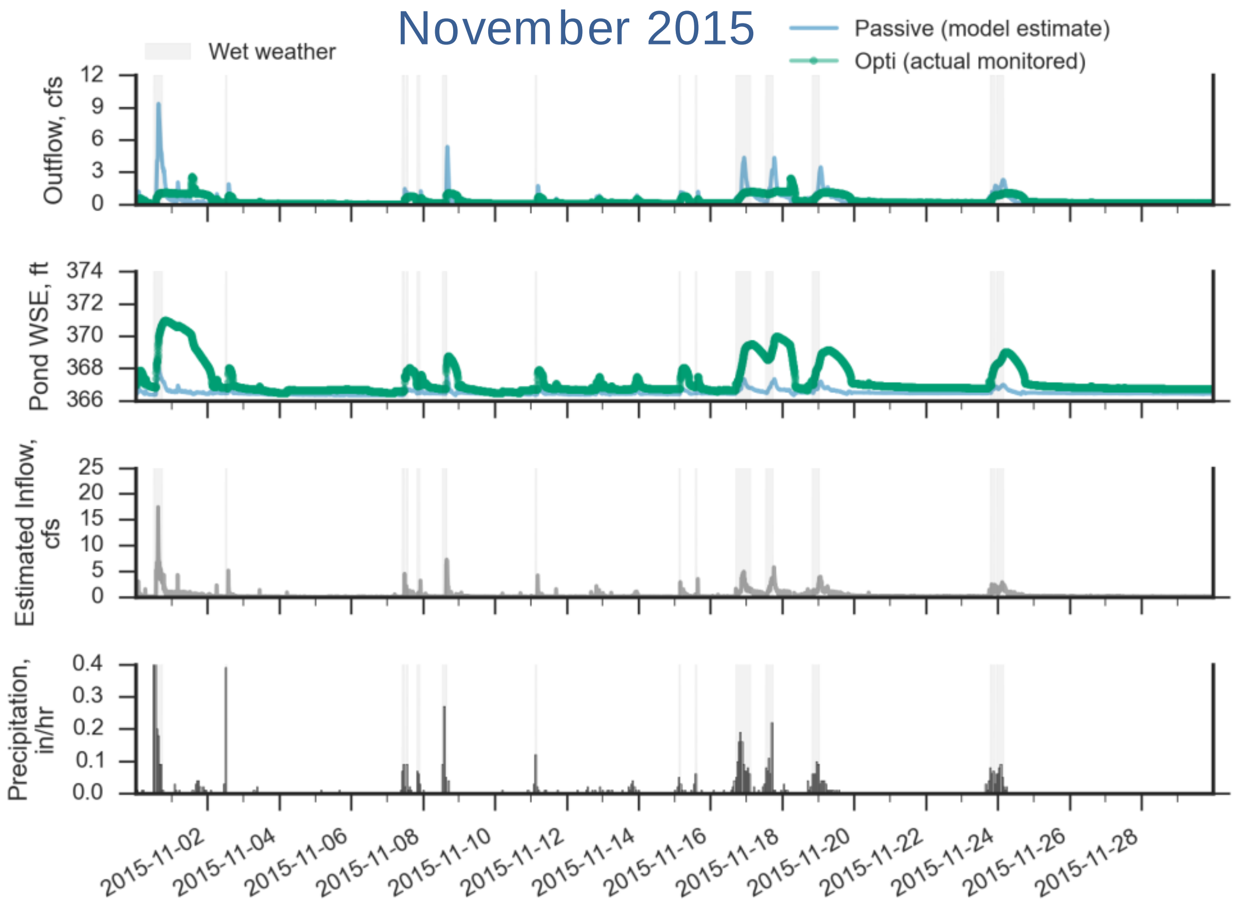
Hydromodification – Dry Pond Oregon



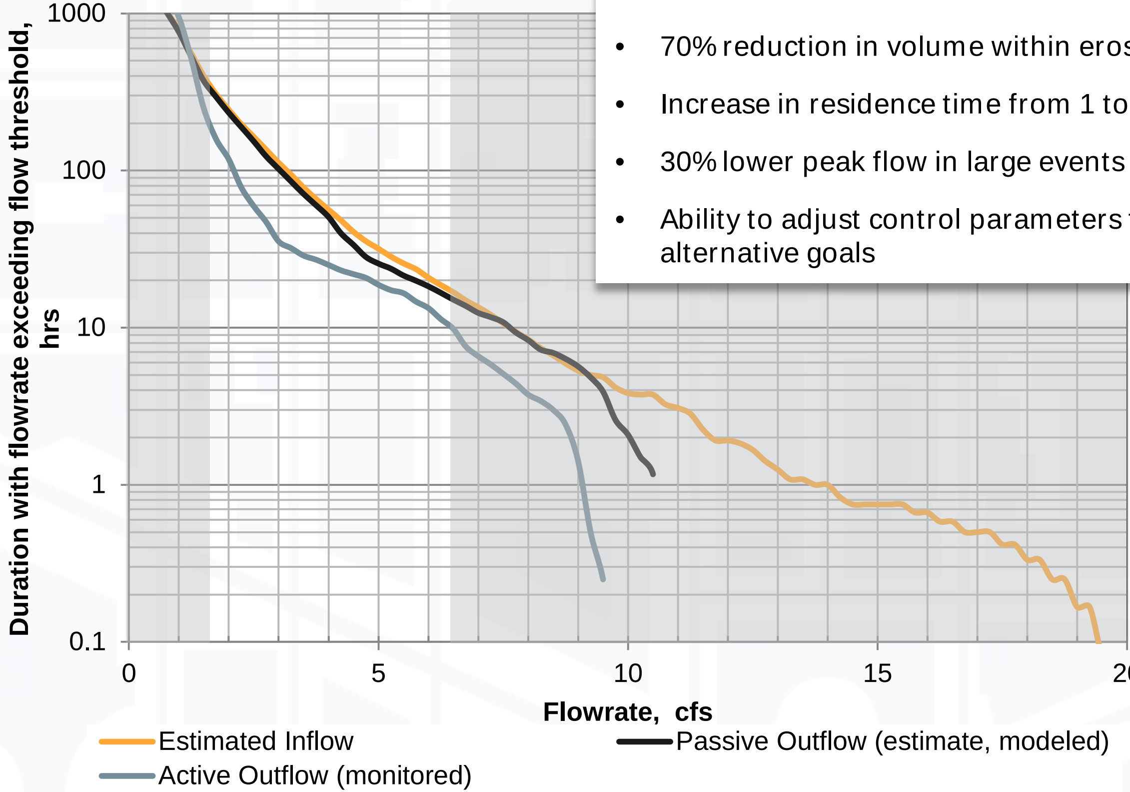
Based on continually updated precipitation forecasts, automated valve controls discharge to achieve **hydromodification goals**

Clean Water Services

Oregon – Performance



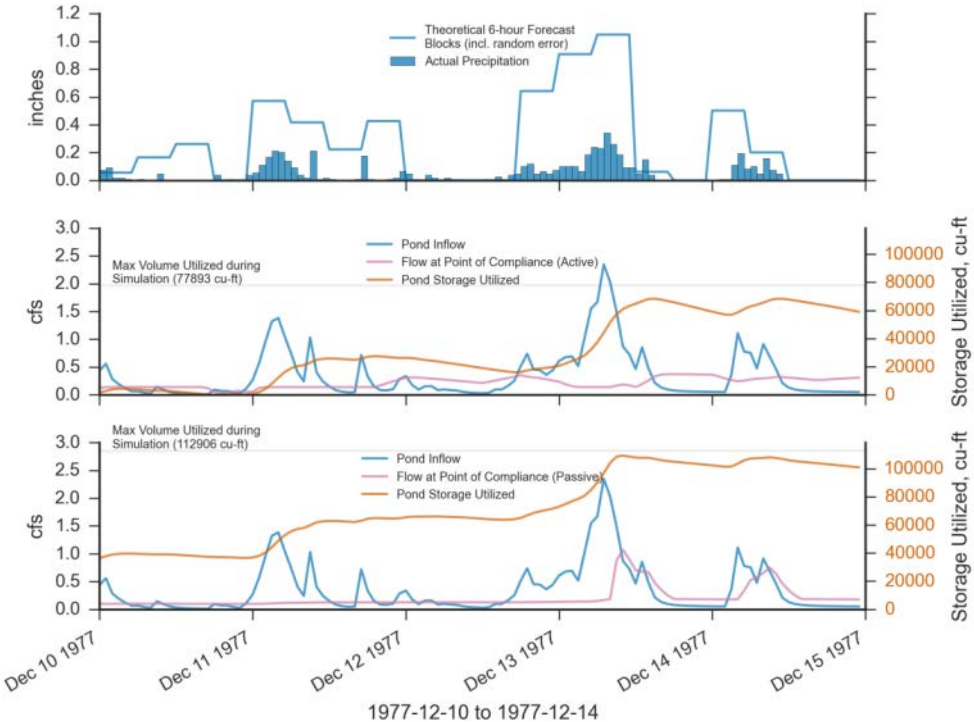
Flow Duration Control Achieved



Highlights

- 60% reduction in wet weather volume
- 70% reduction in volume within erosive flow range
- Increase in residence time from 1 to 19 hours
- 30% lower peak flow in large events
- Ability to adjust control parameters to target alternative goals

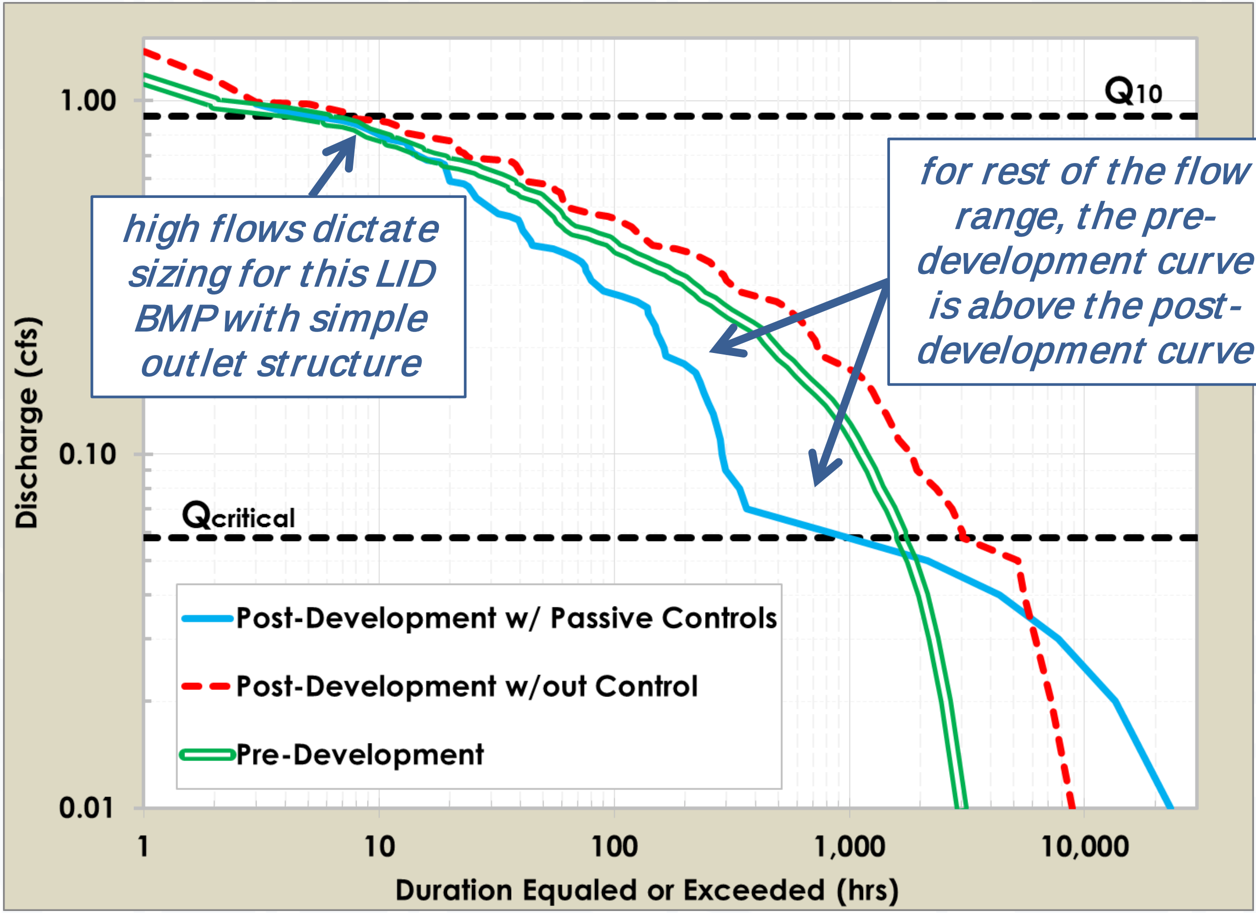
New Development Pond - Oregon



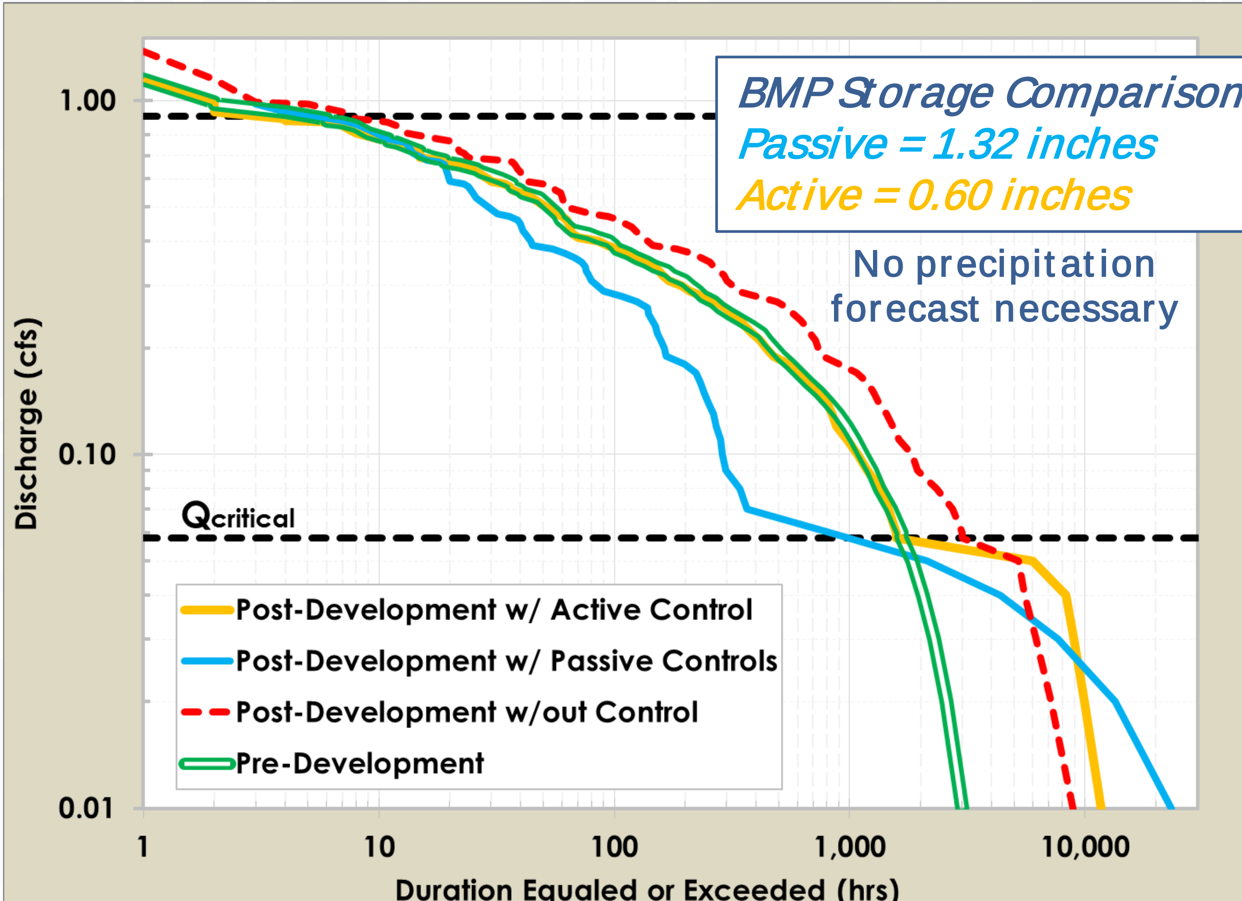
Highlights

- 50% reduction in typical drawdown time
- 70% reduction in maximum inundation period
- Ability to adjust control parameters to target alternative goals
- 30 to 50% reduction in required pond size

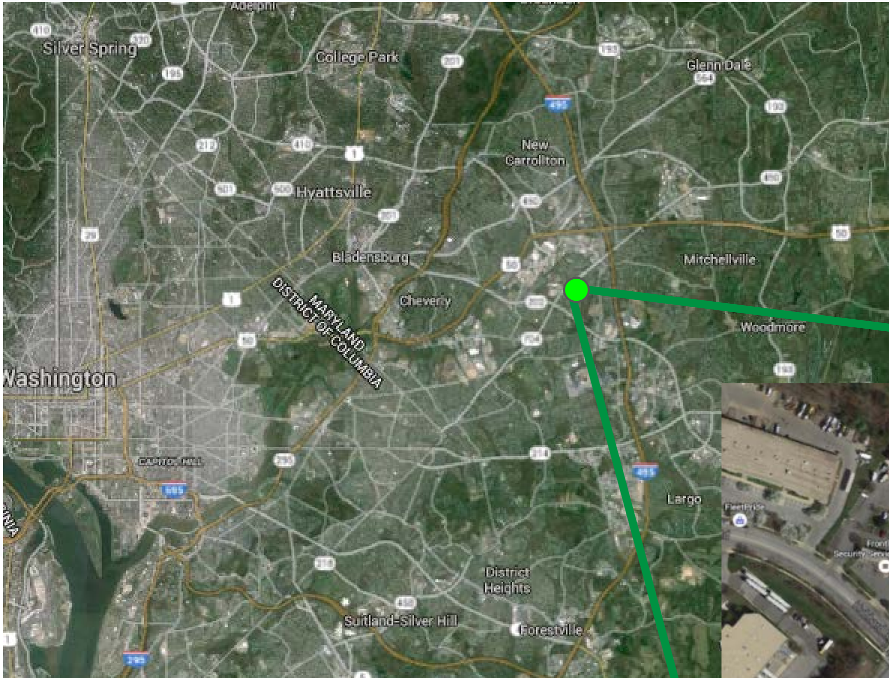
Modeled Flow Duration Curve Comparison



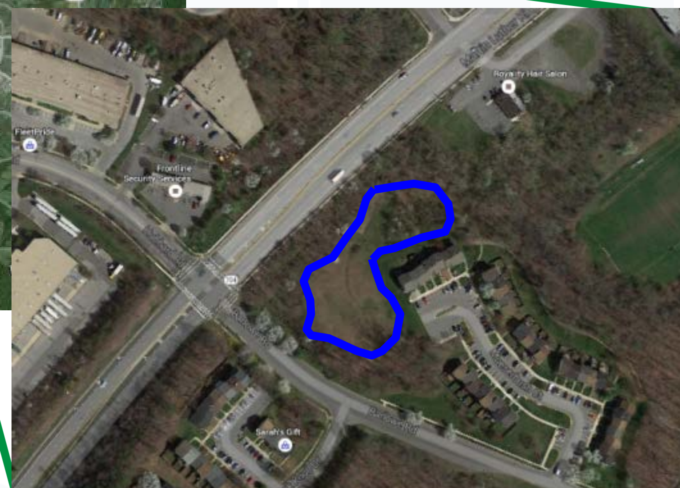
Modeled Flow Duration Curve Comparison



Water Quality Control – Dry to Wet Pond Conversion Maryland



Frost Pond
Prince Georges County, MD
60 Acre Drainage Area
19 Acre Impervious
Approx. 0.5 ac
Peak Shaving Dry Pond
built in 1988

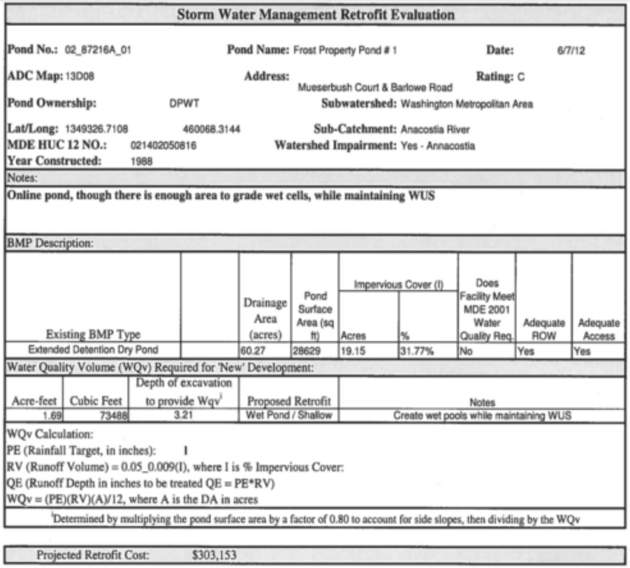


METROPOLITAN WASHINGTON
Council of Governments

NFWF

Frost Pond – Dry Pond
Maryland

Conventional Retrofit
Dig a Bigger Hole!



Storm Water Management Retrofit Evaluation

Pond No.: 02_87216A_01 **Pond Name:** Frost Property Pond # 1 **Date:** 6/7/12

ADC Map: 13D08 **Address:** Mueserbush Court & Barlowe Road **Rating:** C

Pond Ownership: DPWT **Subwatershed:** Washington Metropolitan Area

Lat/Long: 1349326.7108 460068.3144 **Sub-Catchment:** Anacostia River

MDE HUC 12 NO.: 021402050816 **Watershed Impairment:** Yes - Annacostia

Year Constructed: 1988

Notes:

Online pond, though there is enough area to grade wet cells, while maintaining WUS

BMP Description:

Existing BMP Type		Drainage Area (acres)	Pond Surface Area (sq ft)	Impervious Cover (I)		Does Facility Meet MDE 2001 Water Quality Req.	Adequate ROW	Adequate Access
				Acres	%			
Extended Detention Dry Pond		60.27	28629	19.15	31.77%	No	Yes	Yes

Water Quality Volume (WQv) Required for 'New' Development:

Acre-feet	Cubic Feet	Depth of excavation to provide Wqv[1]	Proposed Retrofit	Notes
1.69	73488	3.21	Wet Pond / Shallow	Create wet pools while maintaining WUS

WQv Calculation:
PE (Rainfall Target, in inches): 1
RV (Runoff Volume) = 0.05_0.009(I), where I is % Impervious Cover:
QE (Runoff Depth in inches to be treated QE = PE*RV)
WQv = (PE)(RV)(A)/12, where A is the DA in acres

[1]Determined by multiplying the pond surface area by a factor of 0.80 to account for side slopes, then dividing by the WQv

Projected Retrofit Cost: $303,153

Excavate 3.2 ft to create 1.7 ac-ft of storage

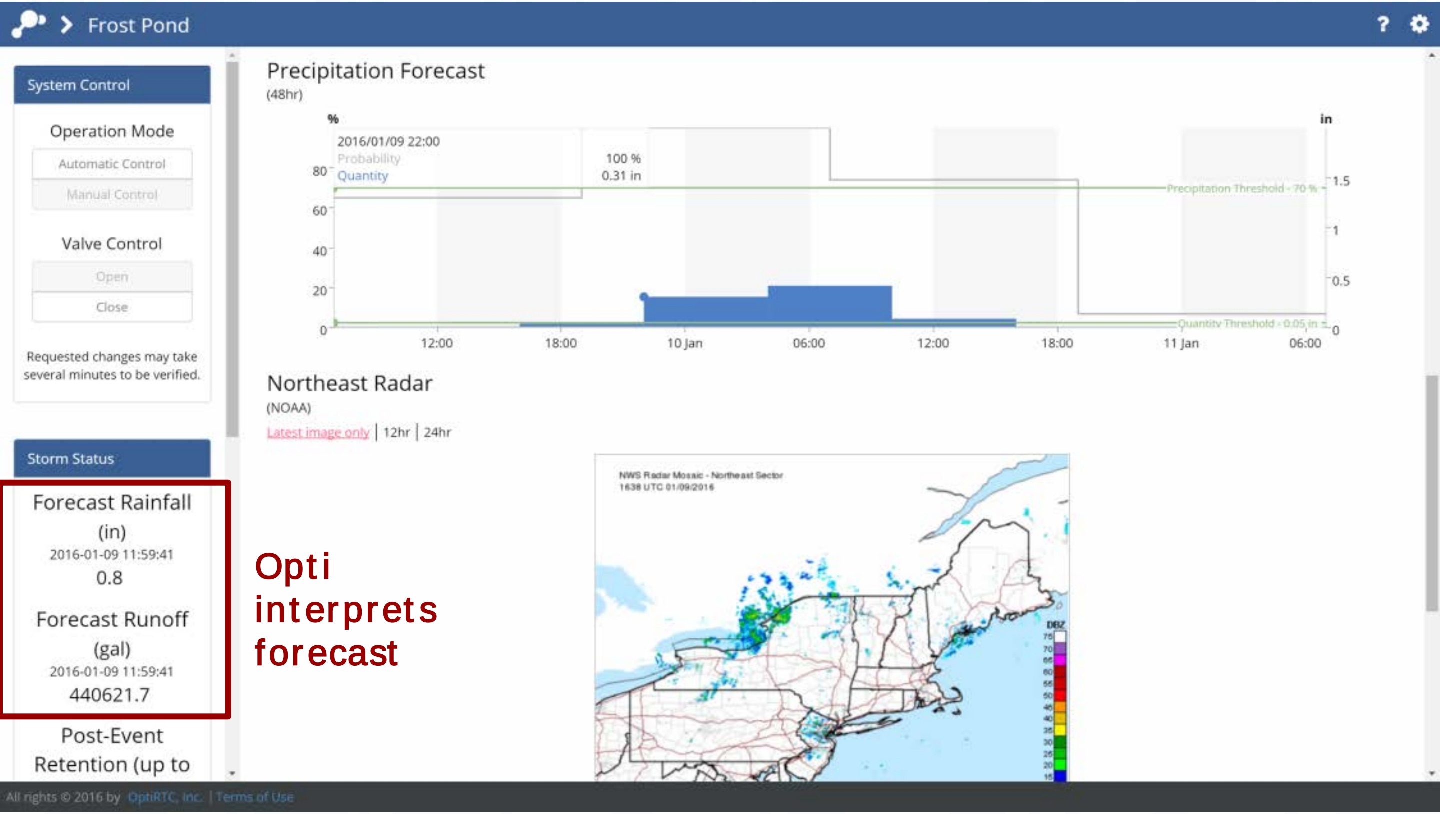
Or…

Opti Retrofit
Adaptively Control Flow

Add a valve and control logic

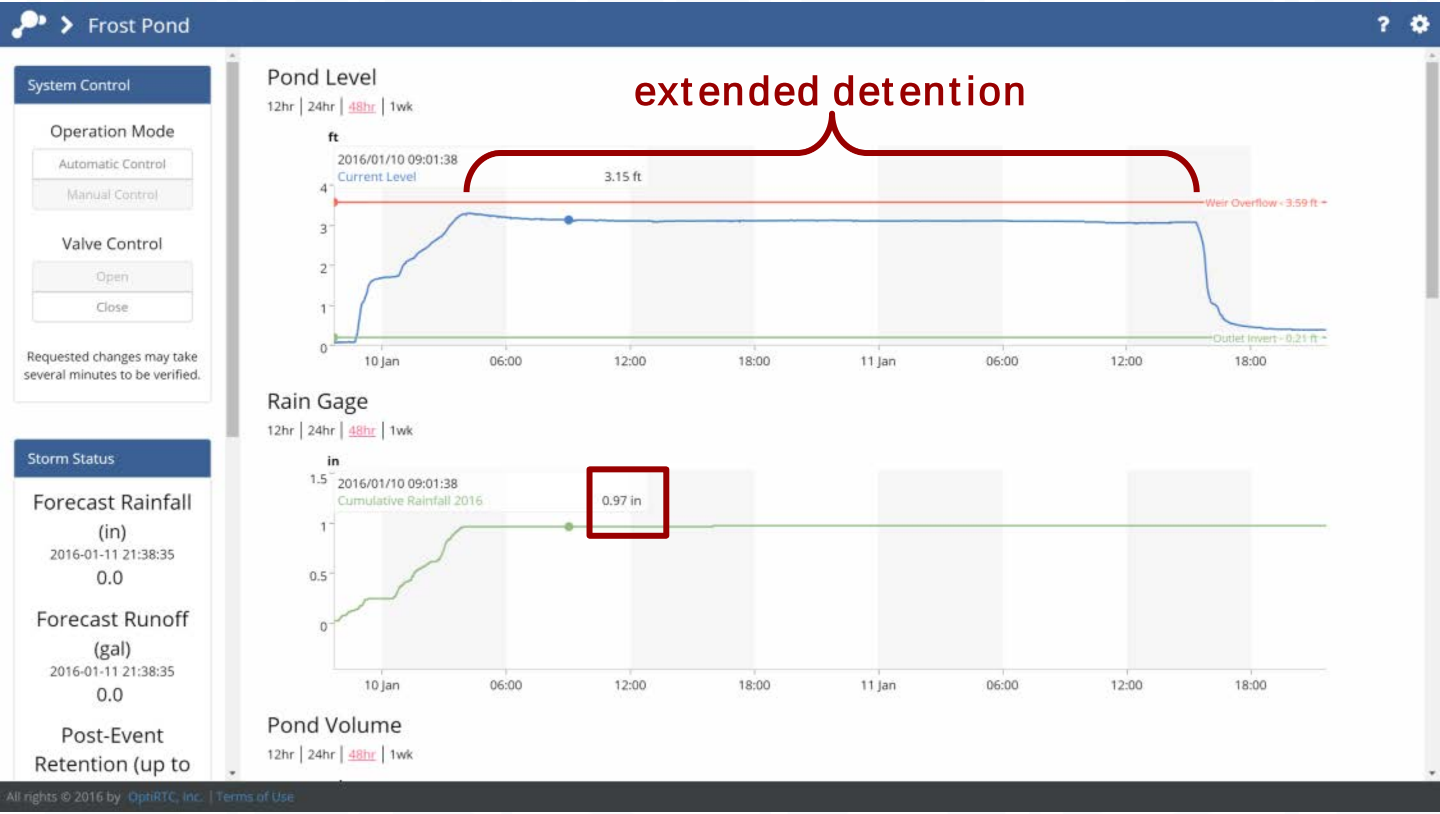
To create >2 ac-ft of extended detention volume

Preparing for Rain:
Pre-Event Forecast

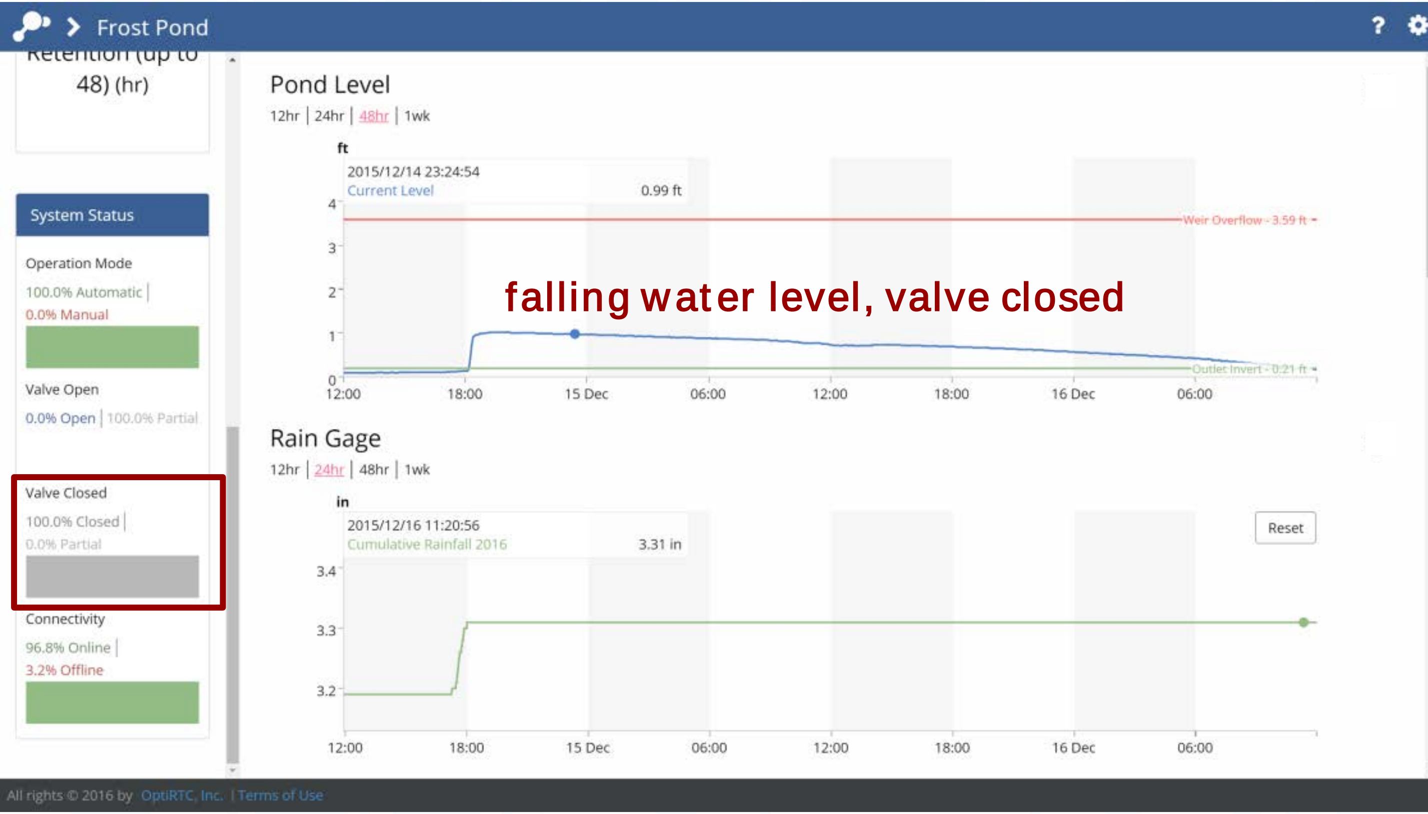


Opti interprets forecast

Example Storm:
January 9 to 11, 2016



Downstream benefits for range of events
Small Event with 100% Infiltration



Wet Pond
Chesapeake Bay Region

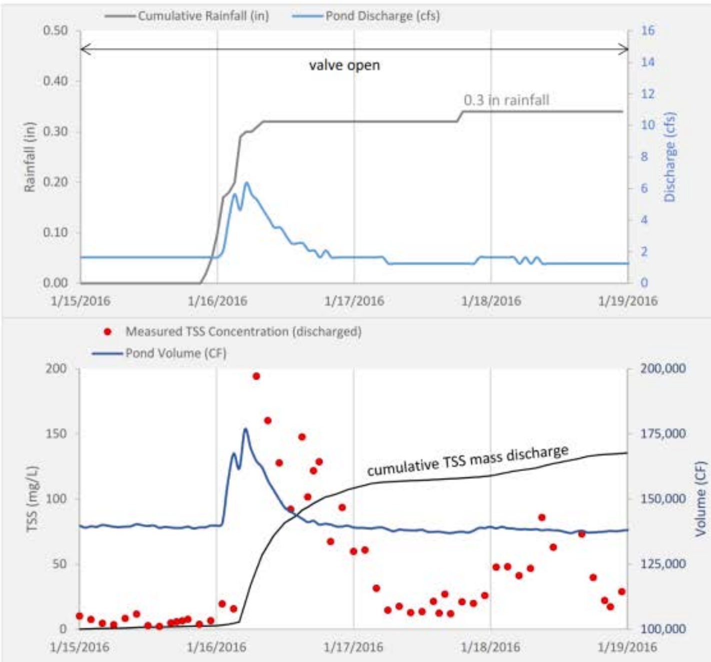
April 6, 2016

Opti Control Panel

Real-Time TSS Monitoring and Active Control

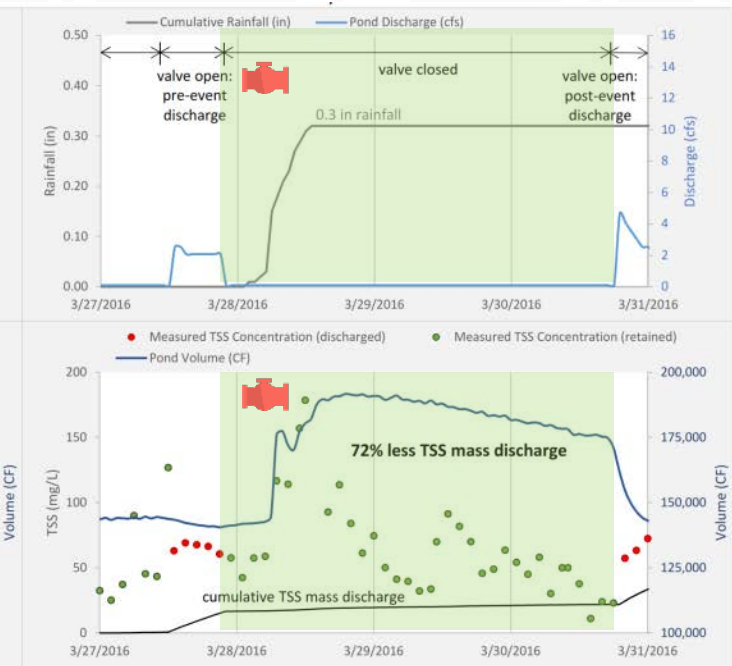
Chesapeake Bay Region

Passive Wet Pond



Jan 2016 - Before Active Control

Active Wet Pond



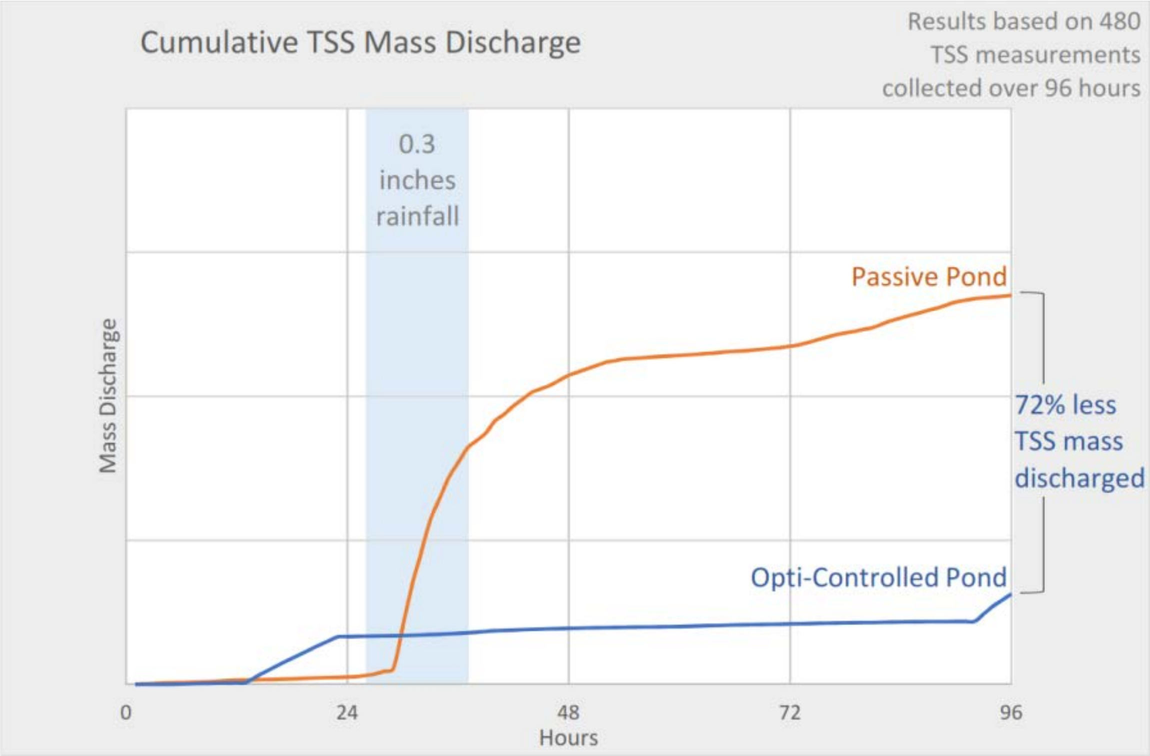
March 2016 - Active Control

In two different storms under different operating conditions.

*Preliminary data collected as part of a NFWF funded study in partnership with MWCOG

Real-Time TSS Monitoring and Active Control

Chesapeake Bay Region



TSS can be measured in real-time to show facility performance

Active operation appears to discharge less TSS by enabling more settling

*Preliminary data collected as part of a NFWF funded study in partnership with MWCOG

CMAC Advantages

- Track event and long-term performance to inform O&M needs and design/operational changes
- Retrofit existing infrastructure to enhance performance at a lower cost than traditional retrofits
- Decrease size of new facilities and/or enhance performance where available footprint is limited
- Adapt infrastructure operation with logic changes as site conditions and climate changes
- Provide site and watershed-scale data to stakeholders

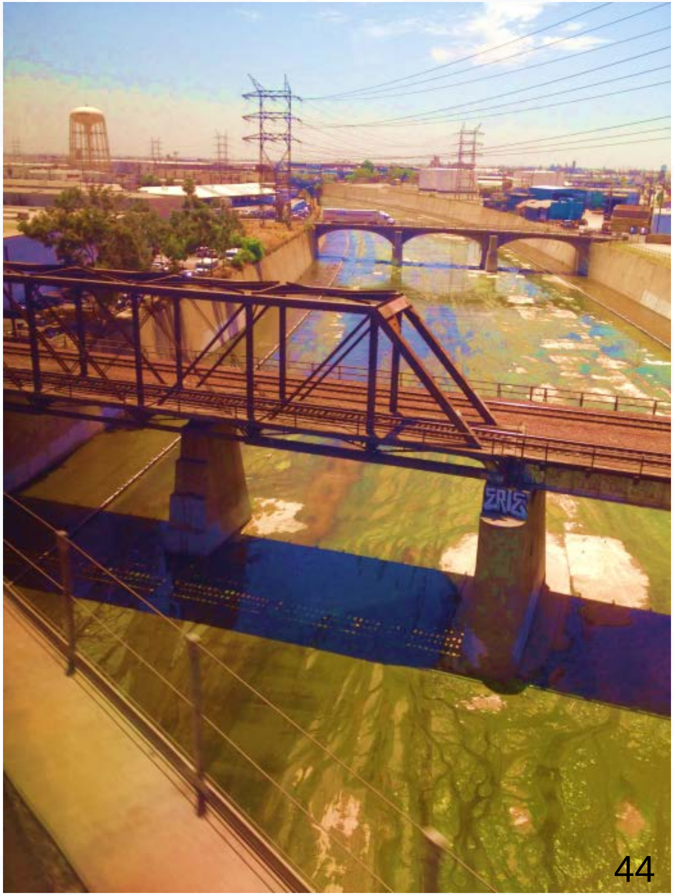
CMAC in California

Regulations and Applications

Regulatory and Programmatic Drivers

Considering…

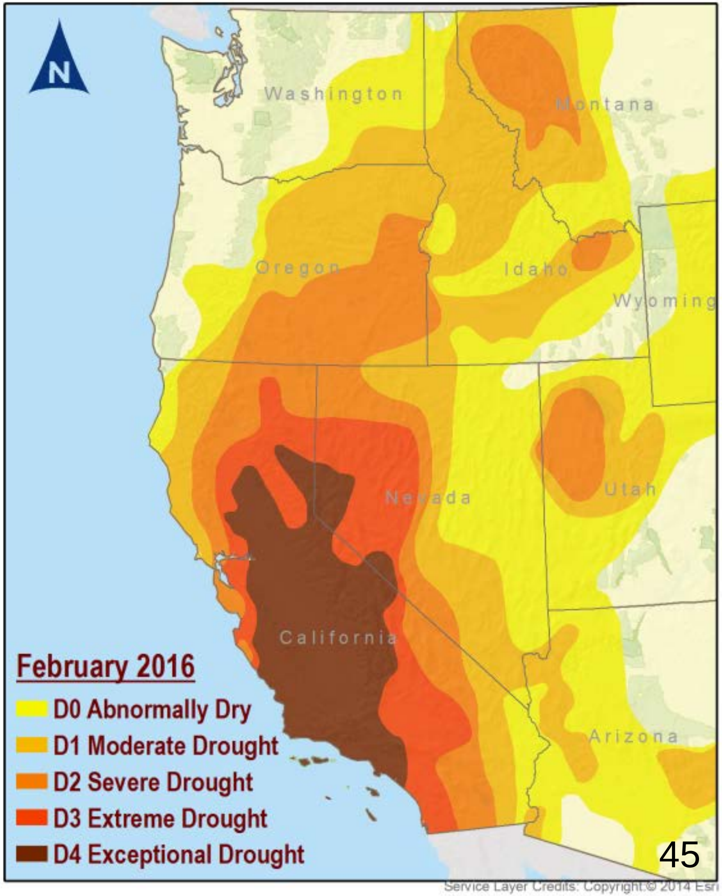
- Water Quality Impairments



Regulatory and Programmatic Drivers

Considering…

- Water Quality Impairments
- Drought & Water Scarcity



Regulatory and Programmatic Drivers

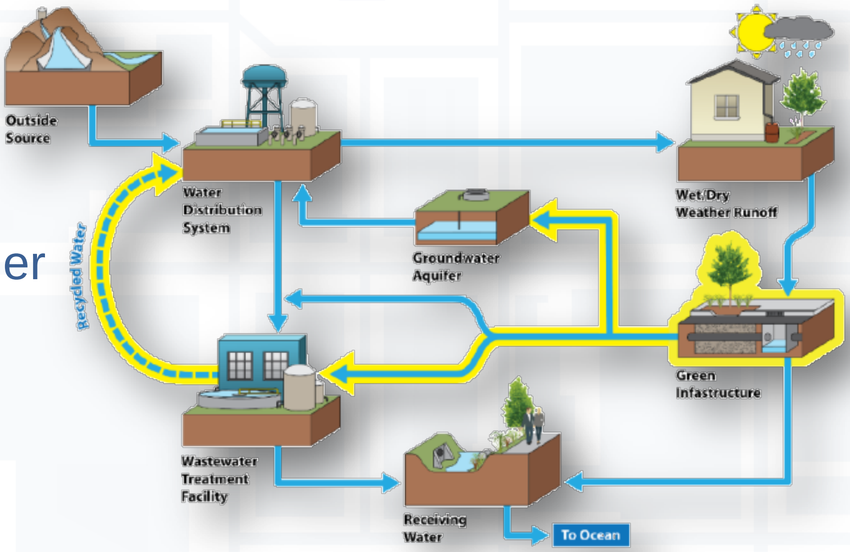
Considering…

- Water Quality Impairments
- Drought & Water Scarcity
- El Niño & Increased Flooding

Regulatory and Programmatic Drivers

Considering…

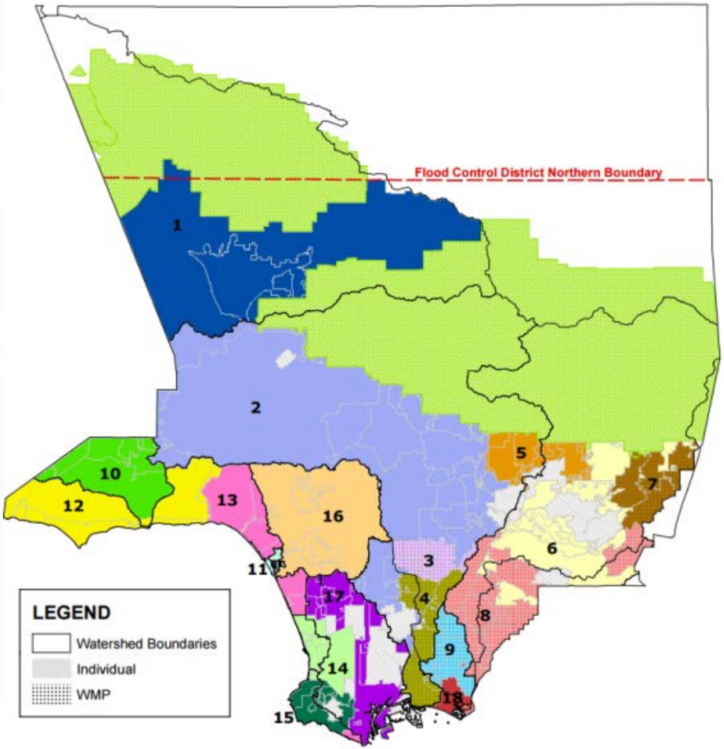
- Water Quality Impairments
- Drought & Water Scarcity
- El Niño & Increased Flooding
- Integrated Water



Southern California MS4 Permit Compliance

EWMPs and WQIPs prescribe over **$25 billion** of stormwater controls (16,000+ ac-ft of BMPs)

Green infrastructure length considered = half Earth's circumference



Southern California MS4 Permit Compliance

EWMPs and WQIPs prescribe over **$25 billion** of stormwater controls (16,000+ ac-ft of BMPs)

Green infrastructure length considered = half Earth's circumference

Operating in built out environment with limited, expensive real estate

Greater LA Water Collaborative

TreePeople

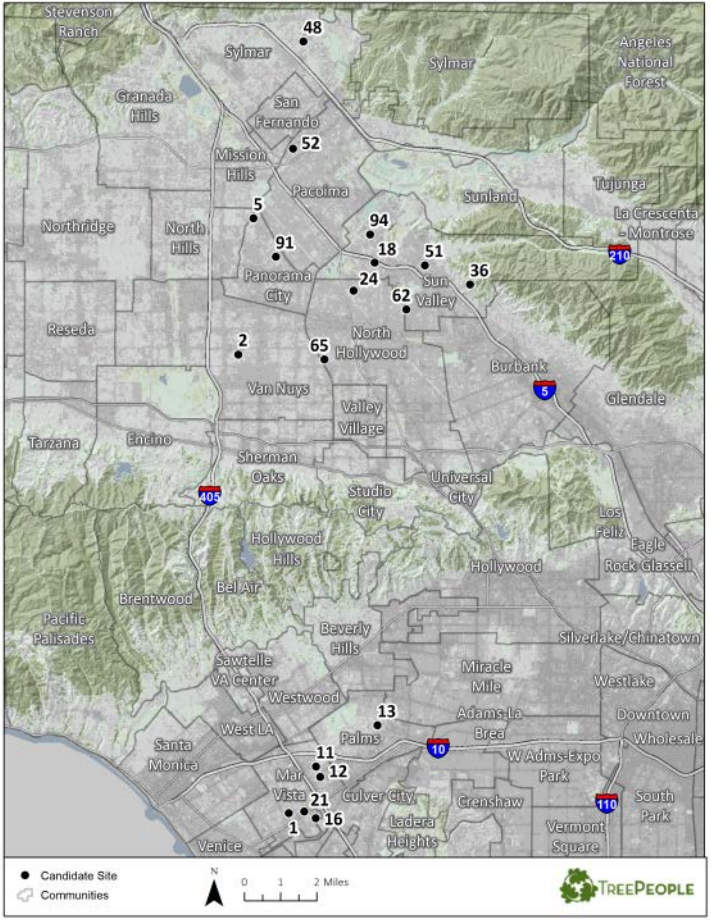
environment
LA SANITATION
CITY OF LOS ANGELES

LA
DWP

LOS ANGELES COUNTY FLOOD CONTROL DISTRICT
100 YEARS 1915–2015

COUNTY OF LOS ANGELES
PUBLIC WORKS
Public Service That Works

Greater LA Water Collaborative



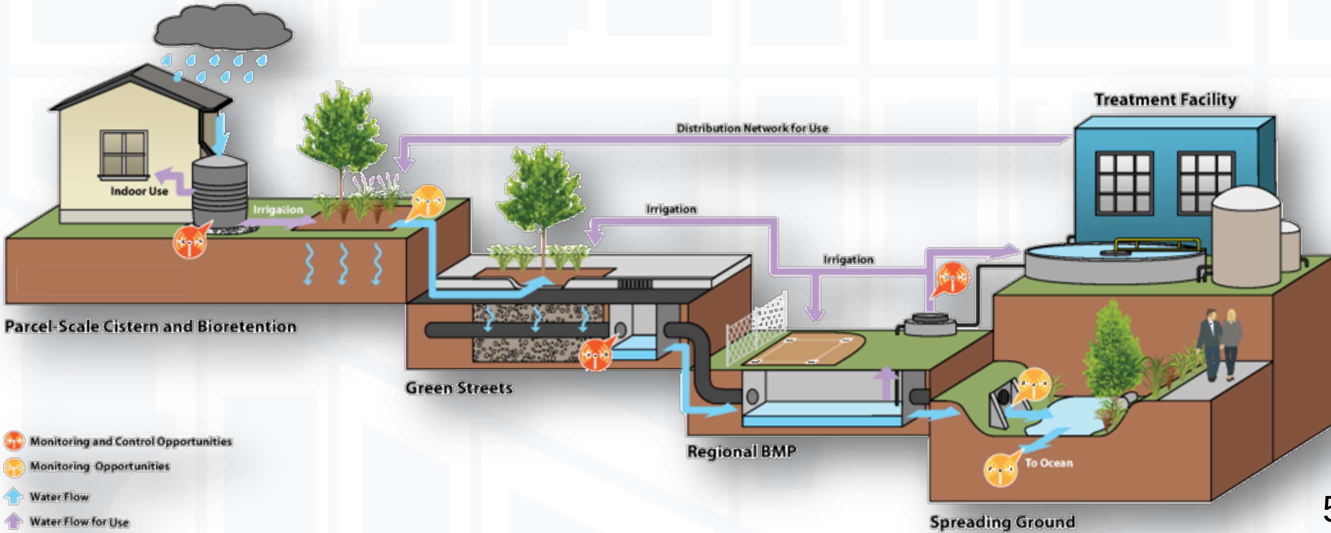
Taking it to Scale

Project vets installation barriers; political obstacles; physical constraints; and public health, safety, and acceptance

Taking it to Scale

Project vets installation barriers; political obstacles; physical constraints; and public health, safety, and acceptance

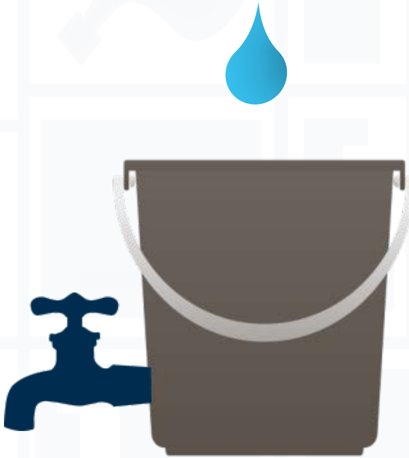
How can concepts be scaled regionally?



Optimizing Multiple Objectives

Water Supply

Water Quality



Flood Control

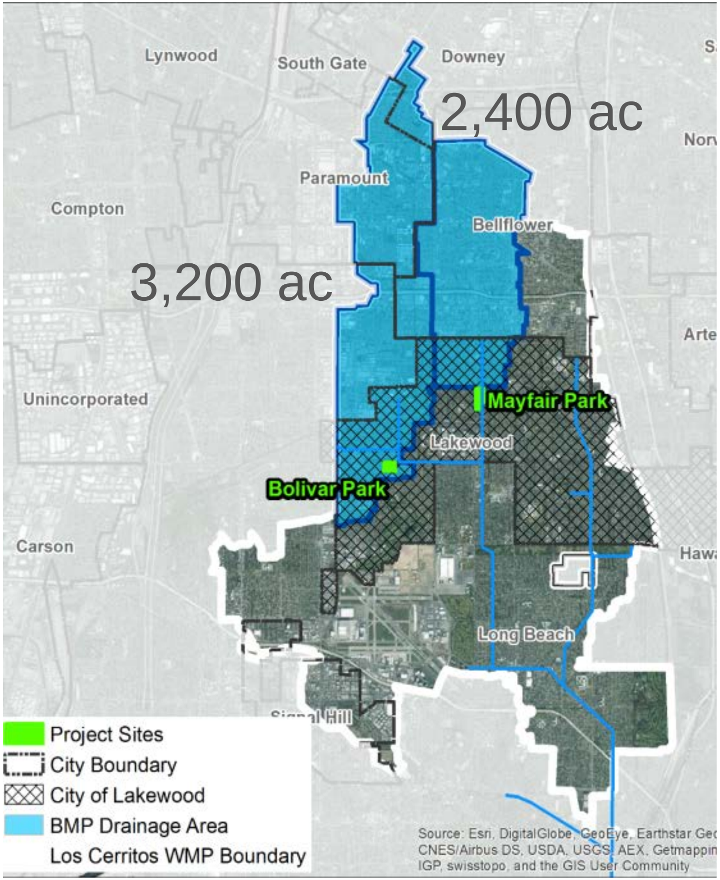
Optimizing Multiple Objectives

Water Supply

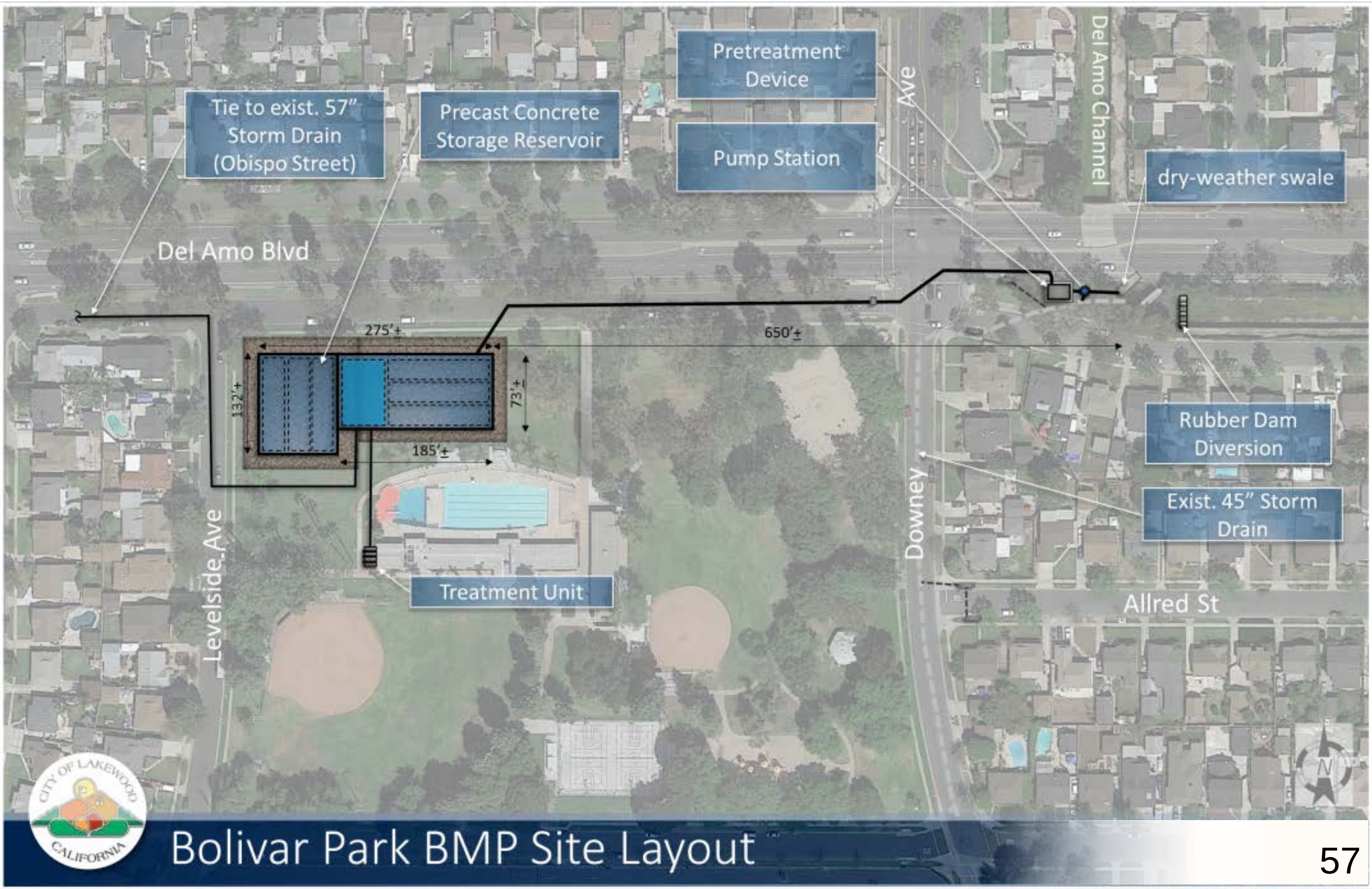
Water Quality

Flood Control

Lakewood Stormwater Capture Project



Lakewood Stormwater Capture Project

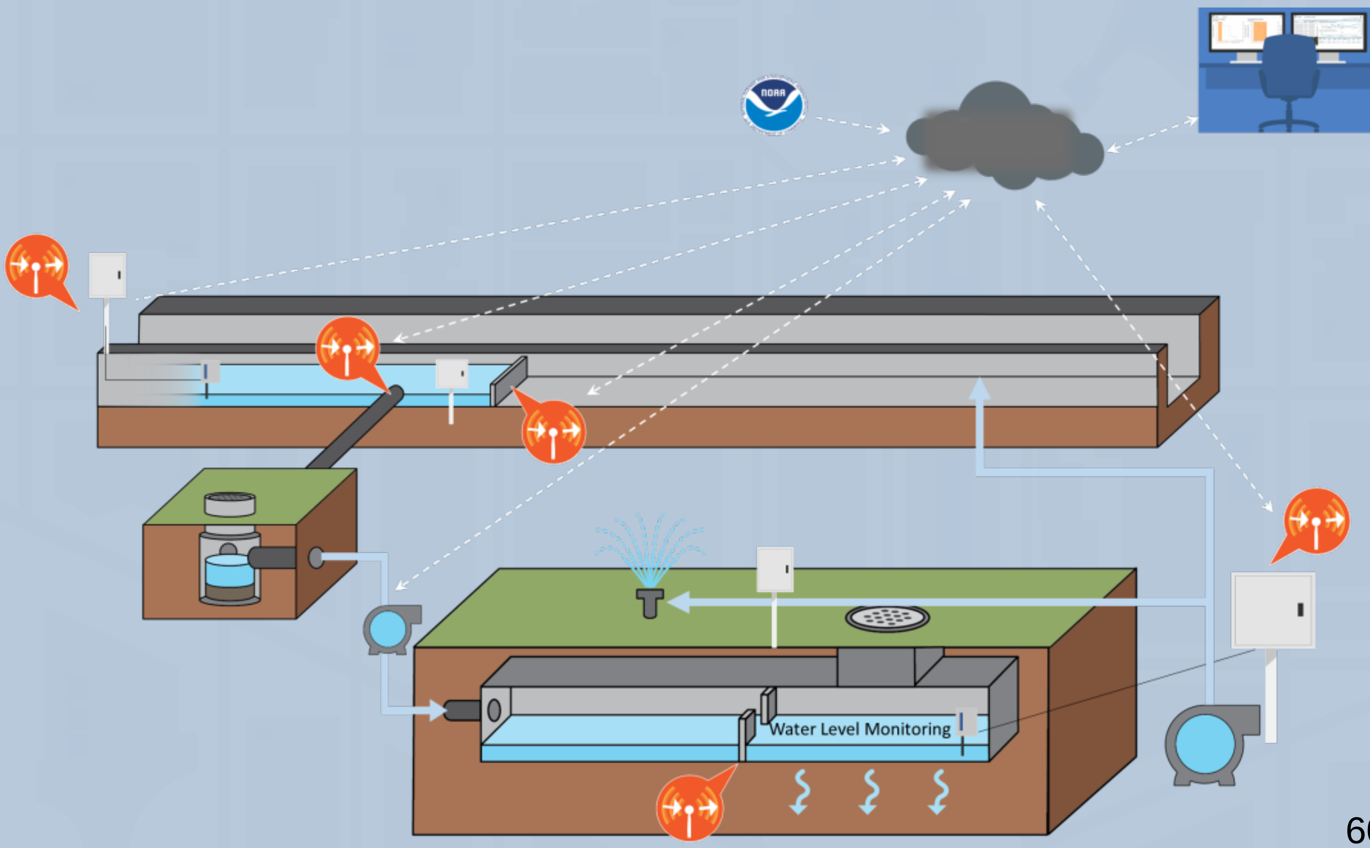


Lakewood Stormwater Capture Project

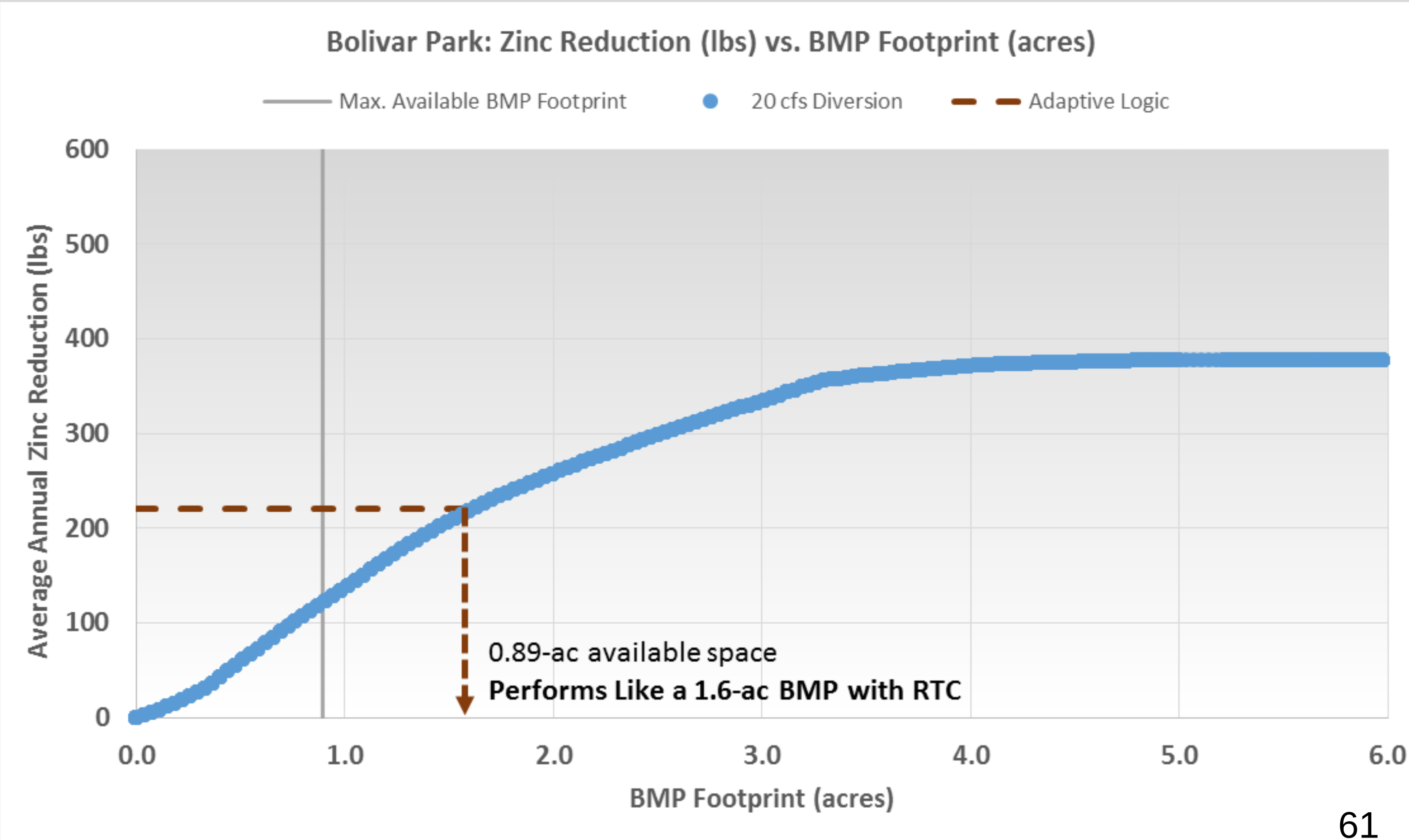
Bolivar Park

Lakewood Stormwater Capture Project

Lakewood Stormwater Capture Project



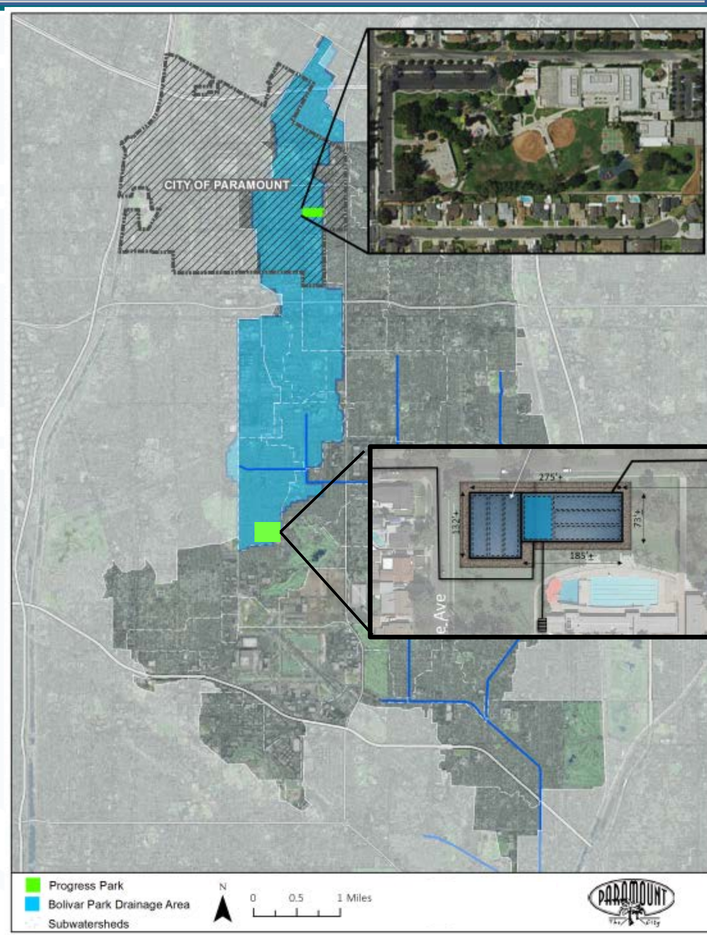
Lakewood Stormwater Capture Project



In Lakewood California,

CMAC installed to….

- Optimize performance
- Reduce risk and provide certainty of performance
- Quantify progress
- Enable interjurisdictional coordination/control
- Adapt to emerging data and performance needs



Challenges for Technology Adoption

Challenges for Technology Adoption

Adoption

- Project Proponents are interested in CMAC, but project approval is uncertain
- Evolution of the science vs. permit cycles
- Permits should continue to allow for performance based options (e.g., 85th percentile runoff storage vs. 80% capture or load reduction)
- Collection of performance data should be encouraged as part of adaptive management vs. creating potential liability
- Analyses need to consider forecast uncertainty

Questions for Water Boards

- How could the Water Boards encourage the application of this technology?
- What are some of the regulatory hurdles that would need to be addressed to make the most of this technology?
- How can collection of performance data be encouraged in support of adaptive stormwater management while limiting potential liability of permittees?

Questions for Water Boards

- Are the Water Boards prepared to handle large performance related data sets this technology would generate?

- What types of information, case studies or training would Water Board staff want to allow the use of CMAC technology to demonstrate compliance with NPDES Permit requirements?

Questions for Permittees

- What resources do Permittees need to approve CMAC technology to meet NPDES Permit requirements?

Discussion

Eric Strecker
estrecker@geosyntec.com

Judd Goodman
jgoodman@geosyntec.com

Owen Cadwalader
ocadwalader@optirtc.com

Chad Helmle
Chad.Helmle@tetratech.com

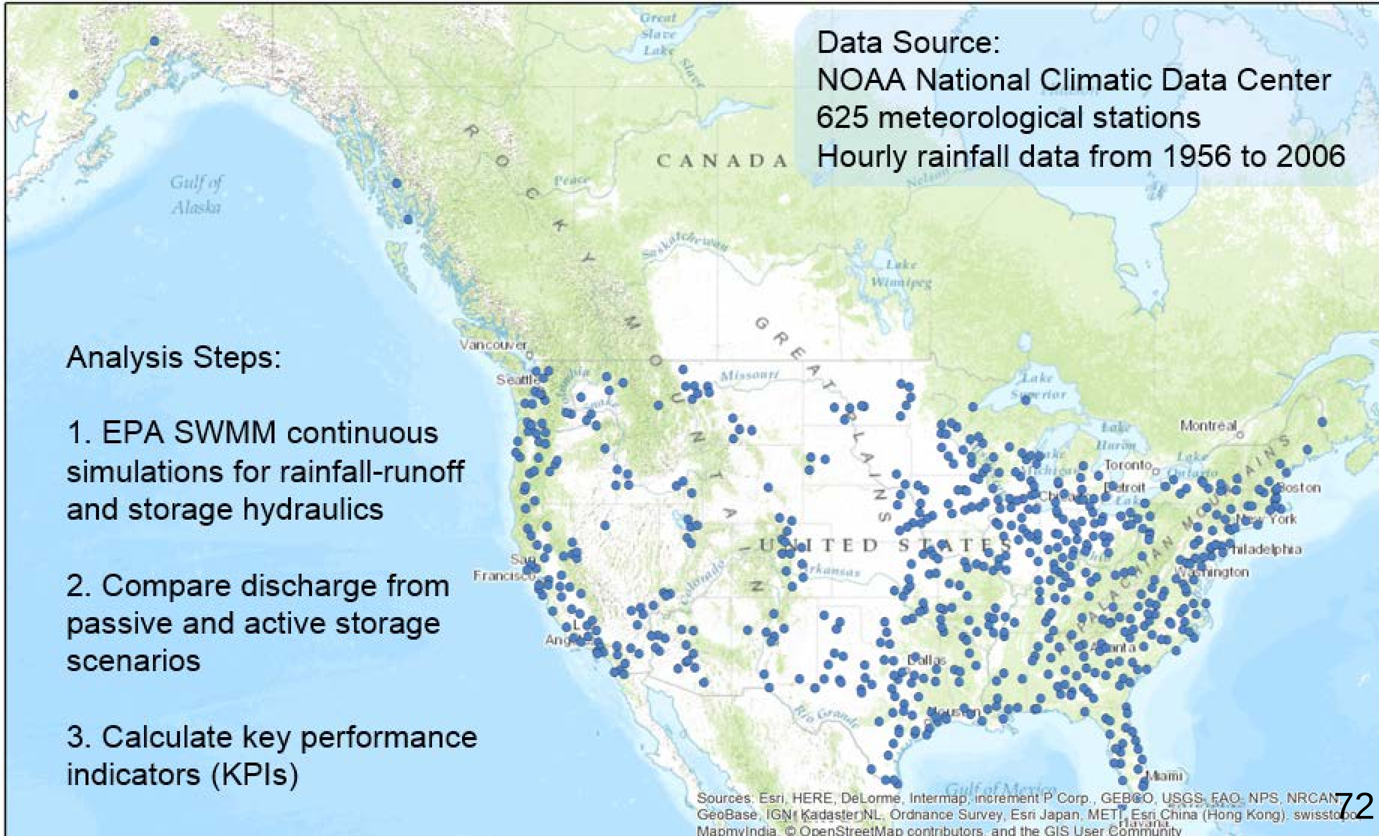
Thank You!

Appendix

Modeling

Nationwide Modeling Study

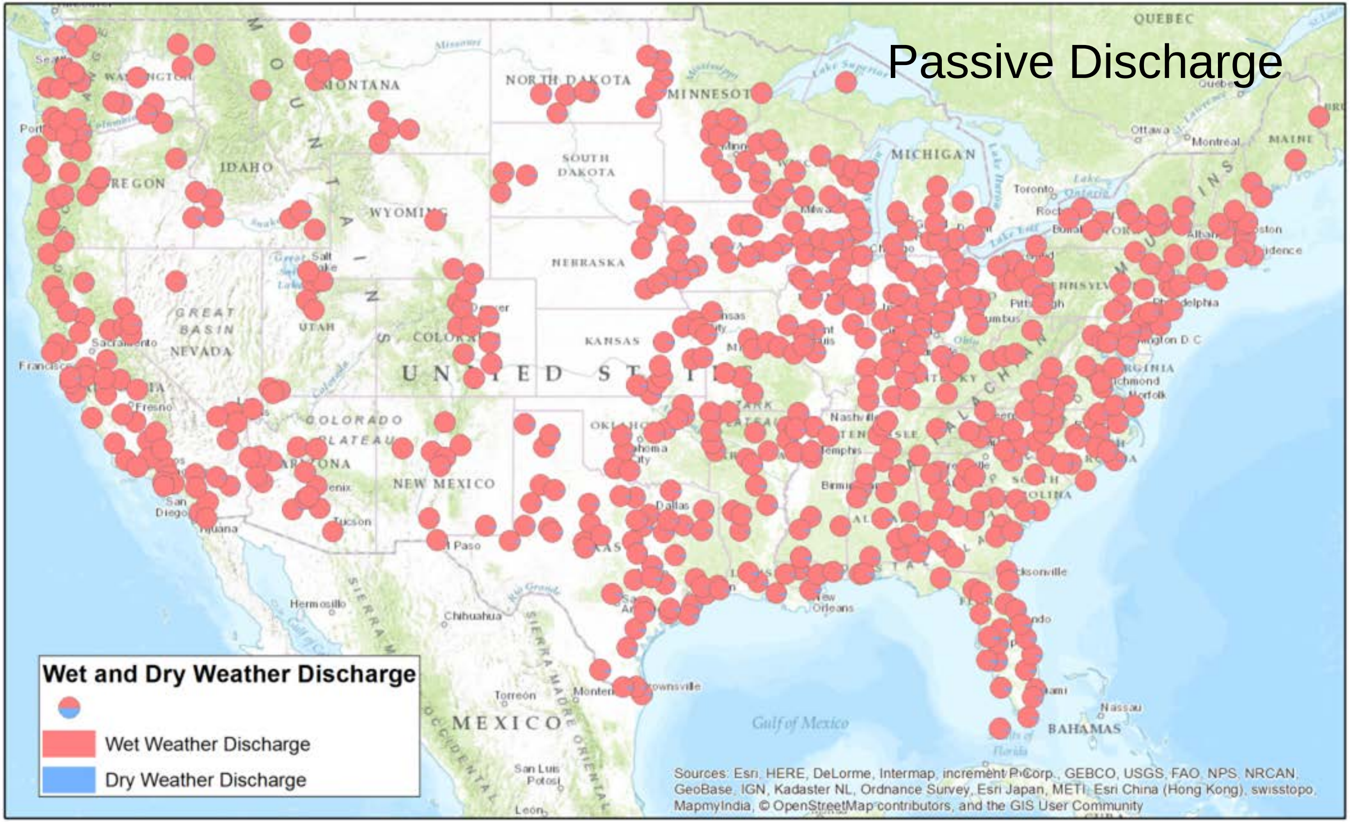
Data Source:
NOAA National Climatic Data Center
625 meteorological stations
Hourly rainfall data from 1956 to 2006



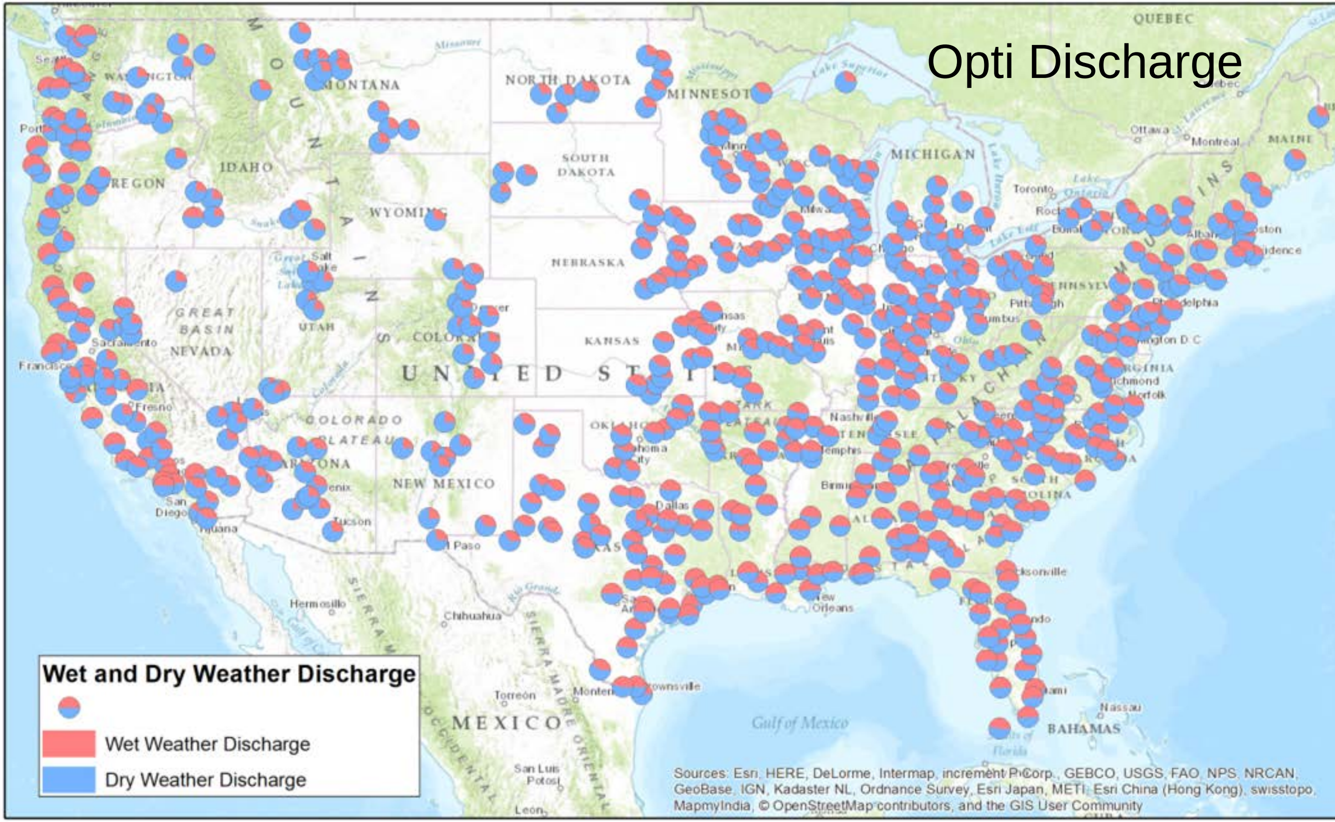
Analysis Steps:

1. EPA SWMM continuous simulations for rainfall-runoff and storage hydraulics
2. Compare discharge from passive and active storage scenarios
3. Calculate key performance indicators (KPIs)

Volume Discharged During Wet vs. Dry Weather



Volume Discharged During Wet vs. Dry Weather



Summary Statistics for 1-in Storm

Median values for all 625 stations

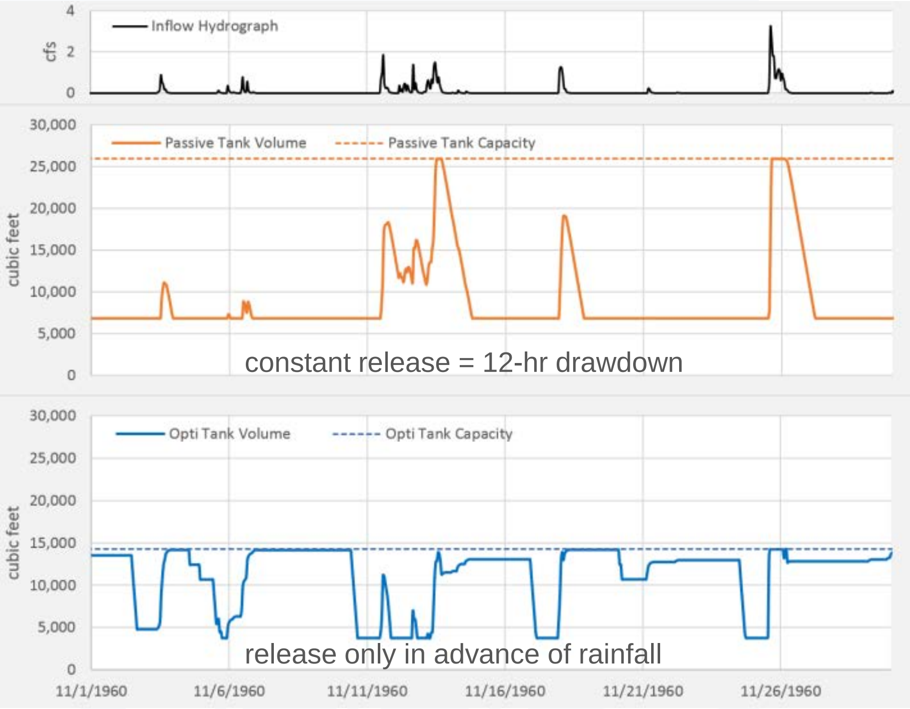
Simulation	Metric	Passive Storage	Opti Active Storage
Water Quality: Maximize Retention Time	Long term average retention time	12 hours	196 hours
	Average water available for use[1]	0	590,000 gal/acre/year
	Average wet weather storage utilization	26%	68%
	Percent time runoff retained	3%	59%
CSO/Flooding: Minimize Wet Weather Discharge	Average wet weather discharge	0.052 cfs	0.021 cfs
	Average wet weather discharge during inflow > 0.25 cfs	0.265 cfs	0.171 cfs
	Wet weather capture	2%	61%
	Percent time runoff retained	2%	91%

Note: median values shown for 1 inch storage size

1: No withdrawals were simulated. In the passive system, no water was available for use because the outflow valve was always open. In the Opti system, water captured and not released during wet weather was considered available for use. The value shown is the annual average capture volume.

Sacramento Model

Goal: Determine allowable reduction in stormwater detention facility size while maintaining capture and treatment performance.



MODEL RESULTS SNAPSHOT

50-year hourly simulation using Folsom rainfall record*

Both meet 85% capture of site runoff

Both provide adequate retention time

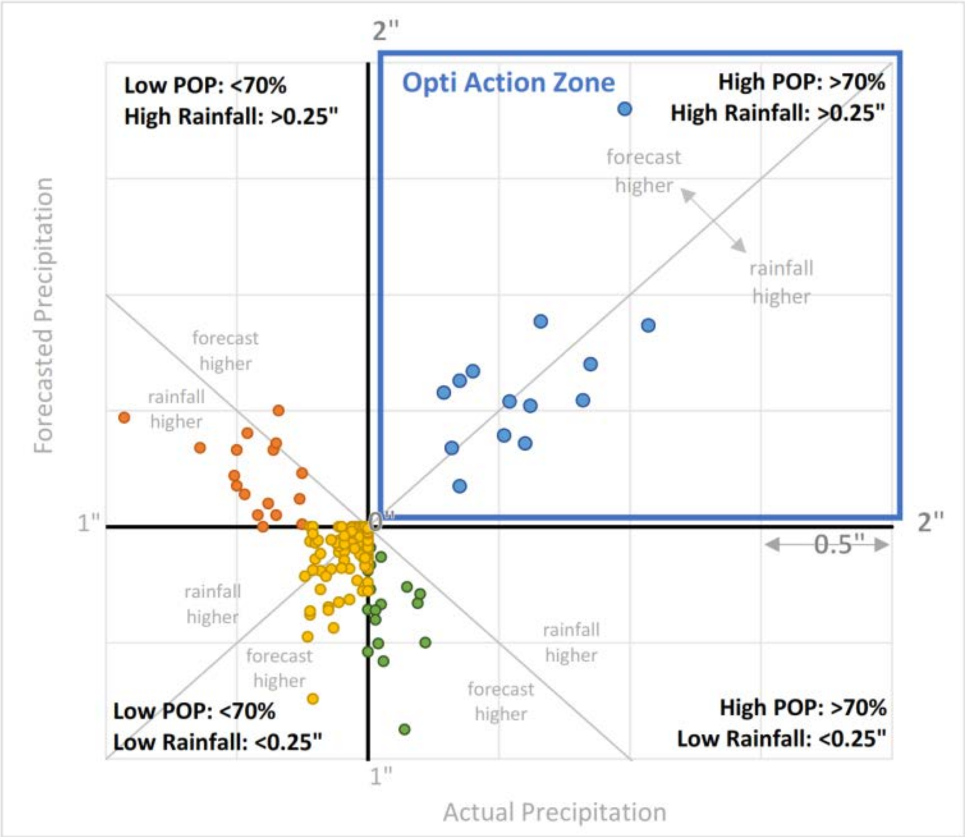
Opti tank is up to 45% smaller

per WEF Manual of Practice No. 23/ASCE Manual and Report on Engineering Practice No. 87

*Rainfall-runoff modeled in SWMM V5.1. 11 acre drainage area, 15% impervious. Volume-discharge modeled in Excel spreadsheet. Perfect forecast assumed for Opti scenario.

Forecast Accuracy

One Year of Forecast and Precipitation Data
Pennsylvania



24hr Forecast and Precipitation Totals

Security

Opti Security

Key Features of the Opti Platform

- All access to Opti Platform services is provided to authorized users over Hypertext Transfer Protocol (HTTP) and Websocket Protocol (WS) within **all connections encrypted** by Transport Layer Security (TLS) via web browser or via application programing interfaces (APIs).
- Storage, monitoring, and alarm services **check on site up to every minute**, 24/7/365, preserving a record.
- Redundant Platform instances across **multiple data center** fault zones.
- Independent Application Performance Monitoring solution provides **real-time visibility into service interruptions**.
- Internal Public Key Infrastructure (PKI) system with credential roles manages rotation and distribution of **least-privilege credentials** to Opti Platform service hosts.

Opti Security

Security Principles of Opti Communications Hardware for Control Applications

- Modern, purpose-specific embedded operating system (FreeRTOS) with **security updates** over-the-air **by Opti**.
- Strong encryption used in **all** external network communications with hardware storage of relevant keys.
- All communications established with **outbound-only** connections from field devices.
- **Device-specific credentials** and identifier guarantees compromise of a single device does not equate to compromise of others.
- **Assumed obsolescence** and planned path for smooth migration. “Future Proof”.
- Commercial off the shelf hardware for direct sensor measurement and control with **physically separate** microcontroller/communications hardware.
- User access and experience is independent of hardware, and can be **upgraded independently**.

Lifetime Costs

Opti can save

up to 90% on capital expenses

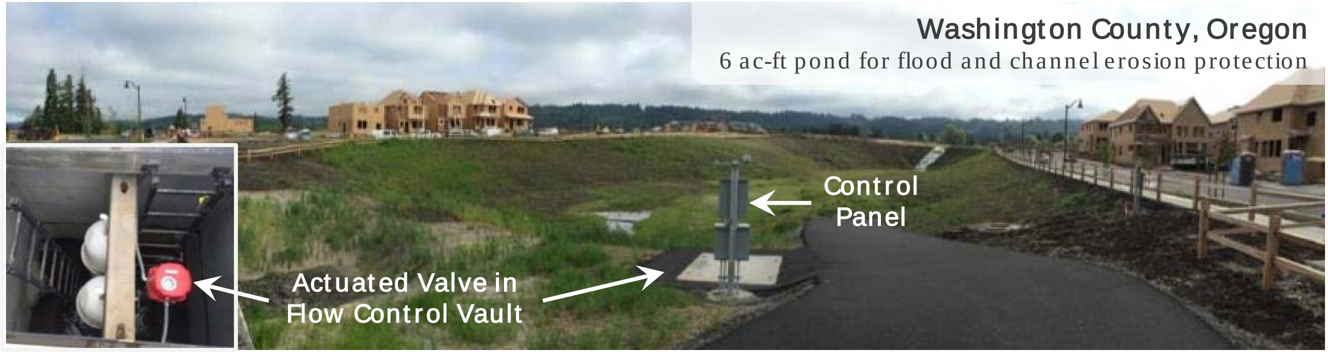
+

25% to 75% **of the 25 year life-cycle cost**
relative to a passive facility with similar performance

Customer Challenges

Limited existing stormwater management facilities – built to various historical standards, constrained floodplains, sensitive riparian areas, soil conditions limit infiltration.

CWS needed solutions to meet MS4 water quality and flow control mandates under constraints.



Opti Solution

In partnership with Clean Water Services (CWS), Opti and Geosyntec ran two pilot tests at ponds in CWS service area during 2015. Extensive modeling shows the potential for long term performance gains at additional facilities identified through a regional evaluation and screening process. The partnership detailed plans to scale up this approach in a 2015 white paper.

*Project funded by CWS

Clean Water Services

Geosyntec consultants

Opti

Case Study 1 – Stream Protection Performance Highlights

Modeled & Monitored	Modeled	
Existing Water Quality Facility (Butternut Creek, Lower Pond)	**Flow Control Facility (Bethany Creek Falls)**	**New Development Flow Duration Control Pond**
• **25% reduction in duration of channel forming discharges** • 20% reduction in wet weather discharge • Performance increases despite very small facility size	• **70% reduction in volume within critical flow range** • 60% reduction in wet weather volume • 30% lower peak flow in largest events • Increase in residence time from 1 to 19 hours	• **30 to 50% reduction in required pond size** • 50% reduction in typical drawdown time • 70% reduction in maximum inundation period

2,667 stormwater management facilities were evaluated as candidates for Opti.

62 were identified as high priority and **hundreds more** as strong candidates.

Case Study 1 – Stream Protection ROI Calculation

Lifecycle Costs

Including Consulting, Design, and Construction

Cost Summary	Opti	Passive	Opti Savings Over Passive
Total Capital Cost	$100,000 to $150,000	$215,000 to $950,000	**30 to 90%**
Gross Annualized Costs (includes maintenance)	$5,500 to $7,000	$3,000 to $5,000	
Present Value of 25 year Lifecycle Cost	$180,000 to $240,000	$260,000 to $1,000,000	**25 to 75%**

Costs for a 4 ac-ft RTC pond; passive increased in size by 50 to 100% to match RTC performance (approximately 80 acres at 60% impervious)

On average, **the whole lifecycle cost of Opti was approximately 3 times lower than the cost of a passive retrofit** that would achieve the same results

Opti had an estimated whole lifecycle cost of approximately **$4,400 per impervious acre treated compared to a passive alternative of $13,100**

Reference: Poresky, A.; Boyle, R., Cadwalader, O. California Stormwater Quality Association. 2015 Proceedings "Taking Stormwater Real Time Controls to the Watershed Scale: Evaluating the Business Case and Developing an Implementation Roadmap for an Oregon MS4"
*NPV uses a discount rate of 5%

Case Study 2 - Water Quality
Prince George's County, MD

Customer Challenges

Meeting Total Maximum Daily Load in the Chesapeake Bay for nitrogen, phosphorus, and sediment. County needs an efficient way to increase residence time of dry and wet ponds to promote settling and biological removal processes.

The objective is to obtain pollutant reduction credits (treated impervious acres).

Opti Solution

Opti converted a dry pond to a wet pond in Prince George's County, MD in 2015. This 2 ac-ft pond can now treat a total of 60 acres including 19 impervious acres.

The passive retrofit alternative would have required excavating 3.2 ft deeper into the pond to create a permanent pool for water quality treatment.

Prince George's County, Maryland
2 ac-ft dry to wet pond conversion treating 19 impervious acres

*Project funded by NFWF

Lifecycle Costs

Including Consulting, Design, and Construction

Cost Summary	Opti	Passive	Opti Savings Over Passive (Passive – Opti)/Passive
Total Capital Cost	$26,000	$303,000	**90%+**
Gross Annualized Costs (includes maintenance)	$15,000	$5,000	
Present Value of 25 year Lifecycle Cost	$237,490	$373,470	**36%**

Opti's lifetime cost to treat one impervious acre is **$12,500 compared to $20,000** for a passive retrofit.

References:
Construction and annual costs from Opti and from a comparison bid for passive retrofit and maintenance of the same pond.
*NPV uses a discount rate of 5%

Opti

Case Study 3 – CSO & RWH
DDOE, Washington DC

Customer Challenge

Washington DC Department of Energy and Environment need to reduce wet-weather discharge with limited space for tank installation and limited budget.

Ultimate goal is to reduce Combined Sewer Overflows

Opti Solution

Installed two Opti-managed 4,000 gallon cisterns at Engine House 3 and 25 in downtown Washington D.C.

Achieved wet-weather discharge reduction AND rainwater harvesting.

Engine House 3, Washington, D.C.
4,000 gallon cistern to minimize wet-weather discharge

Performance Results

Opti – Achieved wet-weather discharge mandate using a 4,000 gallon cistern at each site while keeping water available for reuse.

Passive Alternative – Would require 23,500 gal cistern at each site for equivalent wet-weather performance without Opti.

*Project funded by WERF

DEPARTMENT OF ENERGY & ENVIRONMENT

WERF Water Environment Research Foundation

Geosyntec consultants

OptiRTC.com

Lifecycle costs of 4,000 gal cistern

Goal: Maximize water available for reuse while minimizing wet-weather discharge

Cost Summary	Opti	Passive	Opti Savings Over Passive (Passive – Opti)/Passive
Total Capital Cost	$37,000	$174,800	**80%**
Annual O&M Cost	$3,000	$500/yr	
Present Value of 25 year Lifecycle Cost	$79,282	$181,871	**55%**

80% savings in Year 1

55% lifetime cost savings

Greater certainty of service, tracking performance, and compliance

Reference: Quigley, M., Brown, C. 2014. Transforming Our Cities: High Performance Green Infrastructure. Water Environment Research Foundation. INFR1R11.

*NPV uses a discount rate of 5%