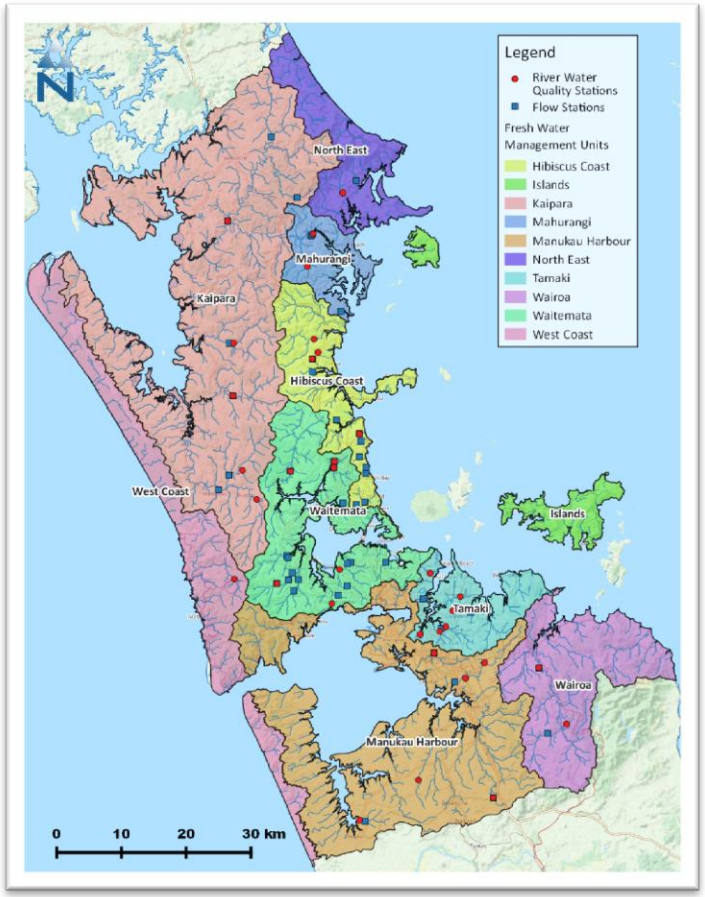
Development of a Freshwater Management Tool to support integrated watershed planning for Auckland waterways

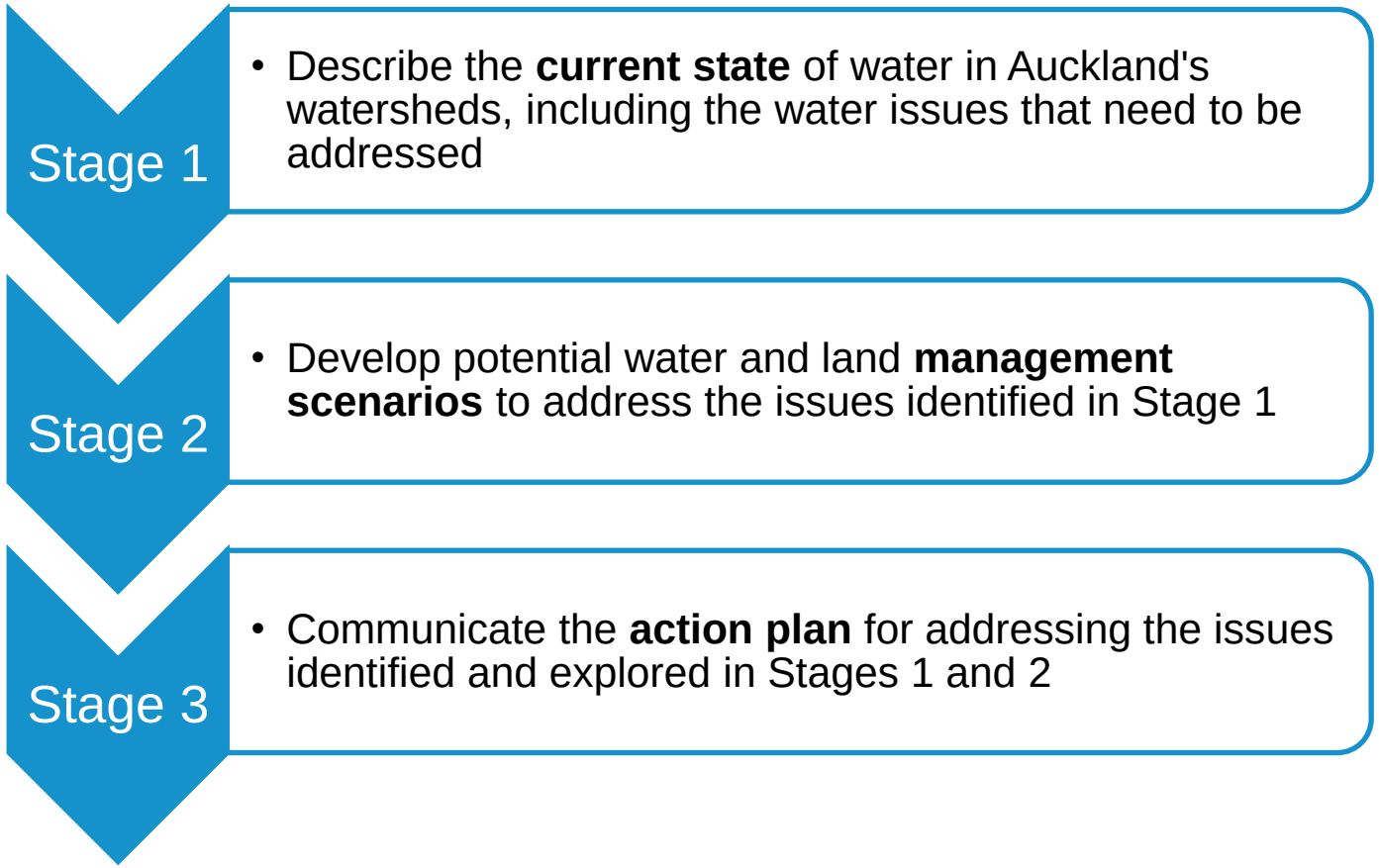
Auckland Council
Te Kaunihera o Tāmaki Makaurau

Long-Term Integrated Watershed Planning

- Auckland Council's Wai Ora Healthy Waterways Programme
- Auckland Unitary Plan (AUP)
- National Policy Statement for Freshwater Management (NPS-FM)
- 10 watersheds in Auckland with Integrated Watershed plans being developed
- Fresh Water Management Tool (FWMT)
- Collaboration with Morphum Environmental & Paradigm Environmental



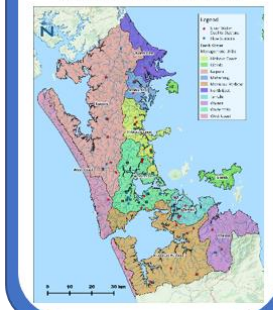
The Freshwater Management Tool



FWMT Process Overview

LSPC
Current Catchment State Model

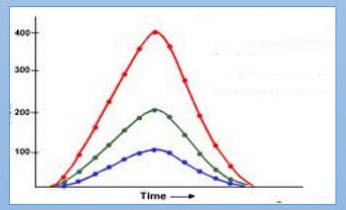
10 Watersheds



Data Input
- Climate / Rain
- Land Use / Soils
- Slope / Imperviousness
- Impoundments
- Point sources / takes
- And much more

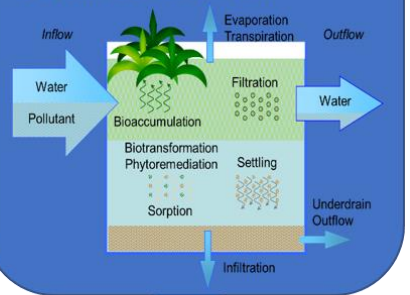
Model Output
- Continuous simulation time series of flow & contaminants for each subwatershed and reach outlet

Baseline Conditions
Runoff
Nutrients
Metals
Suspended solids
Bacteria

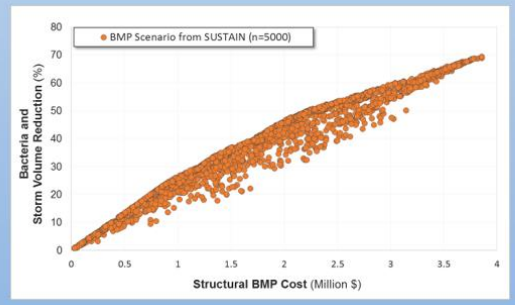


SUSTAIN
Stormwater Management Model

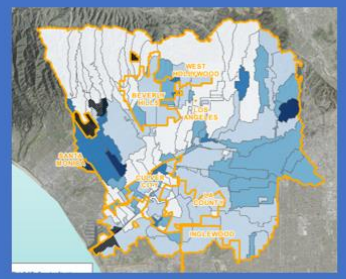
- Time series after implementation of optimised action plan



Optimisation across millions of potential strategies



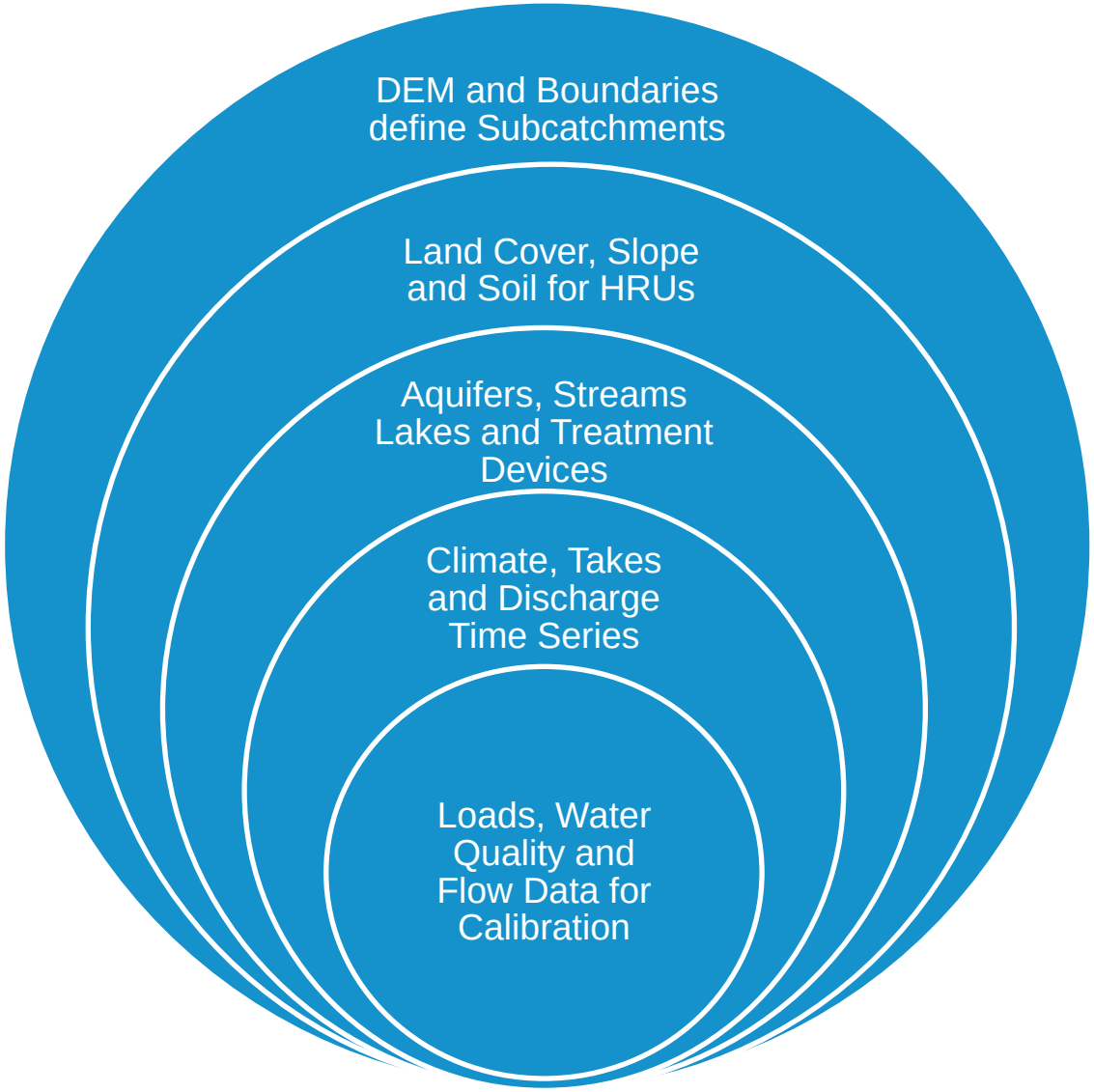
Action Plans for Integrated Watershed Plans



Program

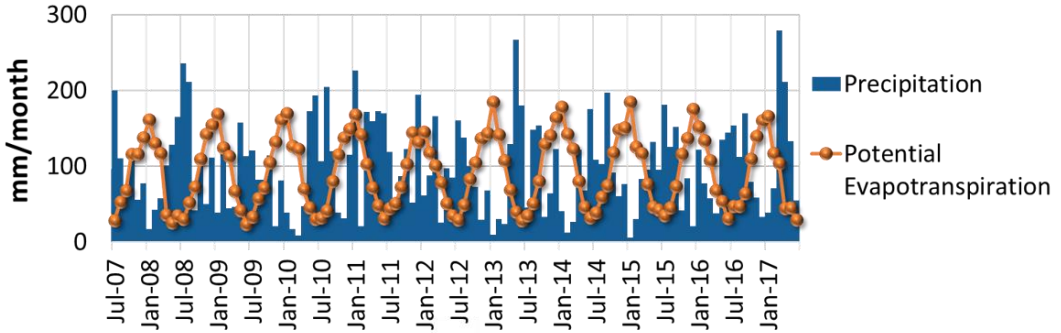

Item
Kick off
Complete
Subcatchment delineation
April 2018
GIS and WQ
May 2018
LSPC Modelling
Nov 2018
Current Catchment State
Nov 2018
Structural Devices
Sept 2018
Source Control
Sept 2018
SUSTAIN
May 2019
FWMT TOOL

Model Inputs



Data Synthesis

Meteorological



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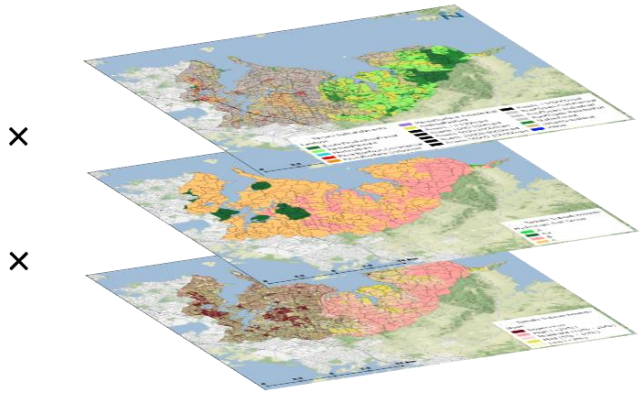

Hydrologic Response Units

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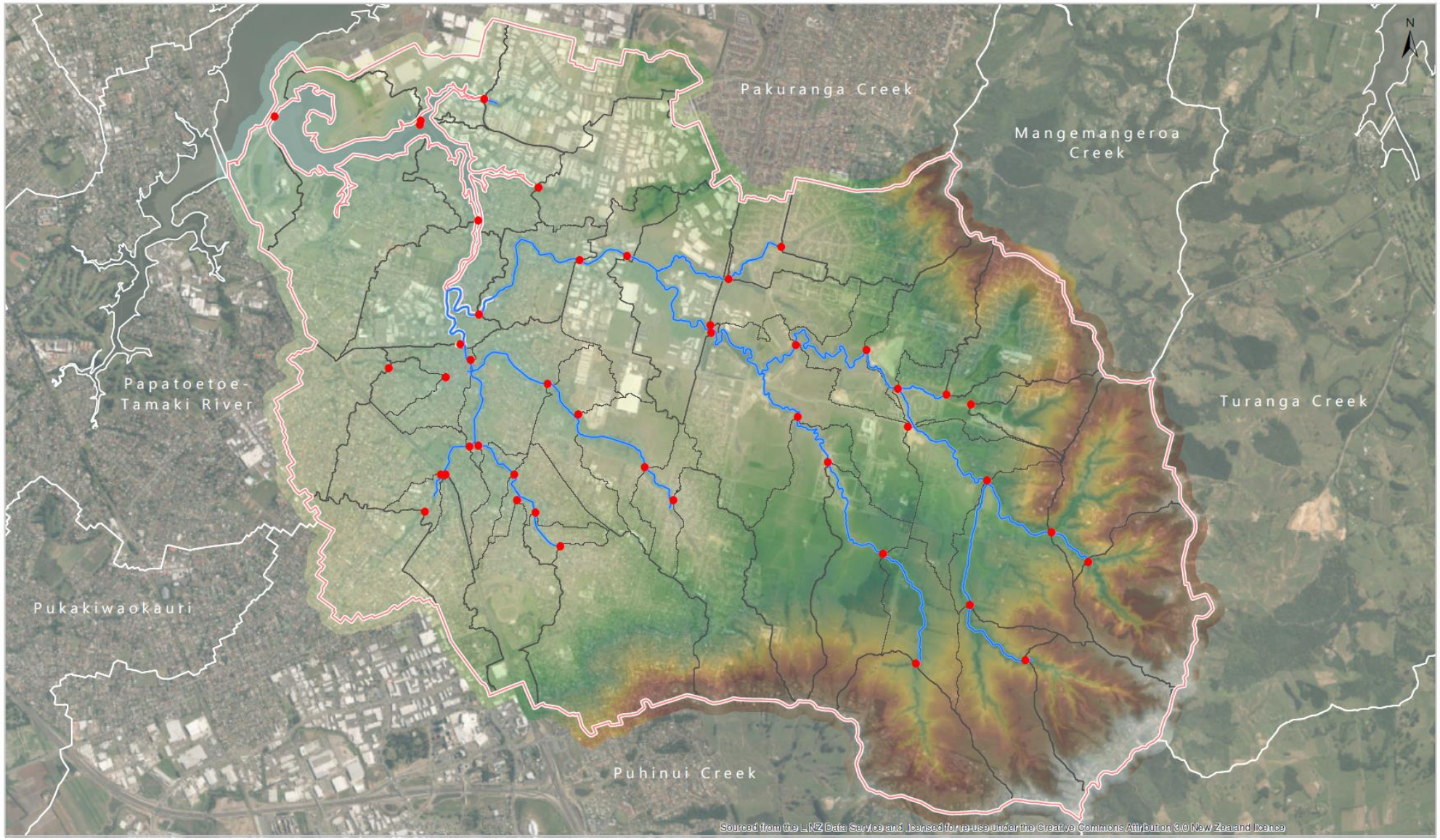
Geological

Parameter Groups

Modelled **Land** Responses

OTARA CREEK CATCHMENT



Legend

- Reporting node
- Digitised watercourse
- Sub-catchment boundary

Client AUCKLAND COUNCIL

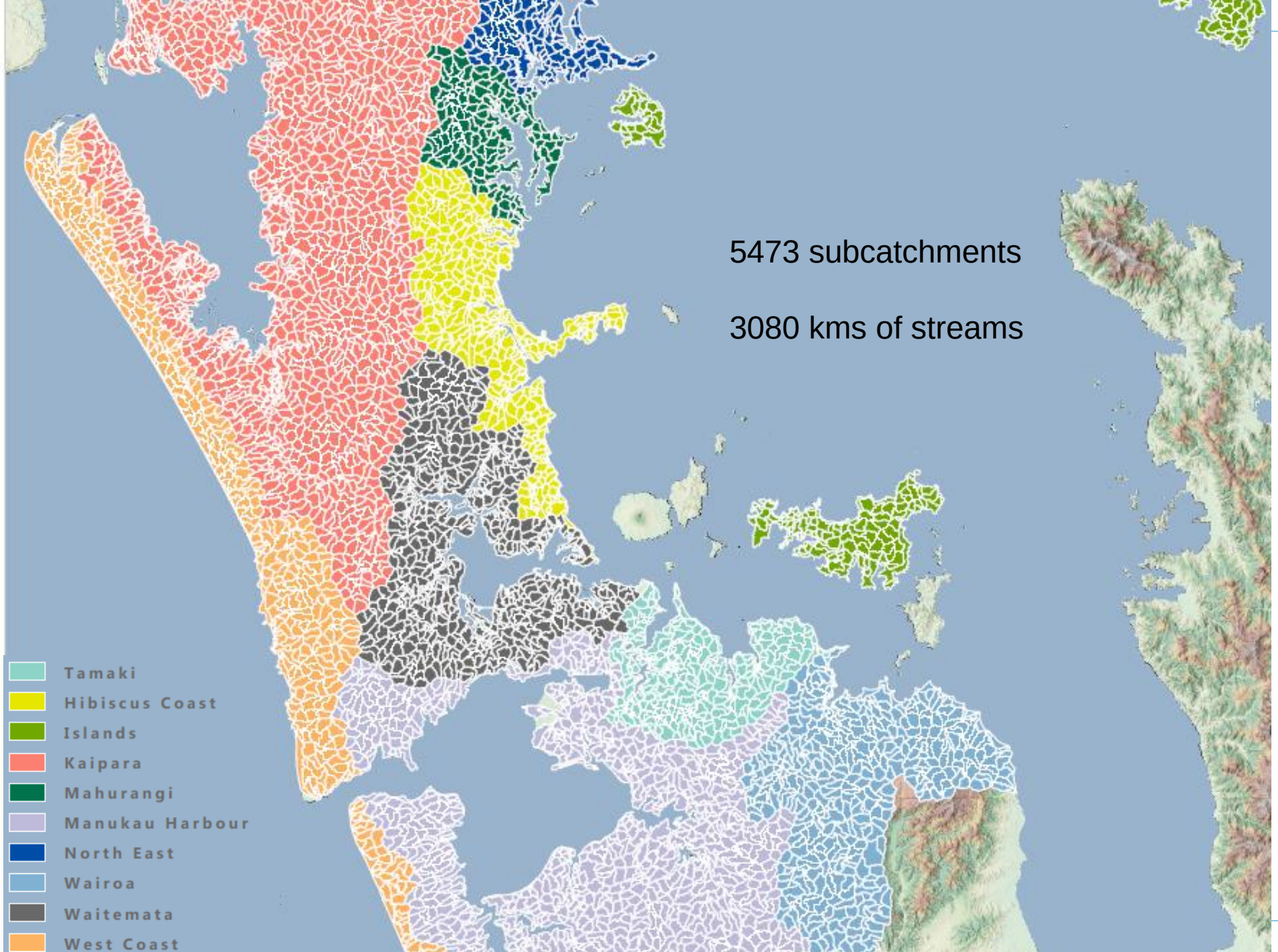
Project **FRESHWATER MANAGEMENT TOOL**

0 1000 2000 m

Project no. P01663

Date 14 Dec 2017

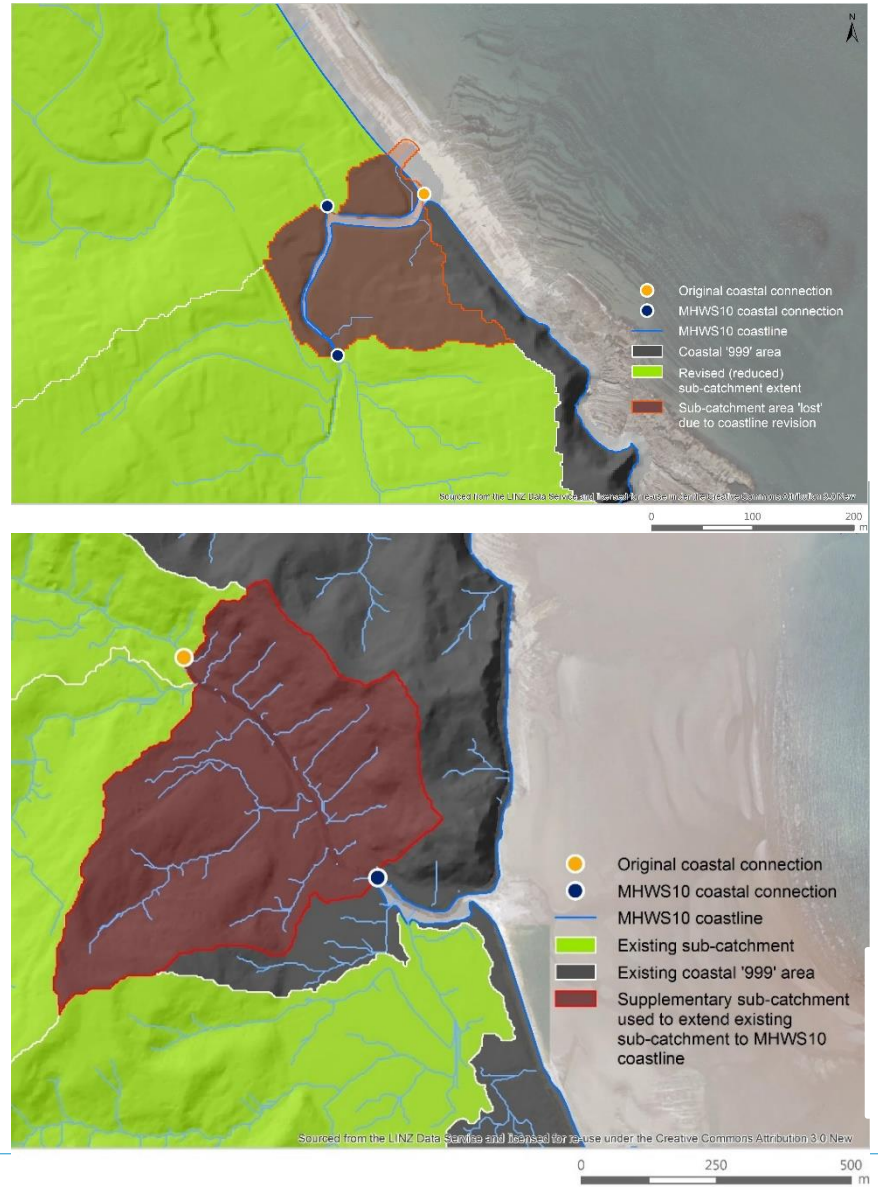
Drawn RF


5473 subcatchments
3080 kms of streams
Tamaki
Hibiscus Coast
Islands
Kaipara
Mahurangi
Manukau Harbour
North East
Wairoa
Waitemata
West Coast

Data: Successes, Challenges and Lessons

- Successes
  - Initial running of the LSPC model is demonstrating the quality of data
  - Great array of available datasets
    - VCSN
    - Lidar
  - Fantastic data library and resource for the Auckland catchments

- Challenges
  - Characterising rural land use
  - Alignment of different catchment boundaries
  - Processing time
  - Data gaps and deficiencies
  - Data incongruencies – varying use and control



First Pilot Model Runs (No parameter adjustment)

Calibration Metrics (07/01/2006 - 06/30/2017)	Relative Mean Error	Recommended Error Criteria			
		Very Good	Good	Fair	Poor
Total Annual Volume	0.4%	≤ 5%	5 - 10%	10 - 15%	>15%
Highest 10% of Flows	-0.2%	≤ 10%	10 - 15%	15 - 25%	>25%
Lowest 50% of Flows	0.8%	≤ 10%	10 - 15%	15 - 25%	>25%
Annual Storm Volume	6.3%	≤ 10%	10 - 15%	15 - 25%	>25%
Summer Storm Volume	12.7%	≤ 15%	15 - 30%	30 - 50%	>50%
Annual Baseflow Volume	-10.6%	≤ 10%	10 - 15%	15 - 25%	>25%
Baseflow Recession	16.4%	≤ 3%	3 - 5%	5 - 10%	>10%

Calibration Metrics (07/01/2006 - 06/30/2017)	Relative Mean Error				
	Annual	Winter	Spring	Summer	Fall
Seasonal Total Volume	0.4%	-9.1%	-1.3%	4.6%	5.3%
Seasonal Storm Volume	6.3%	-5.1%	8.5%	12.7%	5.2%
Seasonal Baseflow Volume	-10.6%	-19.1%	-22.2%	-6.7%	5.4%
Seasonal Baseflow Recession	16.4%	18.9%	15.6%	13.3%	15.0%
Nash-Sutcliffe Efficiency (E)*	0.81	0.80	0.82	0.85	0.76

* E = 1 Perfect match of modeled to observed
0 < E < 1 Model predictions as accurate as observed mean
E < 0 Observed mean better predictor than model

Performance Metrics

Very Good	Good
Fair	Poor

- Initial results highlight the power of high-resolution model setup for reducing calibration burden (land uses, subwatershed and weather).
- Will adjust baseflow/ groundwater parameters regionally

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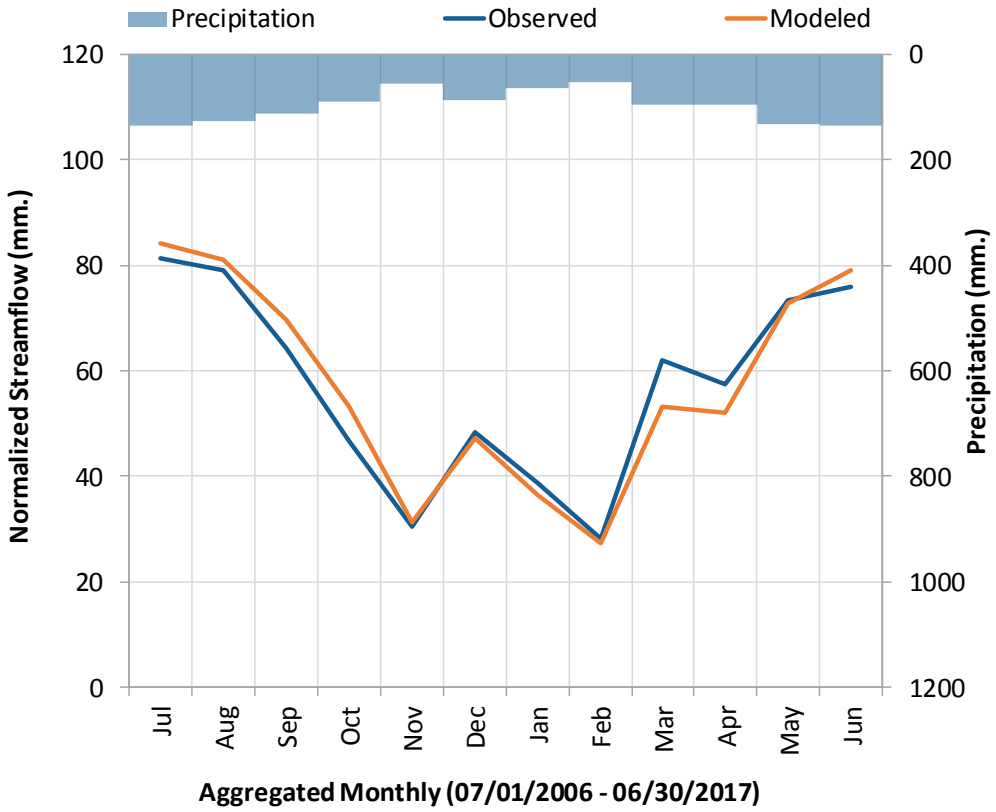

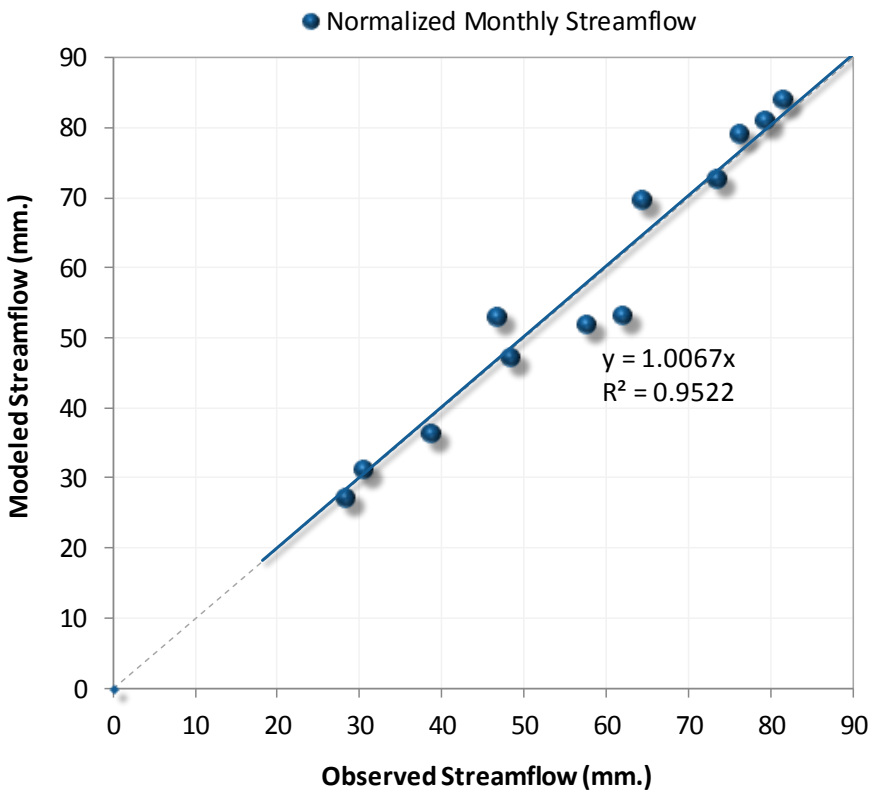

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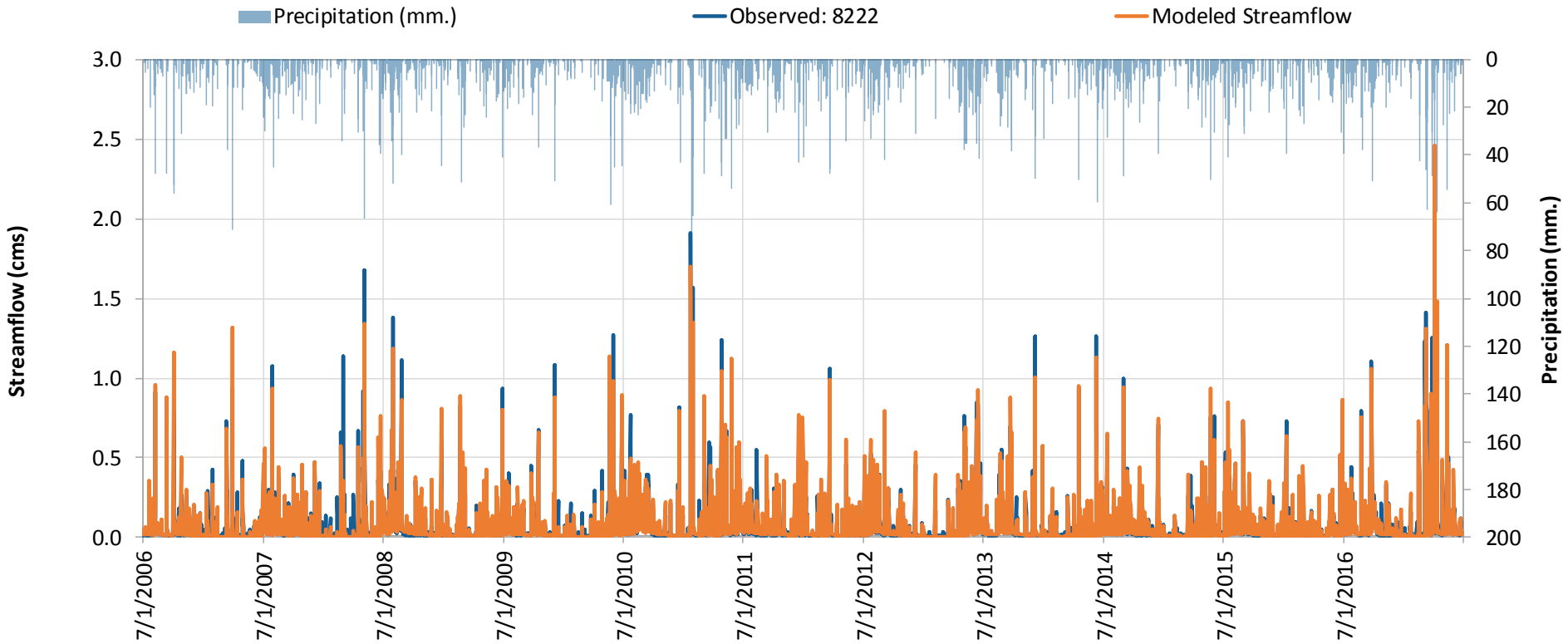

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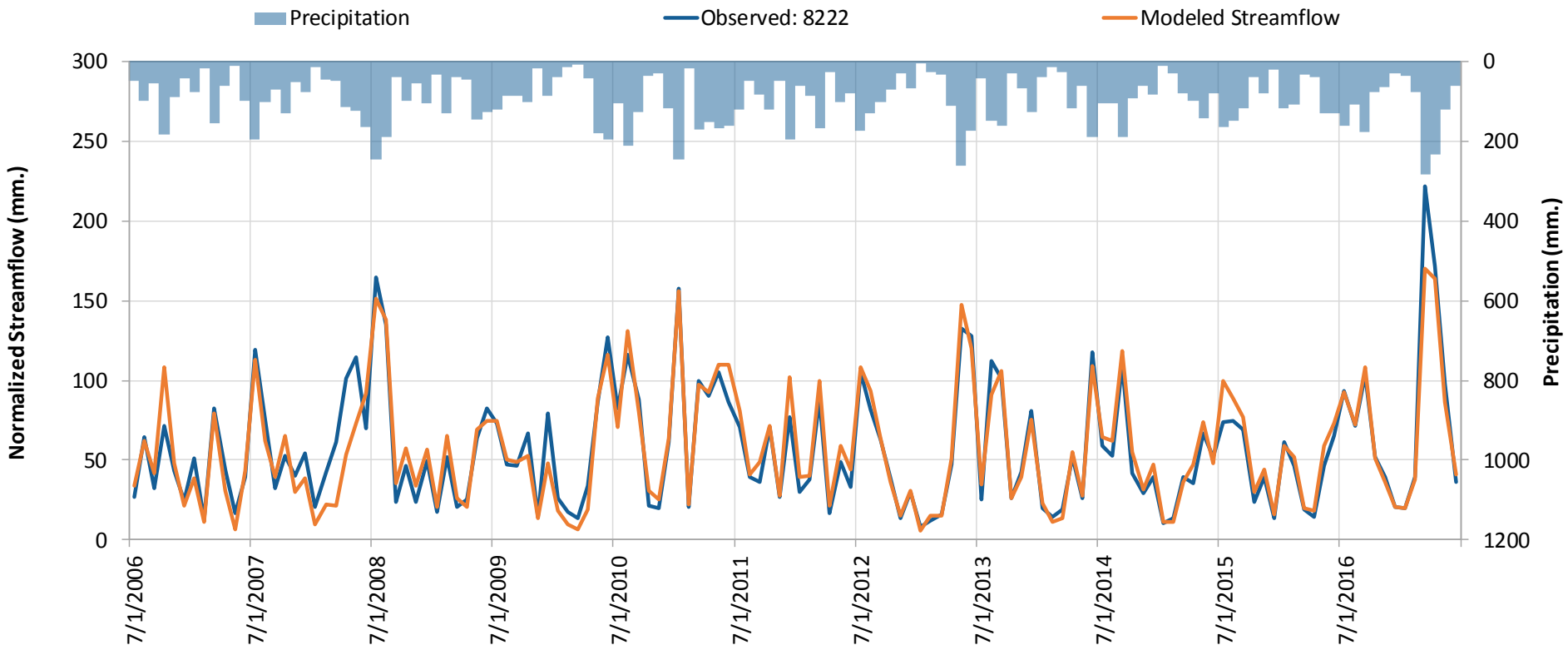
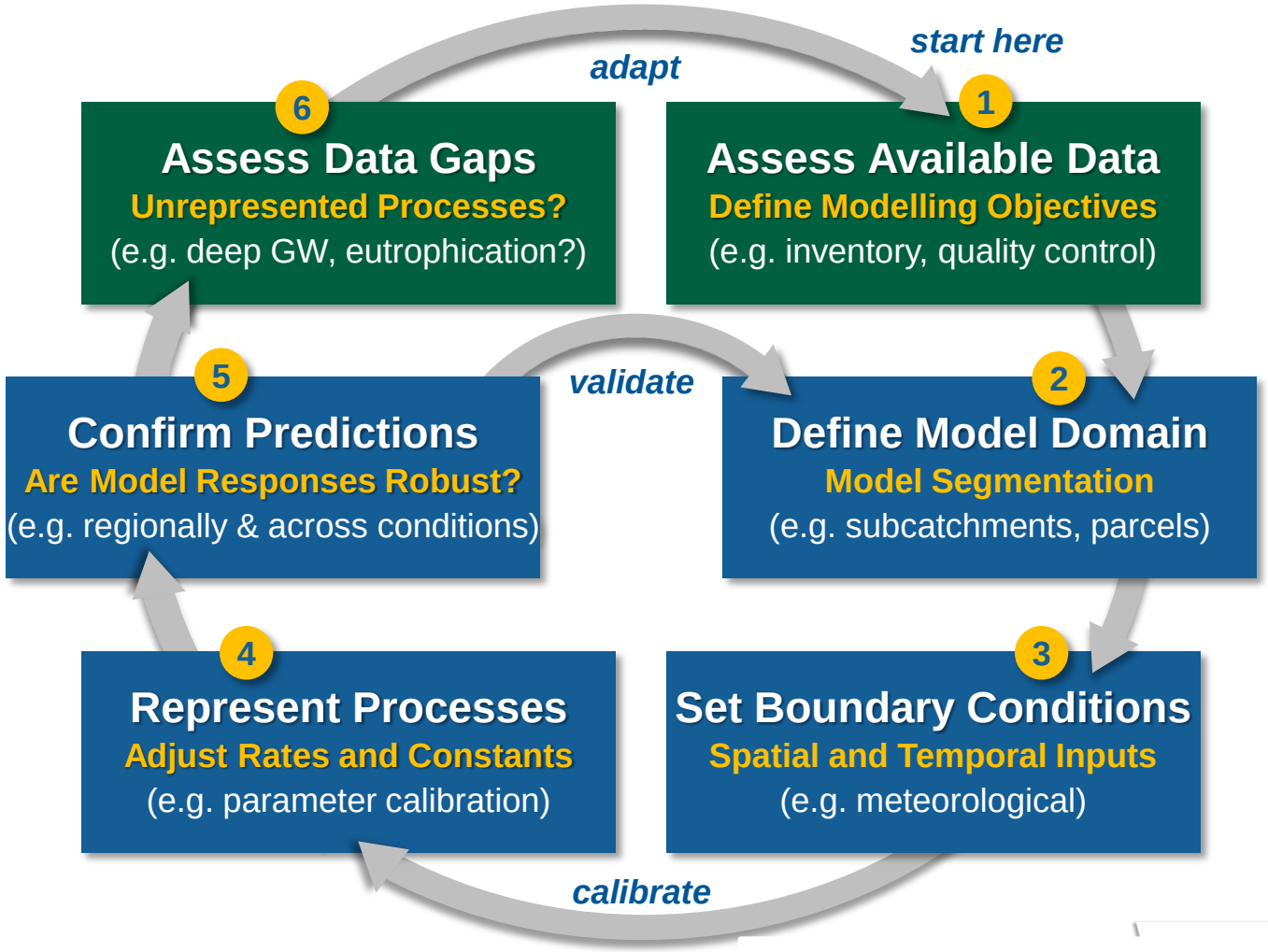


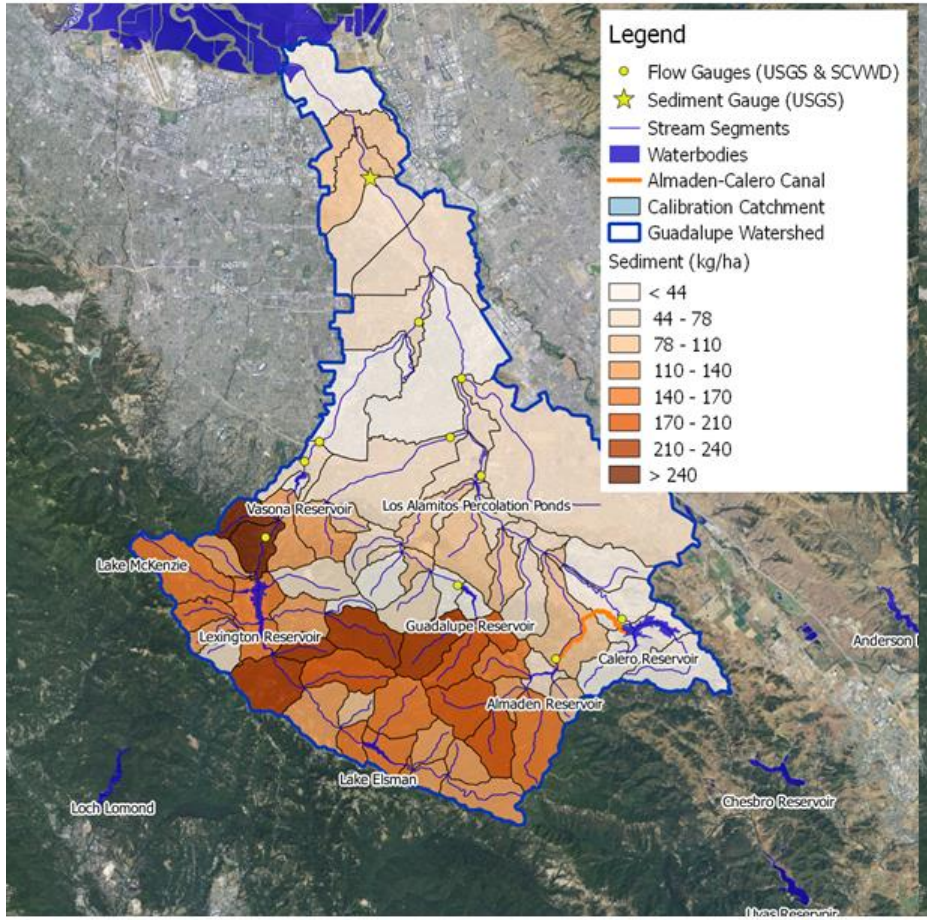
Top-Down Weight-of-Evidence Modelling Approach



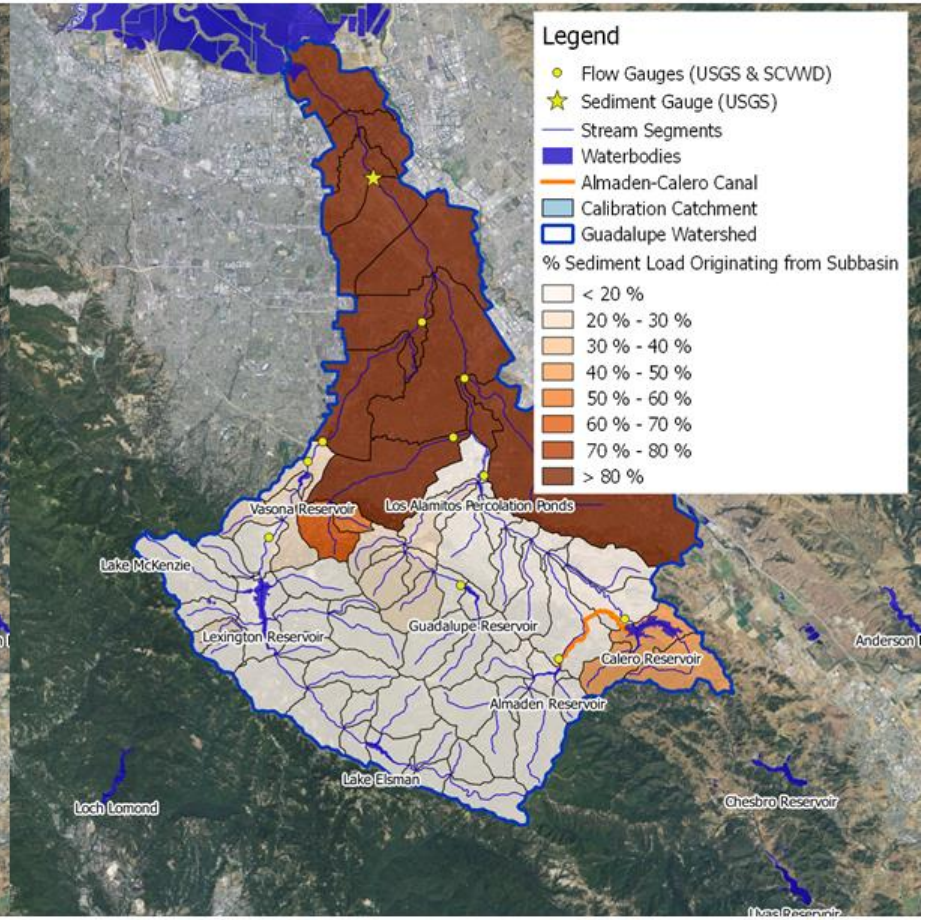
Model Outputs

- The LSPC model for each watershed is being developed and calibrated instream with an emphasis on hourly or finer time series outputs for the following “primary” constituents:
  - Flow rate
  - Sediment (total suspended solids)
  - Bacteria (E. coli *and Enterrococci*)
  - Metals (total zinc and copper)
  - Nutrients (total nitrogen and phosphorous))
- In addition, the LSPC model for each watershed will include outputs for additional “secondary” constituents:
  - Temperature
  - Nutrient species (nitrate, nitrite, organic nitrogen, ammonia, phosphate and organic phosphorous)
  - Dissolved oxygen, biochemical oxygen demand
  - Phytoplankton, chlorophyll-a

Sediment (at Source)



Sediment (Delivered to Mouth)



Average Annual Model Results: 10/1/1999 – 9/30/2015

Determination of yeild at source or after delivery

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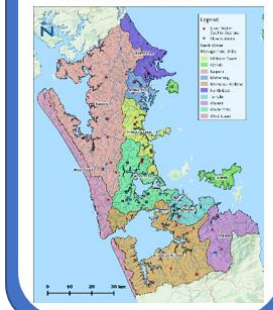

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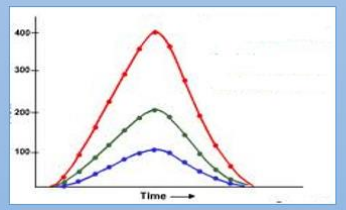

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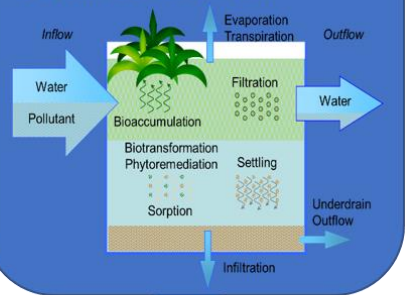

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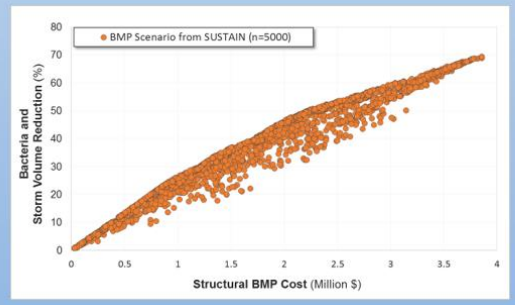
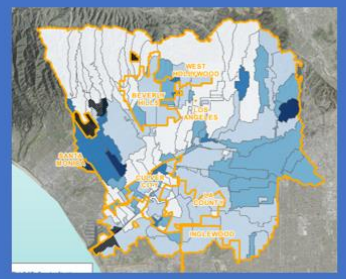


Action Plans for Integrated Watershed Plans



Example Interventions (Urban)

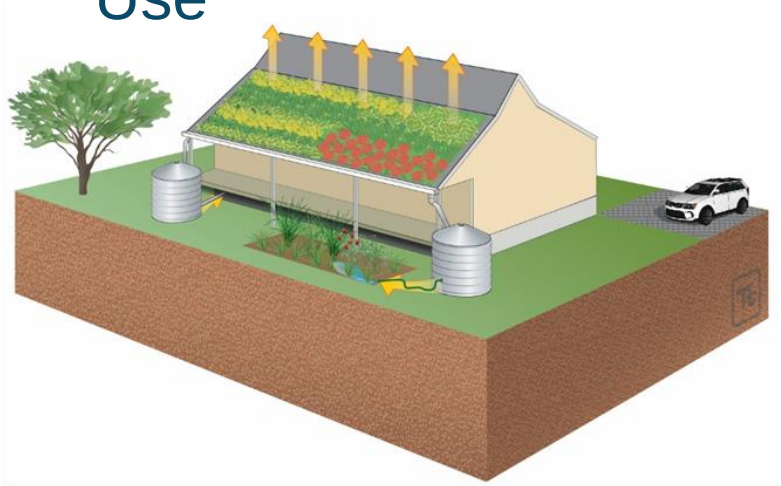
(1) Source Control

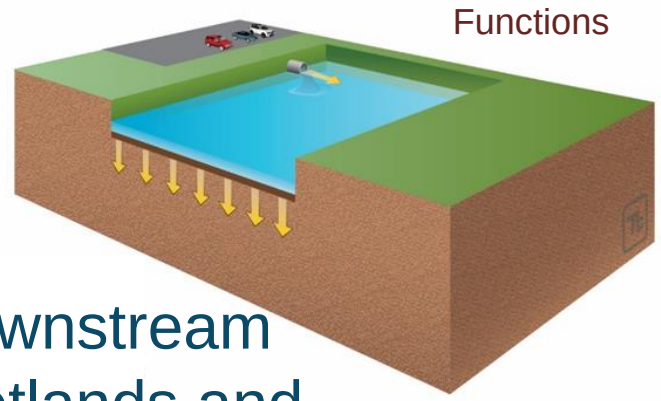
- Enhanced sweeping
- Zinc roof reduction
- Reduced brake pad emissions

(2) Linear Bioretention

With: Opportunities and Cost Functions

(3) Parcel-scale Retention and Use





(4) Downstream Wetlands and Basins

Example Interventions (Rural)

(1) Source Control

- Reduced stock density
- Good farm practices
- Improve onsite WW systems

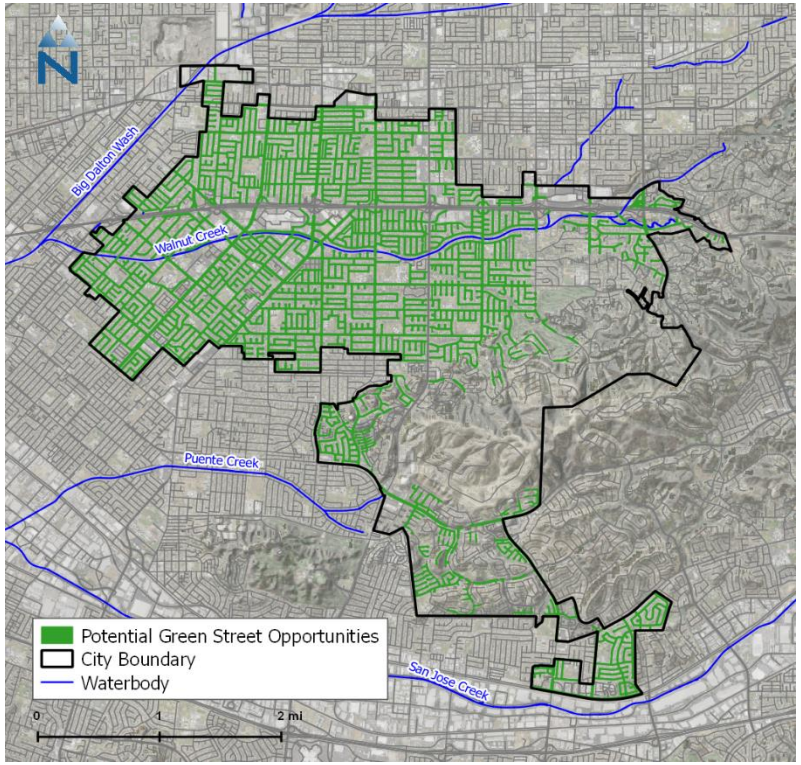
(2) Land Interventions

- Riparian buffers (1m, 5m, …)
- Buffer strips

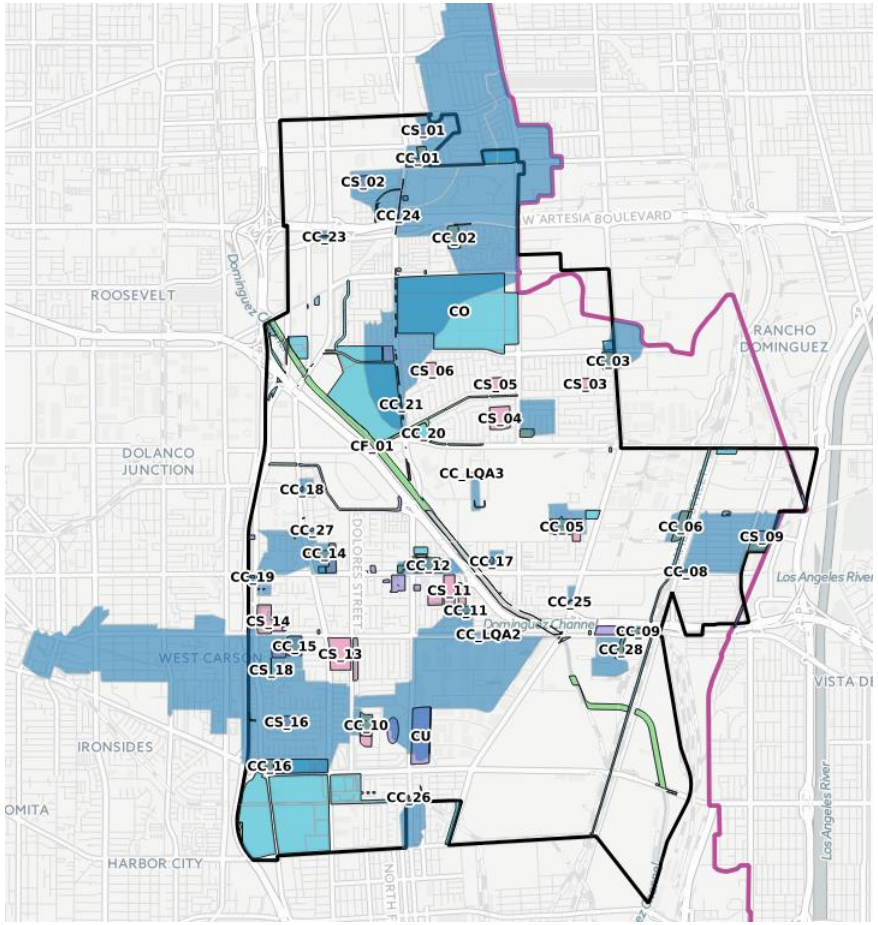
(2) Downstream Wetlands and Basins

Example Opportunity Screening (Max)

Street Retention Opportunity Screening



Infiltration Basin Opportunity Screening



Example Representation of Structural Interventions (SUSTAIN)

Unit Cost Functions

BMP Category	BMP Types	Formulas For Estimating Total Costs [1]	
		Capital Costs	Annual O&M
LID and Green Streets	Bioretention with Underdrain	*Cost = 17.688 (A) + 2.165 (Vt) + 2.64 (Vm) + 3.3 (Vu)*	*Cost = 2.54 (A)*
	Bioretention without Underdrain	*Cost = 9.438 (A) + 2.165 (Vt) + 2.64 (Vm)*	*Cost = 2.54 (A)*
	Residential LID	*Cost = 4.000 (A)*	--
	Permeable Pavement with Underdrain	*Cost = 33.594 (A) + 3.3 (Vu)*	*Cost = 1.74 (A)*
	Permeable Pavement without Underdrain	*Cost = 25.344 (A)*	*Cost = 1.74 (A)*
Regional BMPs	Pump	*Cost = 56,227*(Pump Capacity$_{cfs}$) + $1,207,736*[2]*	
	Regional Project on Public Parcel	*Cost = 10.01 (A) + 2.296 (Vt) + 2.8 (Vm)*	*Cost = 1.918 (A)*
	Regional Project on Private Parcel	*Cost = 139.01 (A) + 2.296 (Vt) + 2.8 (Vm)*	*Cost = 1.918 (A)*

Typical Designs

PA

Table 1-2. Existing, Planned, and Proposed Public LID design criteria

Parameter		Value	Units
Surface	Design Drainage Area	*Sized to capture 85th percentile volume*	
	BMP Footprint		
	Ponding Depth	9	*in.*
Soil	Depth	2	*ft.*
	Media Porosity	0.35	*n/a*
	Media Infiltration Rate	2	*in/hr*
Underdrain	Use underdrain if underlying soils are less than	0.3	*in/hr*
	Depth	1.5	*ft.*
	Media Porosity	0.4	*n/a*
	Subsoil Infiltration Rate	*Match underlying soils*	

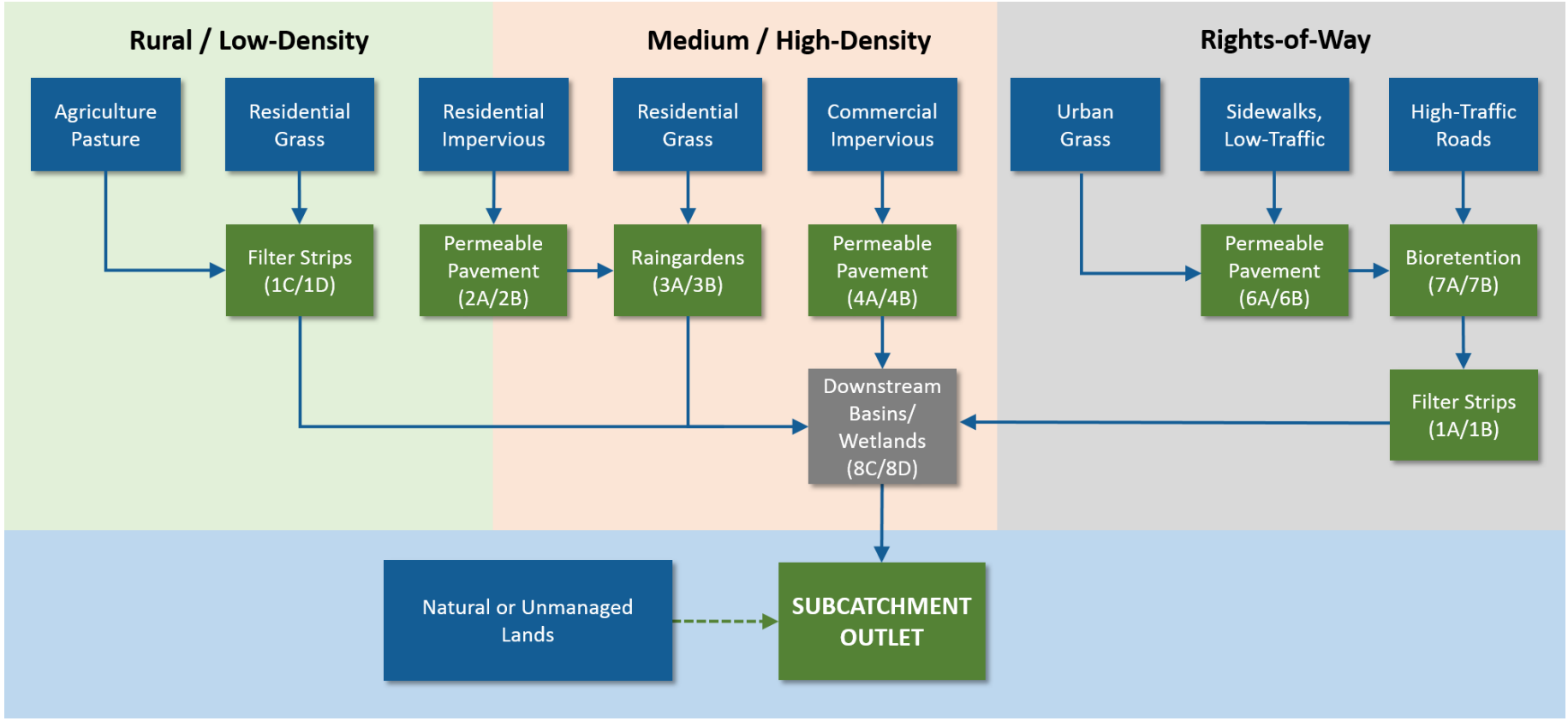
Table 1-3. Regional BMPs on public parcels design criteria

Parameter		Value	Units	Notes
Surface	Design Drainage Area	*Specified explicitly for each Regional BMP*		
	BMP Footprint			
	Ponding Depth	3	*ft*	*Assumed*
	Weir Length	25	*% of width*	*Assumed to allow free overflow*

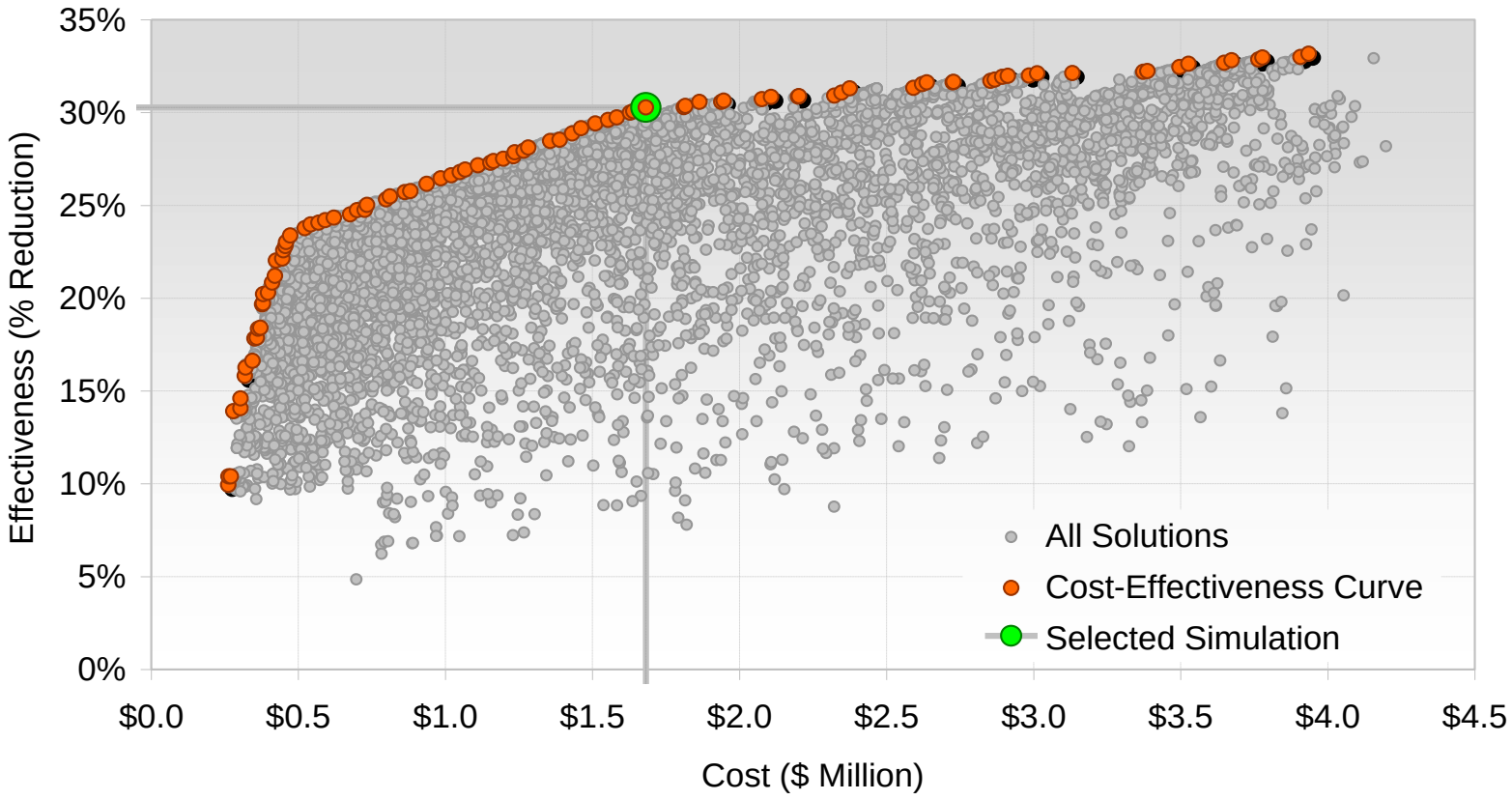
Table 1-4. LID on Private Residential Parcels design criteria

Parameter		Value	Units
Surface	Design Drainage Area	*Sized to capture 85th percentile volume*	
	BMP Footprint		
	Ponding Depth	9	*in.*
Soil	Depth	2	*ft.*
	Media Porosity	0.35	*n/a*
	Media Infiltration Rate	*Match underlying soils*	

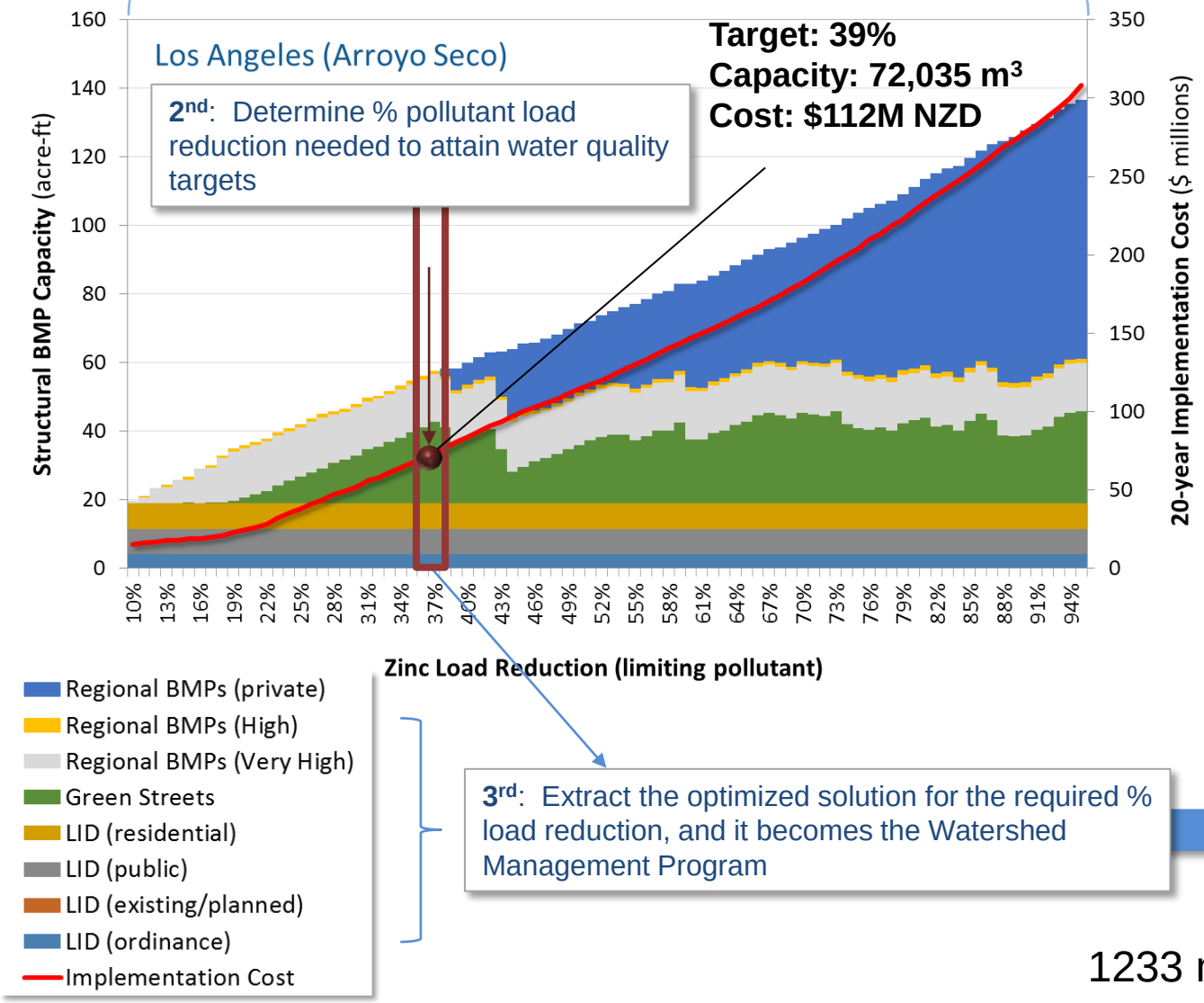
Example Routing Network



Cost Effectiveness Curve



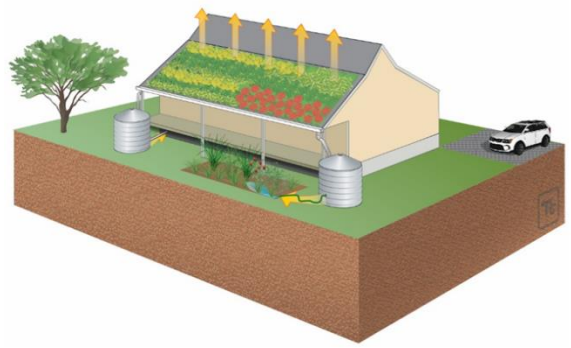
1st: Use cost-optimization to identify solutions to achieve a wide range of contaminant load reductions for each watershed.

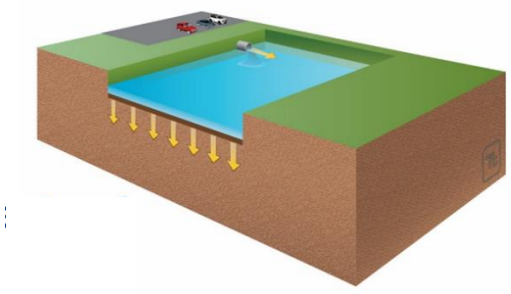


3rd: Extract the optimized solution for the required % load reduction, and it becomes the Watershed Management Program

1233 m^3 = 1 ac-ft

Interventions

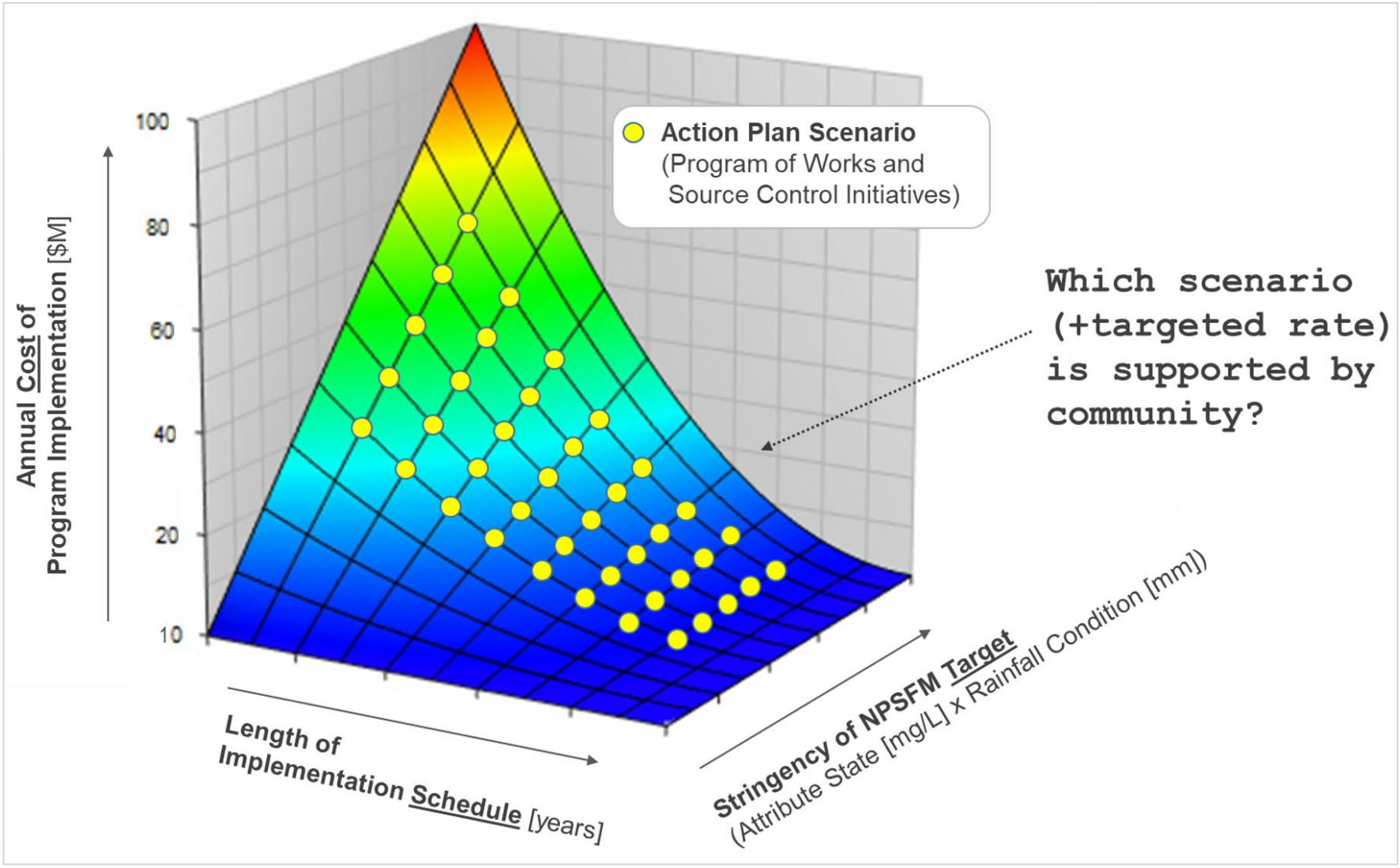




1233 m^3 = 1 ac-ft

Subwatershed ID	COMPLIANCE TARGETS: MEASURABLE AND ENFORCEABLE		EWMP IMPLEMENTATION PLAN: APPROACH TO ACHIEVE COMPLIANCE TARGETS, SUBJECT TO ADAPTIVE MANAGEMENT (BMP capacity expressed in units of acre-feet)								
			Low-Impact Development				Streets	Regional BMPs			
	% Load Reduction Critical Condition	24-hour Volume to be Managed (acre-ft)	Ordinance	Planned LID	Public LID	Residential LID	Green Streets, All Components	Regional BMPs (Very High)	Regional BMPs (High)	Private Regional BMPs	Total BMP Capacity (acre-ft)
640249	9%	1.66	1.03	---	1.36	1.80	0.00	0.00	0.00	0.00	**4.2**
640349	19%	0.94	0.18	---	0.90	0.01	0.36	0.00	0.00	0.00	**1.4**
640449	14%	0.15	0.15	---	0.38	0.03	0.00	0.00	0.00	0.00	**0.6**
640549	67%	26.30	1.14	0.04	0.14	3.14	9.63	13.75	0.00	0.00	**27.8**
640649	84%	13.22	0.31	---	0.54	0.33	3.98	0.00	0.00	6.44	**11.6**
640749	38%	2.70	0.50	0.00	2.07	0.48	2.98	0.00	0.00	0.00	**6.0**
640849	16%	1.94	0.48	---	0.81	1.22	0.35	0.00	1.00	0.00	**3.9**
640949	27%	0.80	0.08	---	0.36	0.02	0.22	0.00	0.00	0.00	**0.7**
641049	39%	1.81	0.12	---	0.07	0.20	0.06	0.00	0.00	0.00	**0.5**
641149	7%	0.09	0.05	---	0.18	0.09	0.35	0.00	0.00	0.00	**0.7**
641449	8%	0.00	0.00	---	---	0.00	0.00	0.00	0.00	0.00	**0.0**
641549	26%	0.52	0.09	---	0.41	0.30	0.05	0.20	0.00	0.00	**1.0**
641649	12%	0.00	0.00	---	---	0.01	0.00	0.00	0.00	0.00	**0.0**
642049	6%	0.00	0.00	---	---	---	0.00	0.00	0.00	0.00	**0.0**
Total	**39%**	**50.1**	**4.1**	**0.0**	**7.2**	**7.6**	**18.0**	**14.0**	**1.0**	**6.4**	**58.4**

Action Planning – Costs and Benefits



FWMT - Looking forward

- Adaptive management
- Program not a plan
- Supports an array of programs and policy decisions
- Adapt and improve strategies through new data
- Incorporate multiple benefits
- Incorporate lessons learned from implementation
- Track progress toward tangible goals

Questions and Discussion

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