WATER ENVIRONMENT FEDERATION
COLLECTION SYSTEMS CONFERENCE
2020

Data Management Tool Facilitates Long Term Flow Reduction

Catherine Morley, PE

Zach Matyja, PE

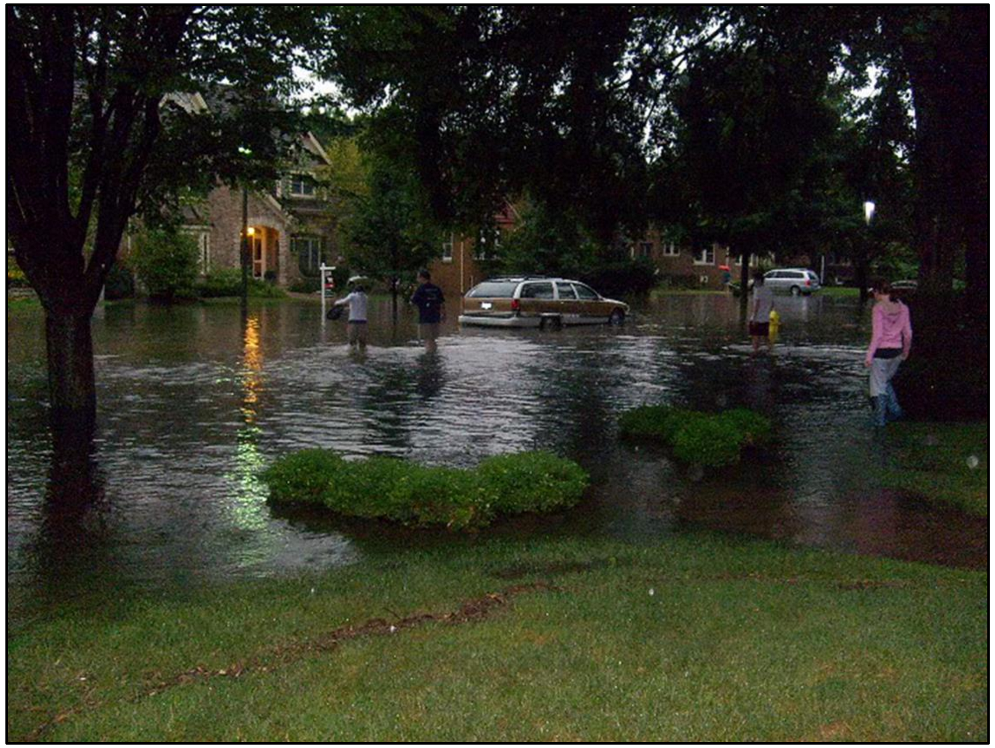
rjngroup
Engineering infrastructure for tomorrow

History

- City just under 50,000
- 143 miles sewer (many formerly combined)
- ADF 4.24 mgd 1-year 60 min storm 70 mgd
- 1987 Consent Order – Comprehensive I/I Reduction
- 36 Permitted Overflows
- 40% Homes Foundation Drains
- Removed 60% excess flow

2010 Storms

- June 23, 2010 – 10-YEAR STORM EVENT
- July 23, 2010 – 100-YEAR STORM EVENT
- City inundated
- Overland flooding
- Hundreds basement backups – mainly south



Sanitary System - 2012

- 12 permitted emergency sewer overflows (ESOs)
- Majority sump pumps removed
- Foundation Drains remaining
- ADF 3.9 mgd
- 1-year 60-minute storm 54 mgd

Consent Order Investigations

- Smoke testing all basins in south
- Manhole inspections
- Building inspections
- Dye flooding of smoking storm structures
- Dye Testing area drains and driveway drains

Consent Order Rehabilitation

- Mainline Lining
- Manhole Rehabilitation
- Remaining Sump Pump Disconnection
- Area Drain removal
- Lateral Rehabilitation – lining replacement
- 5 Permanent Flow Meters

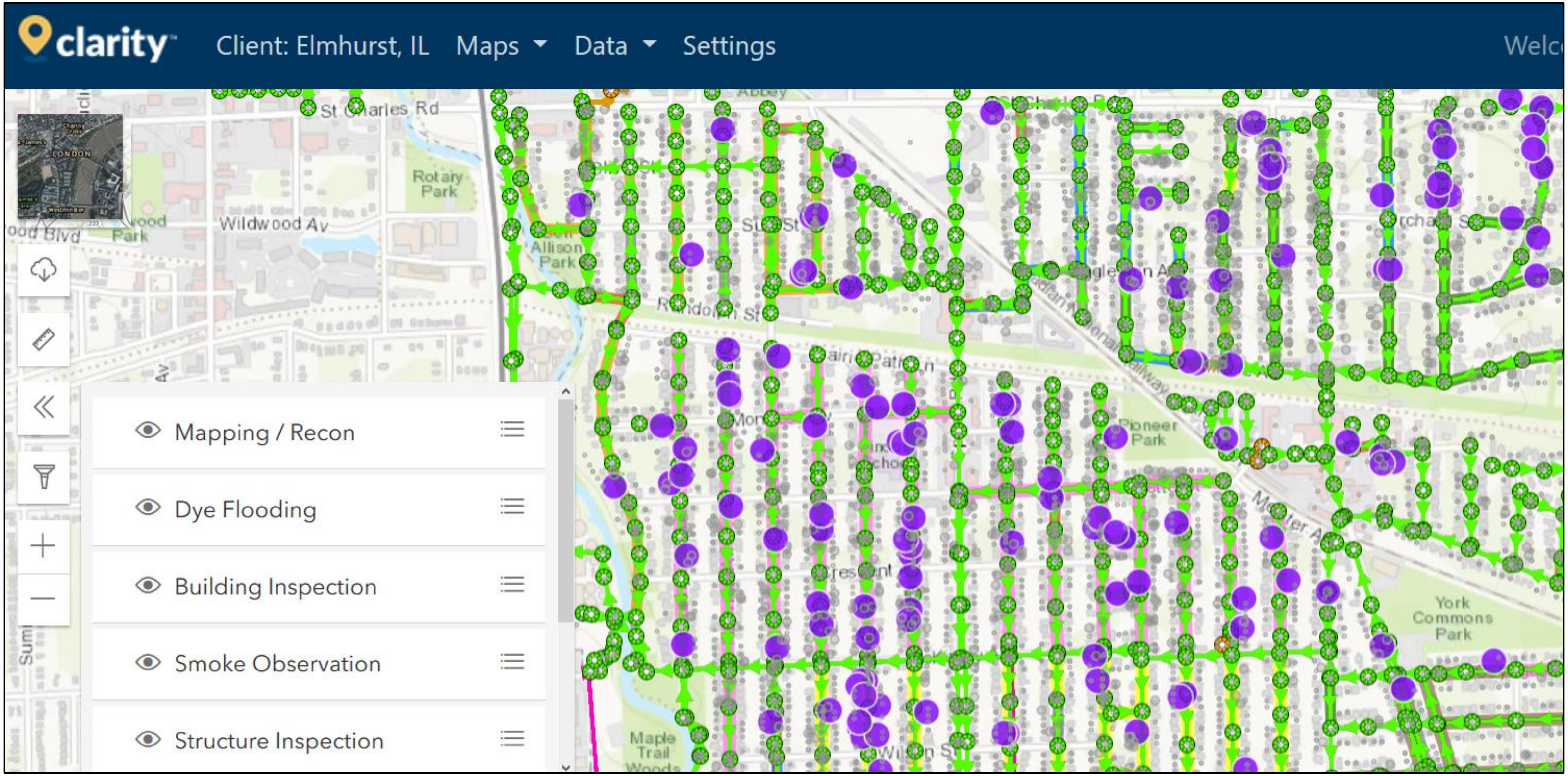
Data Management

- Vast Quantities of Data
- Easily Accessible
- Ability to Query and Filter
- Granular Level
- Tool for Engineering and Public Works
- Flow Monitoring Integration

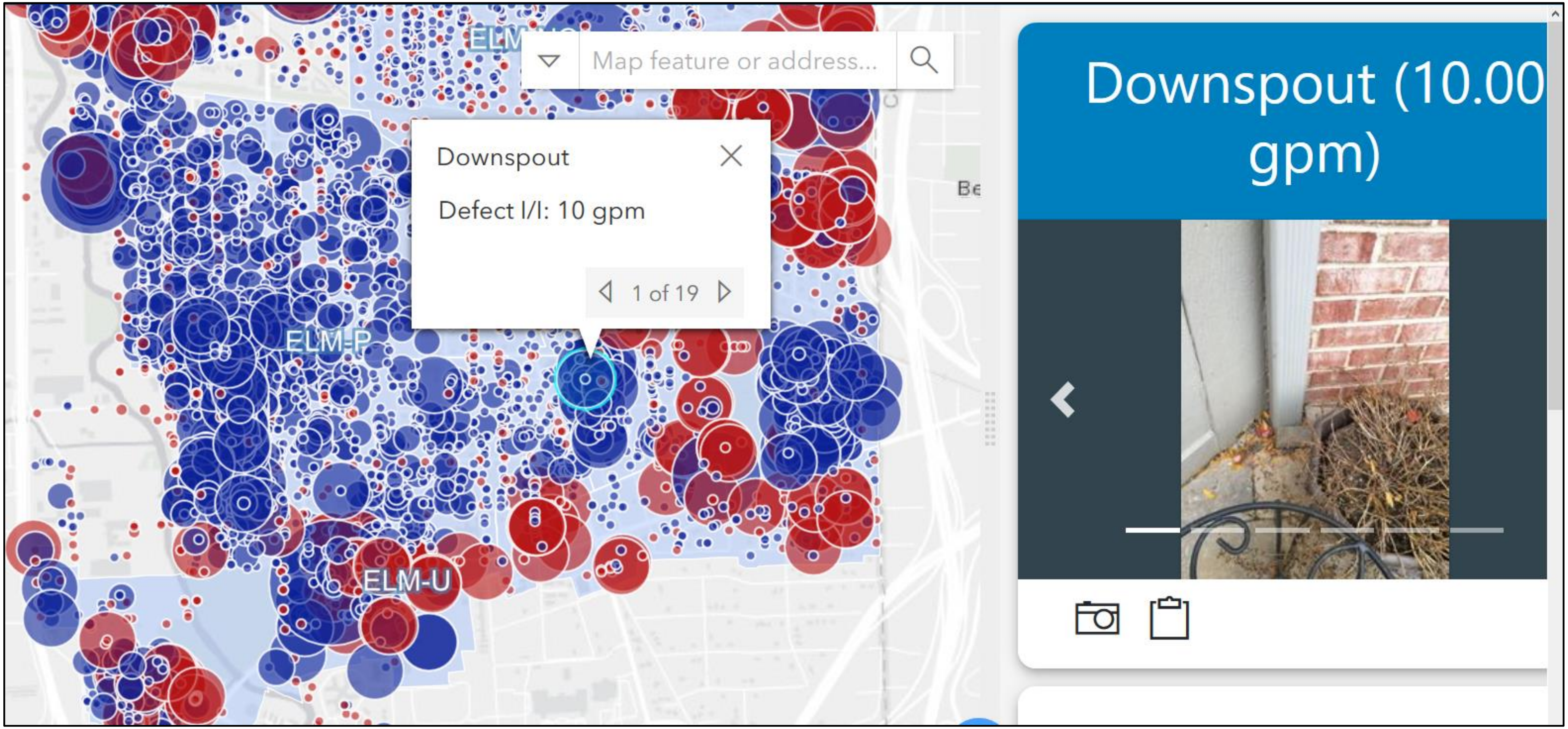
3,000+ Building Inspections
500,000 ft of Smoke Testing
3,500+ Manhole Inspections
900 Laterals Televised
3,000+ Smoke Defects

Poll Question

- How do you access SSES inspection data?
  - Paper/pdf reports and maps
  - GIS
  - Online data platform
  - Other


clarity
Client: Elmhurst, IL
Maps
Data
Settings
Mapping / Recon
Dye Flooding
Building Inspection
Smoke Observation
Structure Inspection
St Charles Rd
Wildwood Av
Rotary Park
Allison Park
Randolph St
Pioneer Park
York Commons Park
Maple Trail Woods

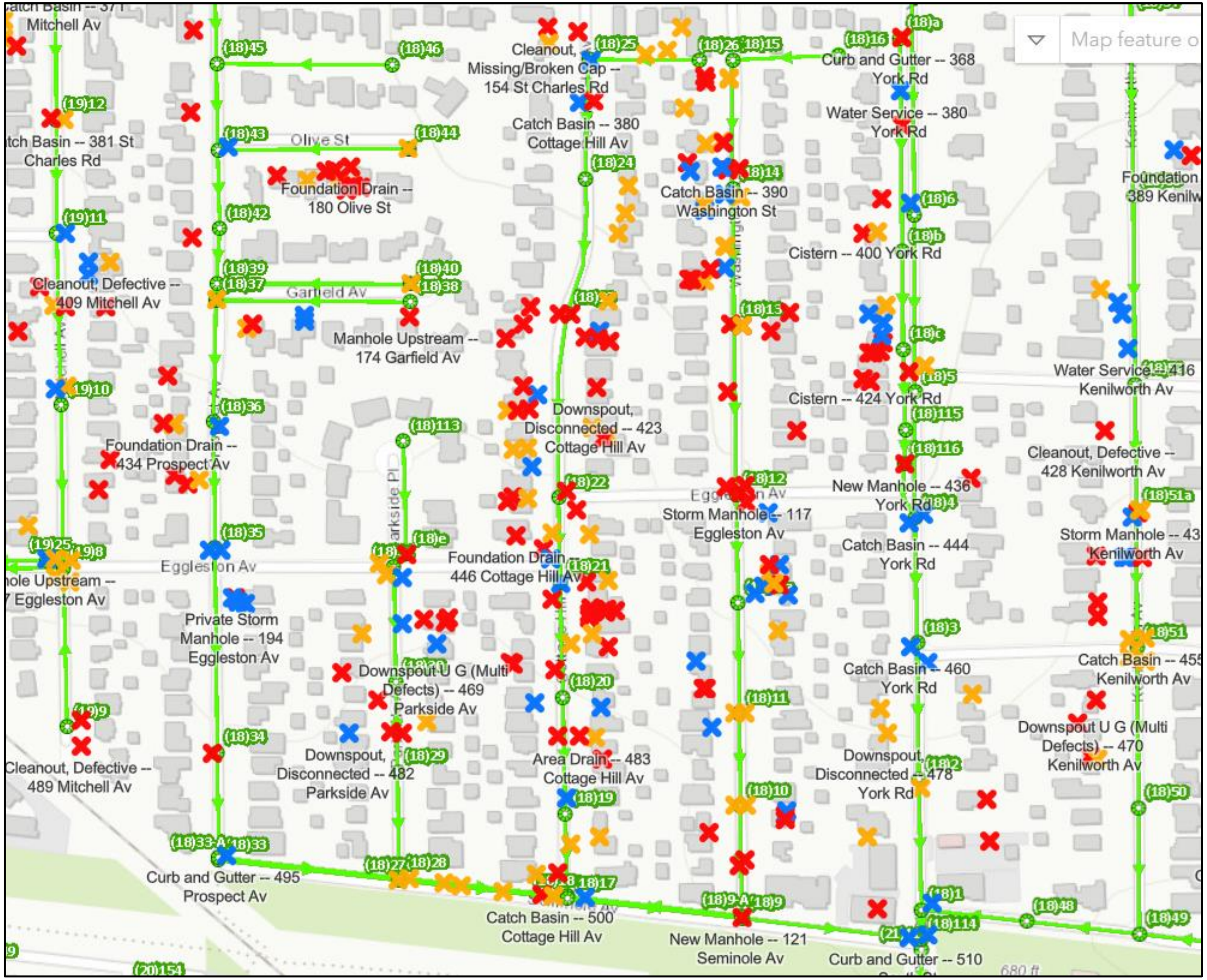
Public/Private



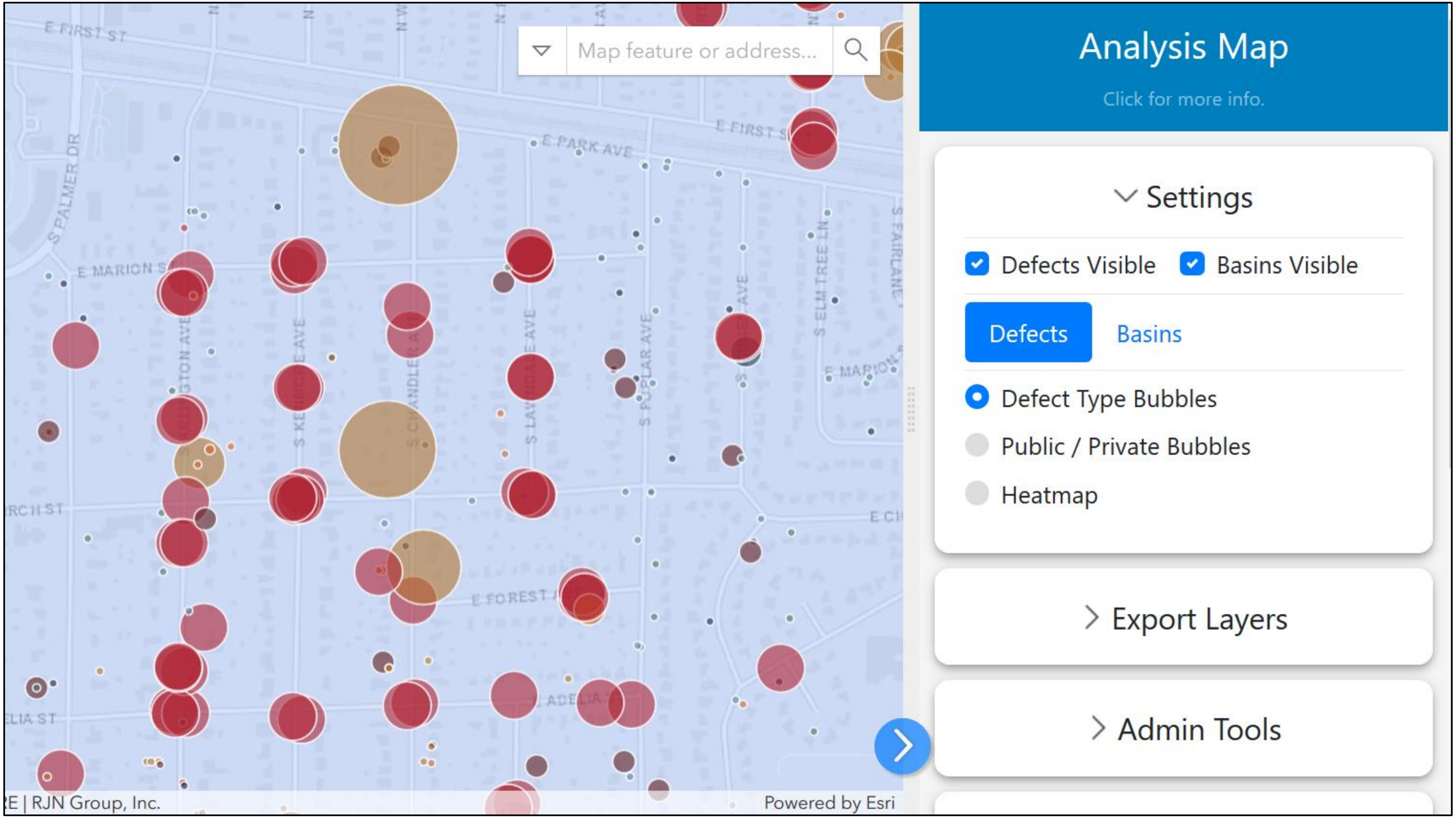
Heat Maps

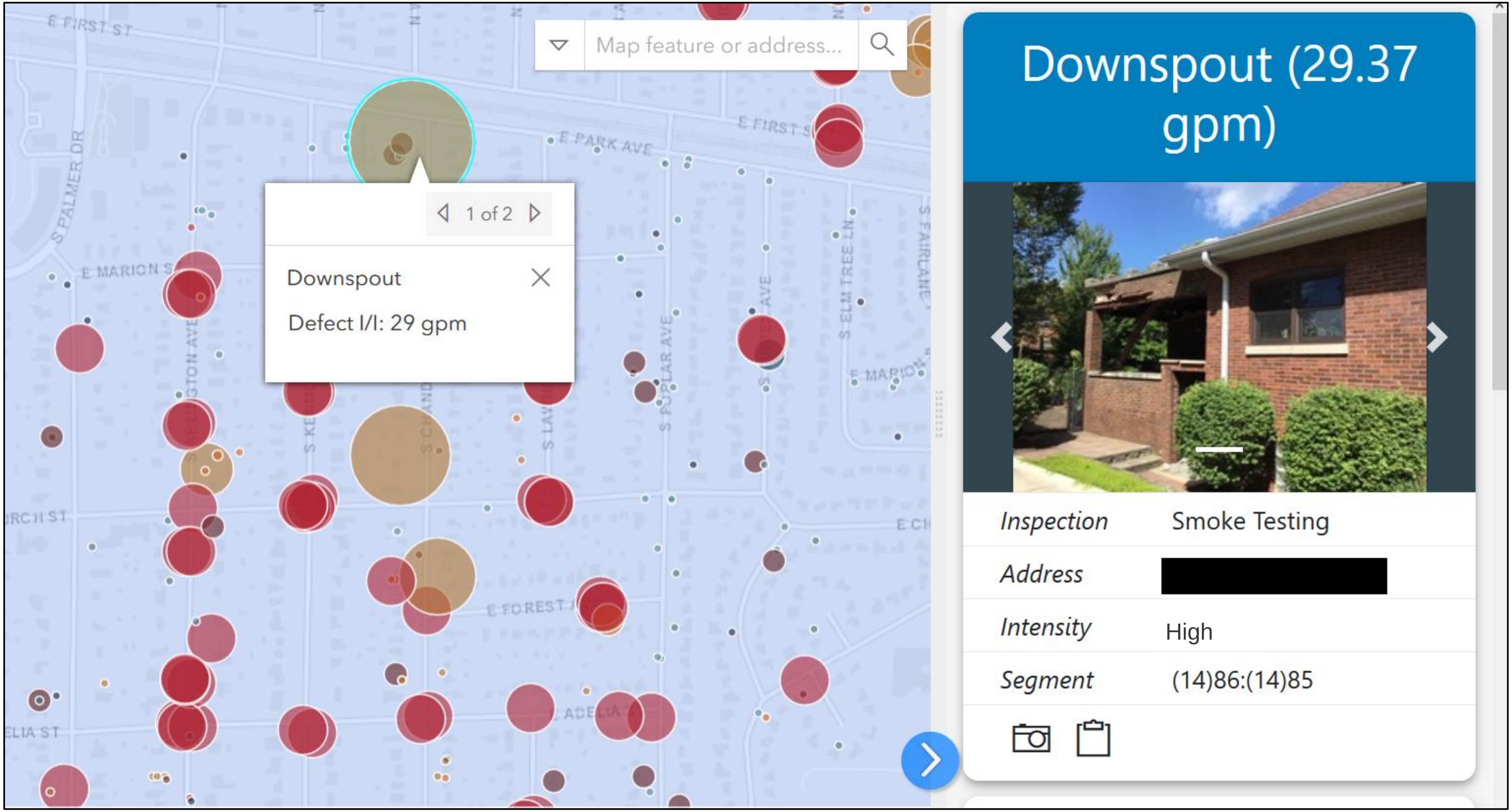
Basin 18
Basin 19
Basin 20
Basin 22
Basin 23
Basin 24
Basin 27
Berkley and Adams Pump Station
Saylor and Jackson Pump Station
Atrium Pump Station
Legend
Manholes
Pump Stations
Gravity Mains
Force Mains
Low Density of Flow
Medium Density of Flow
High Density of Flow
Smoke Tested City Basins
Roosevelt Rd
Butterfield Rd
Tri State Tollway

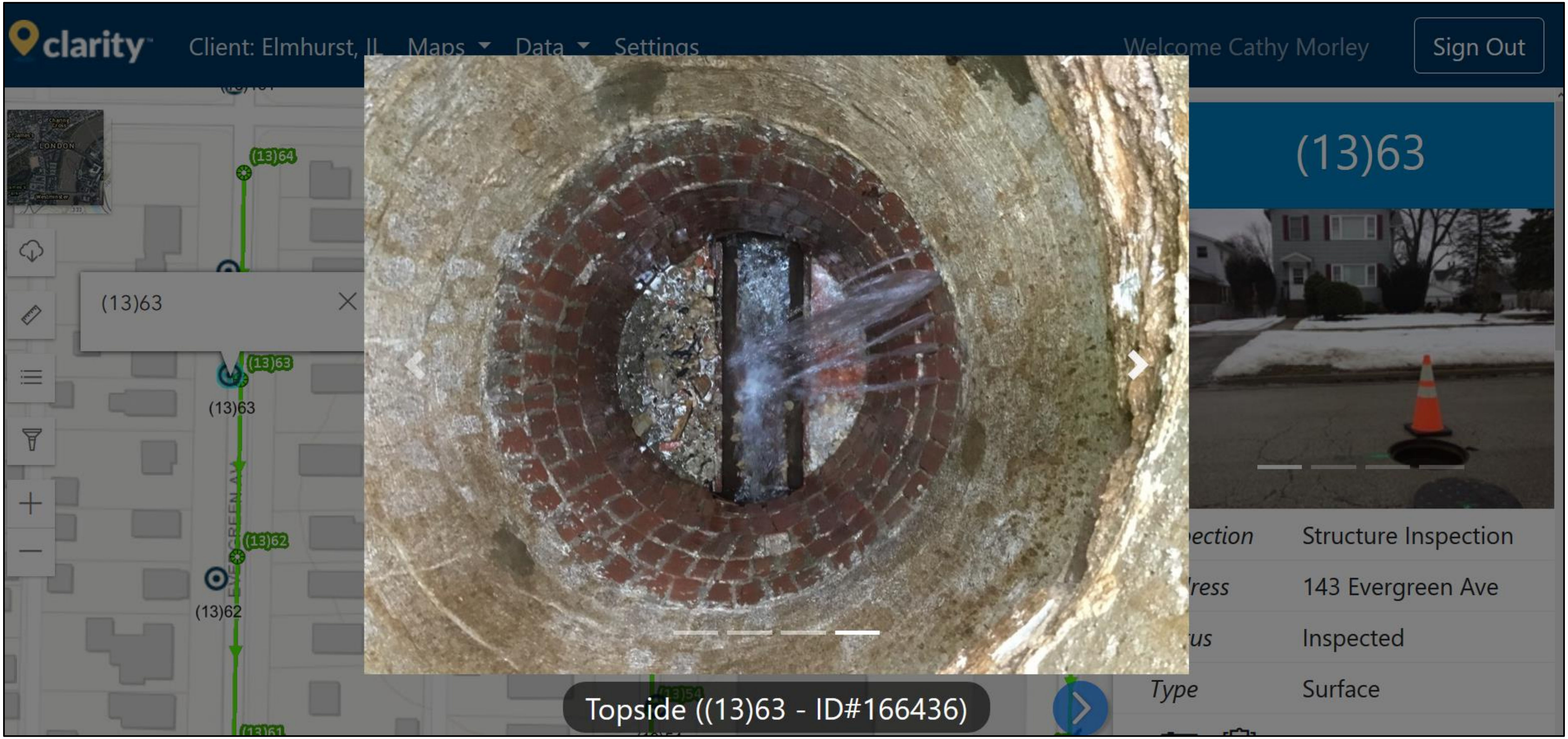
Detailed Data



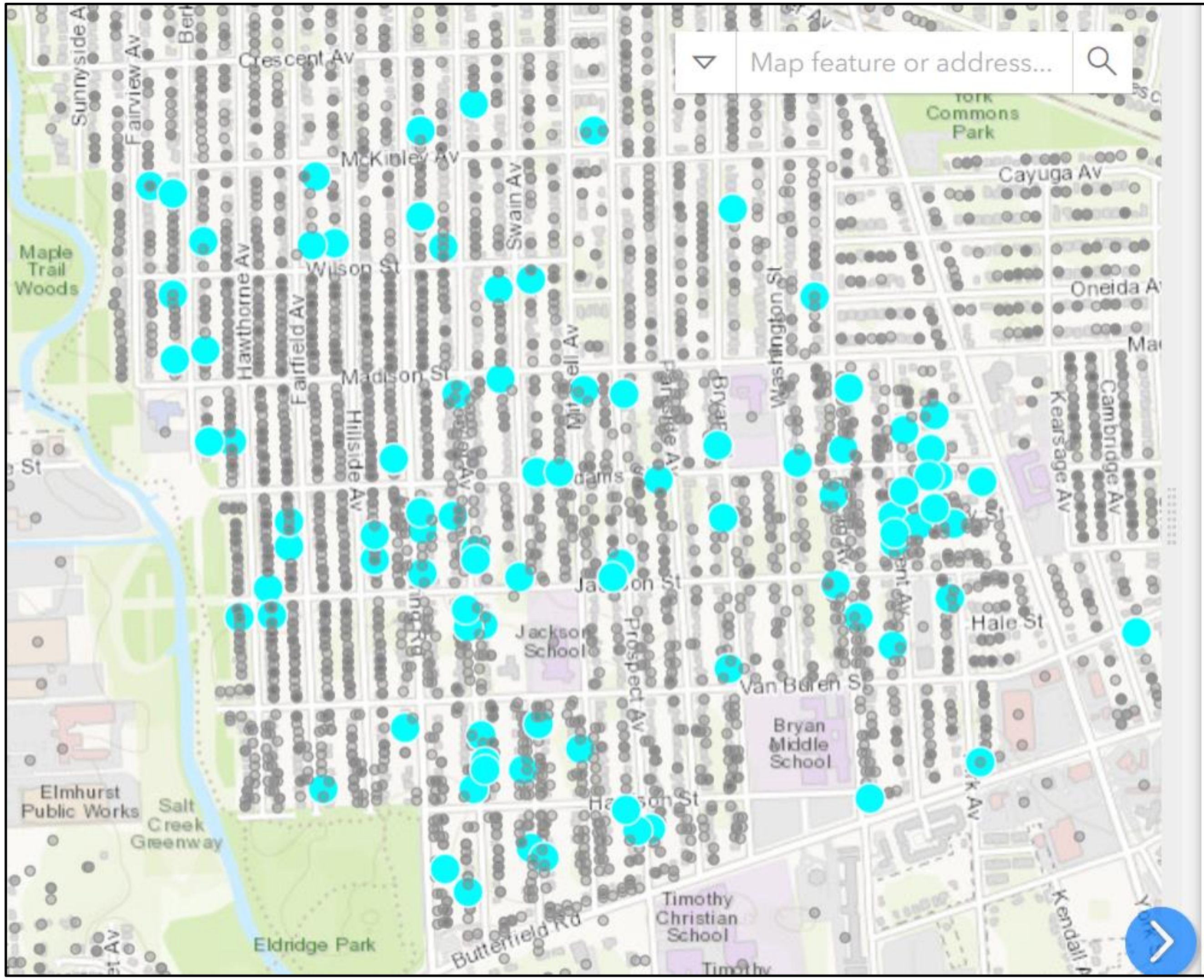
Catch Basins


Map feature or address...
Analysis Map
Click for more info.
Settings
Defects Visible
Basins Visible
Defects
Basins
Defect Type Bubbles
Public / Private Bubbles
Heatmap
Export Layers
Admin Tools
E FIRST ST
E PARK AVE
E FOREST
RJN Group, Inc.
Powered by Esri


E FIRST ST
E PARK AVE
S PALMER DR
E FOREST
Map feature or address...
1 of 2
Downspout
Defect I/I: 29 gpm
Downspout (29.37 gpm)
Inspection
Smoke Testing
Address
[redacted]
Intensity
High
Segment
(14)86:(14)85


clarity
Client: Elmhurst, IL
Maps
Data
Settings
Welcome Cathy Morley
Sign Out
(13)63
(13)64
(13)62
(13)61
Structure Inspection
143 Evergreen Ave
Inspected
Type
Surface
Topside ((13)63 - ID#166436)

Building Diverter Valves



Recent Inspections

Query

Color

Size

Inspection Type

Building Inspection

Criteria #1

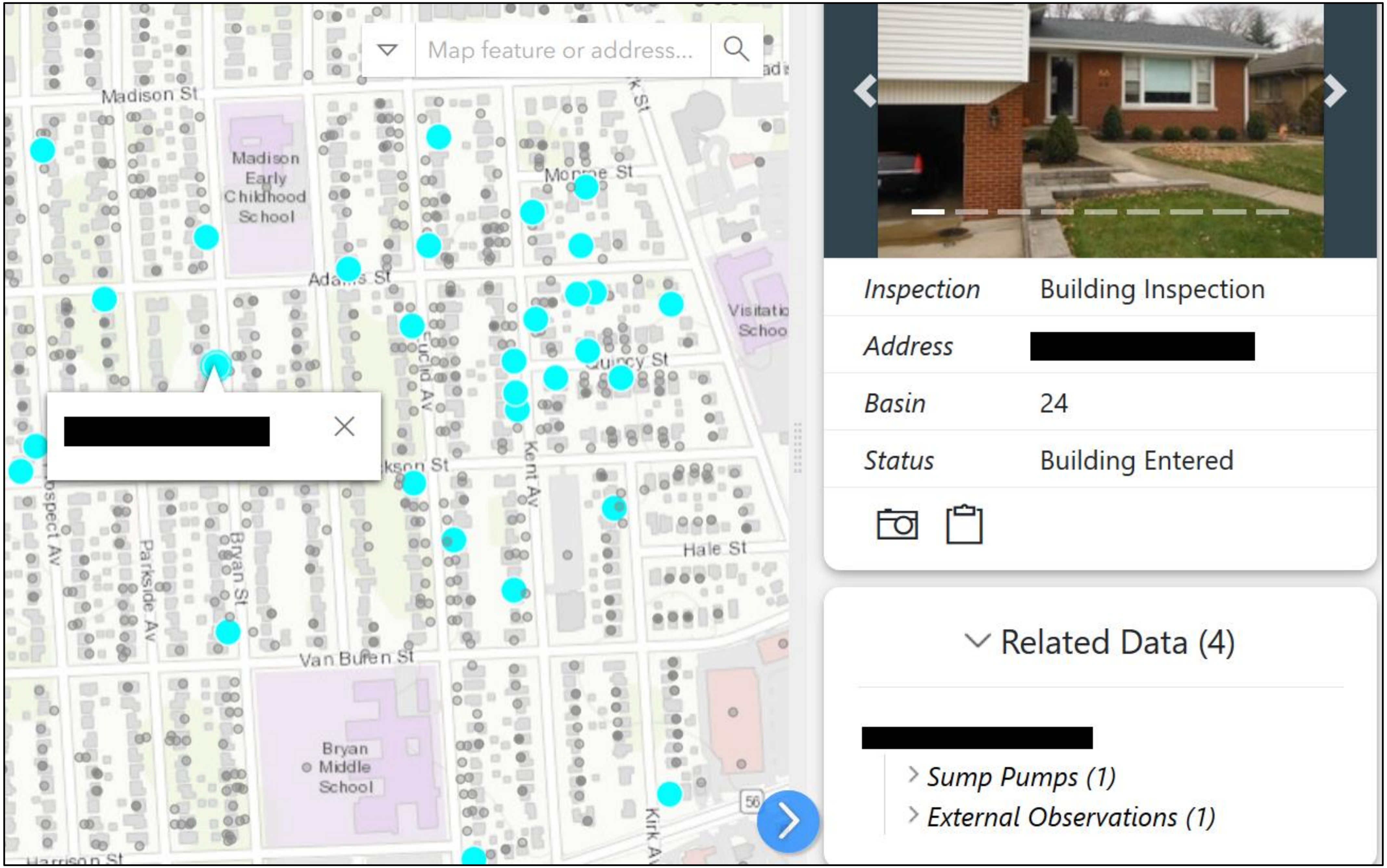
Data Type

Sump Pump

Diverter Valve

= Yes

'Diverter Valve' = "Yes"


Map feature or address...
Madison St
Madison Early Childhood School
[redacted]
Kent Av
Hale St
Parkside Av
Bryan St
Van Buren St
Bryan Middle School
Inspection Building Inspection
Address [redacted]
Basin 24
Status Building Entered
Related Data (4)
[redacted]
Sump Pumps (1)
External Observations (1)

clarity

Data Sheet Viewer

Print | New Tab

Building Type	Residential
Foundation Type	Partial Basement
Previous Flooding	No
Sanitary Pipe Discharge	Above Basement Floor
Has Stand Pipe	No
Lot Drainage Adequate	Yes
Has Flood Control	No
Basement Grade	7 ft
Basement Length	23 ft
Basement Width	22 ft

Discharge - Storm Sump

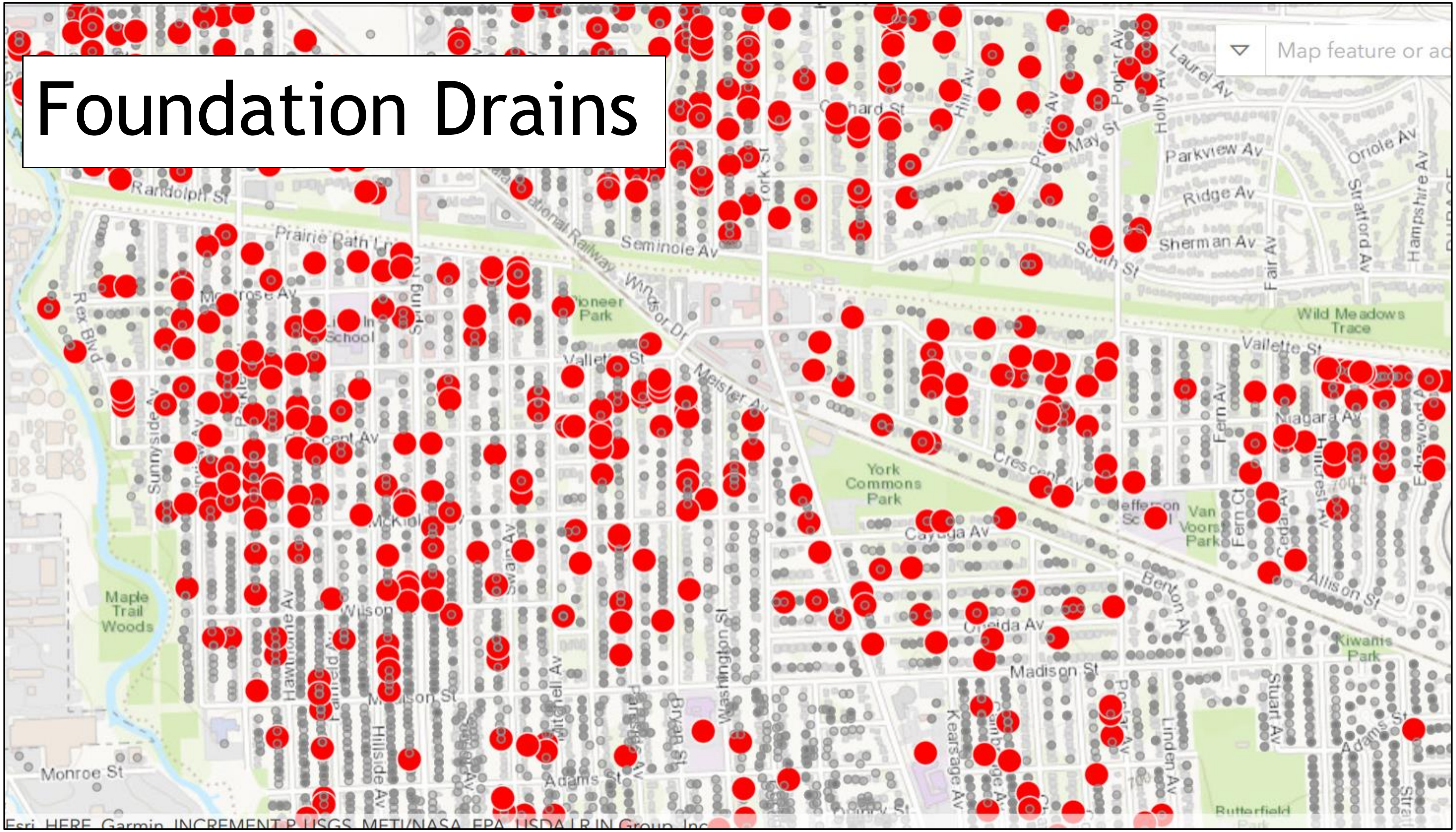
Sump Pump: Storm Sump

Sump Info

Sump Pump Type	Storm
Cover Type	Loose
Check Valve	Yes
Diverter Valve	Yes
Sealed Bottom	Unknown
No Services	No
Sink	No

Pipes - Storm Sump

Foundation Drains



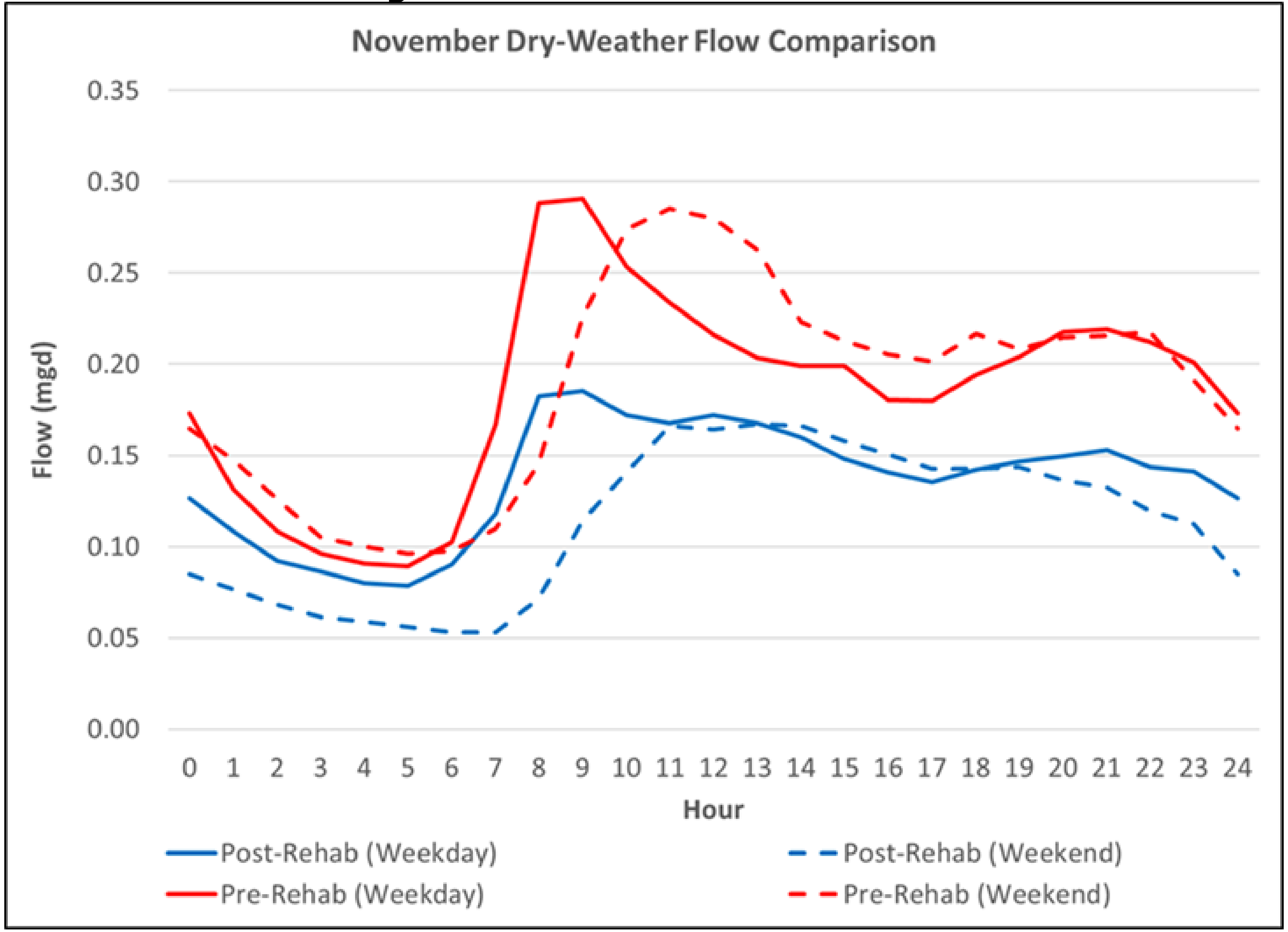
Poll Question

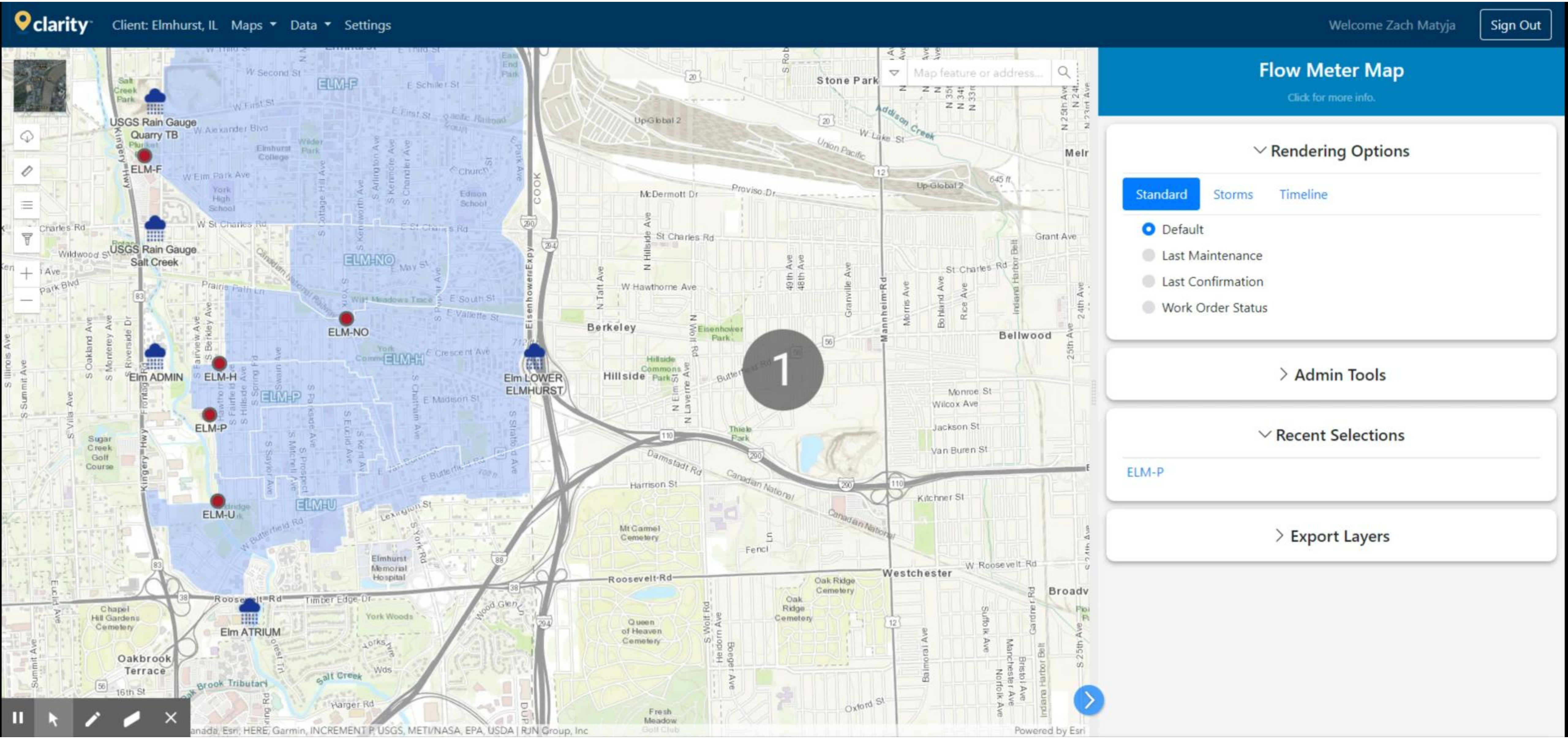
- How do you access flow monitoring data?
  - Paper/pdf reports
  - SCADA
  - Online data platform
  - Other

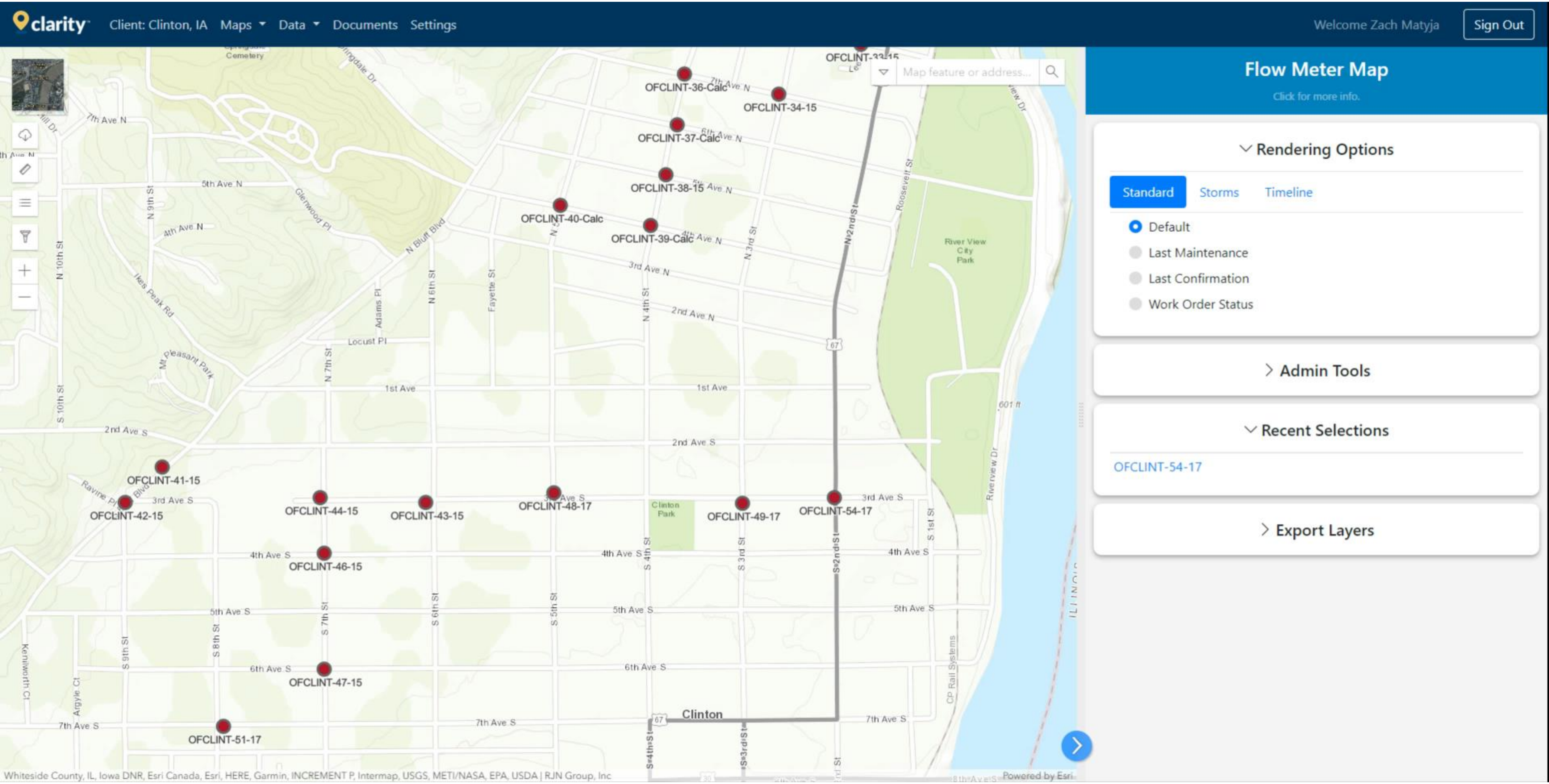
Flow Monitoring

- Gain a long-term understanding of system
- Monitor downstream control
- Long-term analysis of Pilot Basin “N-O”

Basin “N-O” Dry-Weather Flow Analysis




clarity
Client: Elmhurst, IL
Maps
Data
Settings
Welcome Zach Matyja
Sign Out
Map feature or address...
Flow Meter Map
Click for more info.
Rendering Options
Standard
Storms
Timeline
Default
Last Maintenance
Last Confirmation
Work Order Status
Admin Tools
Recent Selections
ELM-P
Export Layers
USGS Rain Gauge Quarry TB
USGS Rain Gauge Salt Creek
ELM-F
ELM-NO
ELM-H
ELM-P
ELM-U
Elm ADMIN
Elm LOWER ELMHURST
Elm ATRIUM
1
Powered by Esri


clarity
Client: Clinton, IA
Maps
Data
Documents
Settings
Welcome Zach Matyja
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Flow Meter Map
Click for more info.
Rendering Options
Standard
Storms
Timeline
Default
Last Maintenance
Last Confirmation
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OFCLINT-54-17
Export Layers
Map feature or address...
OFCLINT-36-Calc
OFCLINT-34-15
OFCLINT-37-Calc
OFCLINT-38-15
OFCLINT-40-Calc
OFCLINT-39-Calc
OFCLINT-41-15
OFCLINT-42-15
OFCLINT-44-15
OFCLINT-43-15
OFCLINT-48-17
OFCLINT-49-17
OFCLINT-54-17
OFCLINT-46-15
OFCLINT-47-15
OFCLINT-51-17
Clinton
River View City Park
Clinton Park
Whiteside County, IL, Iowa DNR, Esri Canada, Esri, HERE, Garmin, INCREMENT P, Intermap, USGS, METI/NASA, EPA, USDA | RJN Group, Inc
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Conclusions/Wrap-up

- City is making progress on flow reduction
- Online platform has made it easy for all levels in the City to view data
- Future efforts including completed rehabilitation layer and overflow alarming will increase value to the City

Questions?

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rjn group
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FROM FEAST TO FAMINE

Adapting Your Asset Management Plan based on Data Availability

Ellen McDonald, PhD, PE
Reza Malek, PhD

PLUMMER

"Asset management is the practice of **managing** infrastructure **capital assets** to **minimize the total cost** of owning and operating them, while **delivering the service level** customers desire." - USEPA

Likelihood of Failure (LOF) x Consequence of Failure (COF) = Risk

Calculation of Risk is Data-Dependent

Likelihood of Failure (LOF) x Consequence of Failure (COF) = Risk

- Age
- Material
- Condition

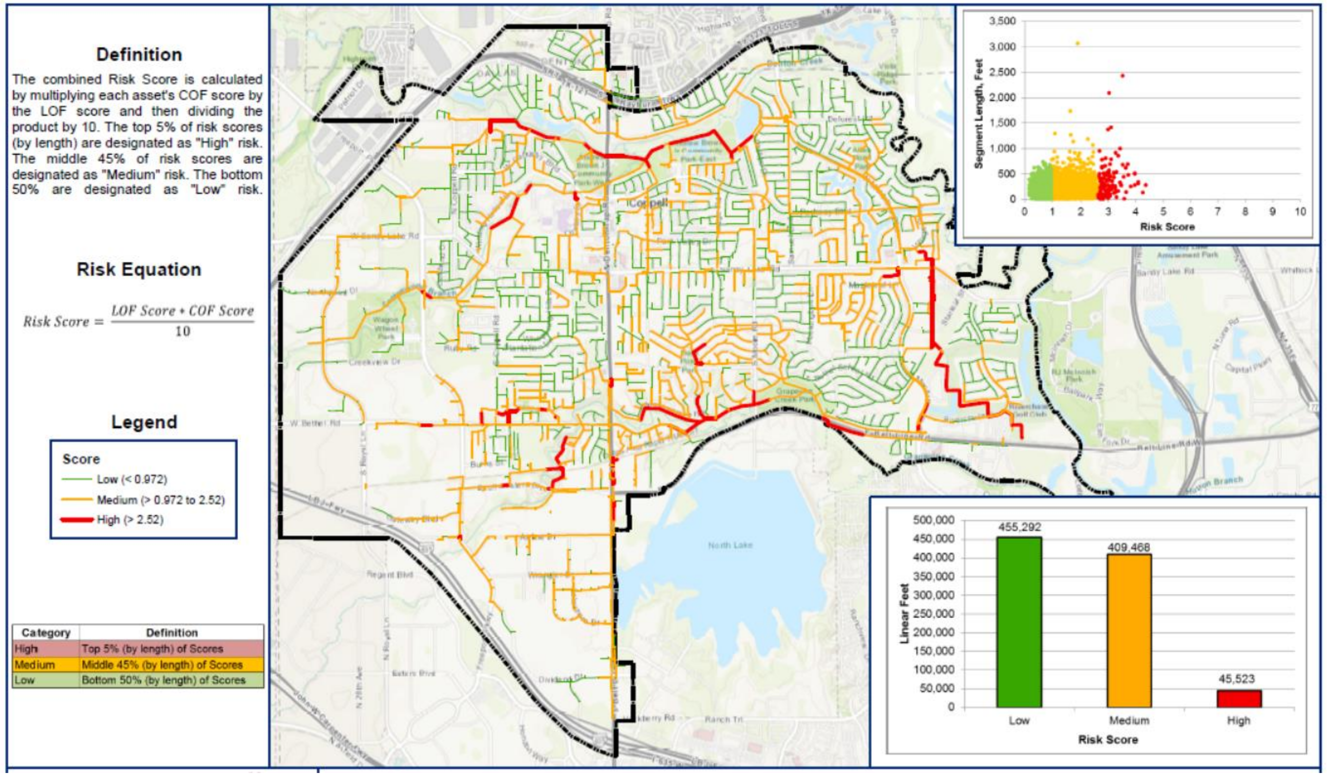
- Proximity to:
  - Major roads
  - Water bodies
- Size/Flow Capacity

Dependent upon Electronic Data

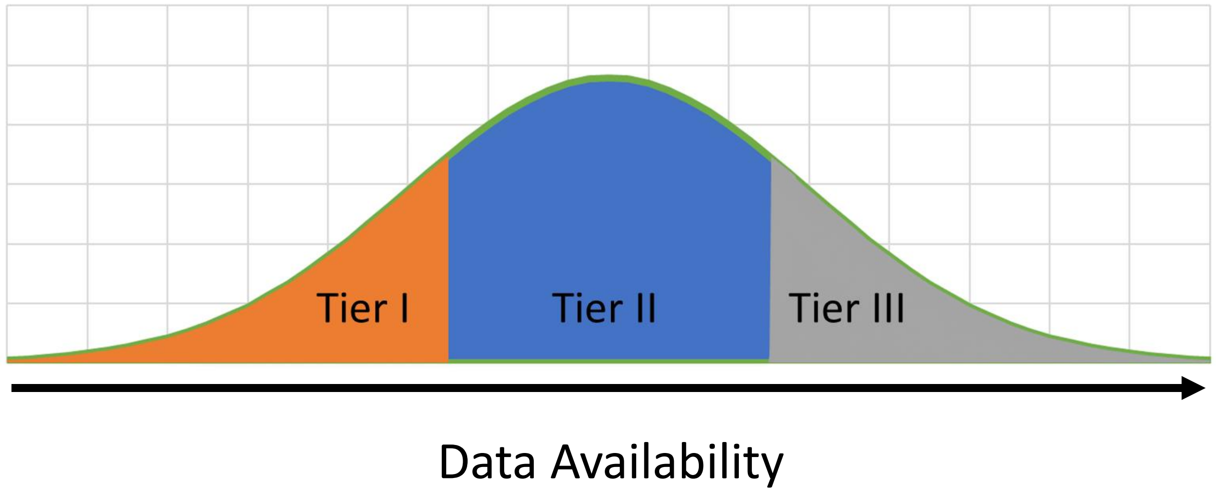
Risk Prioritization Provides Process for Spending $$ Where Needed Most

Example Results

Inspection Year	Risk Rank[1]	Total Footage (LF)	Manhole Inspections (Approx. #)	Opinion of Probable Cost[2]	High Risk Assets Inspected (%)	Medium Risk Assets Inspected (%)
2020	1 to 134	45,553	139	$283,000	100%	-
2021	135 to 303	45,308	164	$285,000	-	11%
2022	304 to 447	45,591	130	$282,000	-	11%
2023	448 to 614	45,541	143	$283,000	-	11%
2024	615 to 791	45,530	153	$285,000	-	11%
2025	792 to 1,000	45,352	177	$287,000	-	11%
2026	1,001 to 1,193	45,518	146	$284,000	-	11%
2027	1,194 to 1,383	45,526	149	$284,000	-	11%
2028	1,384 to 1,593	45,521	143	$283,000	-	11%
2029	1,594 to 1,782	45,563	128	$281,000	-	11%
	TOTAL	455,005	1,472	$2,837,000	100%	100%



Data Availability is Classified for Illustration



Tier	Georeferenced Location	Attributes[1]	Condition Scores
I	Maybe	<50%	No
II	Yes	>50%	No
III	Yes	>90%	Yes

[1] Includes diameter, age, and material

Poll Question

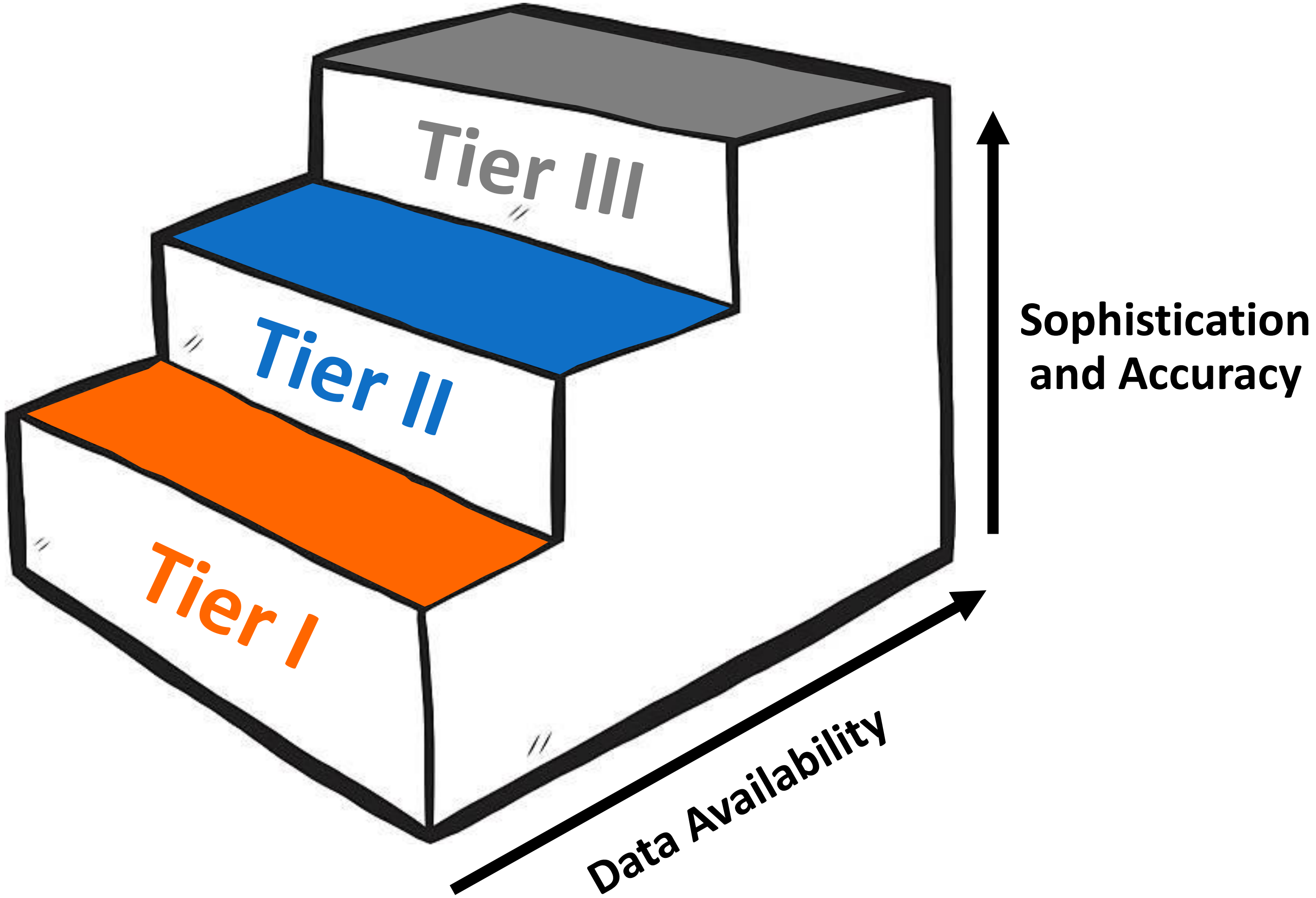
If you represent a wastewater service provider, what Tier category do you fall in?

a. Tier I

b. Tier II

c. Tier III

Data Availability can Impact the Accuracy of Risk Estimates



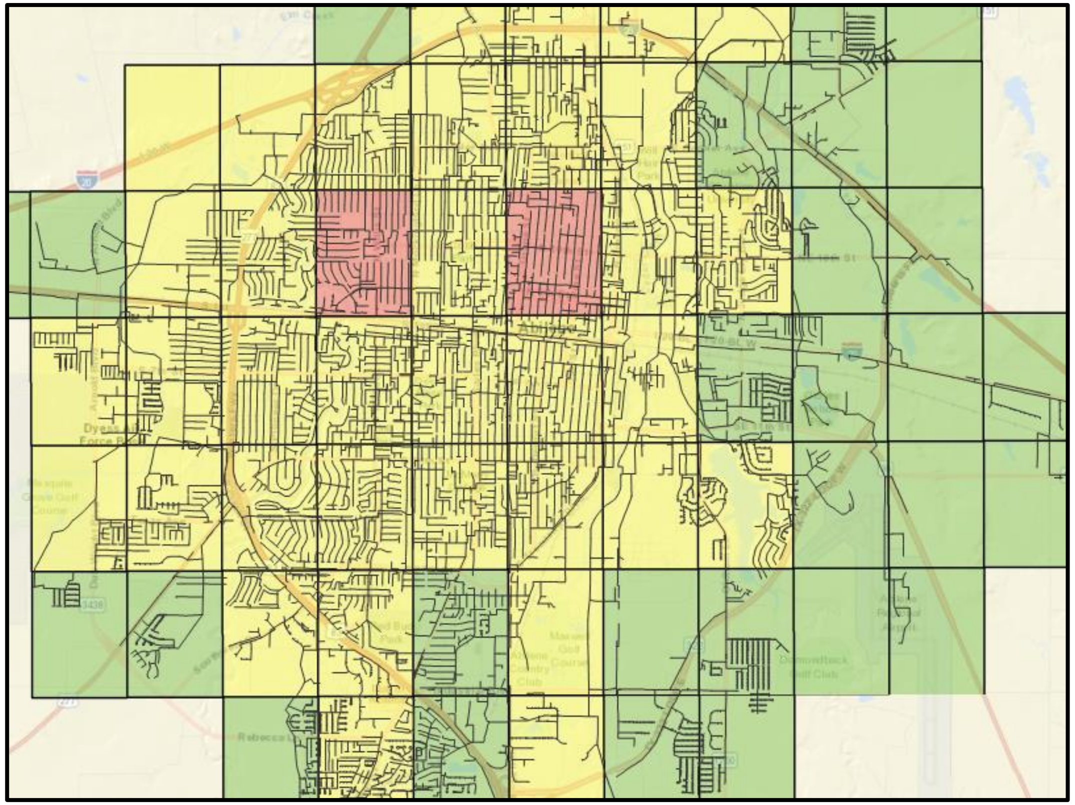
However, even a risk prioritization for a City in Tier I provides value.

Case Study #1 and #2 Comparison

	Case Study #1	Case Study #2
Location	West Texas	DFW Metroplex
Population	>100,000	<50,000
Collection System	700 miles	220 miles
Georeferenced Location	Some	Yes
Pipeline Diameter	90%	100%
Pipeline Material	90%	100%
Pipeline Age	0%	100%
Condition Scores	No	No
Data Availability	Tier I	Tier II

Surrogate Data Were Used to Fill in Missing Age and Condition Data

- **Age** – Initially assigned based on development date of closest land parcel. Refined to match timeframe in which pipe material was typically installed.
  - Example: Asbestos Concrete Pipe installed between 1940 and 1970.
- **Condition** – Staff knowledge capture workshop scoring by grid



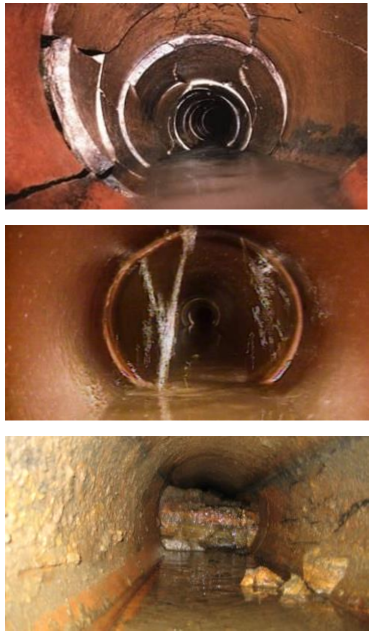
Case Study #3 Included Some PACP Condition Scores

	Case Study #3
Location	DFW Metroplex
Population	>100,000
Collection System	500 miles
Georeferenced Location	Yes
Pipeline Diameter	100%
Pipeline Material	100%
Pipeline Age	100%
Condition Scores	30%
Data Availability	Tier III

For cities in Tier III, more sophisticated models can be used to predict the condition of pipes that have not been inspected.

Statistical Models/Machine Learning can be Used to Predict Condition in Assets without Scores

PACP
CCTV inspection
Nu... of de...
T... e ...efect
...ck rat...
S... ment gra... sc...
Overall pipe rating



Condition Assessment

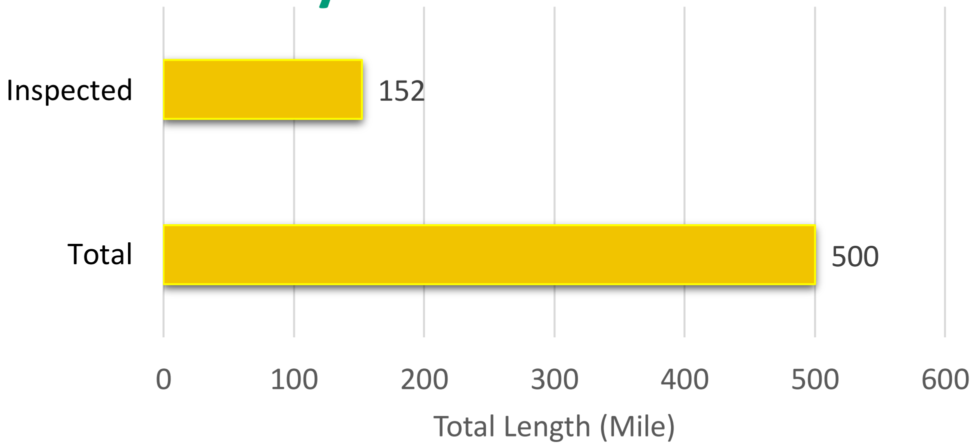
- Condition 1
- Condition 2
- Condition 3
- Condition 4
- Condition 5

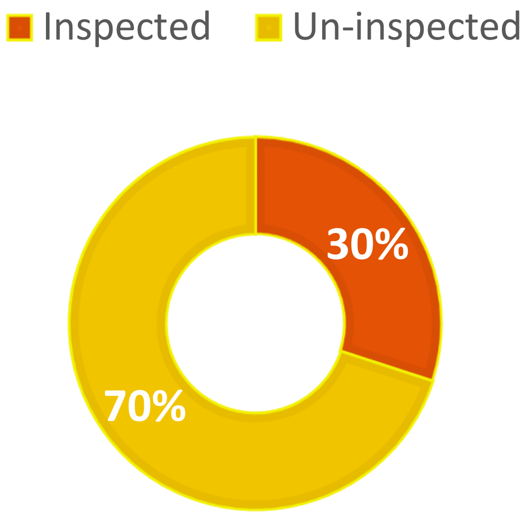
Sewer Inventory (CCTV Inspection Data)		
Physical	**Environmental**	**Operational**
Age	Soil type	Debris
Material	Water table	Blockage
Diameter	Corrosivity	Flow
Length	Moisture	Cleaning
Depth	pH	Overflow
Slope	Bedding	Sediment

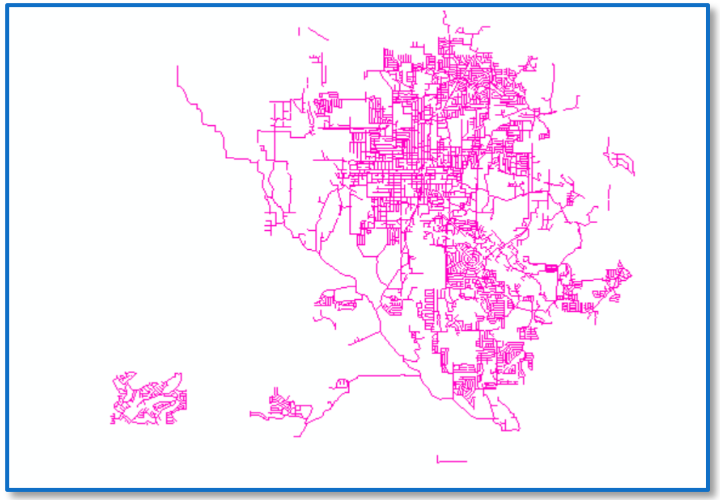
Prediction Model

Even in Tier 3, Data Availability Varies

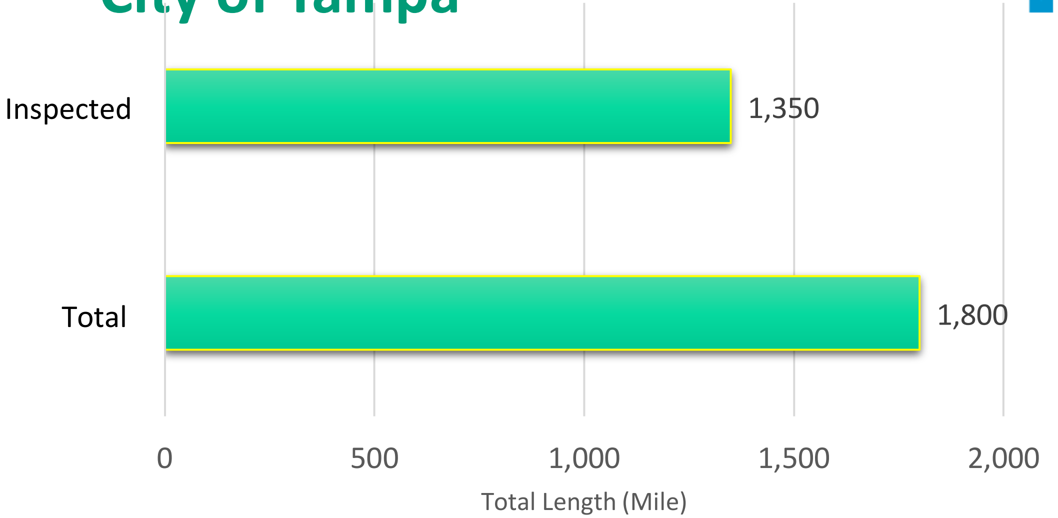
Case Study #3

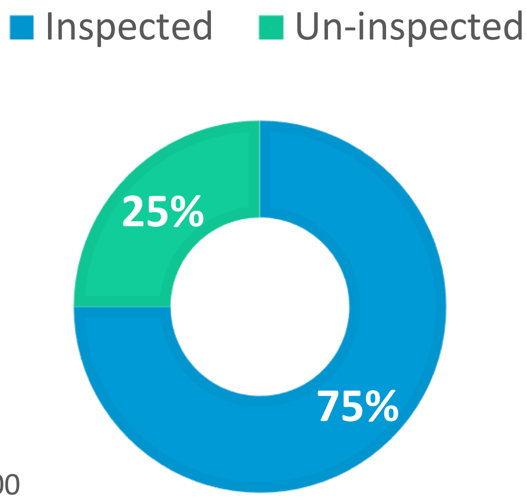


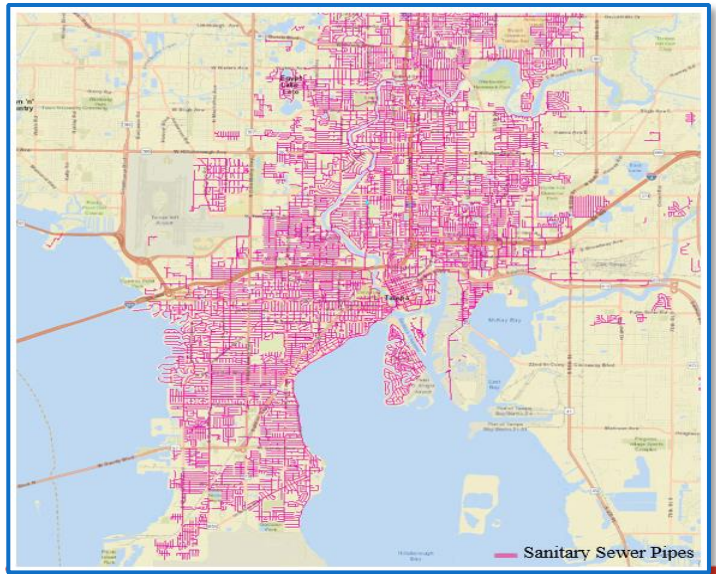




City of Tampa







Available Variables can Impact Results

Case Study #3

Variables	Type
Age	Numerical
Material	Categorical
Diameter	Numerical
Segment Length	Numerical
Paved	Categorical
Blockage	Numerical
H_2S	Categorical
Soil Type	Categorical
Connection	Numerical
RootCount	Numerical

City of Tampa

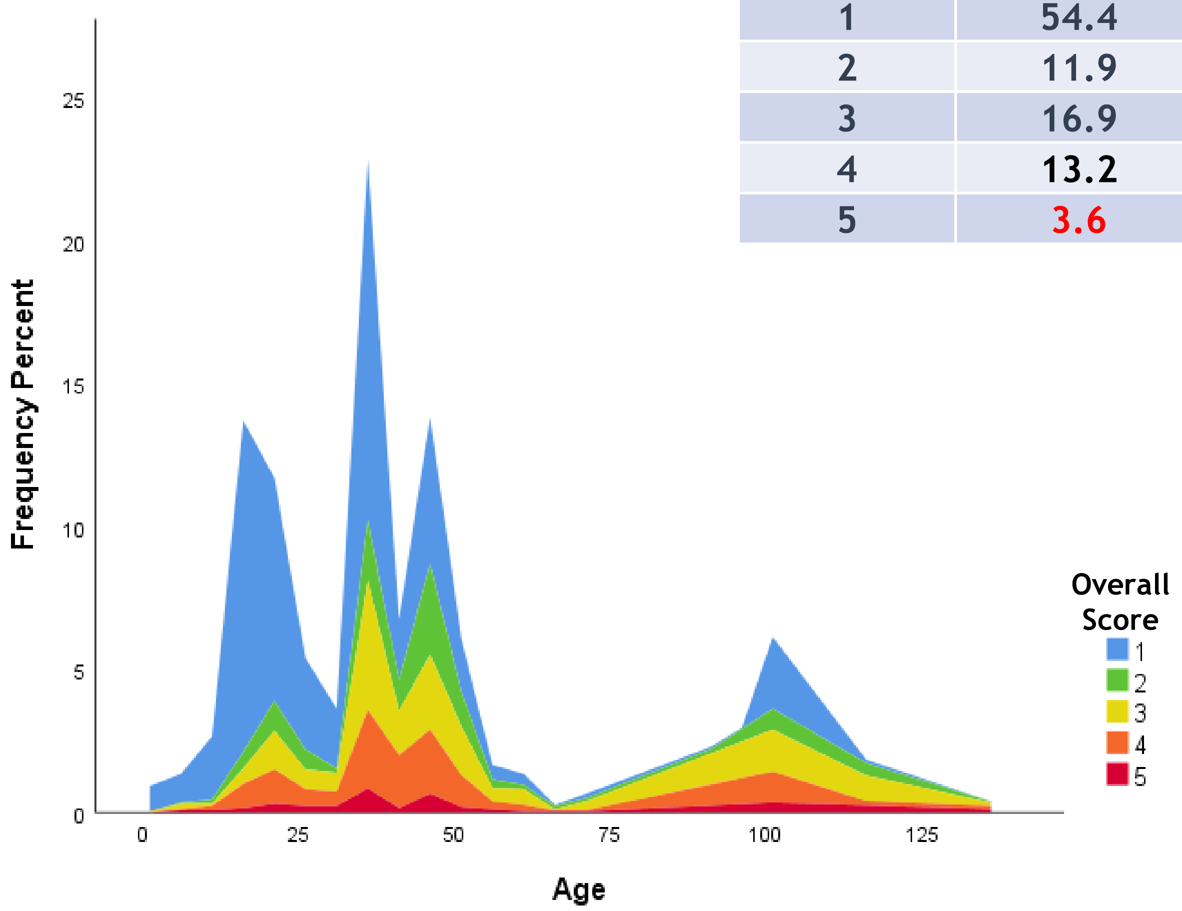
Variables	Type
Age	Numerical
Material	Categorical
Diameter	Numerical
Depth	Numerical
Slope	Numerical
Length	Numerical
Soil Type	Categorical
Water Table	Numerical
Soil pH	Numerical
Soil Sulfate	Numerical
Pipe Flow	Numerical

Condition Spectrum Provides Insights

Case Study #3

- 2,587 pipe segments

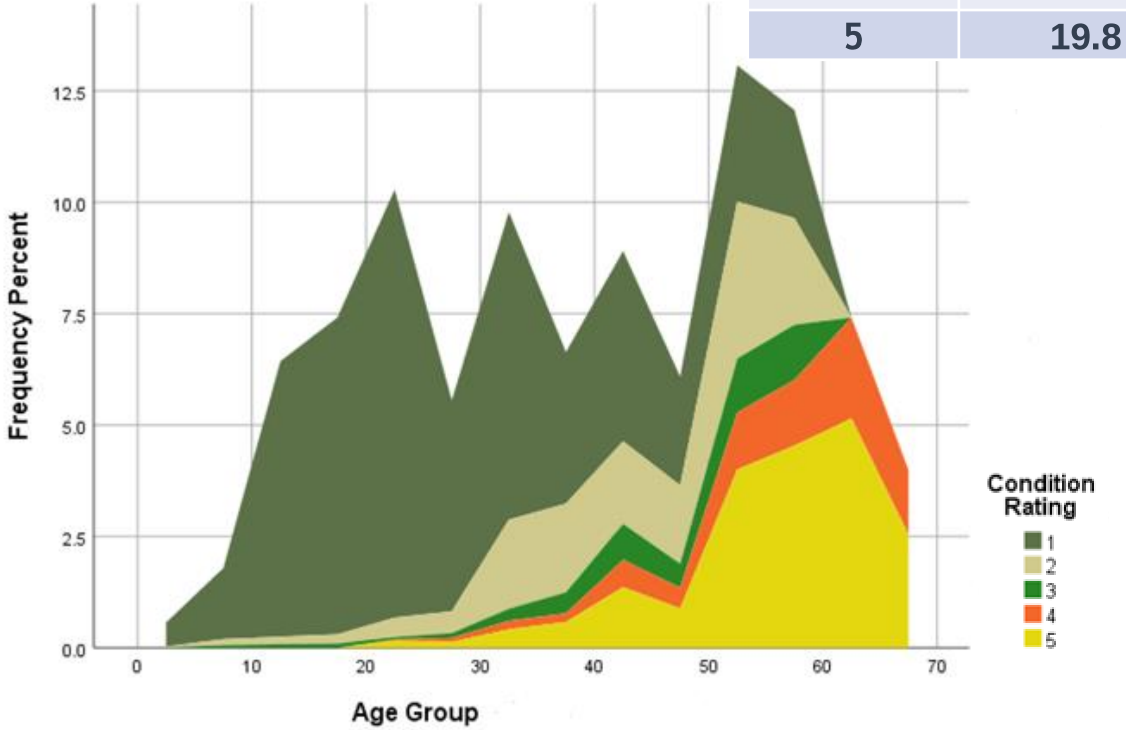
Condition	Percentage
1	54.4
2	11.9
3	16.9
4	13.2
5	3.6



City of Tampa

- 19,766 pipe segments

Condition	Percentage
1	52.3
2	15
3	4.9
4	8
5	19.8



Model Accuracy Improves with More Data

- Pipes were categorized into two groups of **Poor** and **Good** pipes.
- Logistic regression was used to build the model.
- 80% data for training and 20% for test.

Case Study #3

Binary Logistic Regression Classification Table

Observed	Predicted		Percent Correct Predicted
	0	1	
0	170	51	77%
1	98	102	51%
Overall Percentage			**64%**

City of Tampa

Binary Logistic Regression Classification Table

Observed	Predicted		Percent Correct Predicted
	0	1	
0	2,542	315	89%
1	300	824	73%
Overall Percentage			**84%**

Significant Variables can be Identified from the Model

Case Study #3

Significant Variables

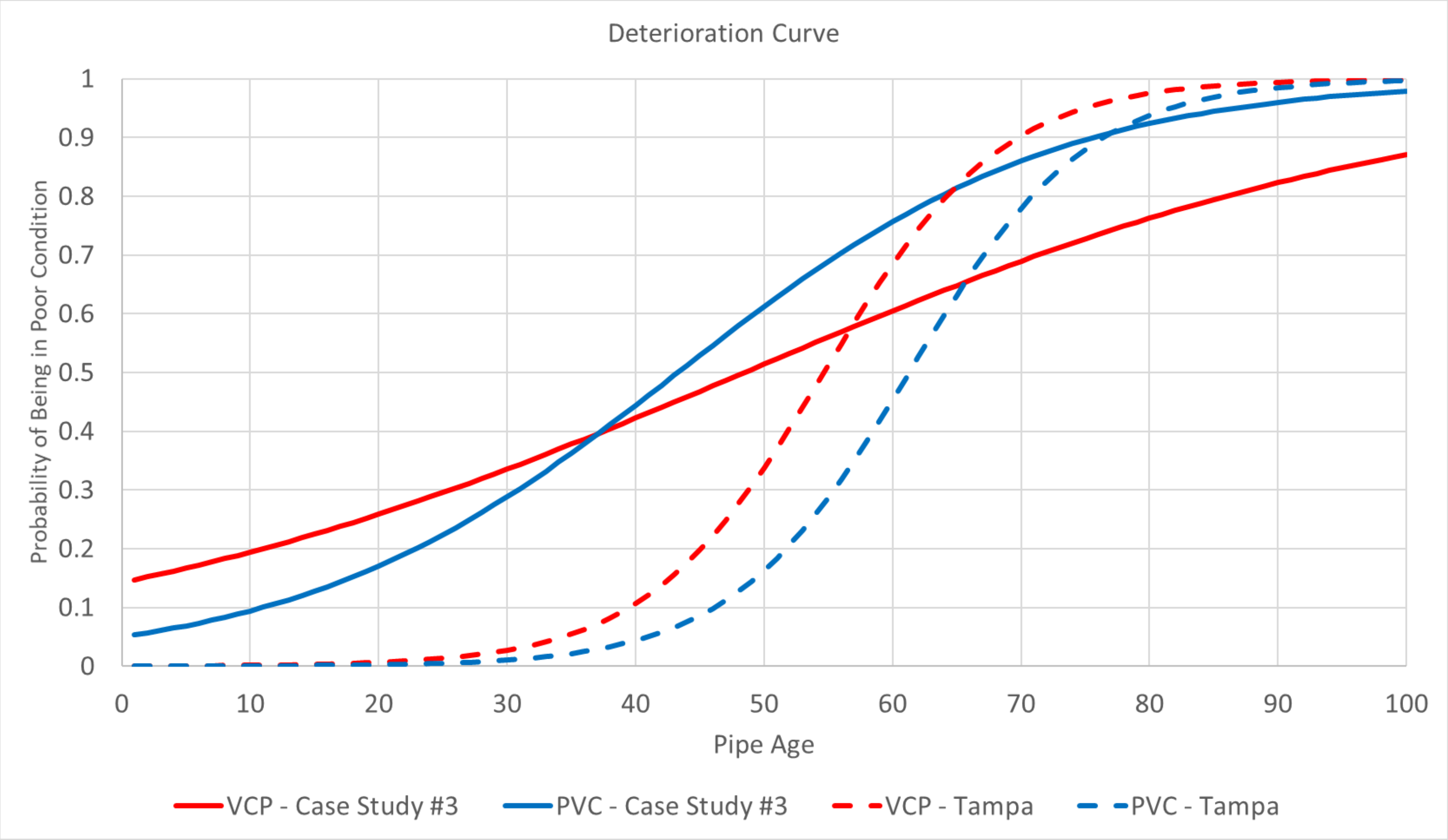
Significant Variables	Rank	Variables
	1	Age
	2	Length
	3	Blockage
	4	Diameter

City of Tampa

Significant Variables

Significant Variables	Rank	Variables
	1	Age
	2	Diameter
	3	Length
	4	Water Table
	5	Material

Reliability of Deterioration Curves Depends on Data Availability and Accuracy



THANK YOU!!

Ellen McDonald, PhD, PE | emcdonald@plummer.com
Reza Malek, PhD | rmalek@plummer.com

PLUMMER

Poll Question

Does your organization have a process to assess condition of pipelines and record the condition scores?

a. No

b. The condition of pipes is assessed based on staff knowledge

c. The condition of pipes is assessed based on pipe age, material and other physical attributes

d. The condition of pipes is assessed using CCTV or other advanced assessment tools

WATER ENVIRONMENT FEDERATION
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2020

Powerful Asset Data Analytics to Support Utility Decision Making

Celine Hyer, PE, IAM

ARCADIS Design & Consultancy for natural and built assets

Today’s Agenda

- Introduction to Risk Based Capital Planning
  - Data Challenges
  - BI Tools and Benefits
- Case Study Lift Station Replacement Planning
  - Methodology Overview
  - Demonstration of Power BI Dashboards
  - Results & Lessons Learned
- Questions

A Comprehensive Risk Framework is Data Intensive for Asset Risk Scoring

Likelihood of Failure x **Consequence of Failure** x **Redundancy Factor** = **Risk Score**

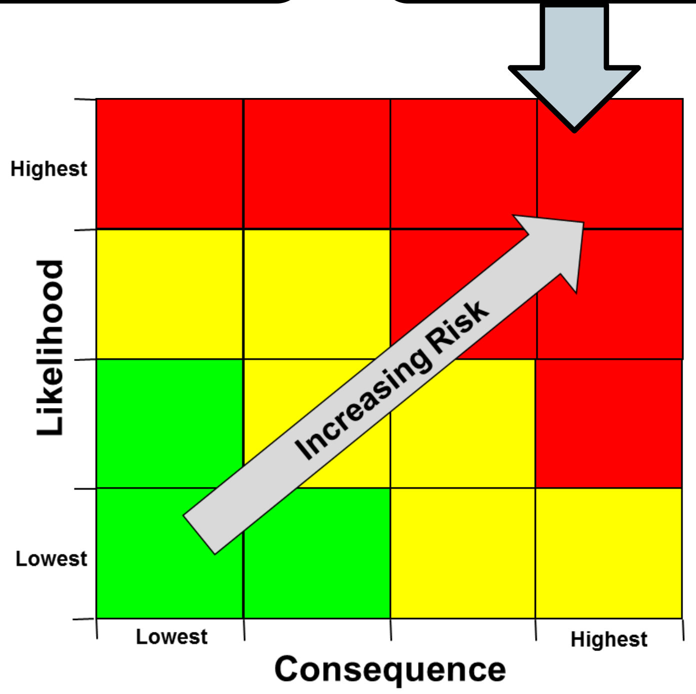
Failure Mode

- Mortality
- Capacity
- Efficiency
- Level of Service

Consequence

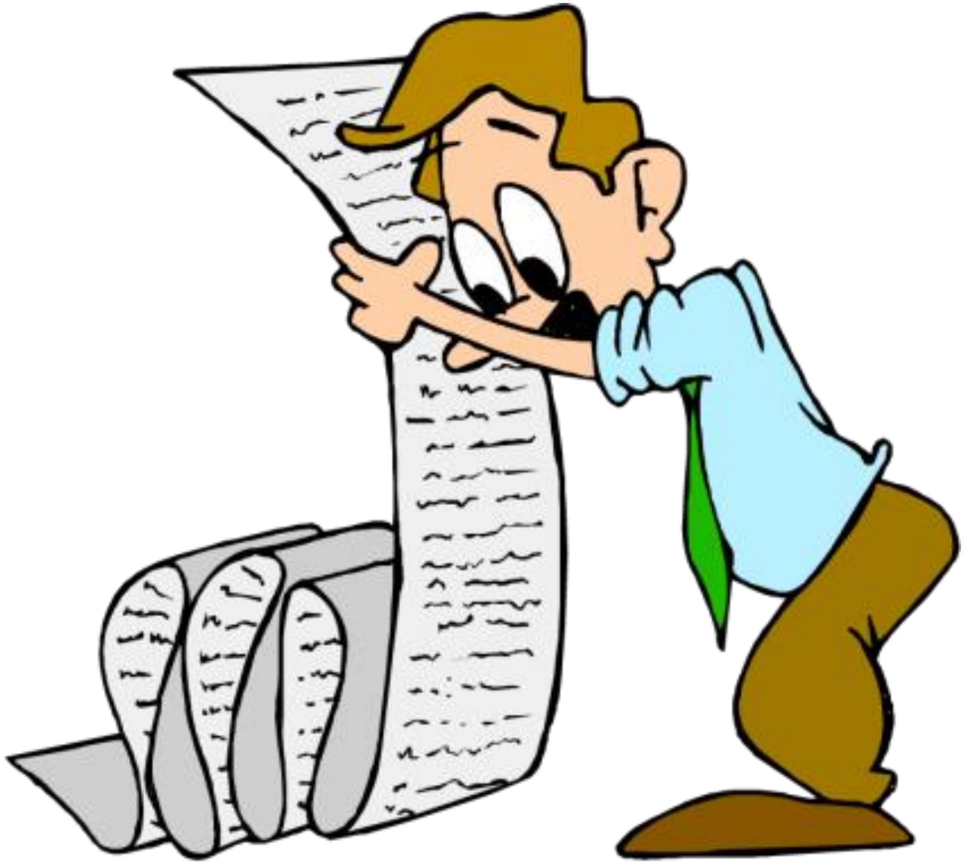
TBL Criteria:

- Social
- Economic
- Environmental



Long-Term Planning Decisions Require More Data on Remaining Useful Life and Life Cycle Costs

- Install Date
- Effective Useful Life
- Replacement Cost
- Repair/Rehabilitation Cost
- Maintenance History
- Adjusted Useful Life
- Remaining Useful Life

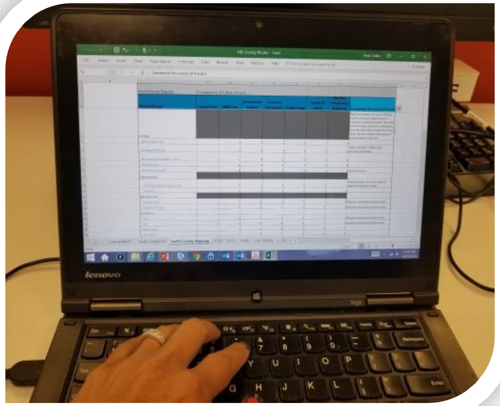


Data is Typically Collected in Multiple Ways but Needs to Merge Together

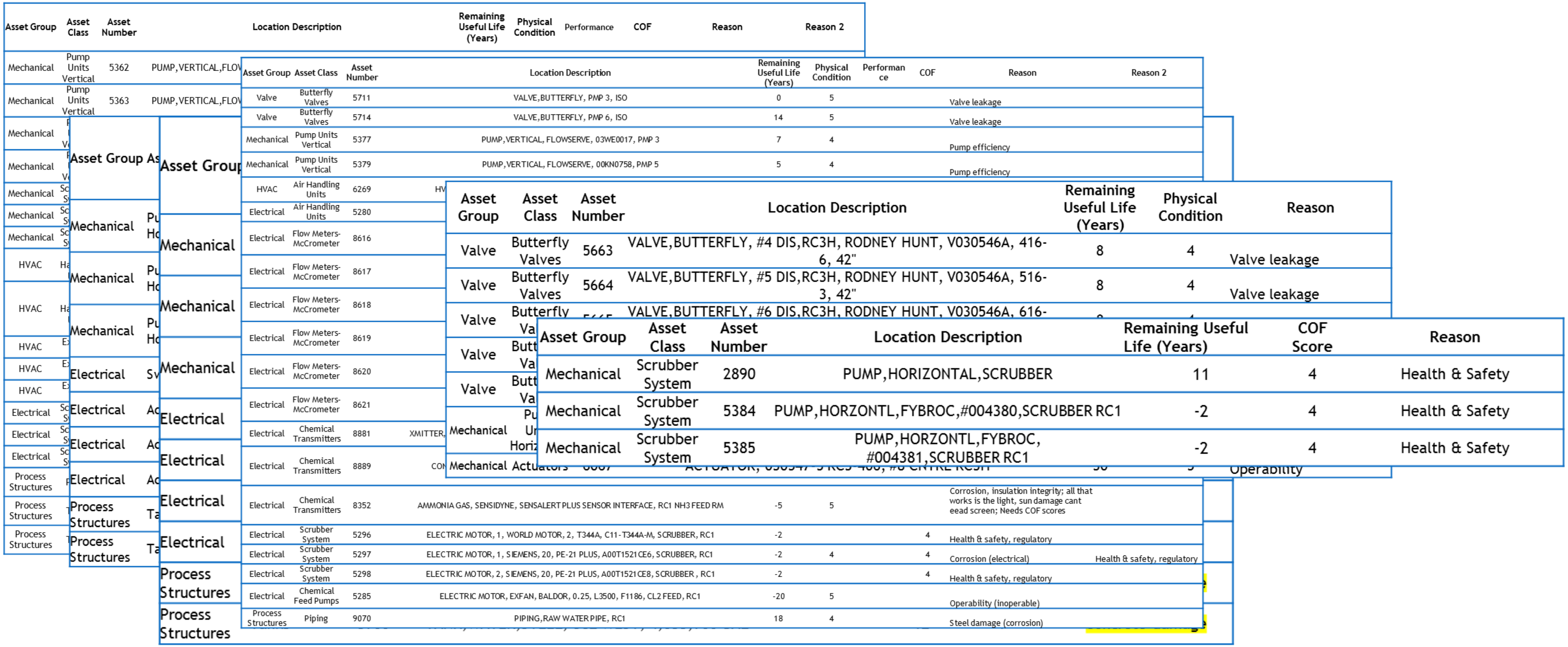
Field Visual Assessment

Data Requirements	Collection Method	Assessment Method
Basic Asset Attributes (install date, capacity)	Tablets	Field Visual Assessment and CMMS
Physical Condition	Tablets	Field Visual Assessment
Performance Condition	Spreadsheet	Interviews and CMMS Reviews
Consequence of Failure	Spreadsheet	Interviews and Document Reviews
Effective Useful Life by Asset Type	Spreadsheet	Interviews
Life Cycle Costs	Spreadsheet	Review of Bid Tabs, CMMS, Engineering Estimates

Office Interviews and Data Reviews



Capital Decision Making Requires Multiple Spreadsheets and is Time Consuming

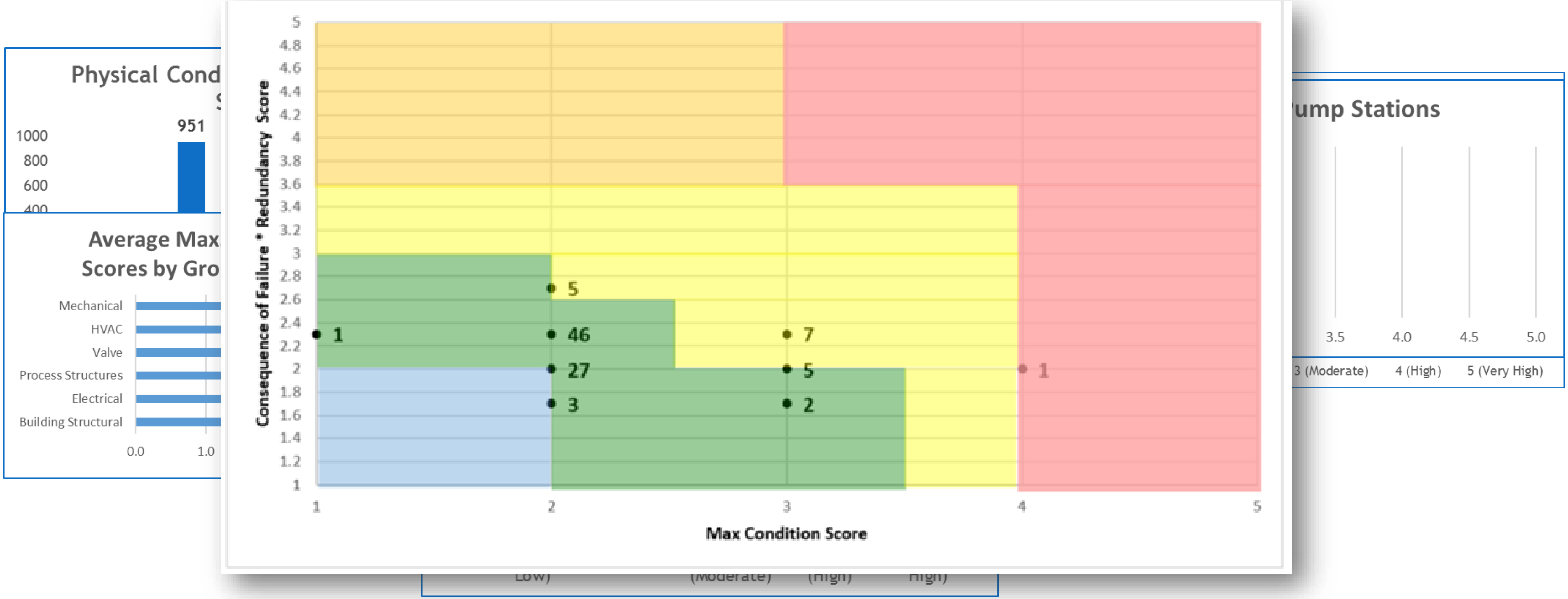


Asset Group	Asset Class	Asset Number	Location Description	Remaining Useful Life (Years)	COF Score	Reason
Mechanical	Scrubber System	2890	PUMP,HORIZONTAL,SCRUBBER	11	4	Health & Safety
Mechanical	Scrubber System	5384	PUMP,HORZONTL,FYBROC,#004380,SCRUBBER RC1	-2	4	Health & Safety
Mechanical	Scrubber System	5385	PUMP,HORZONTL,FYBROC, #004381,SCRUBBER RC1	-2	4	Health & Safety

Utilities are Starting to Capture Better Electronic Data in CMMS to Support Risk Based Planning

Predictive Testing and Trending	→	Asset Physical Condition Score
Downtime Hours by Asset	→	Asset Performance Condition Reliability
Corrective Maintenance Workorders and Hours by Asset	→	Asset Performance Condition Efficiency
Initial Installation Costs	→	Replacement Cost

Reviewing Data From Spreadsheets is Time Consuming and Not Interactive



Poll Question #1

What challenges does your organization face in making data driven decisions?

- Data is inaccurate or not trusted by the organization
- Data is not consolidated in one place to analyze
- Data is not available
- There is no framework in place to analyze the data
- There is no one assigned to analyze the data

Microsoft
Power BI

Data Analytics Tools Can Support Improved Review and Analysis of Data With Little Effort

- Microsoft Power BI Data Analytics Solution
  - Free version available (desktop and web)
  - Can take data form multiple sources (Excel, GIS, CMMS etc.)
  - Built in query editor or programming capabilities
- Create Interactive Reports and Dashboards

Case Study Lift Station Replacement Planning in Texas

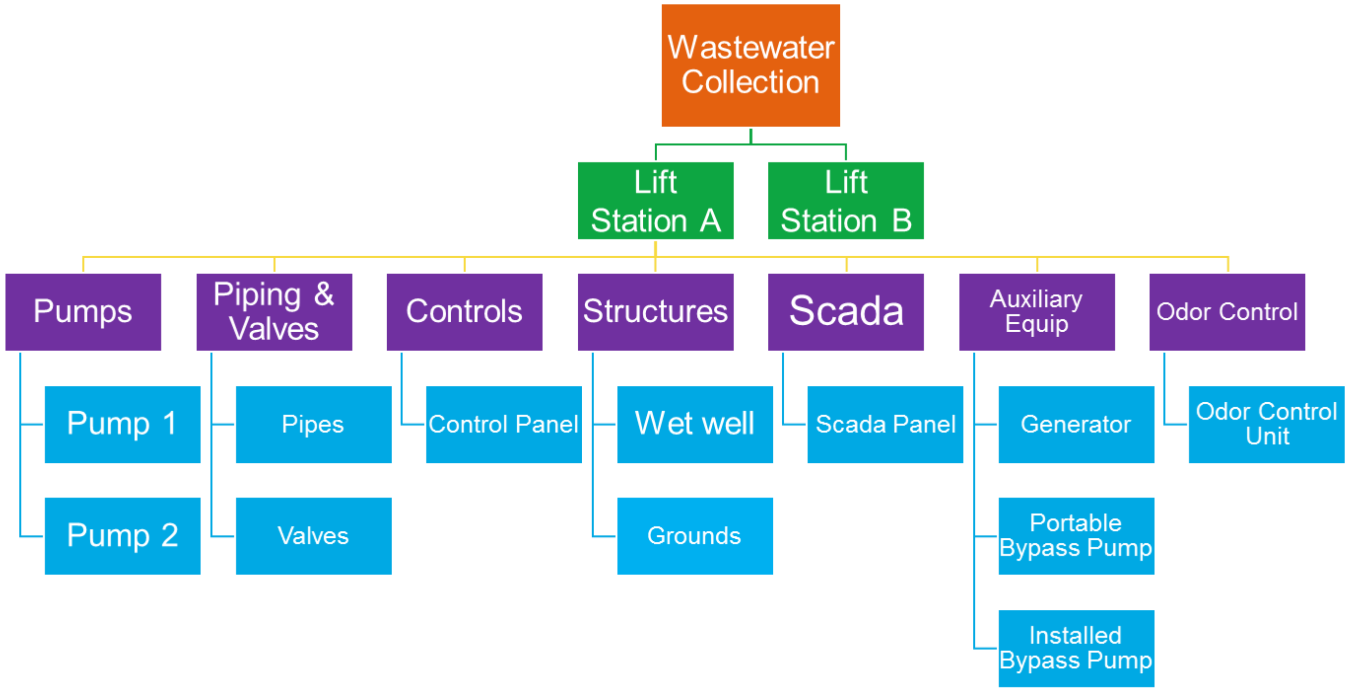
134 Lift Stations

- Duplex and Triplex
- 1980 – 2019 installations

Determine 5 Year CIP

Determine Long Term Funding

- Various service level scenarios
- % Maximum Risk
- System Renewal/Replacement %



Methodology Overview – Likelihood of Failure

Visual Assessments

Tablet Based Forms

- Mechanical
- Structural
- Electrical/I&C

Scoring 1 to 5

- Mortality Failure

Structural Visual Condition Assessment						
Criteria	Condition	1 (best)	2	3	4	5
CORE CRITERIA						
Concrete / Masonry Damage (wet well)	Joint Deterioration	None	<10%	10% - <30%	30% - 50%	>50%
	Cracking (width of crack)	None	< 1mm	1-2mm	>2mm	Not Serviceable
	Exposed Reinforcement	None	-	-	1 location	>1 location
	Spalling, Exposed Aggregate, Pitting, Delamination	None	-	<10%	10% - 30%	>30%
	Liner Failure	None	1 location: weld strip failure of dimpling 1% of area	>10% dimpling blistering	liner failed	-
Fencing and Gates	Surface Corrosion or dry rot	None	<10%	10% - <25%	25% - 50%	>50%
	Operability	Full	-	Minor Issue	1 location	Inoperable
	Loss of Section	None	-	<10%	10% - 30%	>30%
ANCILLARY CRITERIA						
Sidewalks/Driveways	Cracking (width of crack)	None	< 1mm	1-2mm	>2mm	Not Serviceable
	Structural damage	None	-	-	1 location	>1 location
	Surface Damage	<10%	10% - <25%	25% - 50%	>50% - 85%	>85%
Hatches & Grates	Leaks	None	-	-	1 location	>1 location
	Surface Corrosion	None	<10%	10% - <25%	25% - 50%	>50%
	Structural Damage	None	-	-	-	>= 1 location

This form should be used for wet well and grounds assets

Methodology Overview – Likelihood of Failure

- Desktop Assessment
  - Interviews
  - Document Reviews
  - Electrical/I&C
- Scoring 1 to 5
  - Performance Failure

Performance Condition Assessment							
Category	**Criteria**	**Evaluation**	**1 (best)**	**2**	**3**	**4**	**5**
Capacity	Capacity	Ability for station (pumps, wet well, etc.) to meet current and future current capacity related to growth and I&I Peak Issues	Meets requirements for >10 years	Meets requirements for next 10 years	Meets requirements for next 5 to 9 years	Will not meet requirements in < 5 years	Does not meet current requirements
Level of Service	Resilience (Back-up Power)	Back-up Power capabilities for stations serving critical customers, or stations with unreliable power supply	On site bypass pump	On-site generator	Receptacle available for portable pump and power supply is reliable	Electrical receptacle available, power supply is unreliable	N/A
	Resilience (Flooding)	Location of station related to the potential for flooding	Station is not in a flood zone	Station is not located in a 100 year City flood area	Station is located in a 25 year City flood area	N/A	Station is located in a 10 year City flood area
	Regulatory	Ability to meet current regulations related to SSO's and Odors	No odor complaints or SSO's in last year	N/A	One SSO documented related to station control failure in last year and or 1-3 odor complaints	More than one SSO in last three years due to control failure	More than one SSO in last year due to control failure or >5 odor complaints
11 Efficiency	Reliability	Average time equipment is available when needed	99-100%	95-99%	90-94%	85-89%	< 85%
	O&M Issues	Frequency of O&M Issues beyond regular maintenance (excluding breakdowns)	None	Very infrequently (Quarterly)	Infrequently (Monthly)	Frequently (Weekly)	Very frequently (>Weekly)
	Obsolescence	Status of Equipment Technology, Operating Efficiency, Spare Parts Availability, Energy Efficiency	Best available Operating cost optimal Obsolescence expected >10 years	Technology industry standard/ "Tried and True" Obsolescence expected >5 years	Technology considered appropriate Obsolescence expected within 5 years	Technology nearing obsolescence: (SCADA and Controls installed <2000) Spares still available Parts cost excessive	Technology obsolete Spares not available

Capacity and Level of Service criteria are evaluated at the station level. Efficiency Criteria are evaluated at the asset level. Exceptions at the asset level are made as needed.

Methodology Overview – Consequence of Failure

- Desktop Assessment
  - Interviews
  - Visual Adjacency

- Scoring 1 to 5
  - Economic
  - Social
  - Environmental

Consequence of Failure Assessment						
Category	**Criteria/Measure**	**1**	**2**	**3**	**4**	**5**
Economic	Replacement Cost	<$250,000	$250,000 - $1,000,000	$1,000,001 - $3,000,000	$3,000,001 - $10,00,000	>$10,000,00
	O&M – Staffing impacts for asset replacement/emergency response	No impact	Low impact <=2 FTE for >=1 day	Moderate impact 2+FTE's for <+ 1 week	High impact 2+FTE's for > 1 week, emergency contract, or requires work at multiple stations	N/A
Social	Service Disruption Magnitude	Station with 2 pumps	Station with 3 pumps	Station with 4 pumps	Station with 5+ pumps or regional pump station	N/A
	Public Health & Safety and Utility Reputation	Remote station	Station visibly located in subdivision or commercial center	Station can cause upstream back-ups with 3rd party damage, and or is located near to a school or hospital	N/A	N/A
Environmental	Potential for sewage discharge - proximity	N/A	N/A	Adjacent to a stormwater system	Adjacent to a water body	N/A
	Response time required before sanitary sewer overflow	No impact	>=8 hours	2 to 8 hours	<2 hours	Immediate

Redundancy Not Considered to be Conservative

Risk Scoring Application: Piping & Valves

- LoF = 4
- CoF = 3
- Risk = 4 * 3 = 12

High Score & Poor Condition

- 5 Year CIP

Decay Curves & Remaining Life

- Long Term Planning

Physical Condition		
Core Criteria	**Score**	**Comment**
Corrosion	4	Corrosion throughout
Leakage	1	No leakage present
Vibration / Noise	2	<10% of normal
Concrete Supports	1	No damage
Steel Supports	1	No damage
Evidence of Repair		

Performance Condition		
Criteria	**Score**	**Comment**
Capacity	1	Meets needs for 10 years
Regulatory	1	Meets needs for 10 years
Reliability	1	Uptime <90%
O&M Issues	1	Clogs monthly
Obsolescence	2	Still in production
Resilience	2	Impacts >50 years

Redundancy
Two pumps are provided with one needed at peak flow. Overall pump reliability is poor, and no redundancy credit is calculated.

Consequence of Failure			
Category	**Criteria**	**Score**	**Comment**
Economic CoF	Replacement cost	1	Replacement Cost <$250k
	O&M Cost	1	No impact
Social CoF	Service Disruption	1	Station with 2 pumps
	Health & Safety	3	Station is near school
Environmental CoF	Discharge Potential	3	Adjacent to storm sewer
	Response Time	2	No impacts up to 8 hours

Poll Question #2

Which types of IT systems do you use to support capital or O&M decision making?

- Access Databases
- Excel Databases
- Computerized Maintenance Management Systems
- Business Intelligence Software: Power BI, Tableau, etc.
- Advanced Decision Support Software: Optimatics, InfoAsset Planner, Baseform, PowerPlan, etc..
- None of the above

Developing the CIP Using Power BI

Results & Lessons Learned

- Funding Needs to Increase From \$1.6M to \$3M Per Year
- Rehabbing 6 Selected Stations Per Year Does Not Maximize Risk Reduction or Target Poor Condition
- Service Level Targets for Lift Stations are Complicated
- CMMS Data Can Effectively Interface with GIS and Power BI for Risk Based Planning

Thank You for Your Time
Questions?

Celine Hyer, PE, IAM
Celine.hyer@arcadis.com
ARCADIS Design & Consultancy for natural and built assets

WATER ENVIRONMENT FEDERATION
COLLECTION SYSTEMS CONFERENCE 2020

WELLINGTON WATER'S APPLICATION OF ARTIFICIAL INTELLIGENCE FOR WASTEWATER INFRASTRUCTURE PLANNING

Andrew Faulkner – WCS Engineering

Joel Wilson – WCS Engineering

Steve Hutchison – Wellington Water

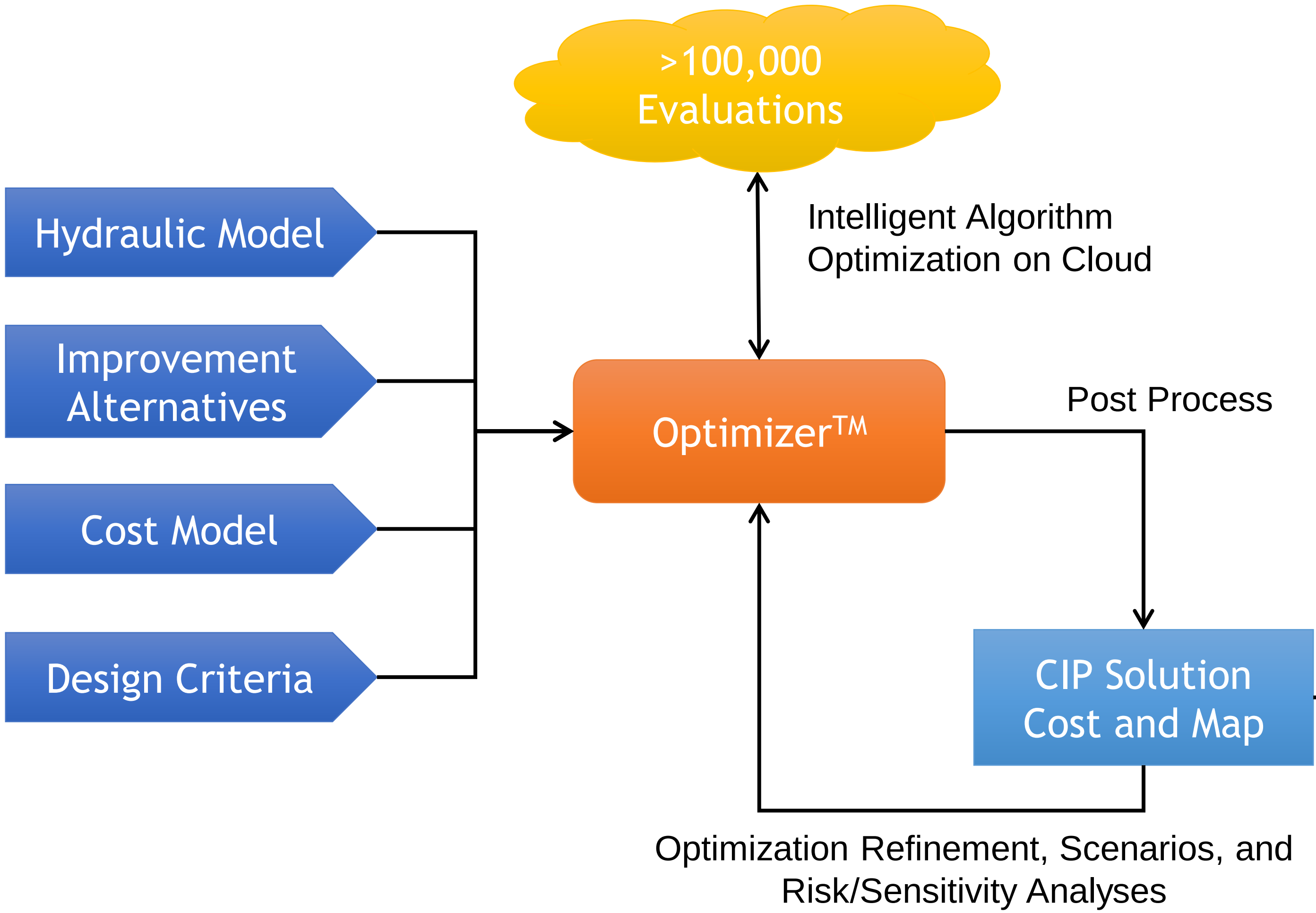
Abby Jensen - Beca

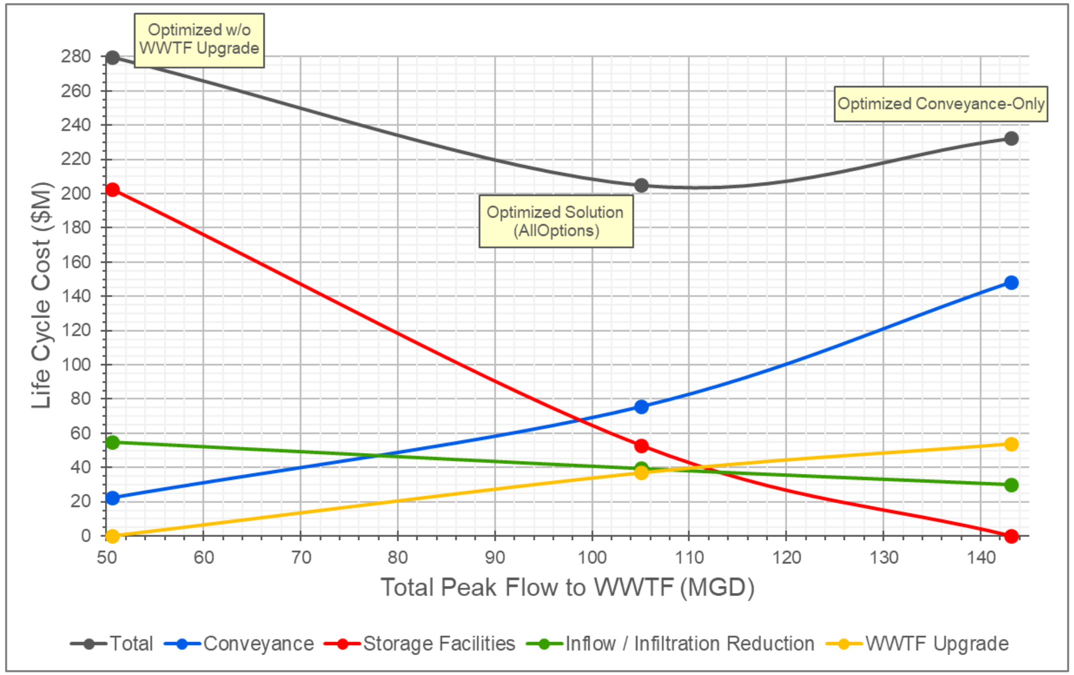
Presentation Overview

- Overview of Optimatics' optimization technology and its application to the Porirua Capital Improvement Program (Wellington Water)
- Porirua Network Improvement Program Optimization:
  - Existing System Performance
  - Optimization of Improvement Alternatives to determine preliminary Preferred Master Plan
  - Prioritization of Preferred Master Plan
  - Project Outcomes

US Dept of State Geographer
© 2020 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2020 GeoBasis-DE/BKG
Google Earth
Imagery Date: 12/14/2015 31°45'42.92" N 106°29'06.63" W eye alt 20071.60 km

Overview of Optimization Process
(Optimizer™ by Optimatics)





Porirua Optimization and Prioritization

How can we use optimization to evaluate SSO control measure alternatives?

INPUTS

Hydraulic Model (ICM)
Population Growth Projection
Design Storm ARI
Life Cycle Cost Data

ALTERNATIVES

Conveyance upgrades (inc. lift stations and force mains)
I/I reduction
Storage facilities
Treatment Plant upgrade

CRITERIA

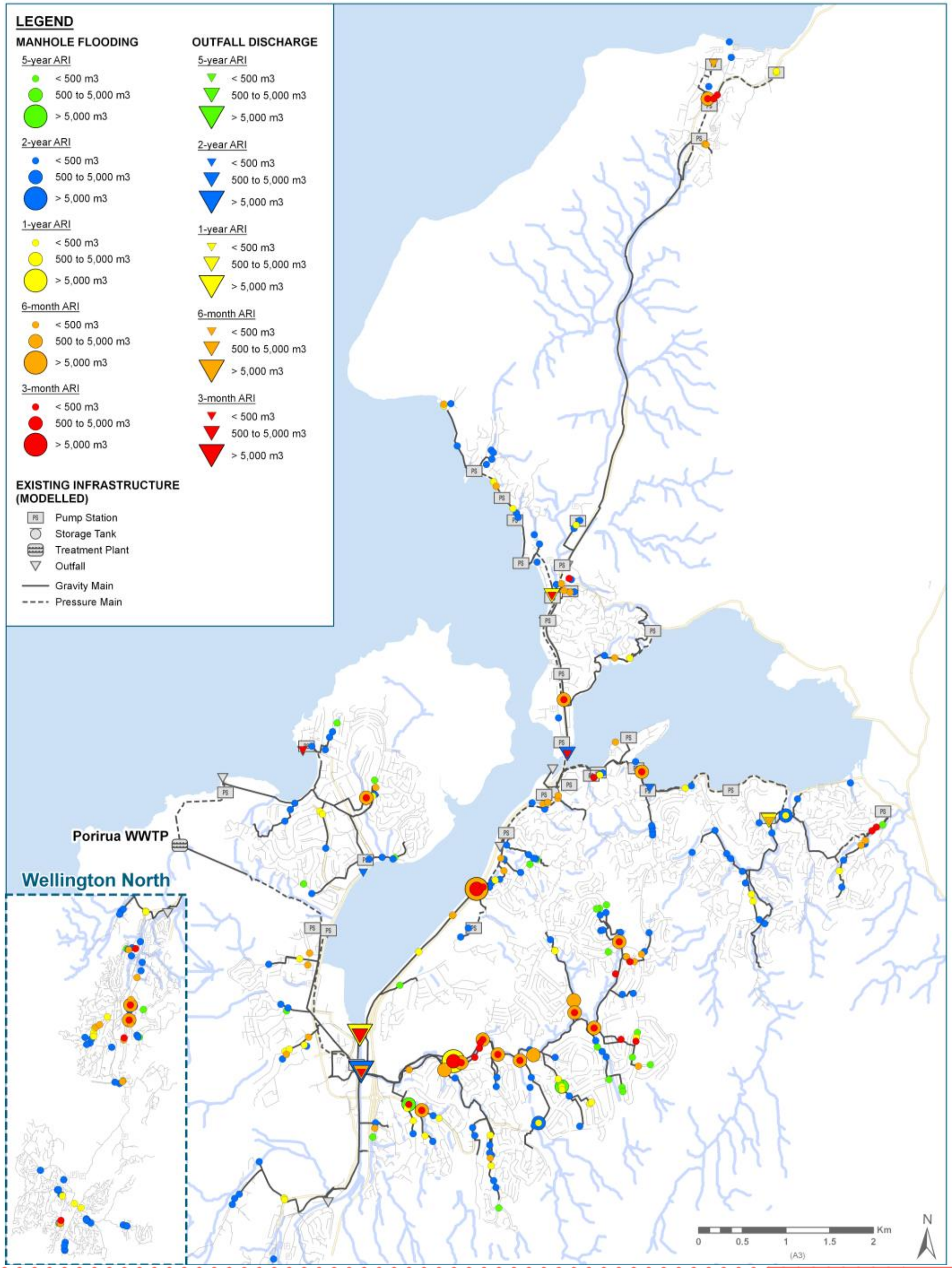
Eliminate uncontrolled sanitary sewer overflow (SSO)
Eliminate constructed outfall structure discharge
Consider a range of level of service targets for each
(e.g. composite design target of 1-year for uncontrolled SSO and 6-month for constructed outfall)

Minimize Cost and Prioritize Expenditure

Existing System Performance Results
(2019 Population)

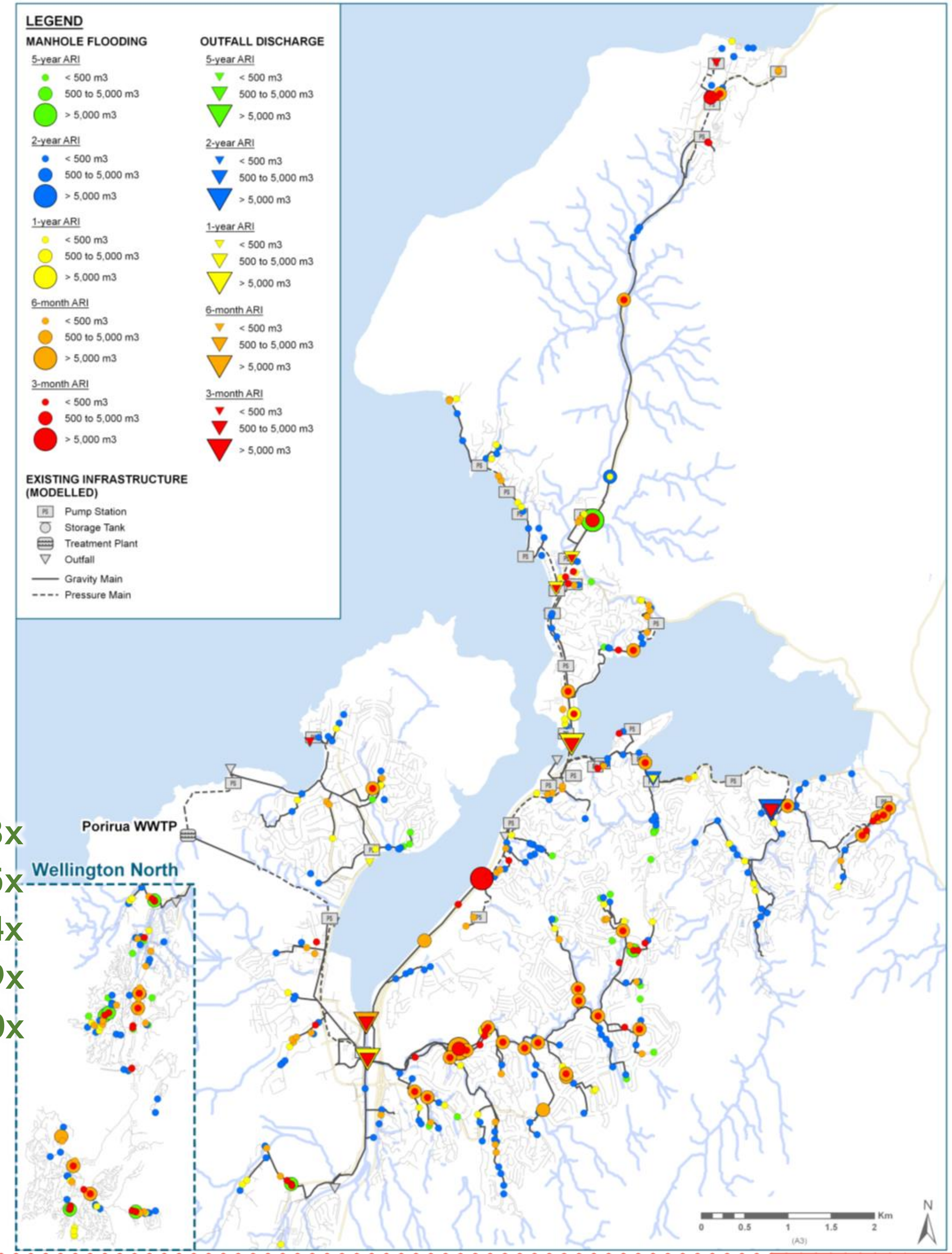
Scenario	Design Storm	Rainfall Event	Uncontrolled SSO Overflows (#)	Constructed Outfall Discharge (#)	Uncontrolled SSO Volume (ML)	Constructed Outfall Discharge Volume (ML)	Total SSO Volume (ML)
2019 Population	4EY	1.6 inches	37	5	7	1	8
	2EY		84	7	13	4	17
	1Y		137	7	36	16	52
	2Y		306	9	58	23	81
	5Y	5.5 inches	325	9	65	29	95

Porirua receives approx. 1200mm (4 feet) of annual rainfall.



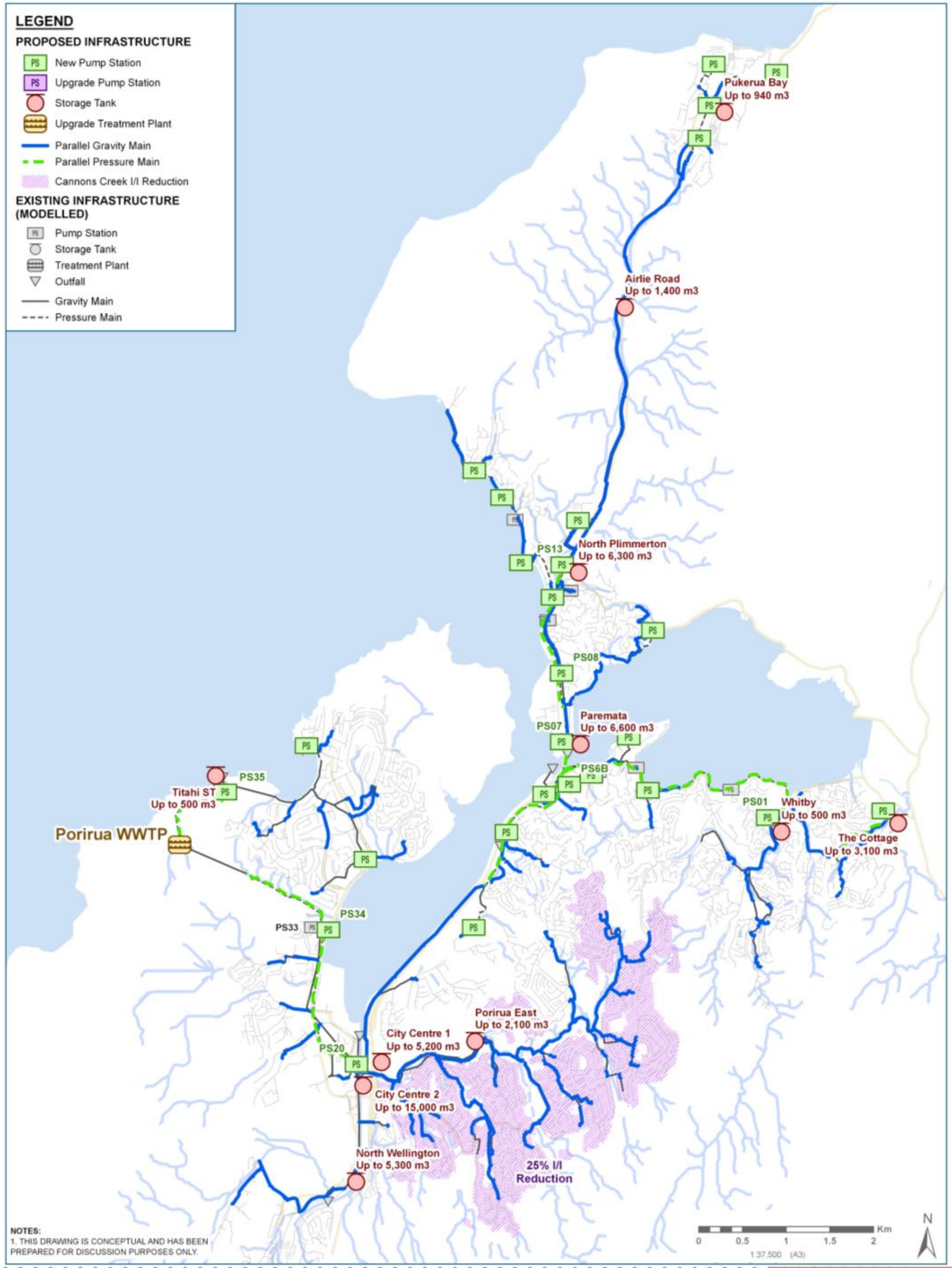
Existing System Performance Results
(2057 Population)

Scenario	Design Storm	Rainfall Event	Uncontrolled SSO Overflows (#)	Constructed Outfall Discharge (#)	Uncontrolled SSO Volume (ML)	Constructed Outfall Discharge Volume (ML)	Total SSO Volume (ML)
2019 Population	4EY	13/08/2010	37	5	7	1	8
	2EY	9/12/2014	84	7	13	4	17
	1Y	5/04/2017	137	7	36	16	52
	2Y	14/11/2016	306	9	58	23	81
	5Y	13/05/2015	325	9	65	29	95
2057 Population	4EY	13/08/2010	79	9	20	8	28 ↑ 3.3x
	2EY	9/12/2014	164	8	30	14	44 ↑ 2.5x
	1Y	5/04/2017	226	10	80	43	123 ↑ 2.4x
	2Y	14/11/2016	439	11	114	41	156 ↑ 1.9x
	5Y	13/05/2015	462	10	129	58	187 ↑ 2.0x



Optimization Alternatives
(2057 Population)

- Conveyance Upgrades:
  - Parallel relief sewers (gravity and pressure)
  - Pumping station upgrades
  - Trimmed model extent based on 1-year design storm deficiencies
- Treatment plant expansion
- Storage facilities at suggested locations
- I/I reduction in Cannons Creek



Porirua Optimization
75,000 Model Evaluations on Cloud Computing Service

Example Animation

(Glass Box View of an Optimization Run)

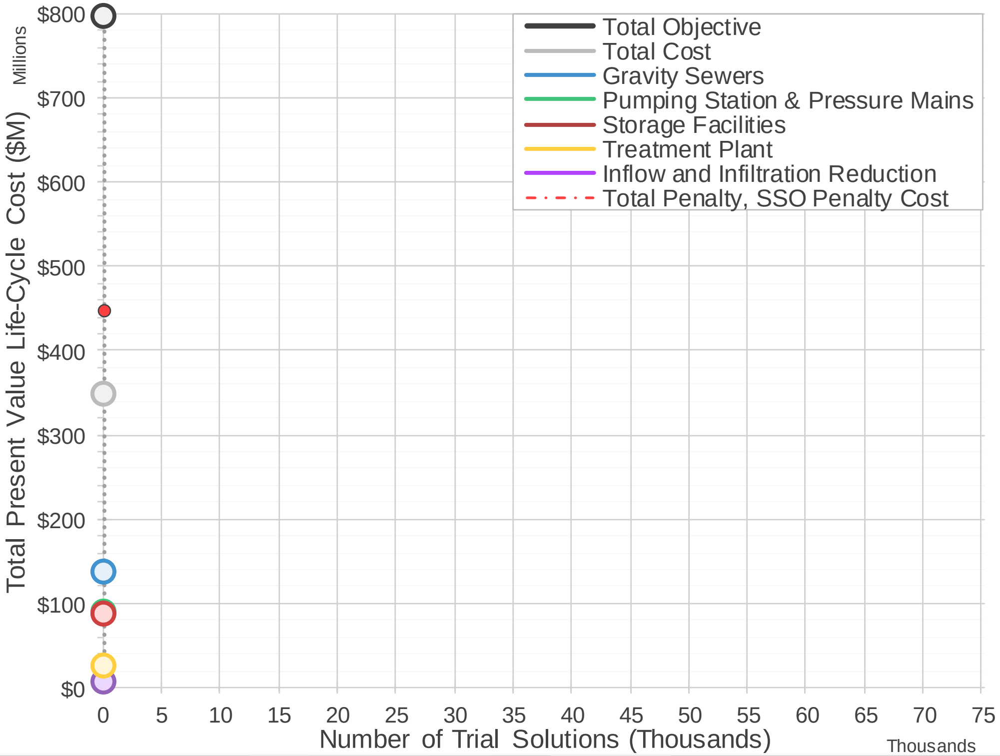
PORIRUA OPTIMIZATION

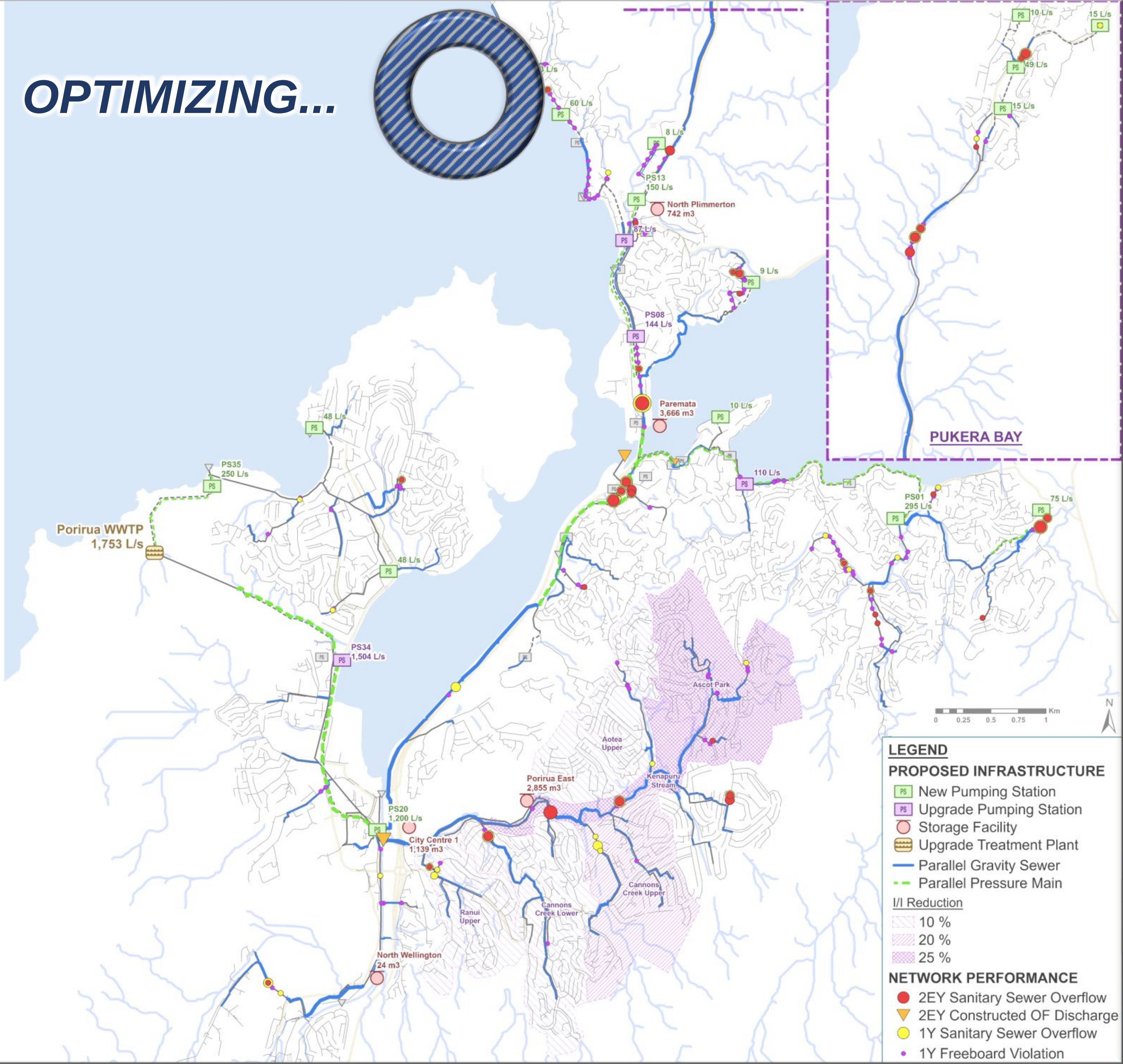
Number of Trial Solutions - 100

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$137.6
Pumping Station & Pressure Main Upgrades	$91.0
Storage Facilities	$87.3
Treatment Plant Upgrade	$24.9
Inflow and Infiltration Reduction	$7.9
TOTAL COST	$348.7
TOTAL OBJECTIVE	$798.0

Sanitary Sewer Overflow (2EY Design Storm):	*8,376 m3*
Constructed Outfall Discharge (2EY Design Storm):	*2,499 m3*
Sanitary Sewer Overflow (1-yr Design Storm):	*20,746 m3*
Freeboard Violations (1-yr Design Storm):	*117*

Optimization Convergence





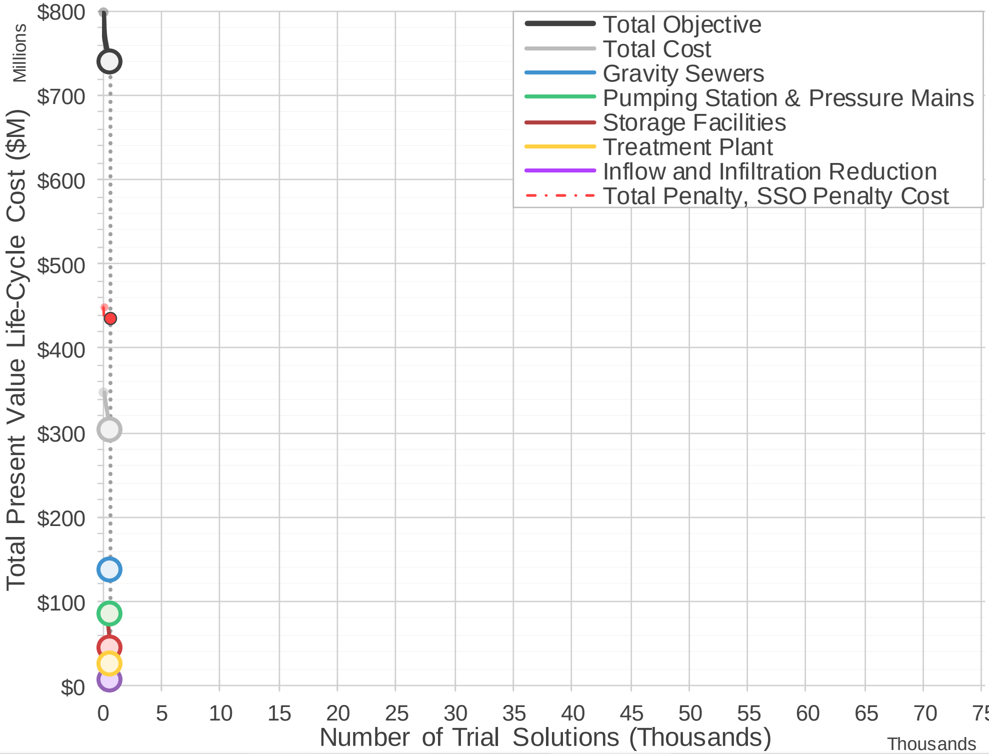
PORIRUA OPTIMIZATION

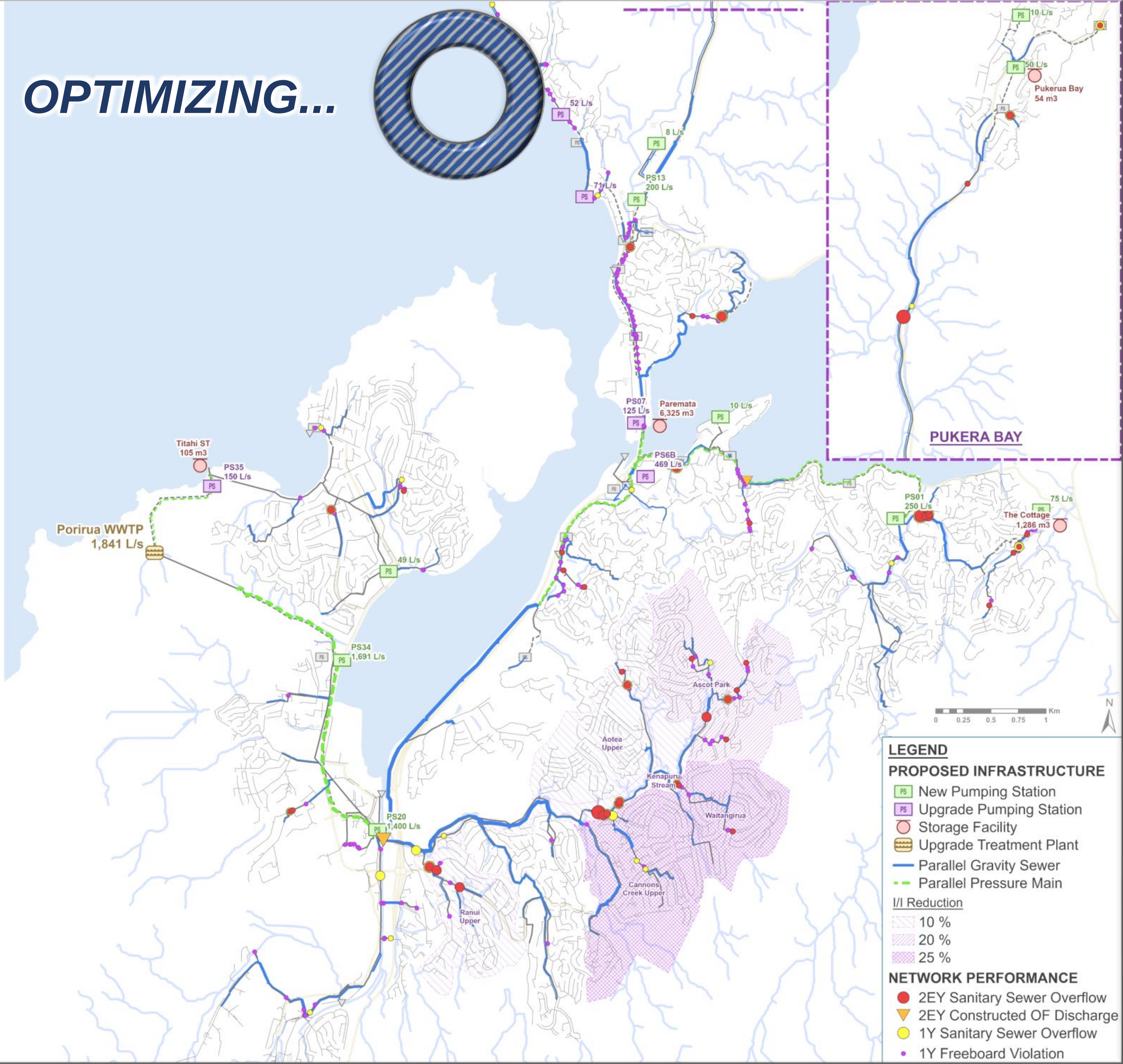
Number of Trial Solutions - 600

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$138.5
Pumping Station & Pressure Main Upgrades	$86.1
Storage Facilities	$45.6
Treatment Plant Upgrade	$24.9
Inflow and Infiltration Reduction	$8.2
TOTAL COST	**$303.3**
TOTAL OBJECTIVE	**$740.8**

Sanitary Sewer Overflow (2EY Design Storm):	*6,443 m3*
Constructed Outfall Discharge (2EY Design Storm):	*1,339 m3*
Sanitary Sewer Overflow (1-yr Design Storm):	*16,801 m3*
Freeboard Violations (1-yr Design Storm):	*146*

Optimization Convergence





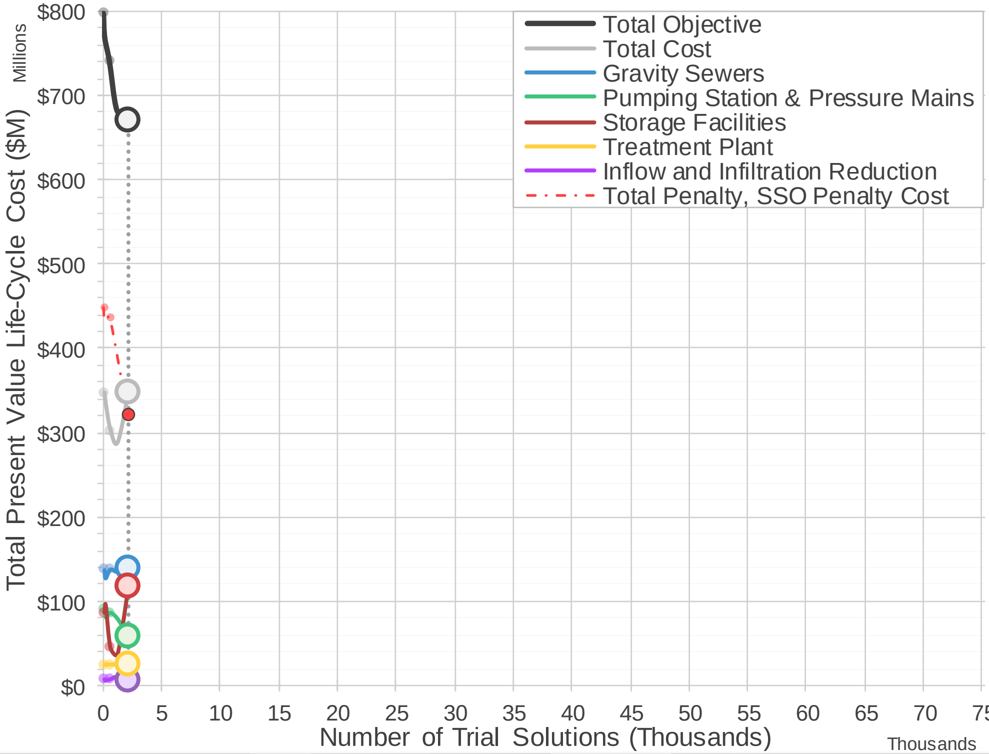
PORIRUA OPTIMIZATION

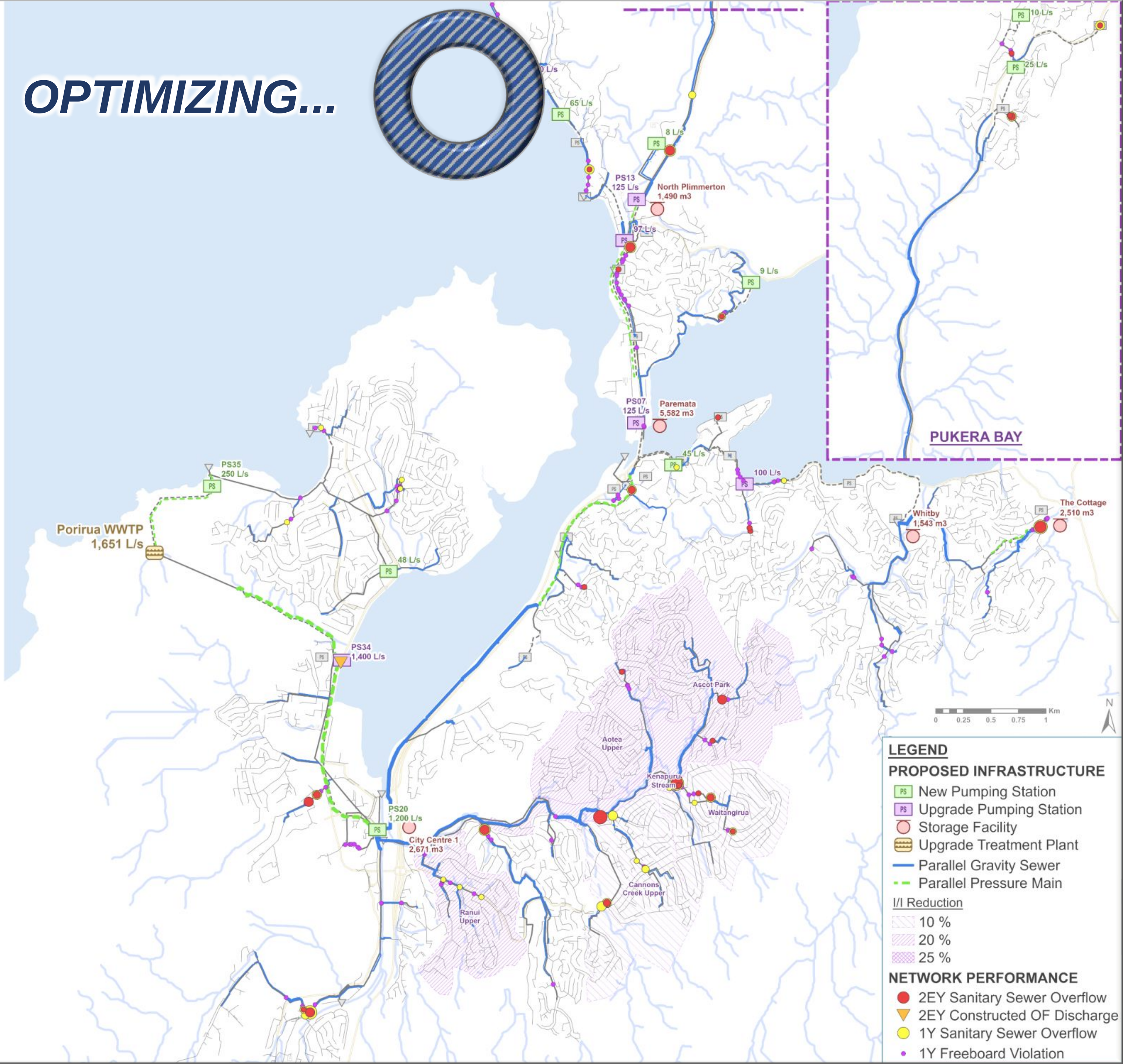
Number of Trial Solutions - 2,101

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$139.5
Pumping Station & Pressure Main Upgrades	$58.6
Storage Facilities	$118.1
Treatment Plant Upgrade	$24.9
Inflow and Infiltration Reduction	$7.4
TOTAL COST	**$348.5**
TOTAL OBJECTIVE	**$671.8**

Sanitary Sewer Overflow (2EY Design Storm):	*4,938 m3*
Constructed Outfall Discharge (2EY Design Storm):	*556 m3*
Sanitary Sewer Overflow (1-yr Design Storm):	*14,063 m3*
Freeboard Violations (1-yr Design Storm):	*103*

Optimization Convergence





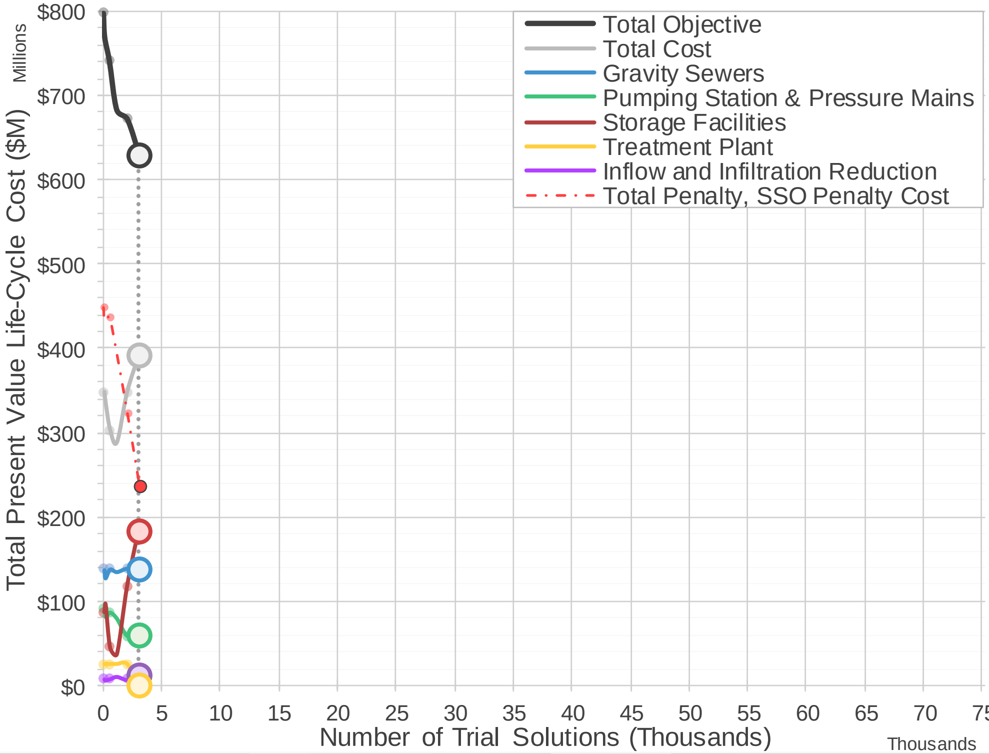
PORIRUA OPTIMIZATION

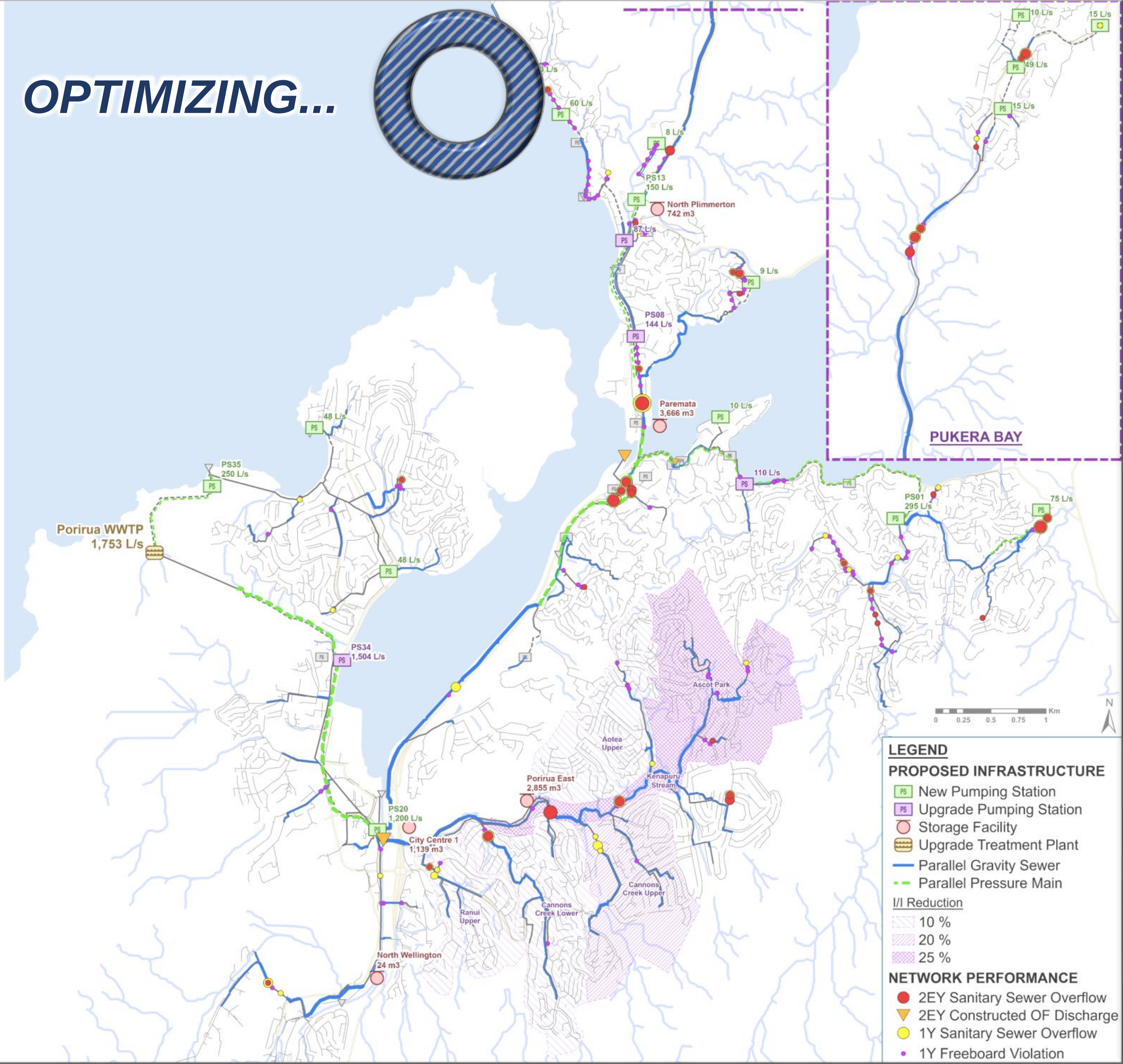
Number of Trial Solutions - 3,100

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$136.9
Pumping Station & Pressure Main Upgrades	$60.0
Storage Facilities	$182.9
Treatment Plant Upgrade	
Inflow and Infiltration Reduction	$11.4
TOTAL COST	**$391.2**
TOTAL OBJECTIVE	**$628.9**

Sanitary Sewer Overflow (2EY Design Storm):	*4,569 m3*
Constructed Outfall Discharge (2EY Design Storm):	*4 m3*
Sanitary Sewer Overflow (1-yr Design Storm):	*11,545 m3*
Freeboard Violations (1-yr Design Storm):	*70*

Optimization Convergence





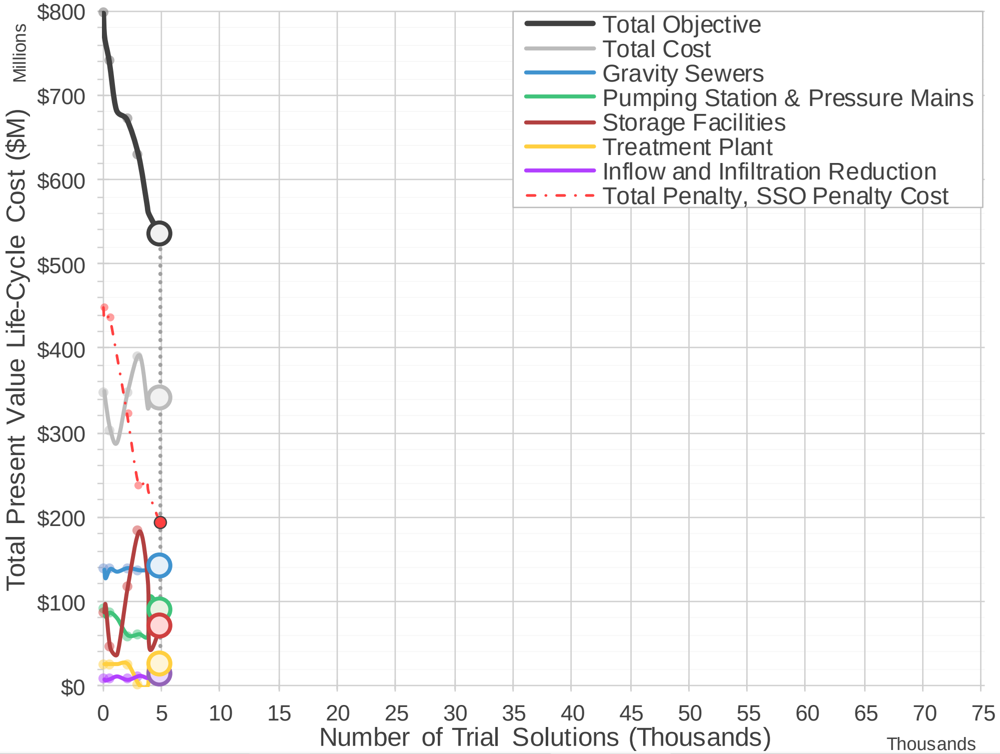
PORIRUA OPTIMIZATION

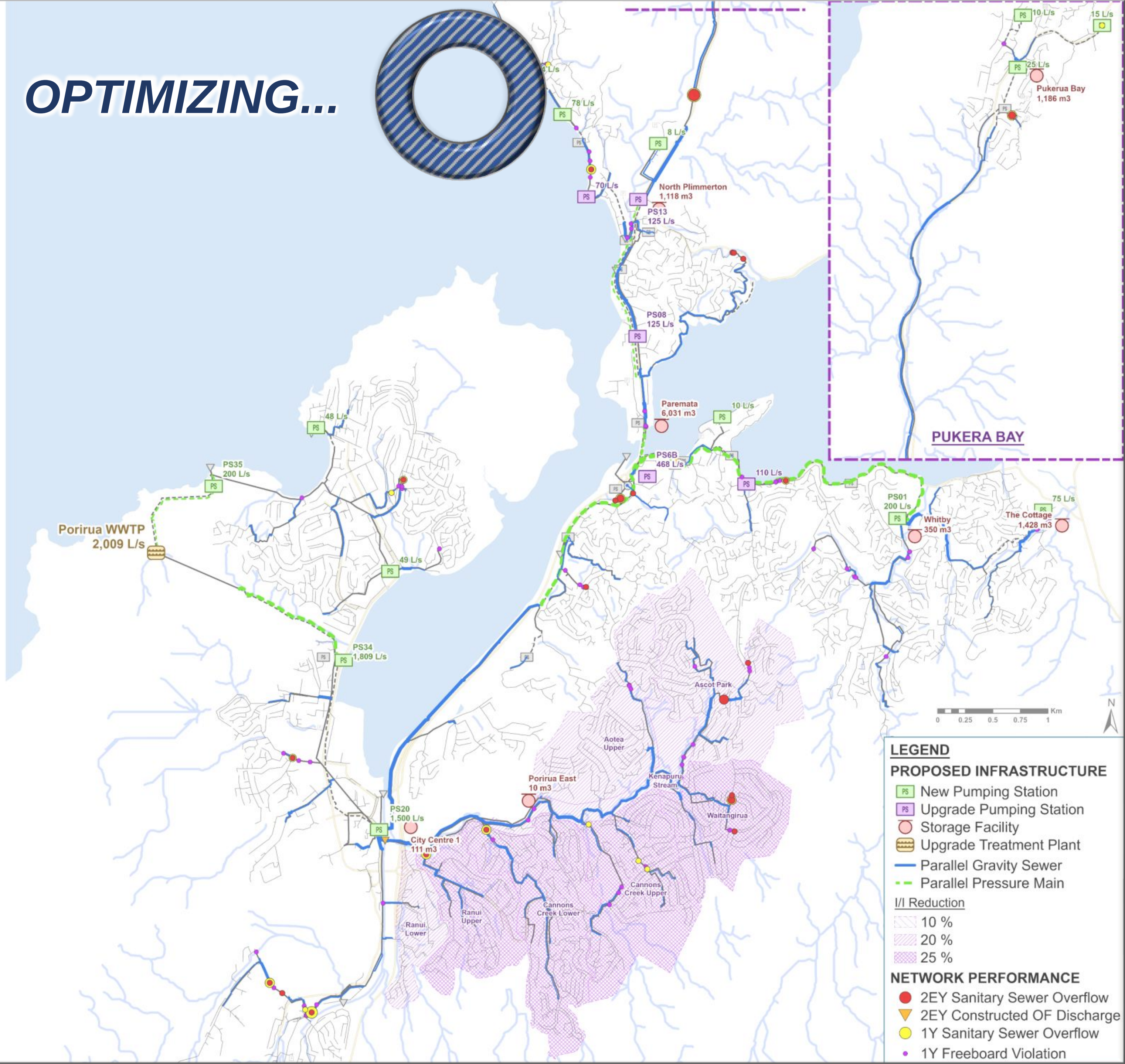
Number of Trial Solutions - 4,866

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$142.8
Pumping Station & Pressure Main Upgrades	$89.5
Storage Facilities	$70.9
Treatment Plant Upgrade	$24.9
Inflow and Infiltration Reduction	$14.2
TOTAL COST	**$342.3**
TOTAL OBJECTIVE	**$536.4**

Sanitary Sewer Overflow (2EY Design Storm):	*1,317 m3*
Constructed Outfall Discharge (2EY Design Storm):	*77 m3*
Sanitary Sewer Overflow (1-yr Design Storm):	*4,064 m3*
Freeboard Violations (1-yr Design Storm):	*48*

Optimization Convergence





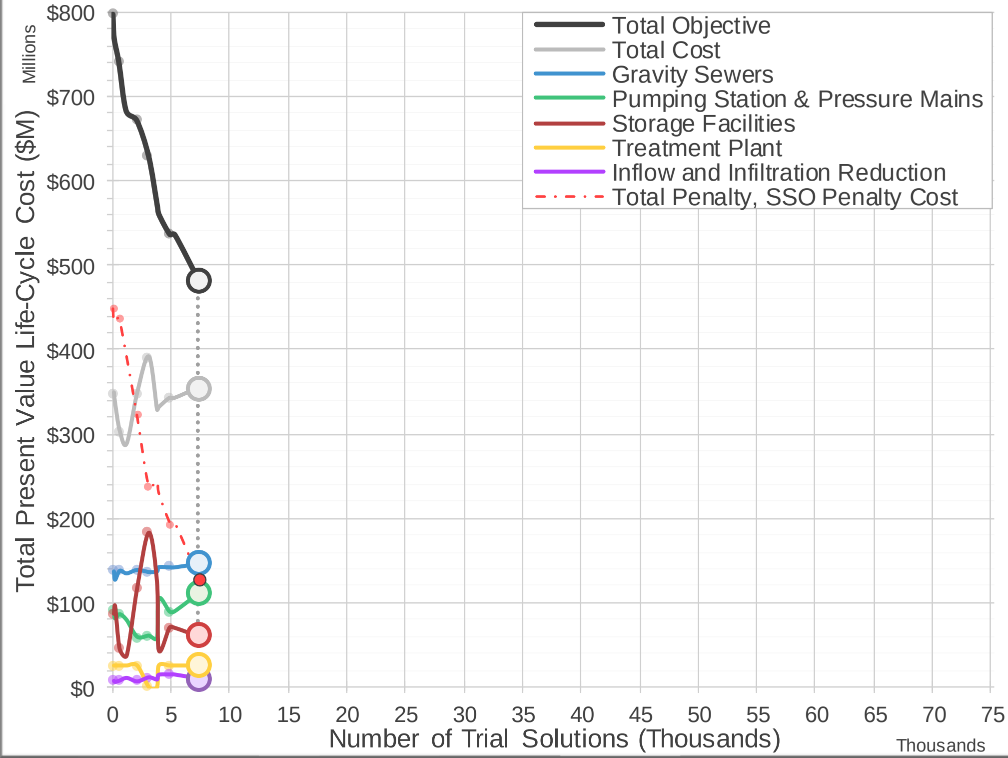
PORIRUA OPTIMIZATION

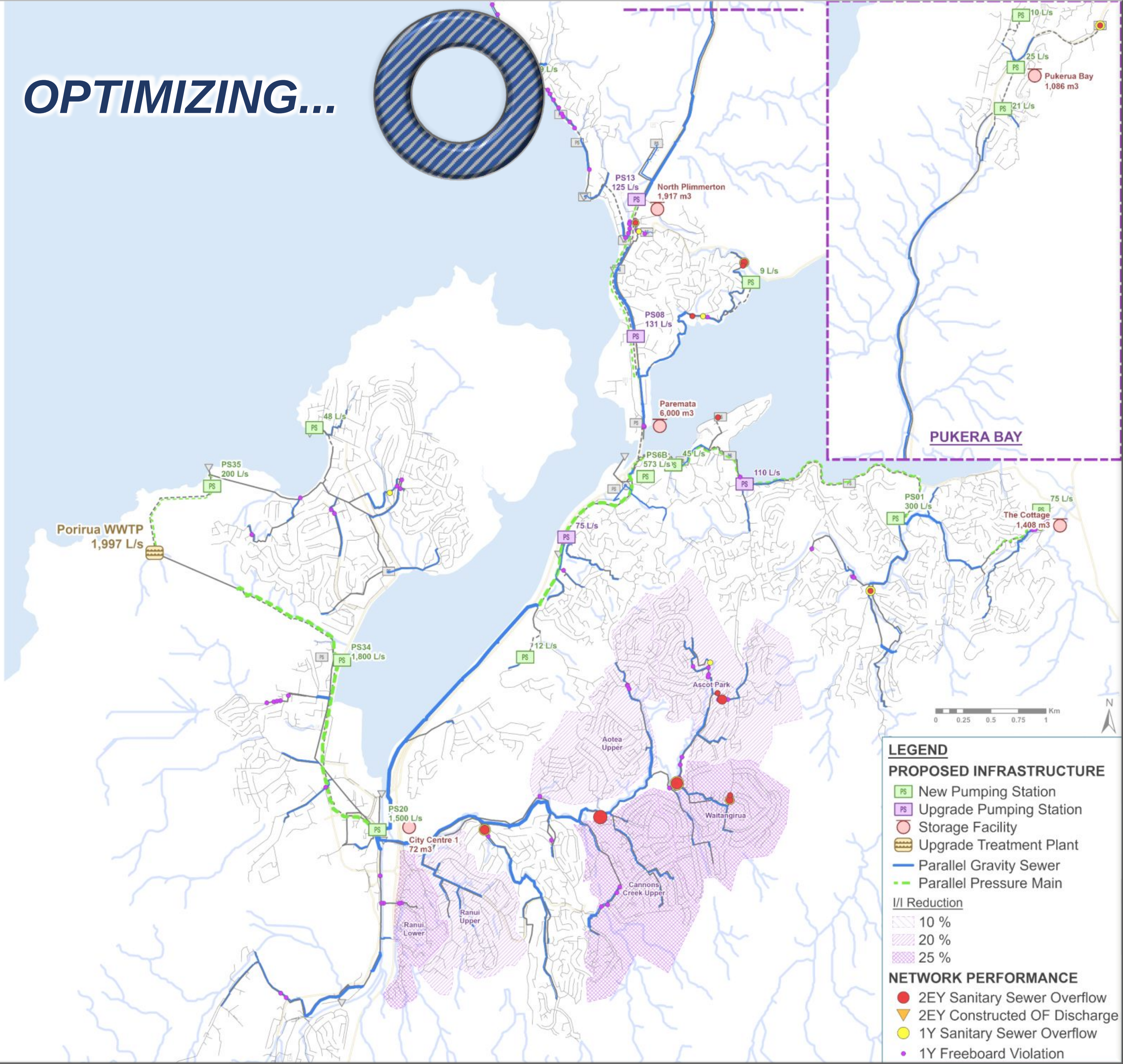
Number of Trial Solutions - 7,300

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$147.1
Pumping Station & Pressure Main Upgrades	$110.8
Storage Facilities	$61.1
Treatment Plant Upgrade	$24.9
Inflow and Infiltration Reduction	$10.4
TOTAL COST	**$354.3**
TOTAL OBJECTIVE	**$481.3**

Sanitary Sewer Overflow (2EY Design Storm): *2,393 m3*
Constructed Outfall Discharge (2EY Design Storm):
Sanitary Sewer Overflow (1-yr Design Storm): *6,641 m3*
Freeboard Violations (1-yr Design Storm): *43*

Optimization Convergence





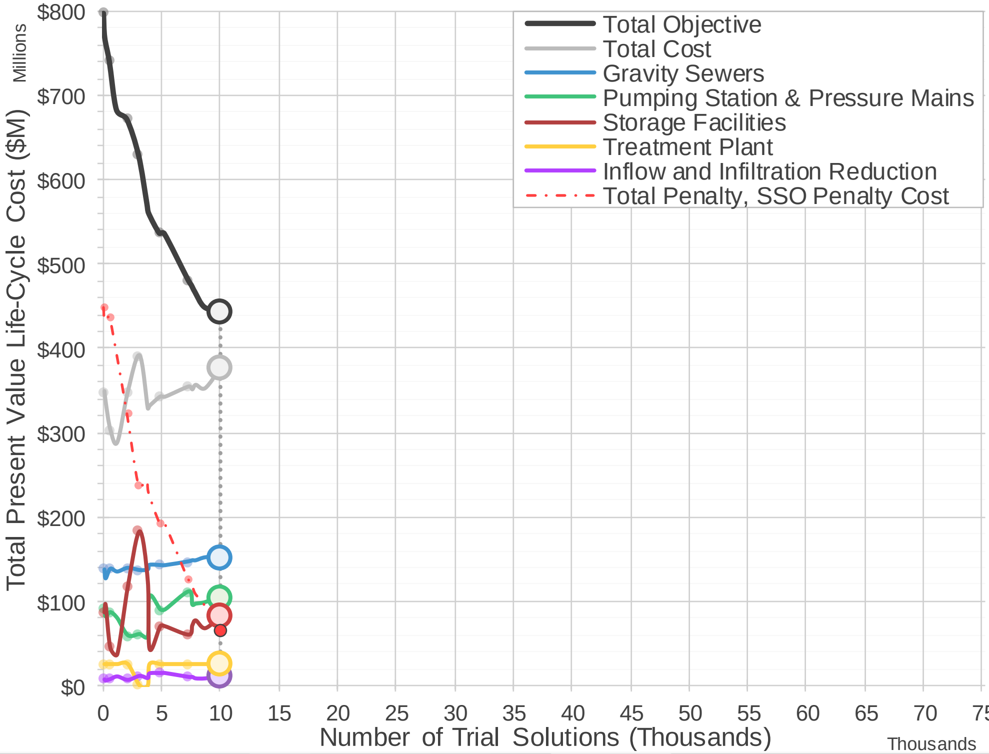
PORIRUA OPTIMIZATION

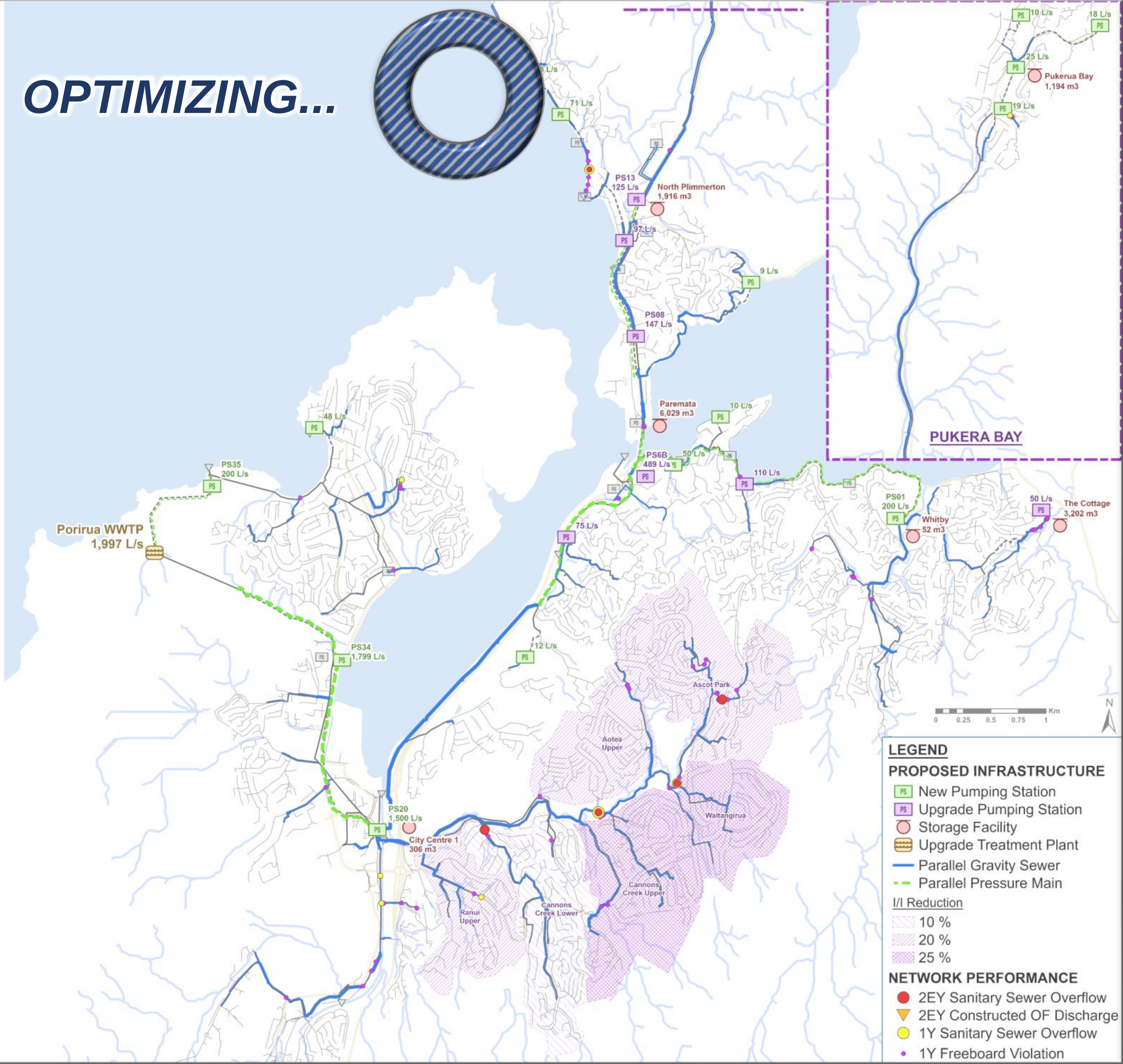
Number of Trial Solutions - 10,001

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$152.7
Pumping Station & Pressure Main Upgrades	$104.9
Storage Facilities	$82.9
Treatment Plant Upgrade	$24.9
Inflow and Infiltration Reduction	$10.8
TOTAL COST	**$376.2**
TOTAL OBJECTIVE	**$443.2**

Sanitary Sewer Overflow (2EY Design Storm): *436 m3*
Constructed Outfall Discharge (2EY Design Storm):
Sanitary Sewer Overflow (1-yr Design Storm): *1,606 m3*
Freeboard Violations (1-yr Design Storm): *34*

Optimization Convergence





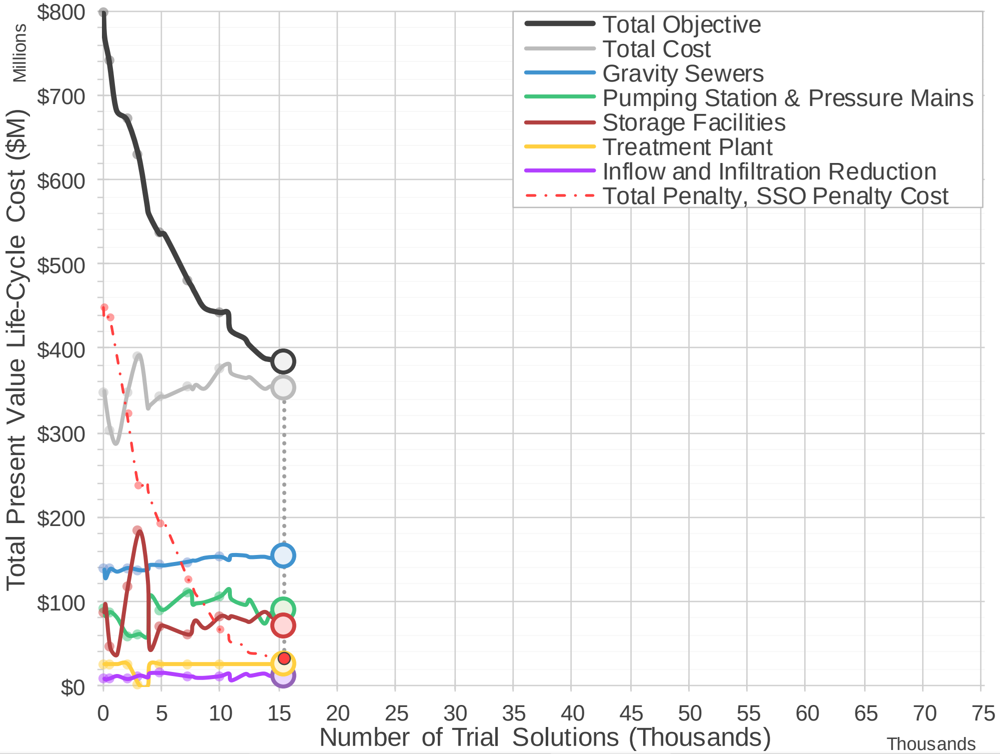
PORIRUA OPTIMIZATION

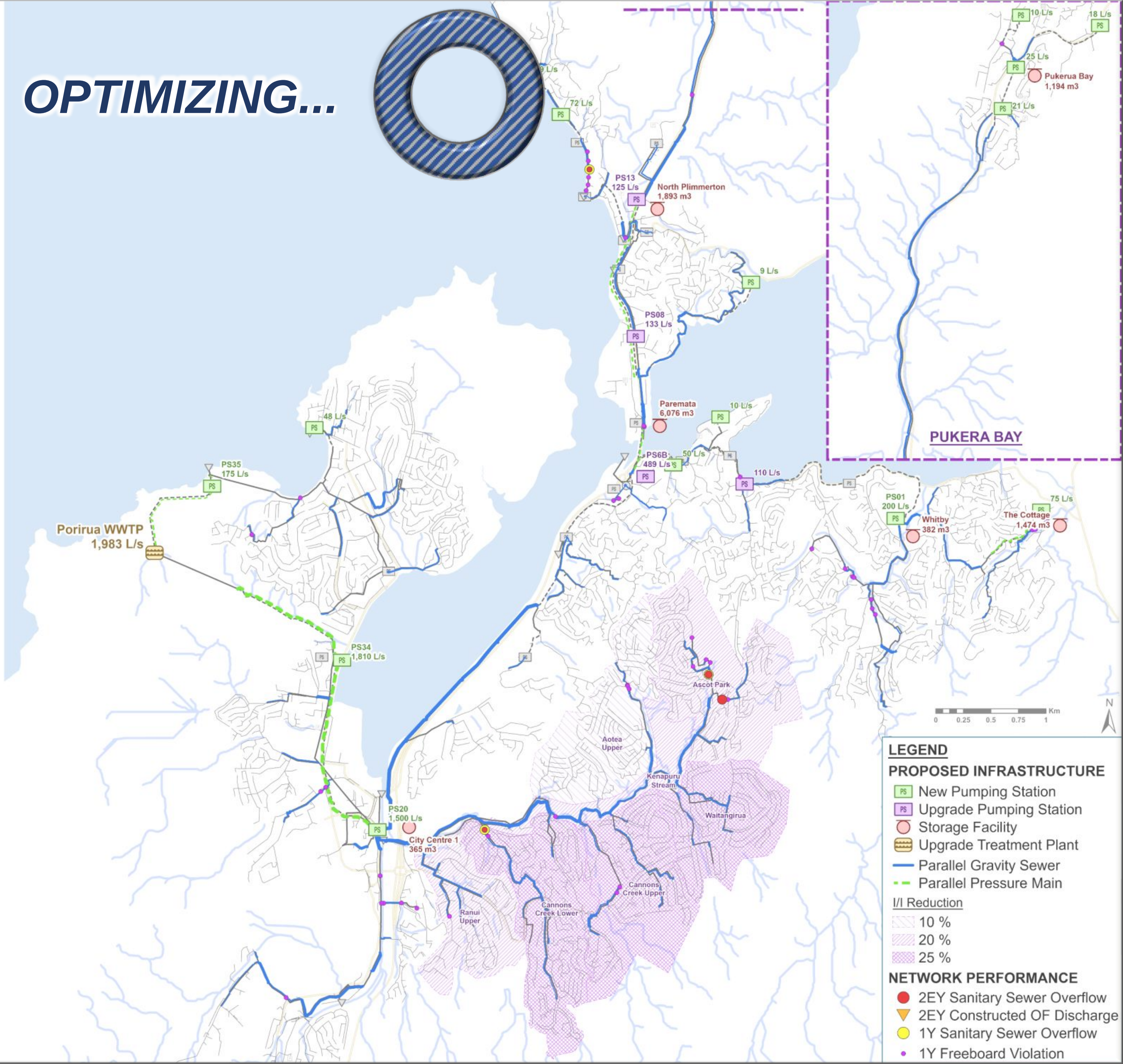
Number of Trial Solutions - 15,401

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$153.9
Pumping Station & Pressure Main Upgrades	$90.6
Storage Facilities	$71.3
Treatment Plant Upgrade	$24.9
Inflow and Infiltration Reduction	$12.3
TOTAL COST	**$353.0**
TOTAL OBJECTIVE	**$385.0**

Sanitary Sewer Overflow (2EY Design Storm):	*250 m3*
Constructed Outfall Discharge (2EY Design Storm):	
Sanitary Sewer Overflow (1-yr Design Storm):	*710 m3*
Freeboard Violations (1-yr Design Storm):	*19*

Optimization Convergence





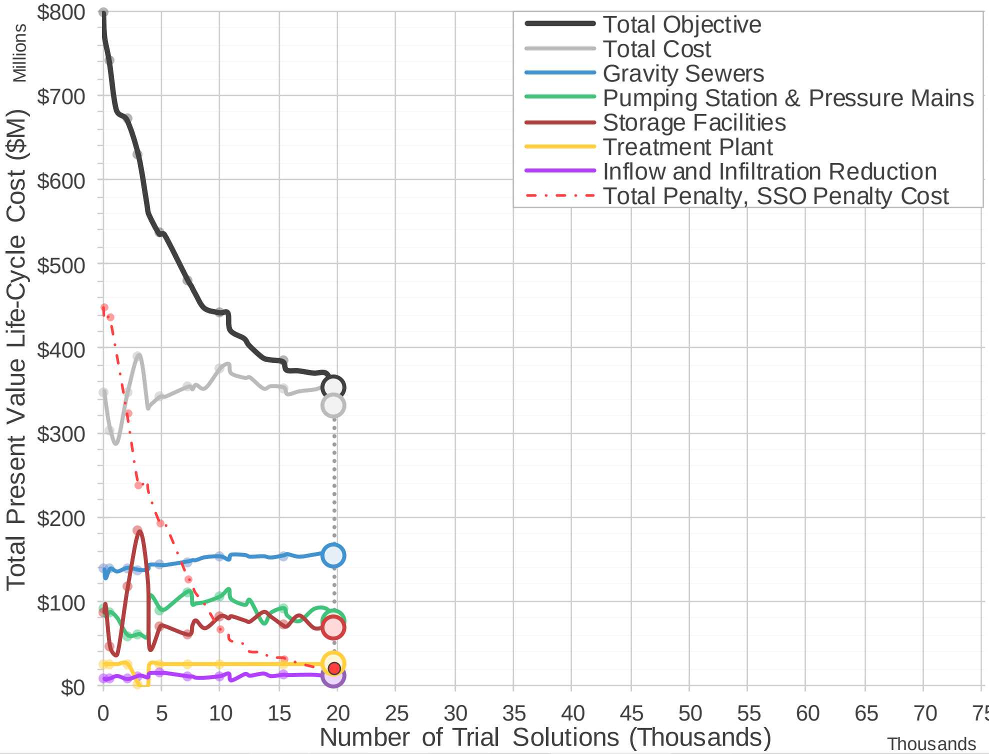
PORIRUA OPTIMIZATION

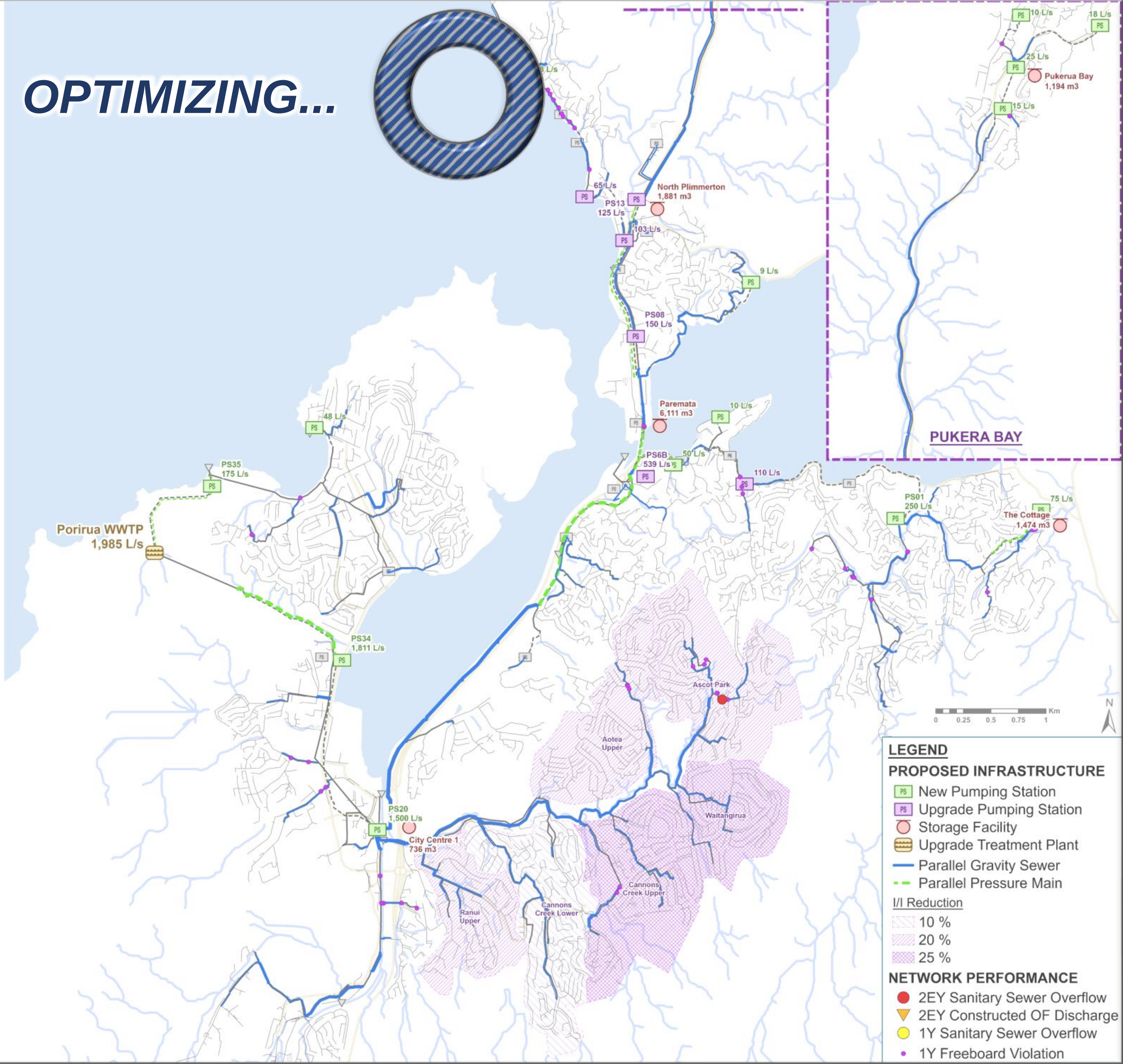
Number of Trial Solutions - 19,700

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$153.1
Pumping Station & Pressure Main Upgrades	$74.9
Storage Facilities	$68.8
Treatment Plant Upgrade	$24.9
Inflow and Infiltration Reduction	$10.8
TOTAL COST	**$332.6**
TOTAL OBJECTIVE	**$354.6**

Sanitary Sewer Overflow (2EY Design Storm): *161 m3*
Constructed Outfall Discharge (2EY Design Storm):
Sanitary Sewer Overflow (1-yr Design Storm): *419 m3*
Freeboard Violations (1-yr Design Storm): *19*

Optimization Convergence





PORIRUA OPTIMIZATION

Number of Trial Solutions - 23,631

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$152.4
Pumping Station & Pressure Main Upgrades	$61.7
Storage Facilities	$71.7
Treatment Plant Upgrade	$24.9
Inflow and Infiltration Reduction	$11.2
TOTAL COST	**$321.8**
TOTAL OBJECTIVE	**$337.1**

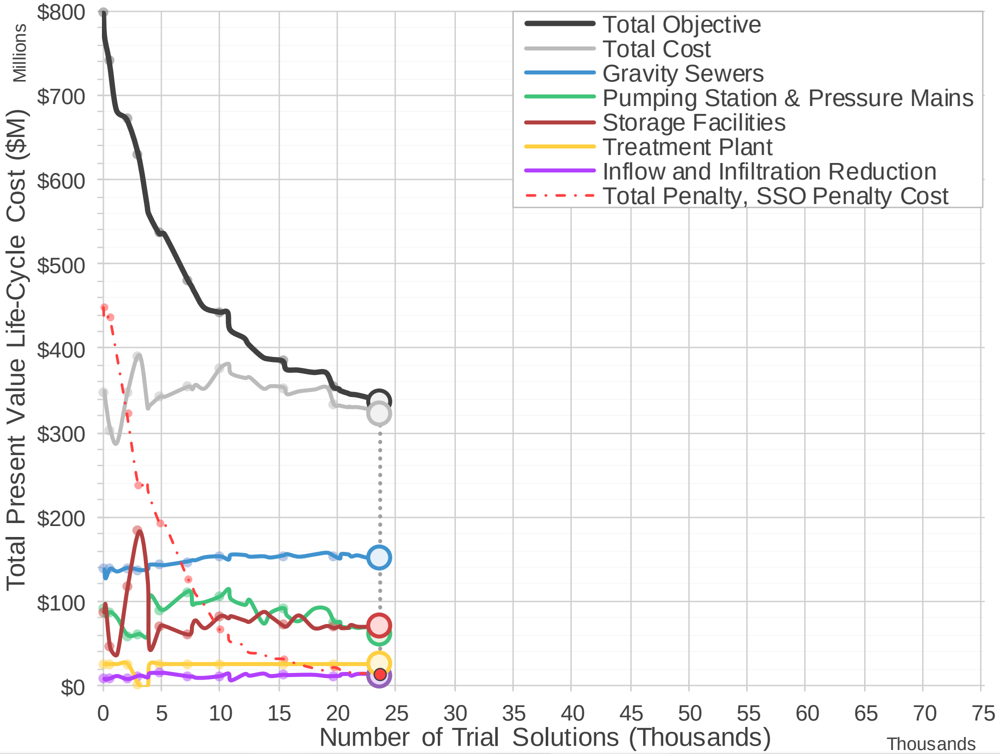
Sanitary Sewer Overflow (2EY Design Storm):

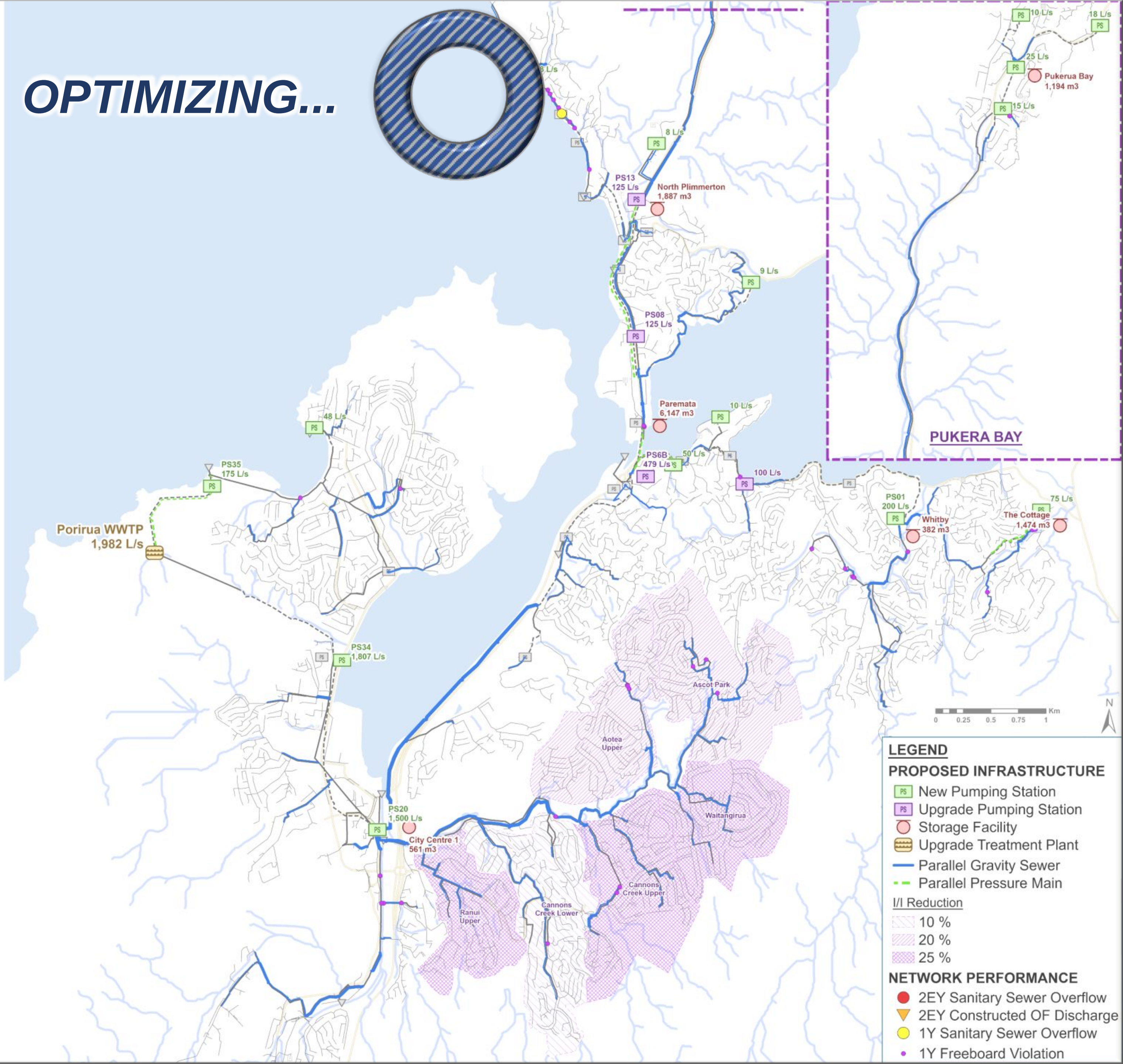
Constructed Outfall Discharge (2EY Design Storm):

Sanitary Sewer Overflow (1-yr Design Storm): *111 m3*

Freeboard Violations (1-yr Design Storm): *14*

Optimization Convergence





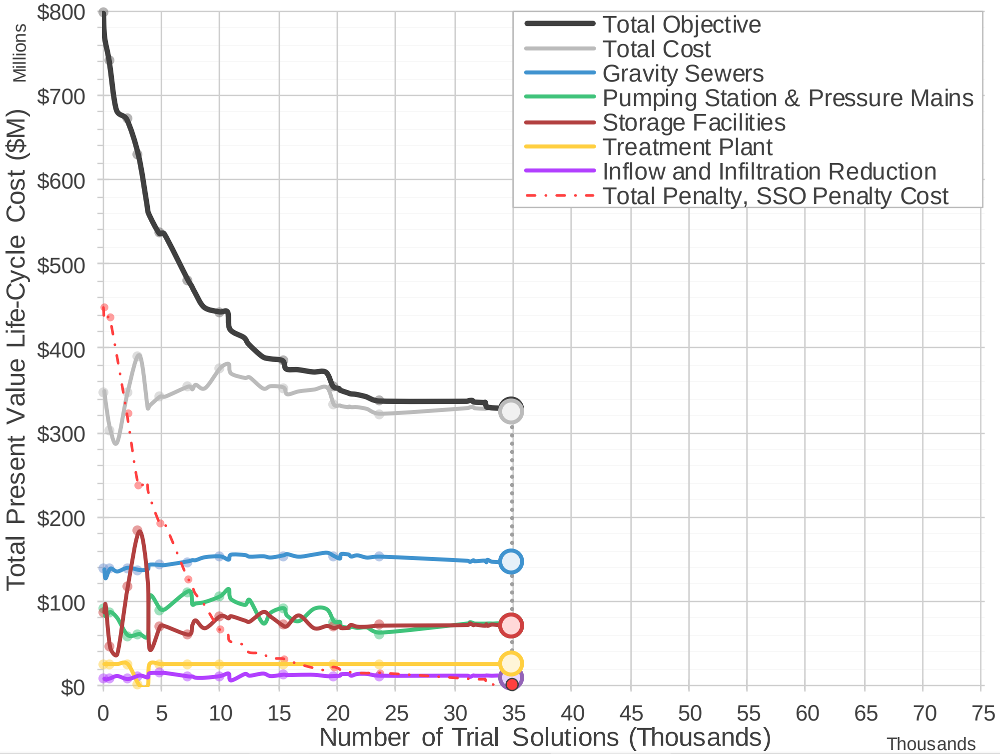
PORIRUA OPTIMIZATION

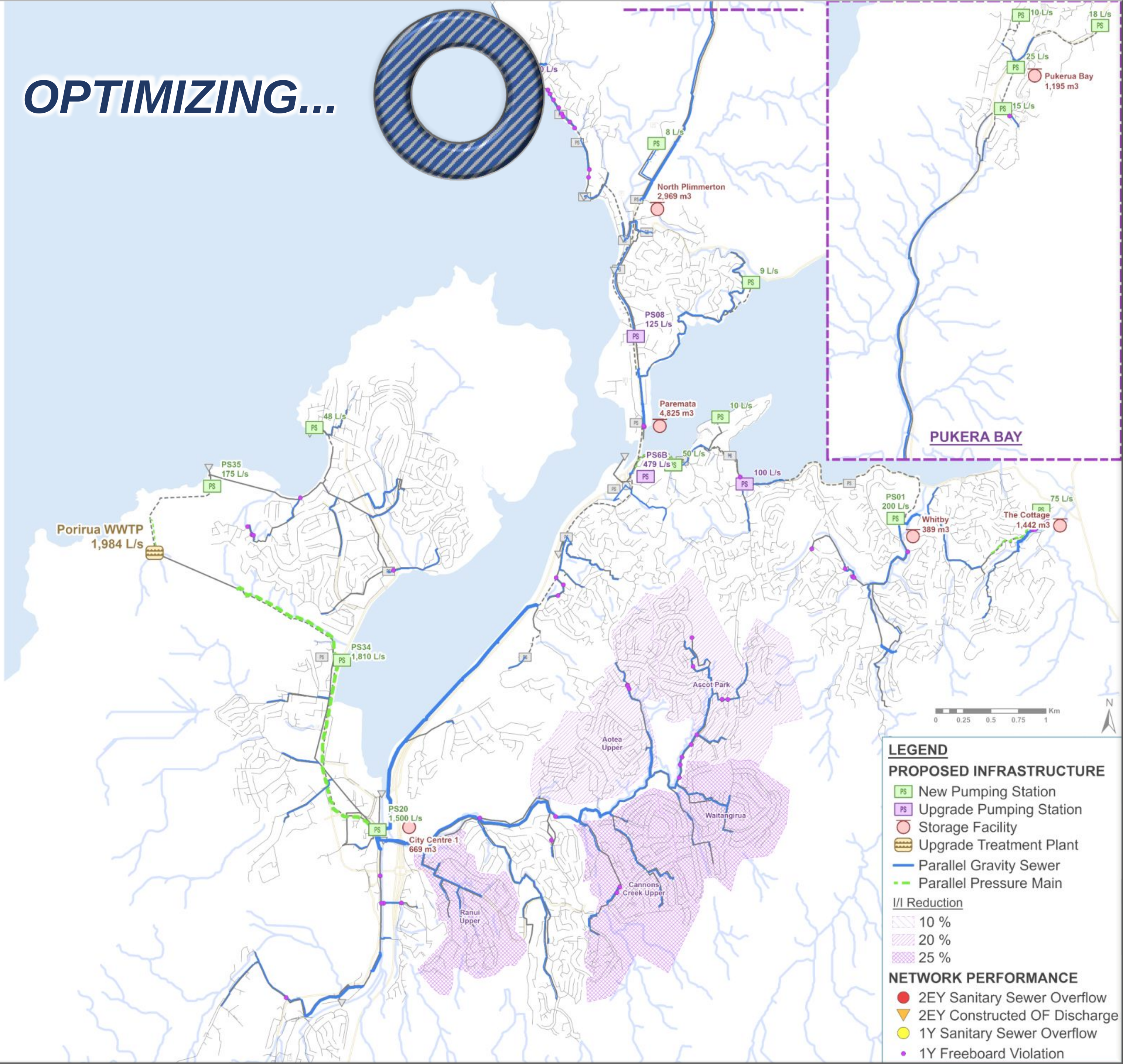
Number of Trial Solutions - 34,900

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$146.3
Pumping Station & Pressure Main Upgrades	$72.2
Storage Facilities	$72.3
Treatment Plant Upgrade	$24.9
Inflow and Infiltration Reduction	$9.9
TOTAL COST	**$325.6**
TOTAL OBJECTIVE	**$327.0**

Sanitary Sewer Overflow (2EY Design Storm):
Constructed Outfall Discharge (2EY Design Storm):
Sanitary Sewer Overflow (1-yr Design Storm):
Freeboard Violations (1-yr Design Storm): *14*

Optimization Convergence





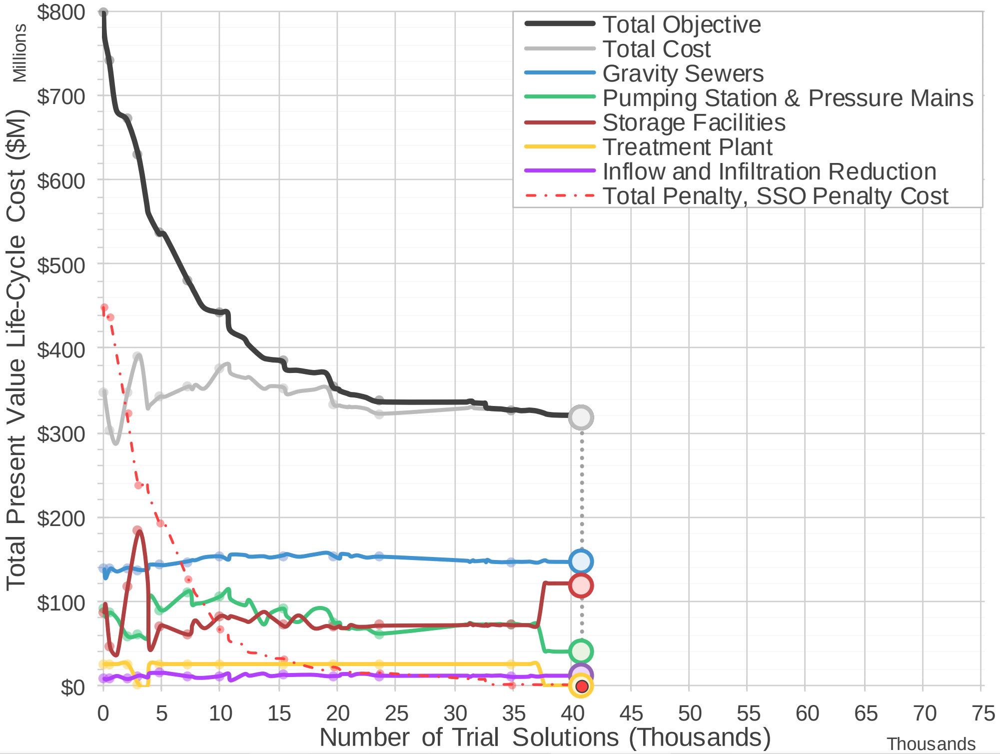
PORIRUA OPTIMIZATION

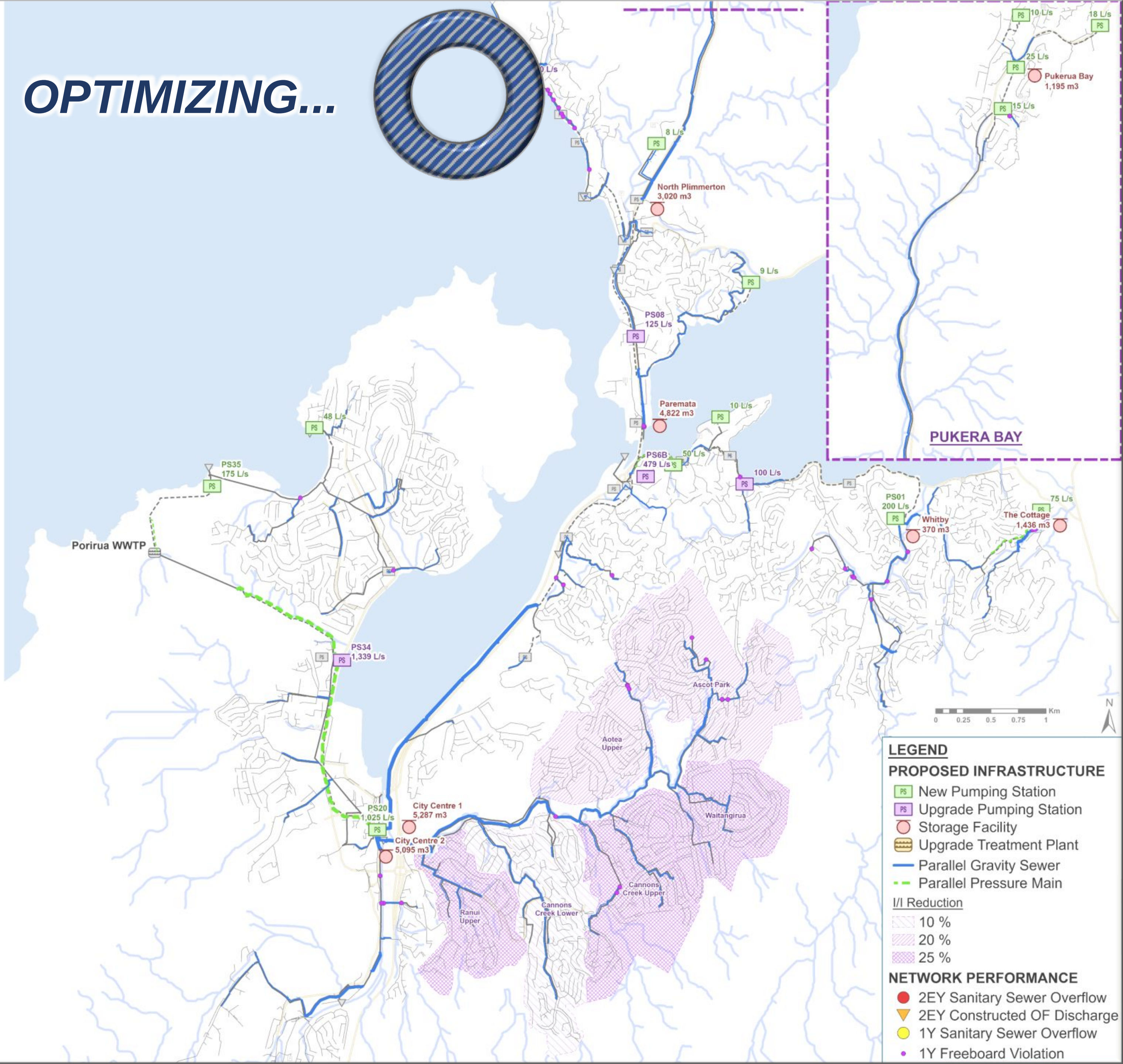
Number of Trial Solutions - 40,900

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$146.8
Pumping Station & Pressure Main Upgrades	$41.2
Storage Facilities	$118.1
Treatment Plant Upgrade	
Inflow and Infiltration Reduction	$11.2
TOTAL COST	**$317.3**
TOTAL OBJECTIVE	**$318.4**

Sanitary Sewer Overflow (2EY Design Storm):	
Constructed Outfall Discharge (2EY Design Storm):	
Sanitary Sewer Overflow (1-yr Design Storm):	
Freeboard Violations (1-yr Design Storm):	*11*

Optimization Convergence





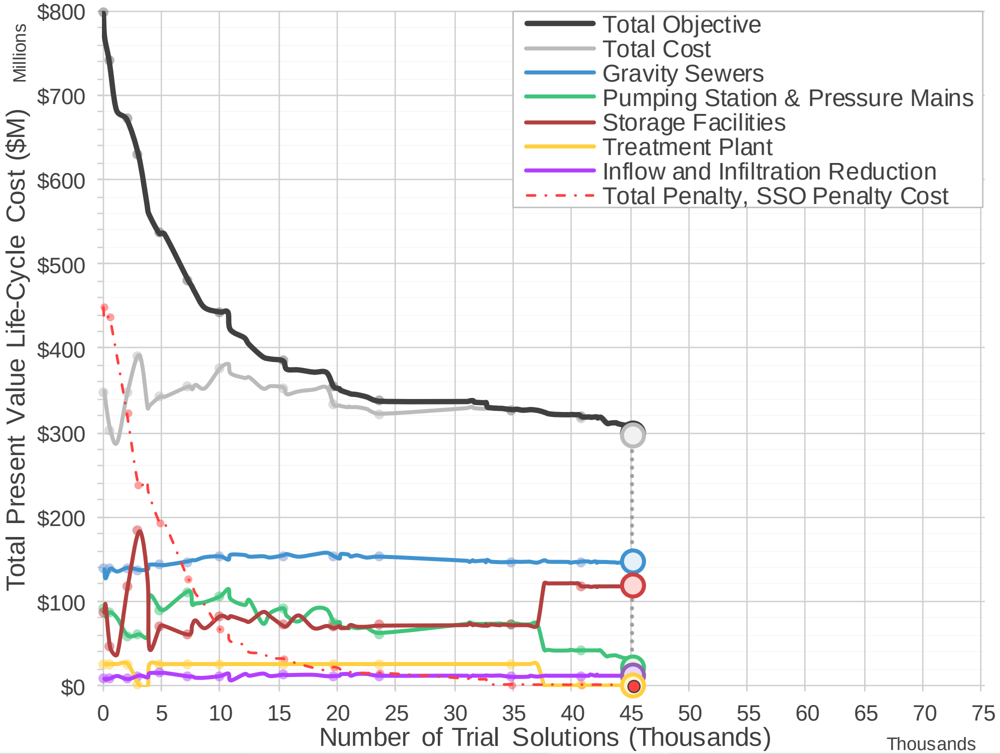
PORIRUA OPTIMIZATION

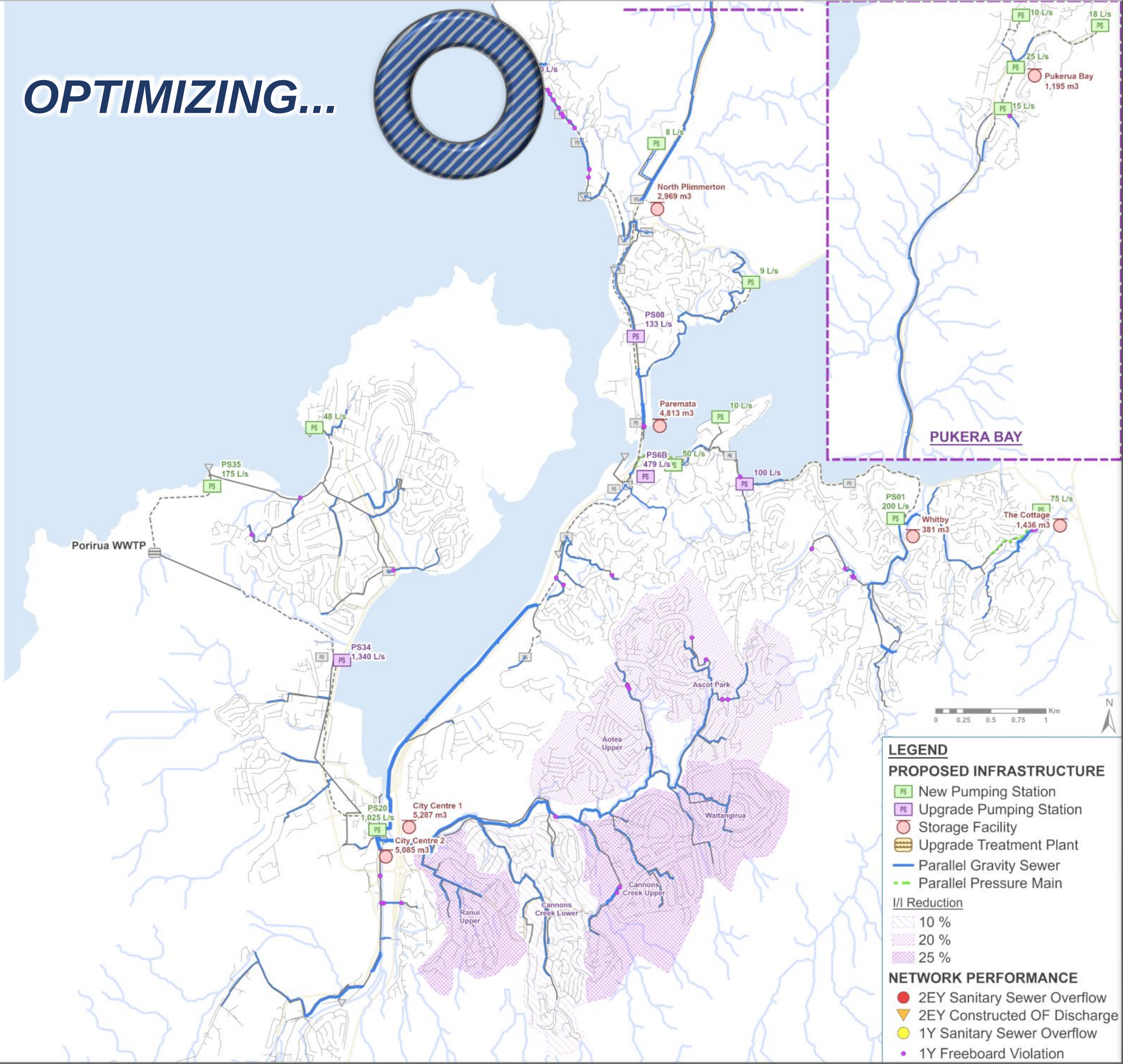
Number of Trial Solutions - 45,201

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$146.1
Pumping Station & Pressure Main Upgrades	$22.3
Storage Facilities	$118.1
Treatment Plant Upgrade	
Inflow and Infiltration Reduction	$11.2
TOTAL COST	**$297.6**
TOTAL OBJECTIVE	**$298.7**

Sanitary Sewer Overflow (2EY Design Storm):
Constructed Outfall Discharge (2EY Design Storm):
Sanitary Sewer Overflow (1-yr Design Storm):
Freeboard Violations (1-yr Design Storm): *11*

Optimization Convergence





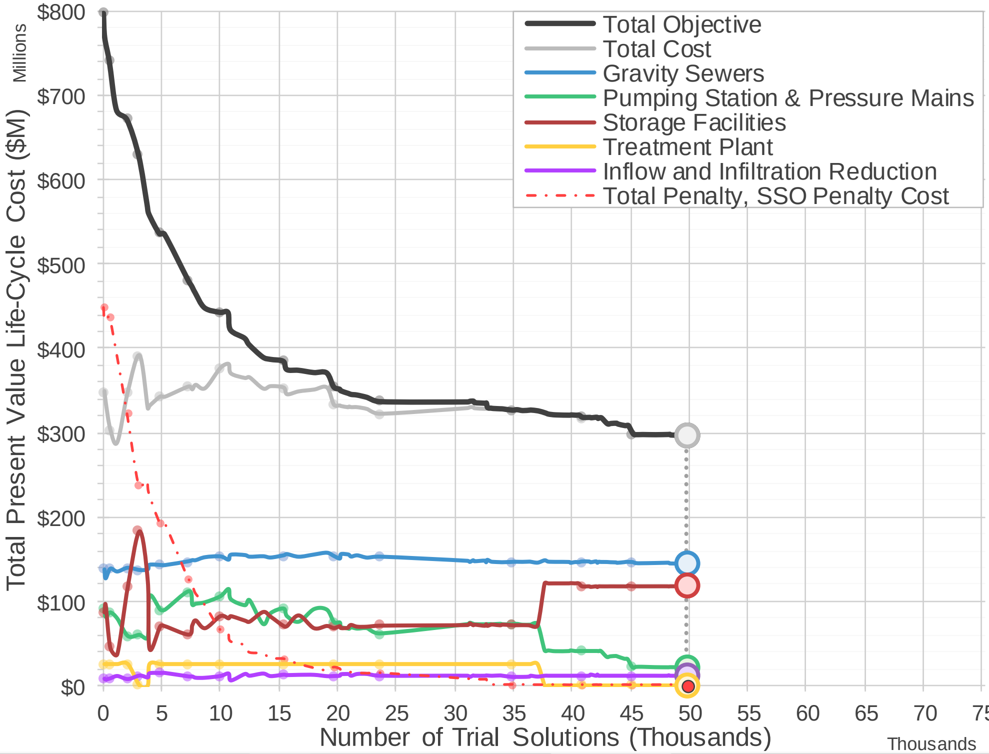
PORIRUA OPTIMIZATION

Number of Trial Solutions - 49,800

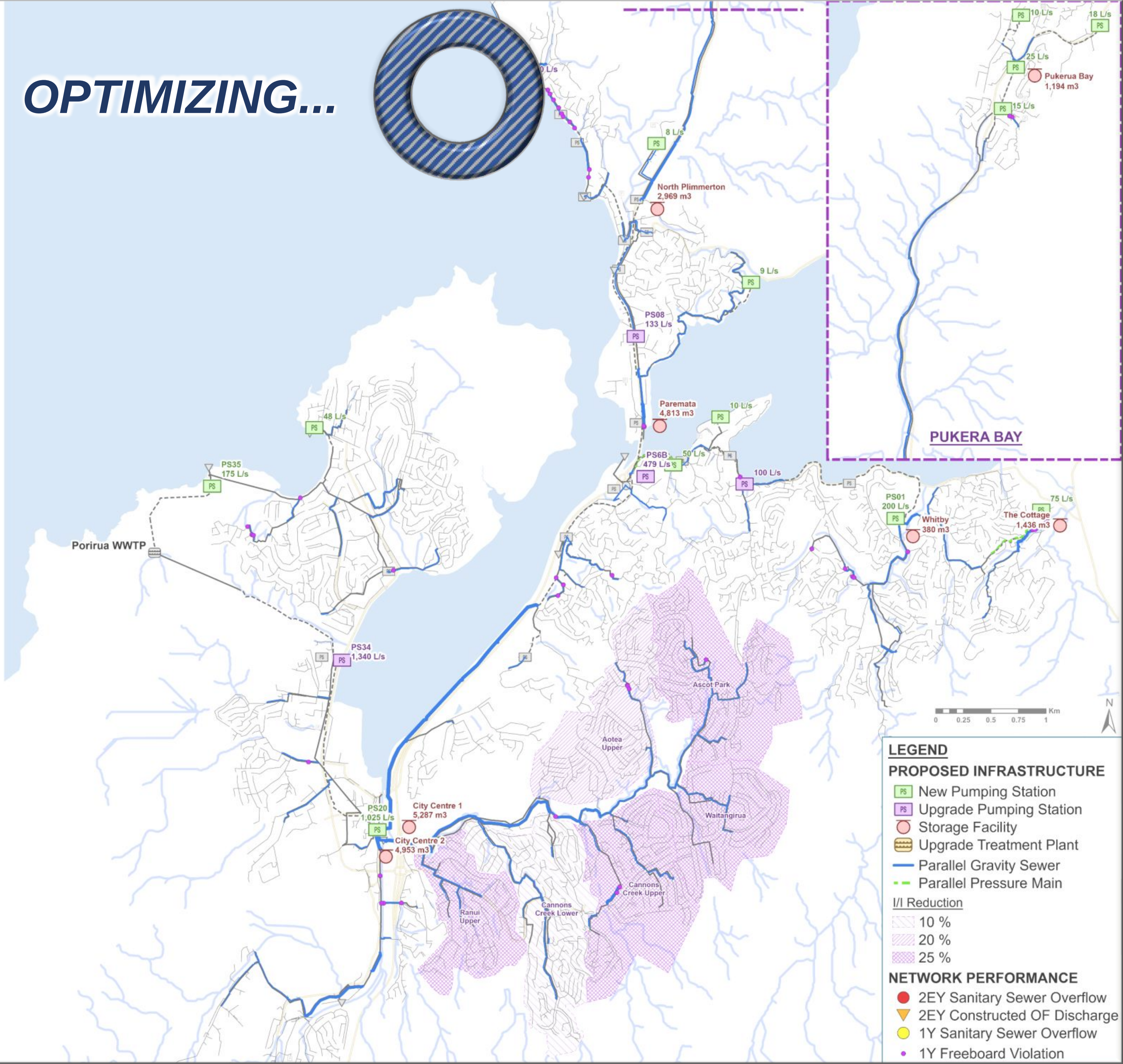
Cost Item	Cost ($M)
Gravity Sewer Upgrades	$144.3
Pumping Station & Pressure Main Upgrades	$22.3
Storage Facilities	$117.7
Treatment Plant Upgrade	
Inflow and Infiltration Reduction	$11.7
TOTAL COST	**$296.0**
TOTAL OBJECTIVE	**$297.0**

Sanitary Sewer Overflow (2EY Design Storm):
Constructed Outfall Discharge (2EY Design Storm):
Sanitary Sewer Overflow (1-yr Design Storm):
Freeboard Violations (1-yr Design Storm): *10*

Optimization Convergence



OPTIMIZING...



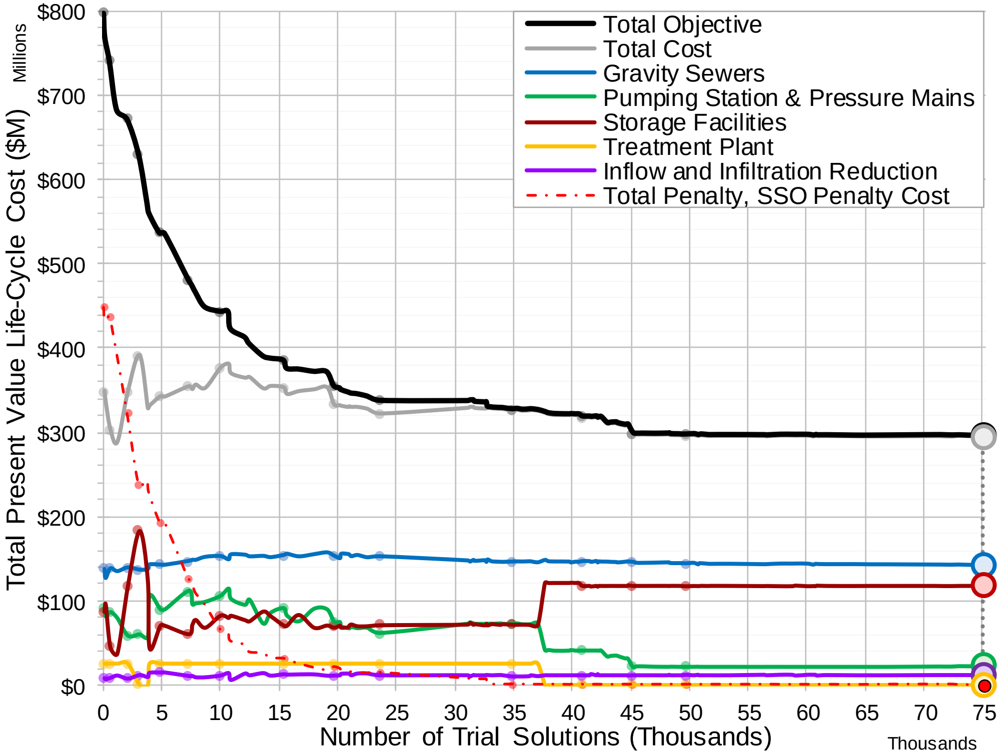
PORIRUA OPTIMIZATION

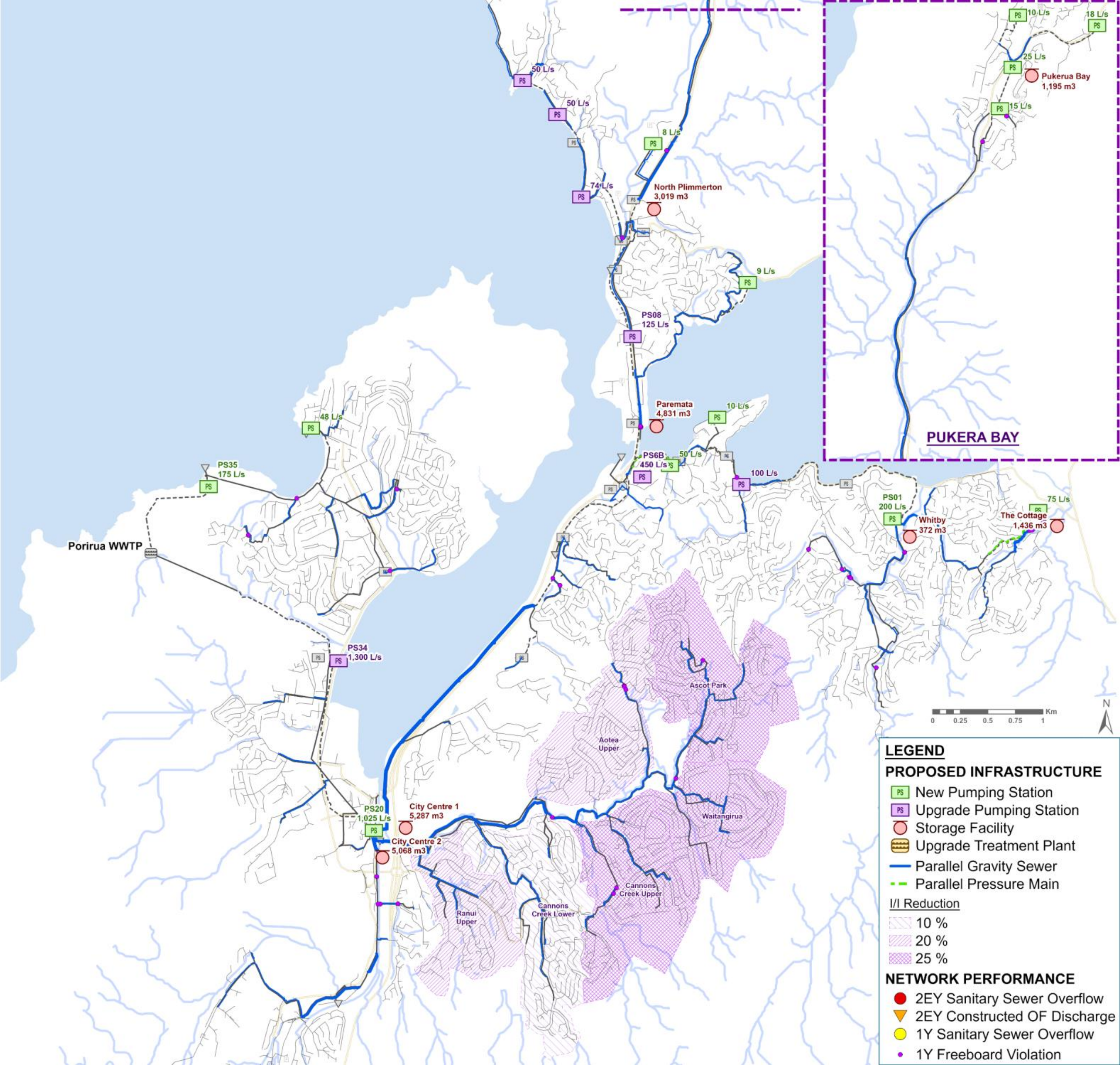
Number of Trial Solutions - 75,071

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$142.4
Pumping Station & Pressure Main Upgrades	$23.0
Storage Facilities	$118.1
Treatment Plant Upgrade	
Inflow and Infiltration Reduction	$11.4
TOTAL COST	**$294.8**
TOTAL OBJECTIVE	**$295.5**

Sanitary Sewer Overflow (2EY Design Storm):
Constructed Outfall Discharge (2EY Design Storm):
Sanitary Sewer Overflow (1-yr Design Storm):
Freeboard Violations (1-yr Design Storm): *7*

Optimization Convergence

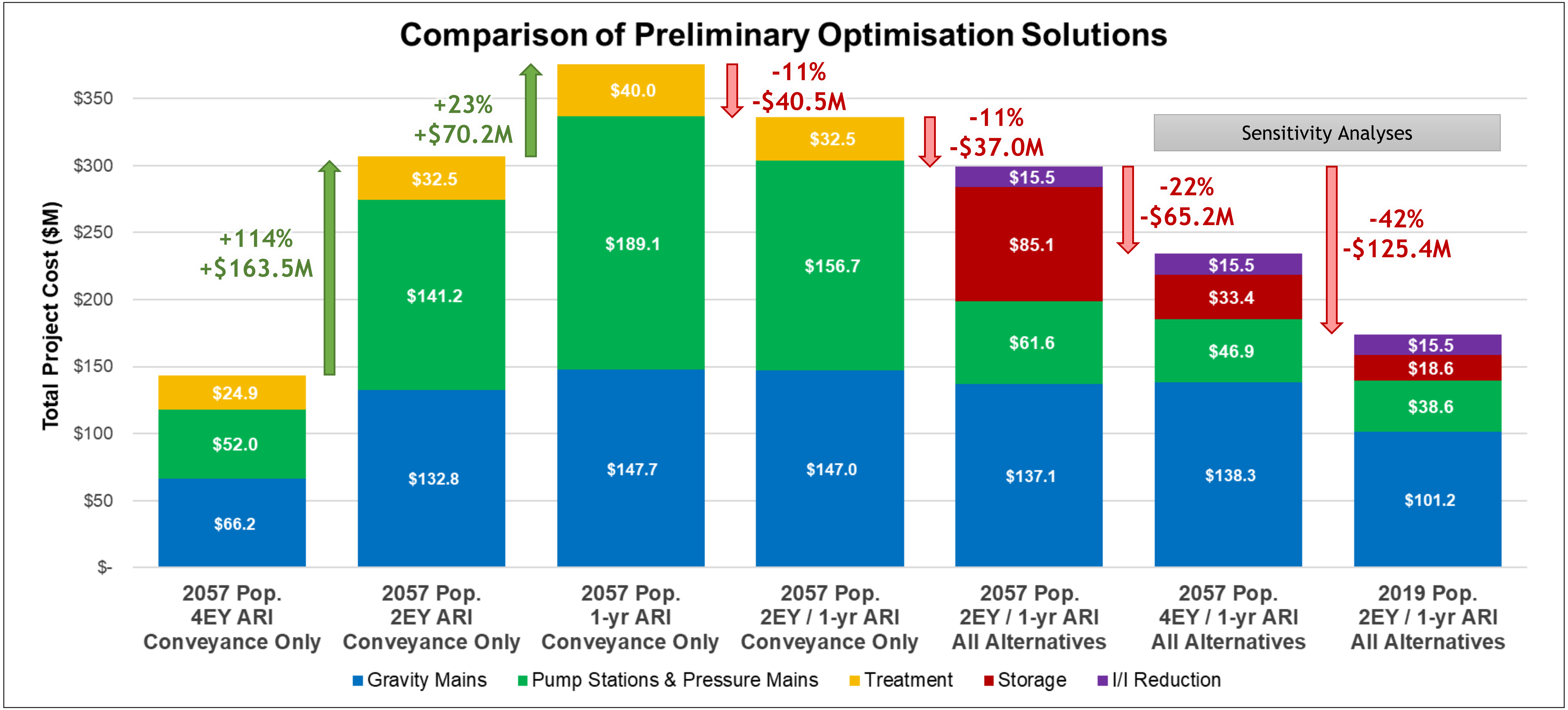




Key Optimization Scenarios Run

- Conveyance-only scenarios
  - 4EY design storm
  - 2EY design storm
  - 1Y design storm
- Composite 2EY/1Y design scenarios – 2057 population
  - Conveyance-only
  - All alternatives (conveyance + storage + I/I)
- Additional sensitivity analyses
  - 4EY/1Y – All alternatives (2057 population)
  - 2EY/1Y – All alternatives (2019 population)

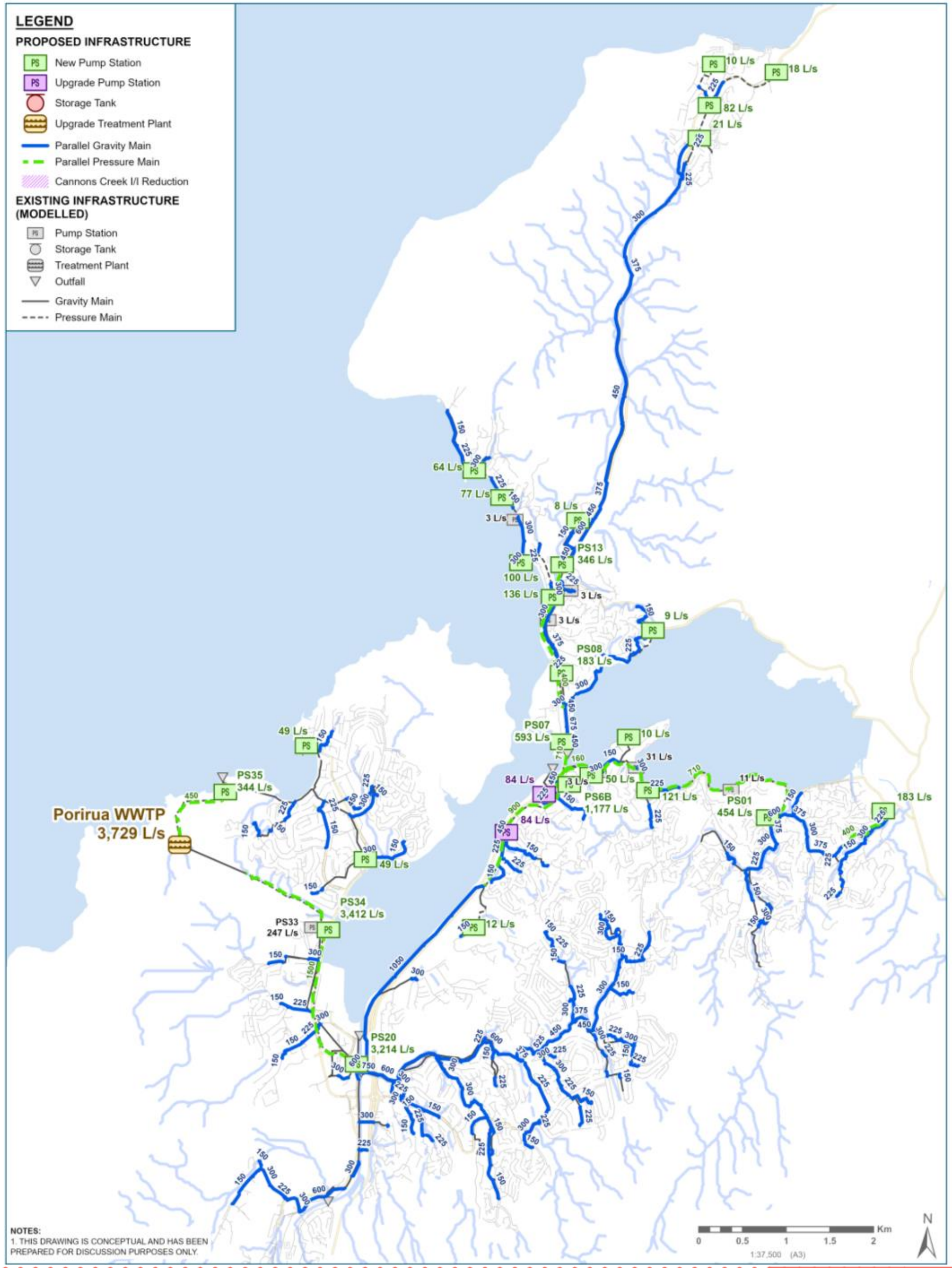
Key Optimization Scenario Results



Optimized Master Plan

- 2057 Population Scenario
- 1 uncontrolled SSO per year
- Conveyance Only

Cost Item	Initial Capital Cost	50-yr PV O&M Cost	50-yr PV Total Cost
Gravity Sewer Upgrades	$143.8	$3.9	$147.7
Pumping Station & Pressure Main Upgrades	$177.6	$11.5	$189.1
Storage Facilities	$0.0	$0.0	$0.0
Treatment Plant Upgrade	$40.0	$0.0	$40.0
Inflow and Infiltration Reduction	$0.0	$0.0	$0.0
Total Capital Cost	**$361.3**	**$15.4**	**$376.8**

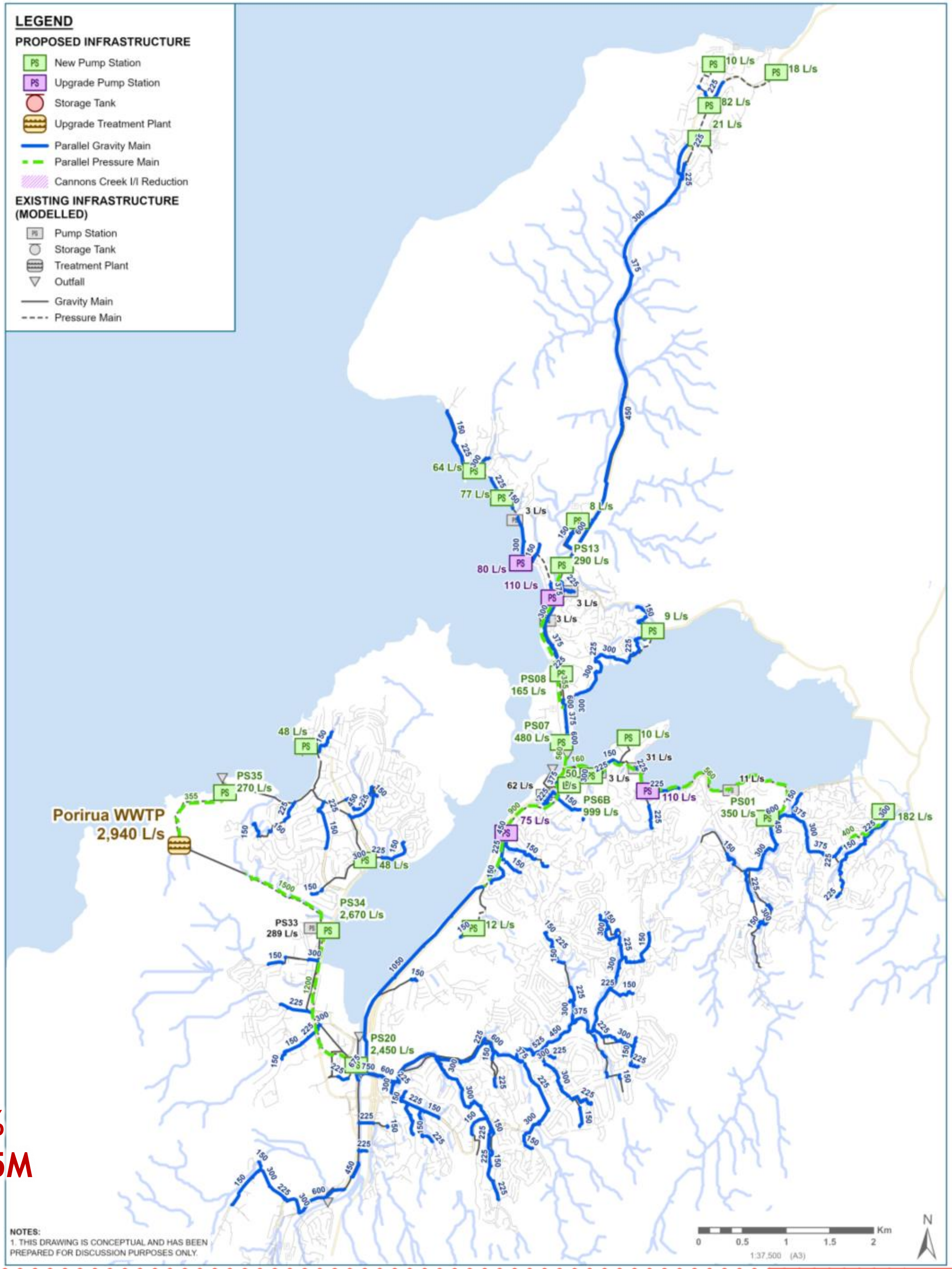


Optimized Master Plan

- 2057 Population Scenario
- 2 discharges per year at constructed outfalls and 1 uncontrolled SSO per year
- Conveyance Only

Cost Item	Initial Capital Cost	50-yr PV O&M Cost	50-yr PV Total Cost
Gravity Sewer Upgrades	$143.2	$3.9	$147.0
Pumping Station & Pressure Main Upgrades	$146.2	$10.6	$156.7
Storage Facilities	$0.0	$0.0	$0.0
Treatment Plant Upgrade	$32.5	$0.0	$32.5
Inflow and Infiltration Reduction	$0.0	$0.0	$0.0
Total Capital Cost	**$321.8**	**$14.4**	**$336.3**

-11%
-$40.5M

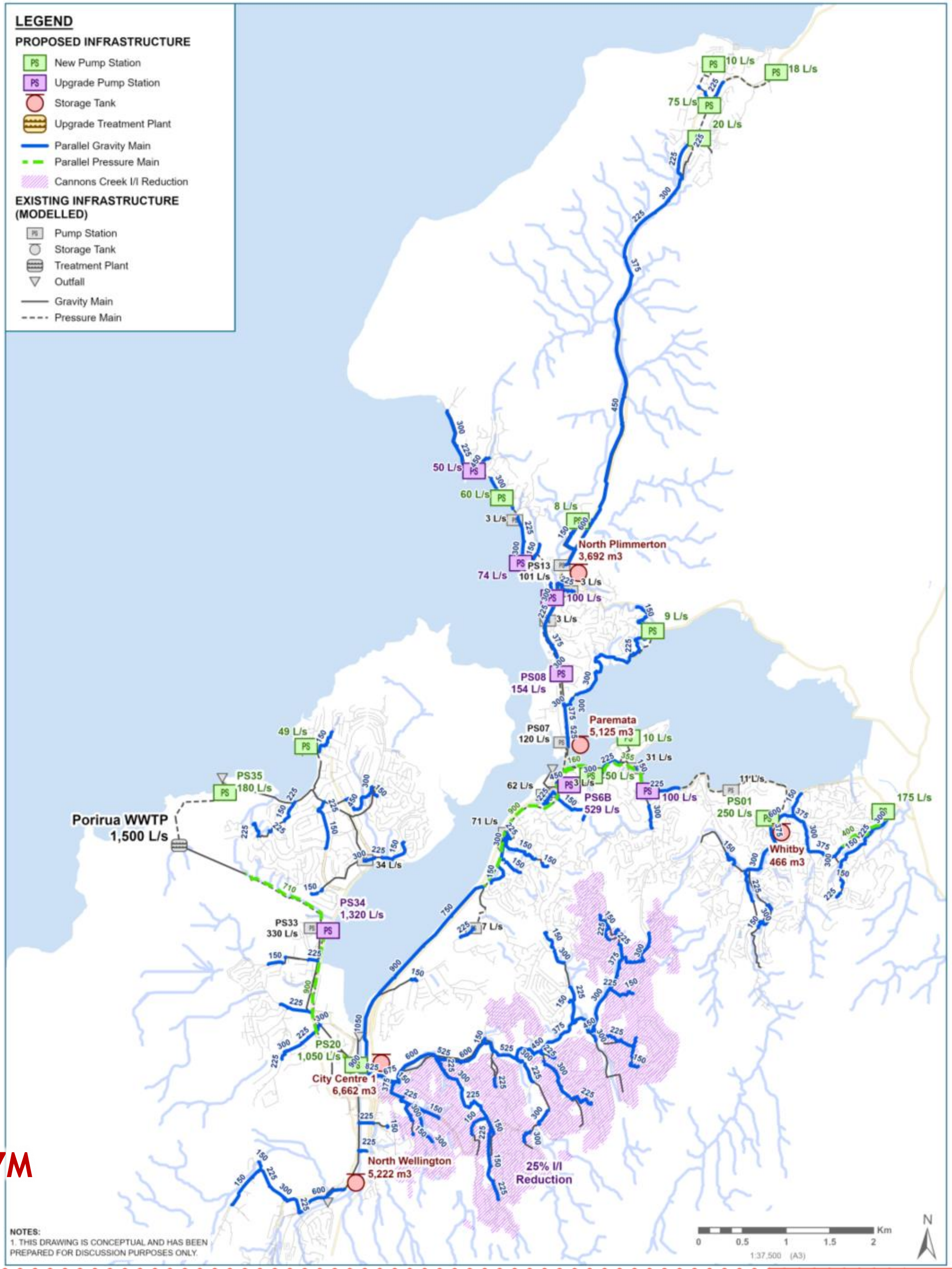


Preferred Master Plan

- 2057 Population Scenario
- 2 discharges per year at constructed outfalls and 1 uncontrolled SSO per year
- All alternatives considered
- Solution remodelled and refined in ICM with 10-year rainfall

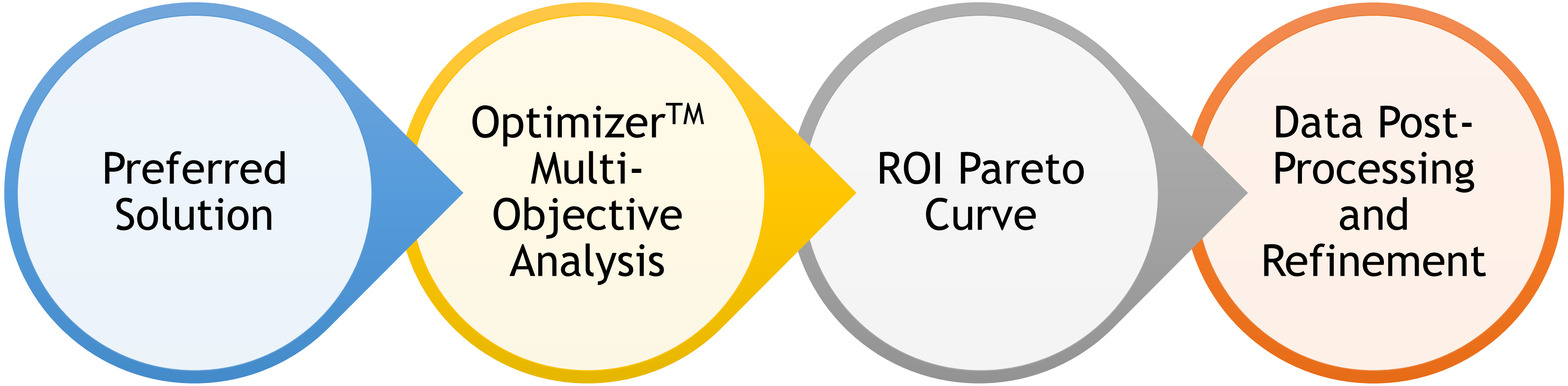
Cost Item	Initial Capital Cost	50-yr PV O&M Cost	50-yr PV Total Cost
Gravity Sewer Upgrades	$132.3	$3.6	$135.9
Pumping Station & Pressure Main Upgrades	$57.3	$6.9	$64.2
Storage Facilities	$88.6	$2.4	$91.0
Treatment Plant Upgrade	$0.0	$0.0	$0.0
Inflow and Infiltration Reduction	$15.5	$0.0	$15.5
Total Capital Cost	**$293.7**	**$12.9**	**$306.6**

-9%
-$29.7M



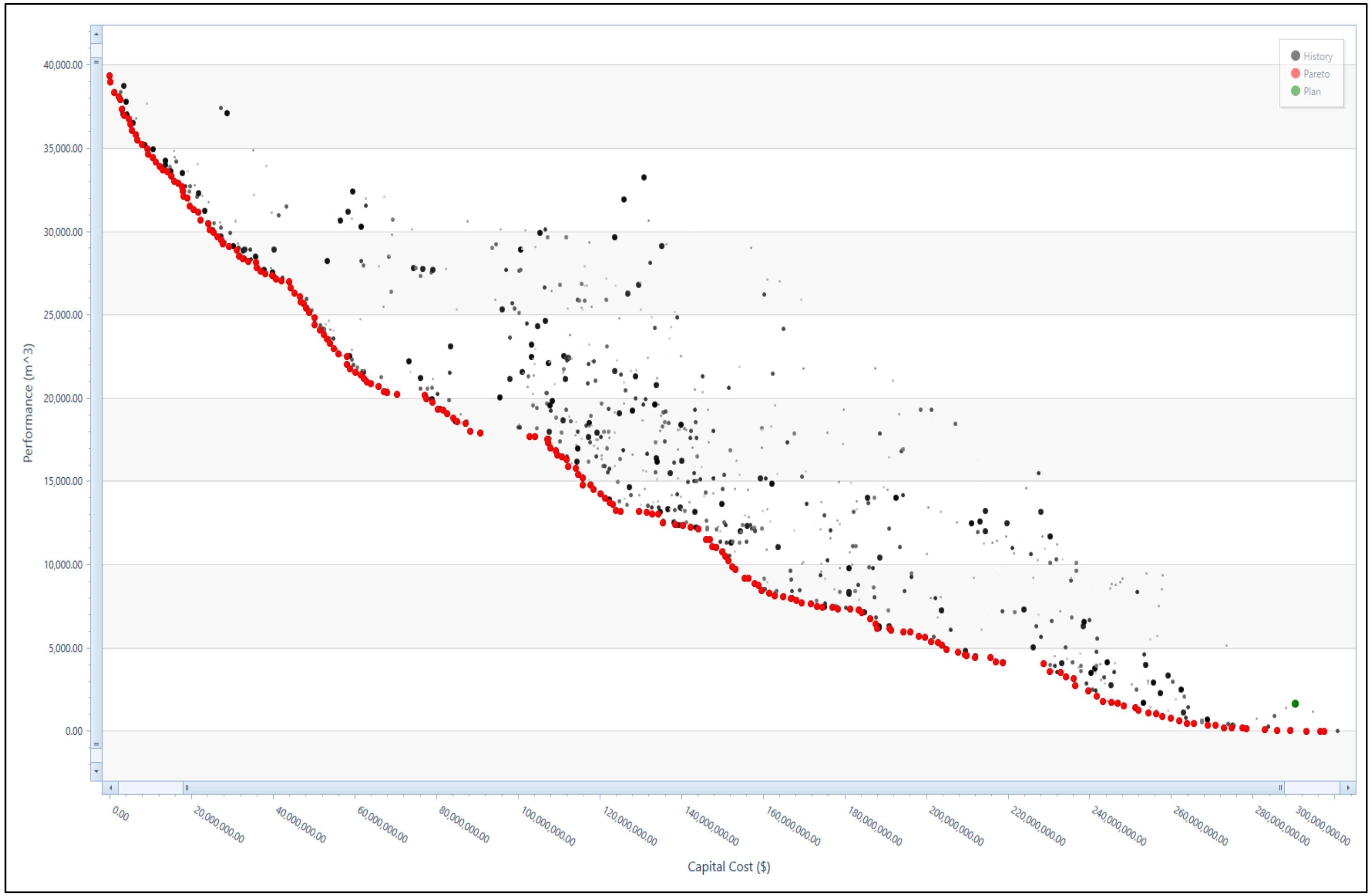
Prioritization Analysis

- Determine the sequence of project implementation that provides the maximum return on investment (ROI) with respect to improved system performance.



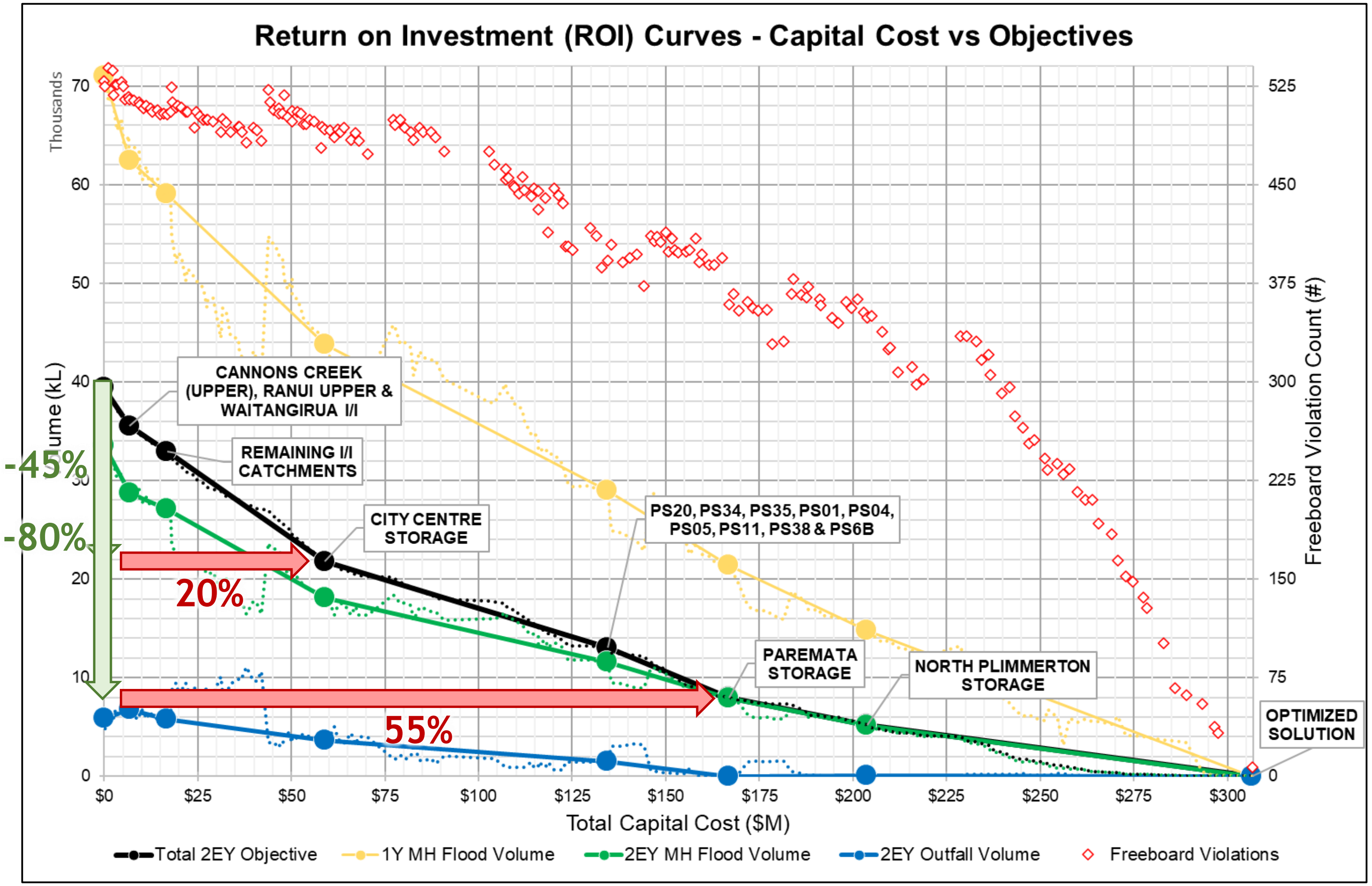
Porirua Prioritized Capital Works Program
(Pareto Curve)

- Pareto Curve directly exported from Optimizer™



Porirua Prioritized Capital Works Program
(Refined ROI Curve for Staging Improvements)

- 45% reduction of 2EY SSO volume in first $60M (20%) of capital expenditure
- 80% reduction in 2EY SSO volume in first $175 M (55%) of capital expenditure



Porirua Prioritization

55,000 Model Evaluations on Cloud Computing Service

Walk-through of Capital Improvements

Identified in each Priority Group

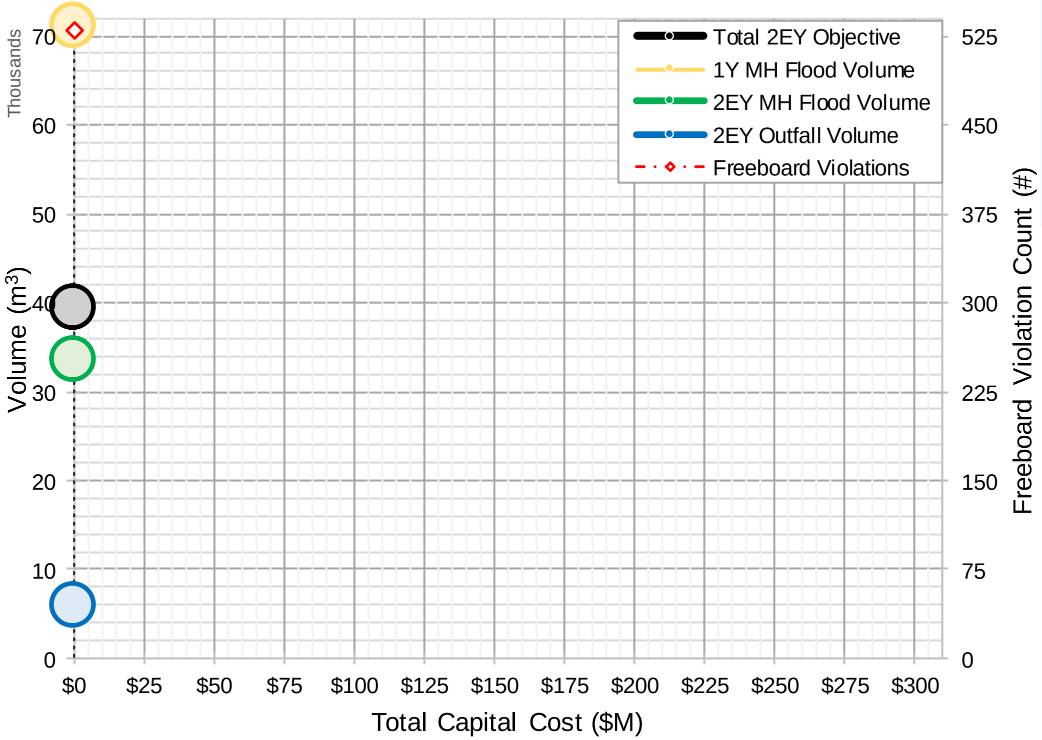
PORIRUA PRIORITIZATION (Existing)

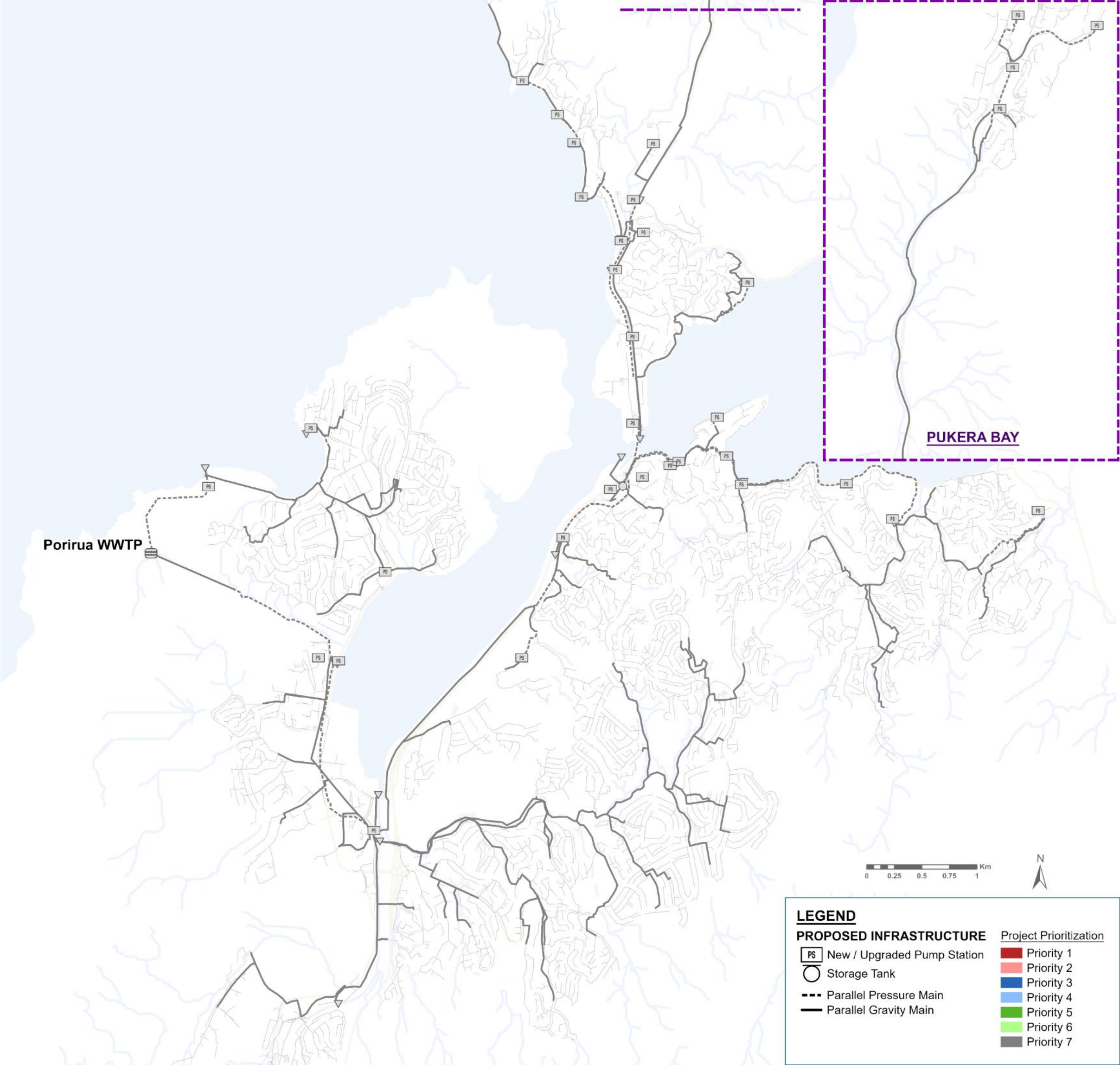
Capital Cost - $0 M

Cost Item	Cost ($M)
Gravity Sewer Upgrades	
Pumping Station & Pressure Main Upgrades	
Storage Facilities	
Treatment Plant Upgrade	
Inflow and Infiltration Reduction	
Total Capital Cost	**$0.0**

Manhole Flood Volume (2EY Design Storm):	**33,500 m3**
Outfall Volume (2EY Design Storm):	**5,900 m3**
Manhole Flood Volume (1-yr Design Storm):	**70,996 m3**
Freeboard Violations (1-yr Design Storm):	**529**

Return on Investment (ROI) Curves - Cost vs Objectives





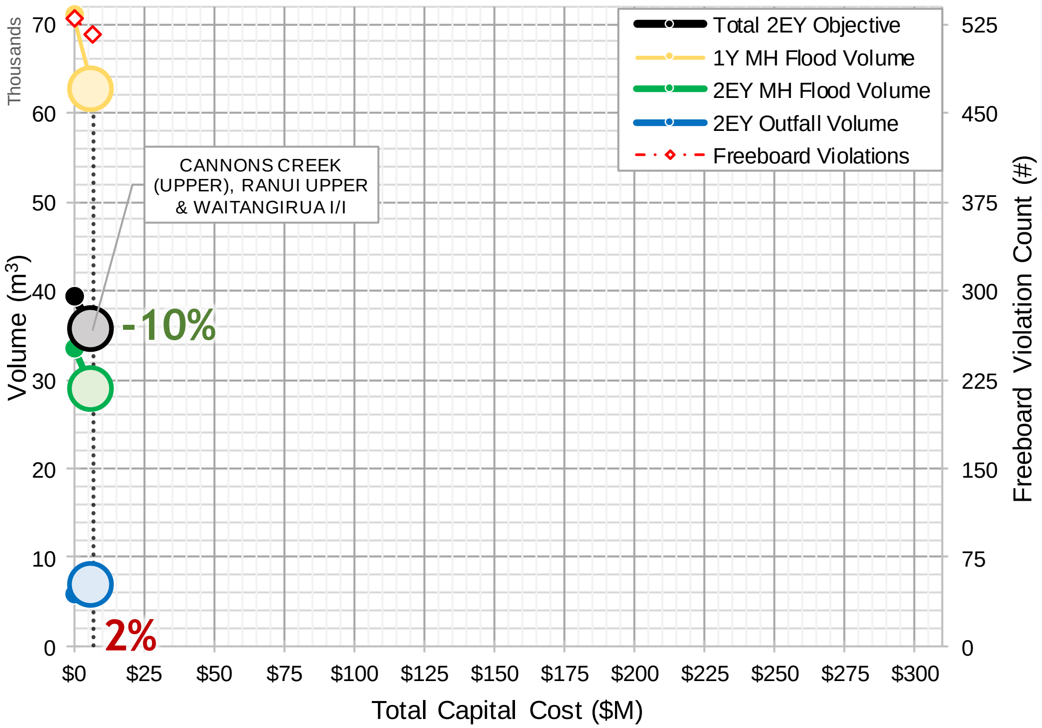
PORIRUA PRIORITIZATION (Priority 1)

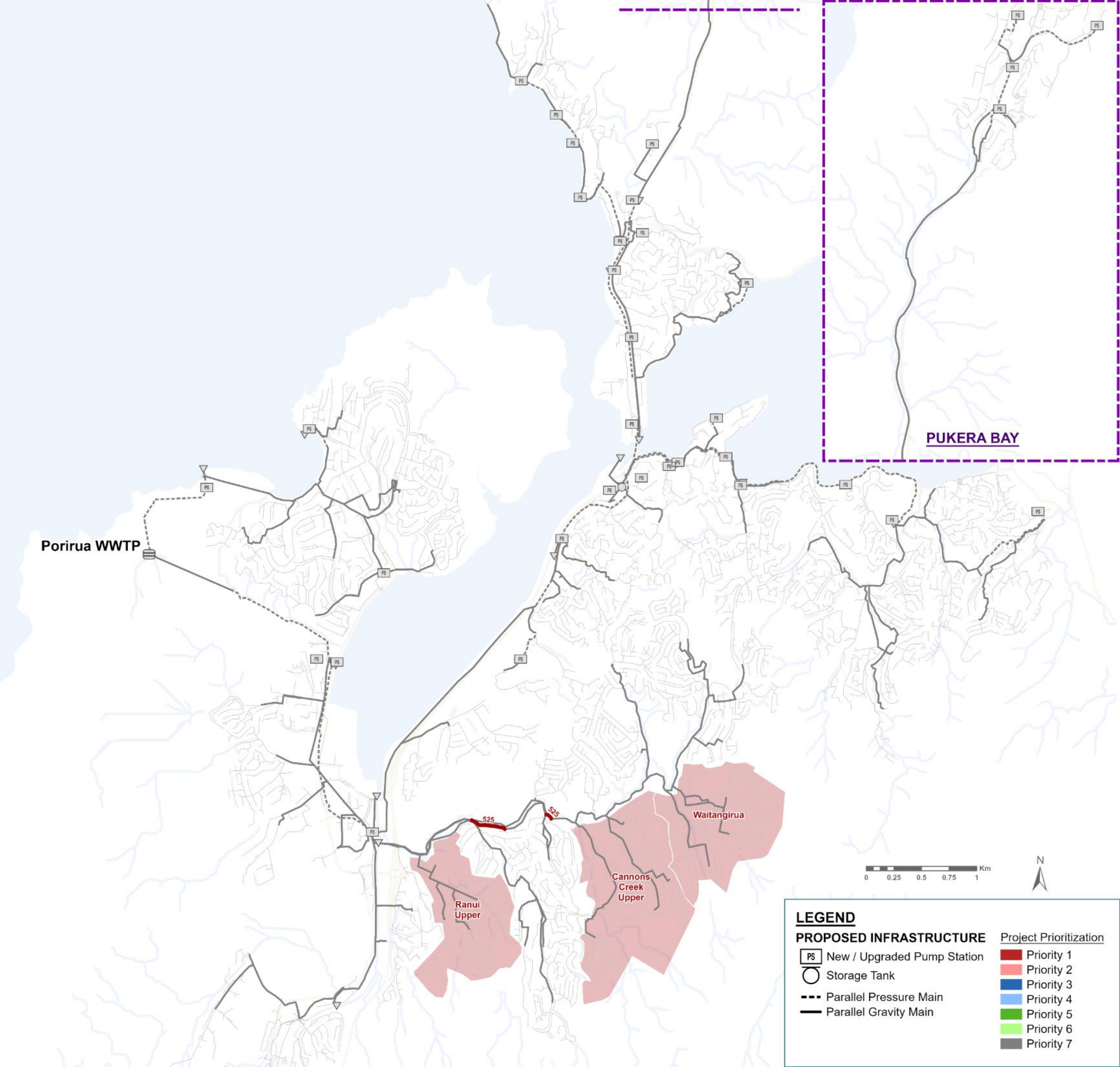
Capital Cost - $6.8 M

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$1.1
Pumping Station & Pressure Main Upgrades	
Storage Facilities	
Treatment Plant Upgrade	
Inflow and Infiltration Reduction	$5.7
Total Capital Cost	**$6.8**

Manhole Flood Volume (2EY Design Storm):	**28,749 m3**
Outfall Volume (2EY Design Storm):	**6,754 m3**
Manhole Flood Volume (1-yr Design Storm):	**62,469 m3**
Freeboard Violations (1-yr Design Storm):	**515**

Return on Investment (ROI) Curves - Cost vs Objectives





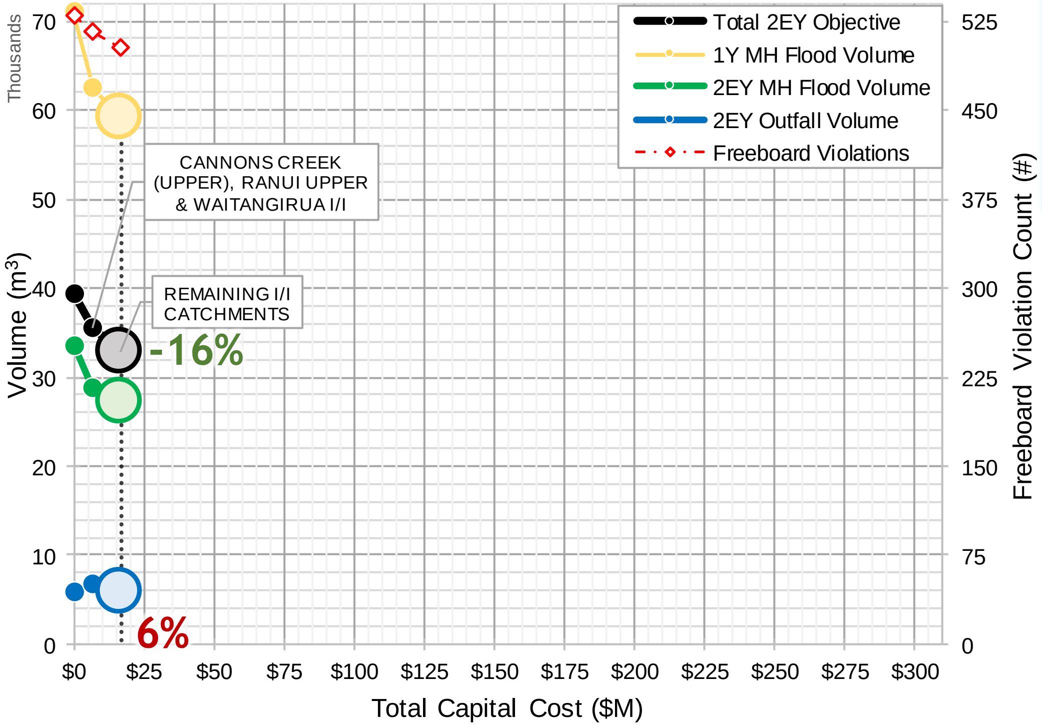
PORIRUA PRIORITIZATION
(Priority 2)

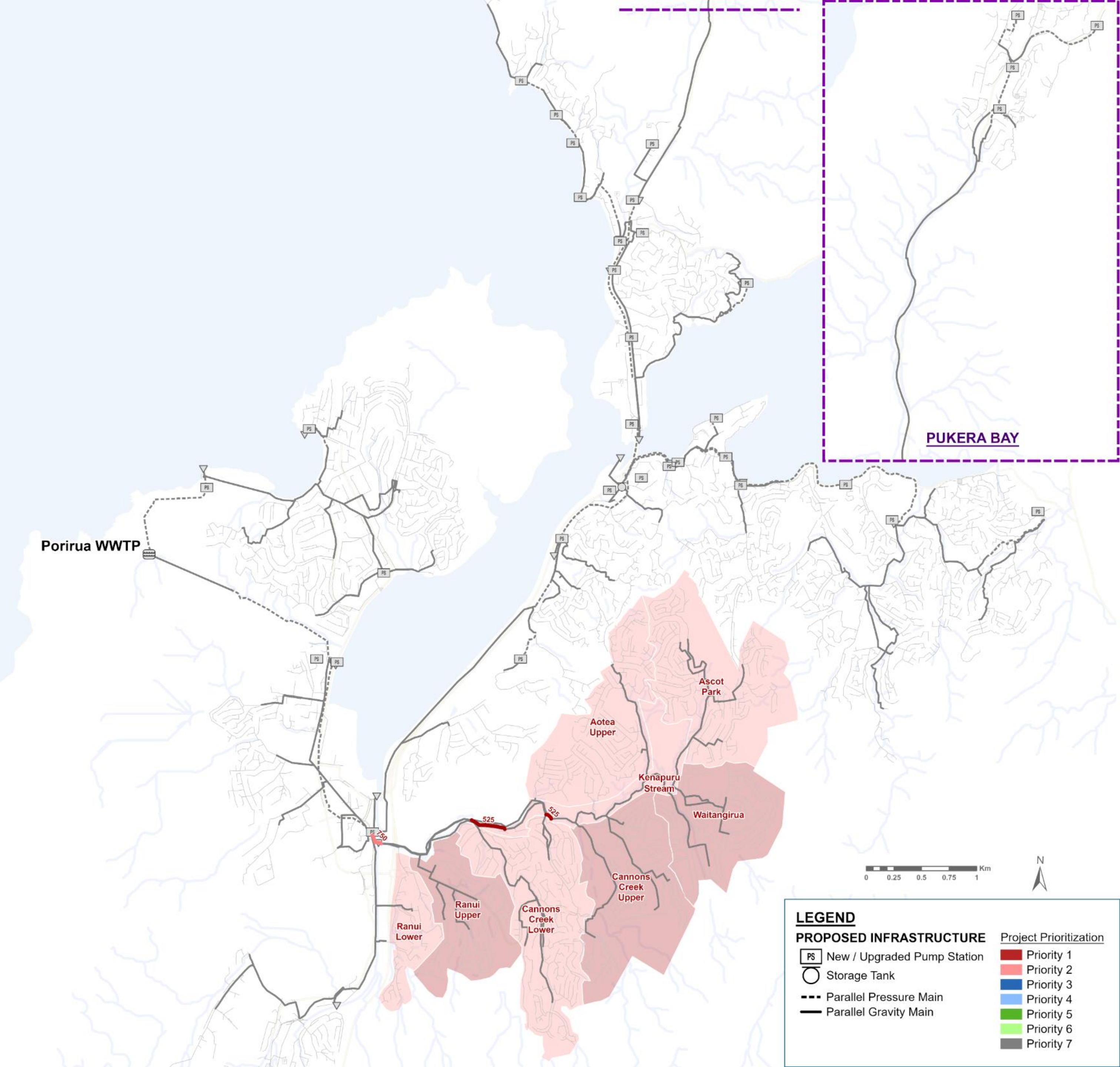
Capital Cost - $17.8 M

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$2.3
Pumping Station & Pressure Main Upgrades	
Storage Facilities	
Treatment Plant Upgrade	
Inflow and Infiltration Reduction	$15.5
Total Capital Cost	**$17.8**

Manhole Flood Volume (2EY Design Storm):	**27,105 m3**
Outfall Volume (2EY Design Storm):	**5,805 m3**
Manhole Flood Volume (1-yr Design Storm):	**59,060 m3**
Freeboard Violations (1-yr Design Storm):	**503**

Return on Investment (ROI) Curves - Cost vs Objectives





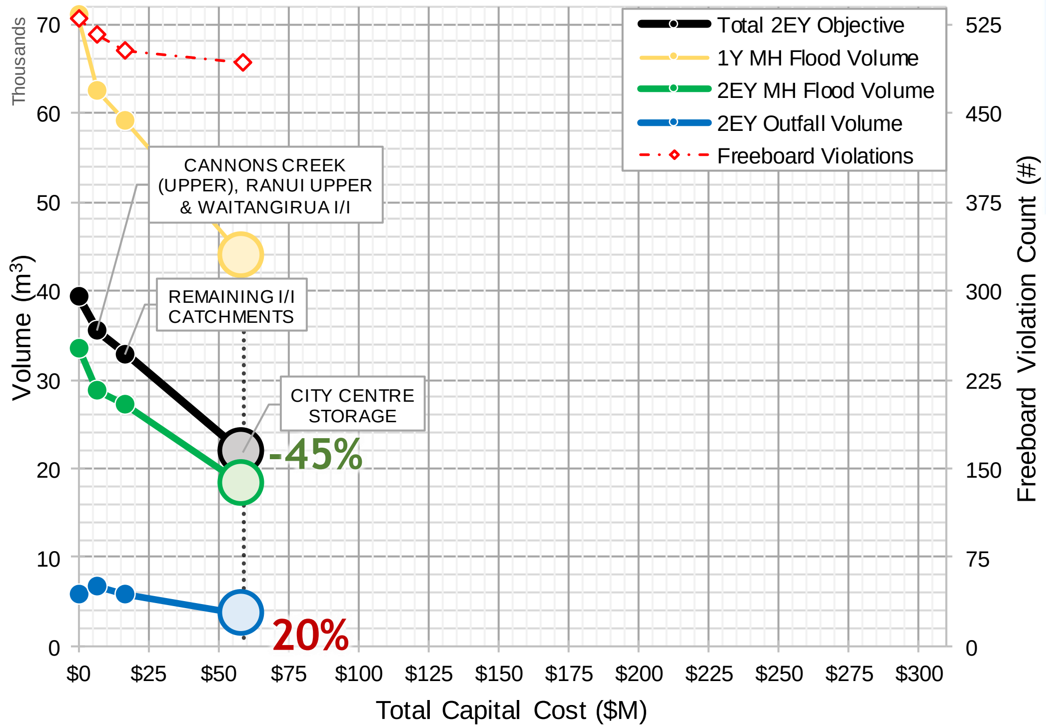
PORIRUA PRIORITIZATION
(Priority 3)

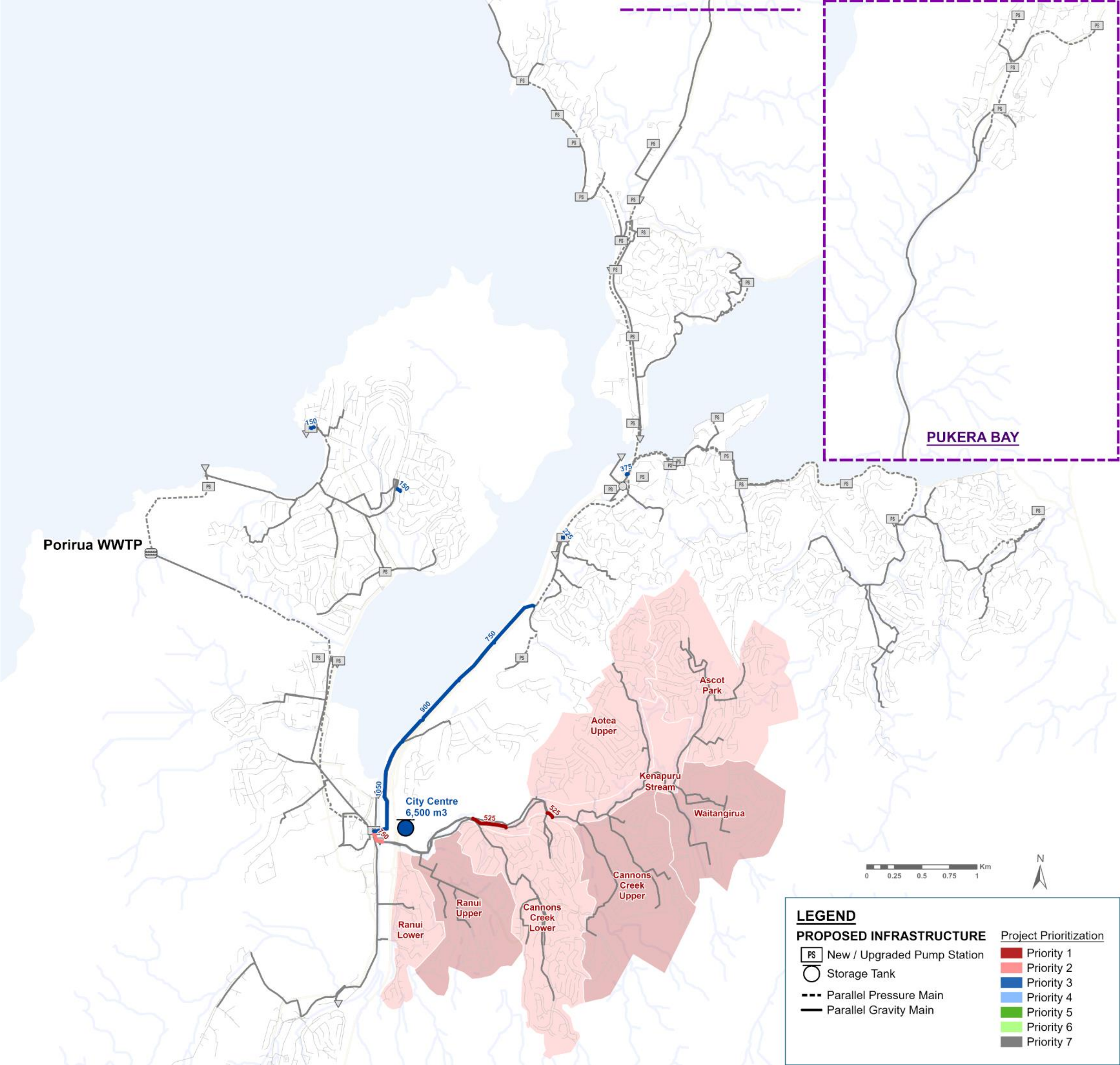
Capital Cost - $57.6 M

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$17.7
Pumping Station & Pressure Main Upgrades	
Storage Facilities	$25.5
Treatment Plant Upgrade	
Inflow and Infiltration Reduction	$14.4
Total Capital Cost	**$57.6**

Manhole Flood Volume (2EY Design Storm):	**18,125 m3**
Outfall Volume (2EY Design Storm):	**3,652 m3**
Manhole Flood Volume (1-yr Design Storm):	**43,771 m3**
Freeboard Violations (1-yr Design Storm):	**492**

Return on Investment (ROI) Curves - Cost vs Objectives





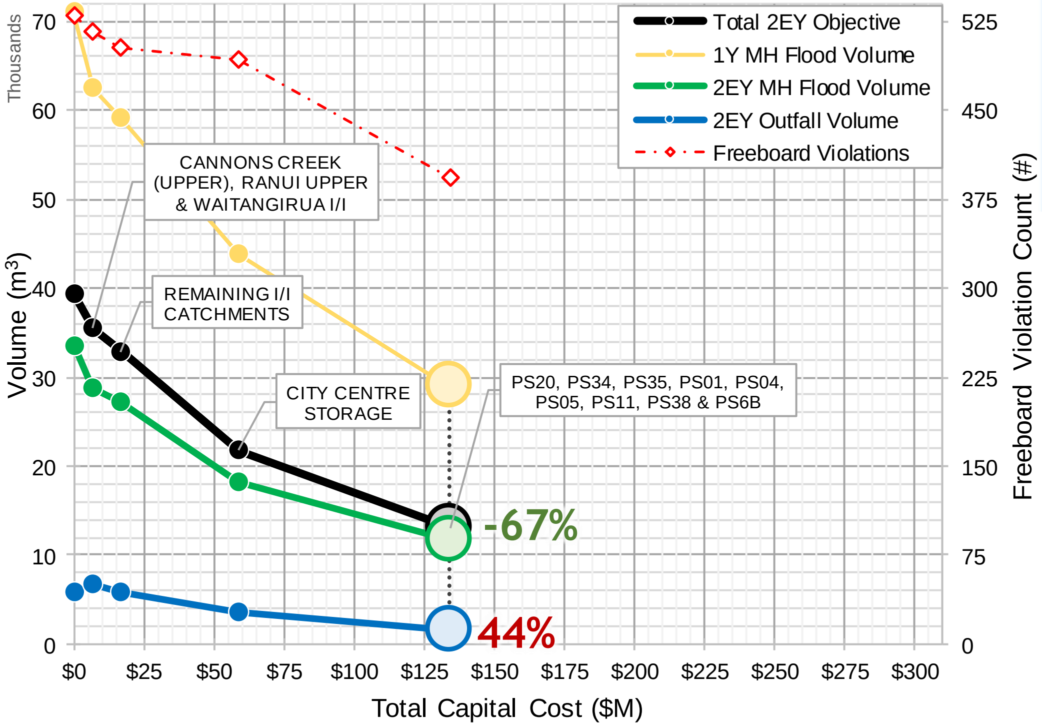
PORIRUA PRIORITIZATION
(Priority 4)

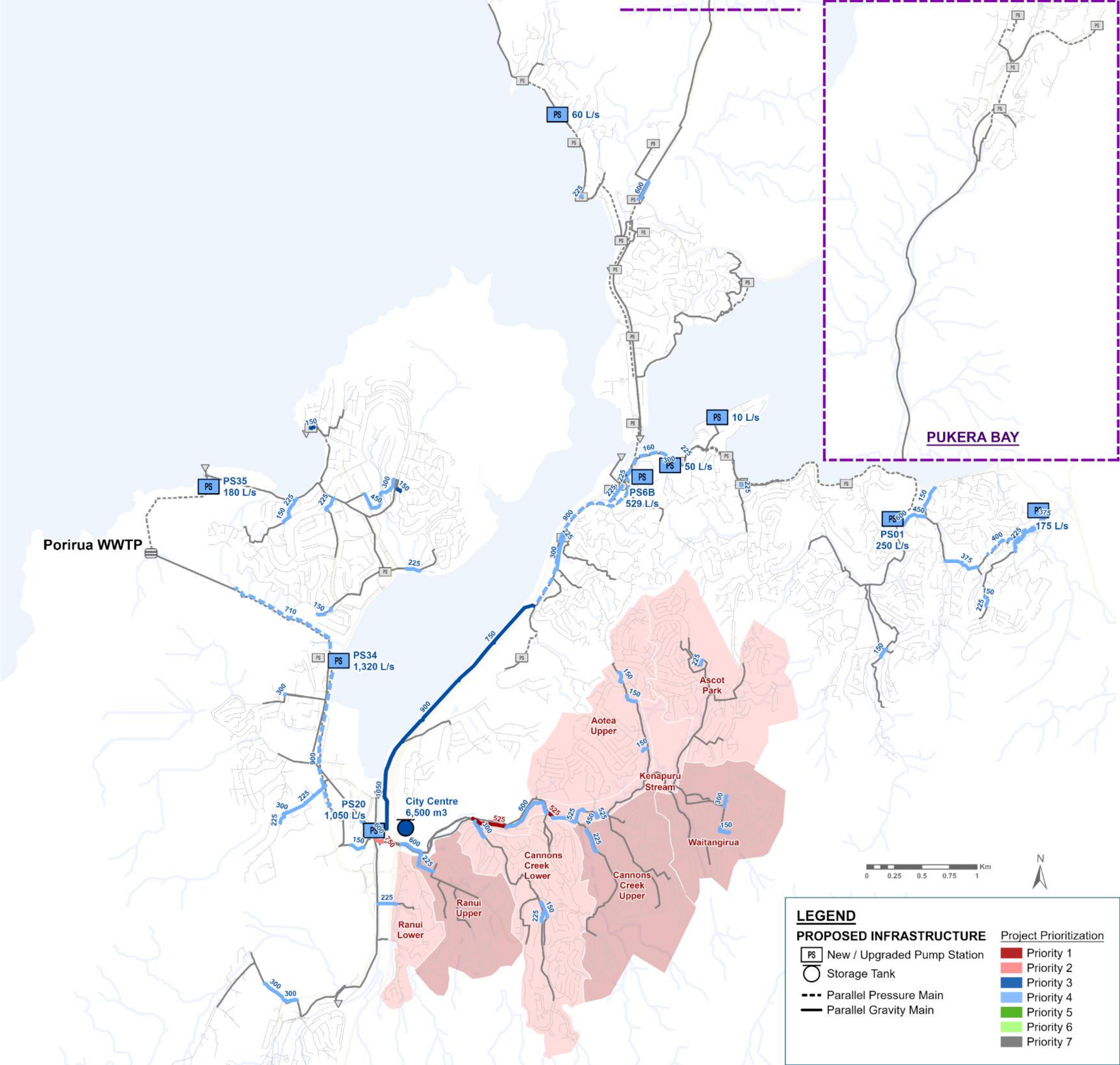
Capital Cost - $128.5 M

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$37.9
Pumping Station & Pressure Main Upgrades	$50.7
Storage Facilities	$25.5
Treatment Plant Upgrade	
Inflow and Infiltration Reduction	$14.4
Total Capital Cost	**$128.5**

Manhole Flood Volume (2EY Design Storm):	**11,568 m3**
Outfall Volume (2EY Design Storm):	**1,483 m3**
Manhole Flood Volume (1-yr Design Storm):	**28,939 m3**
Freeboard Violations (1-yr Design Storm):	**392**

Return on Investment (ROI) Curves - Cost vs Objectives





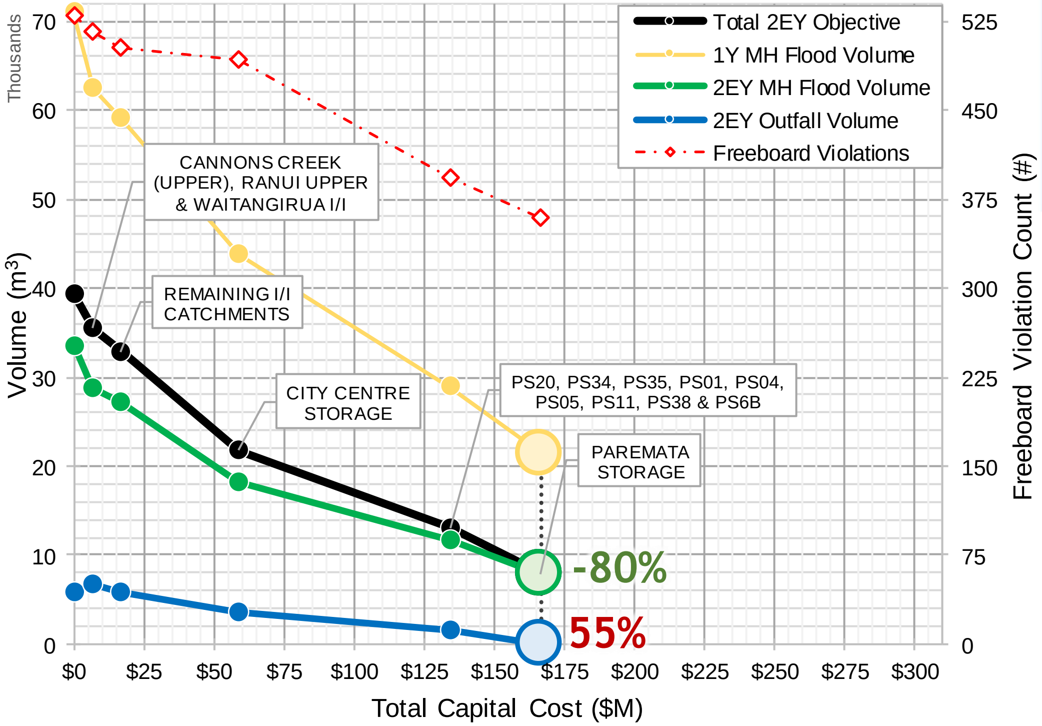
PORIRUA PRIORITIZATION
(Priority 5)

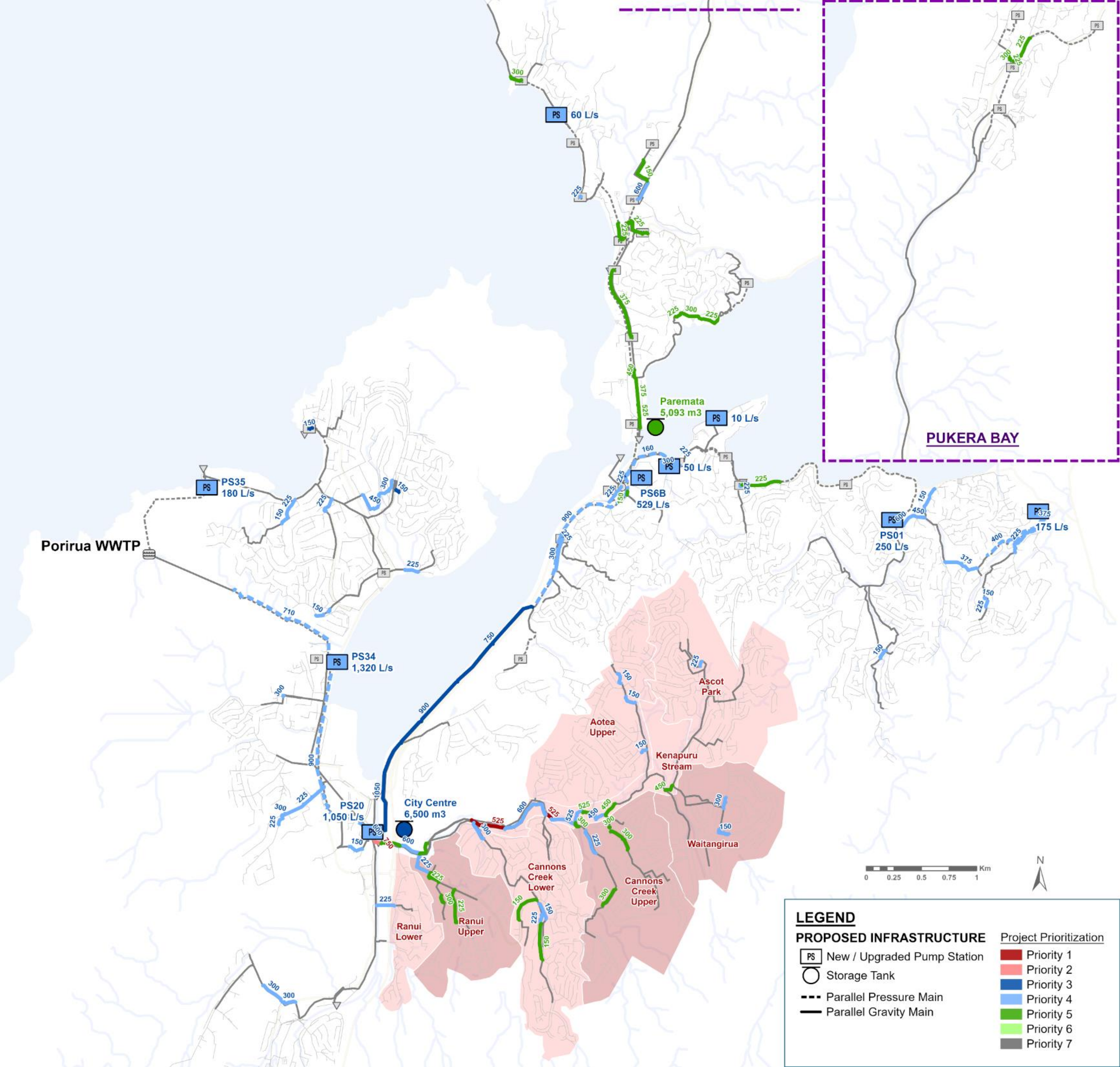
Capital Cost - $160 M

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$48.2
Pumping Station & Pressure Main Upgrades	$50.7
Storage Facilities	$46.8
Treatment Plant Upgrade	
Inflow and Infiltration Reduction	$14.4
Total Capital Cost	**$160.0**

Manhole Flood Volume (2EY Design Storm):	**7,959 m3**
Outfall Volume (2EY Design Storm):	**12 m3**
Manhole Flood Volume (1-yr Design Storm):	**21,372 m3**
Freeboard Violations (1-yr Design Storm):	**359**

Return on Investment (ROI) Curves - Cost vs Objectives





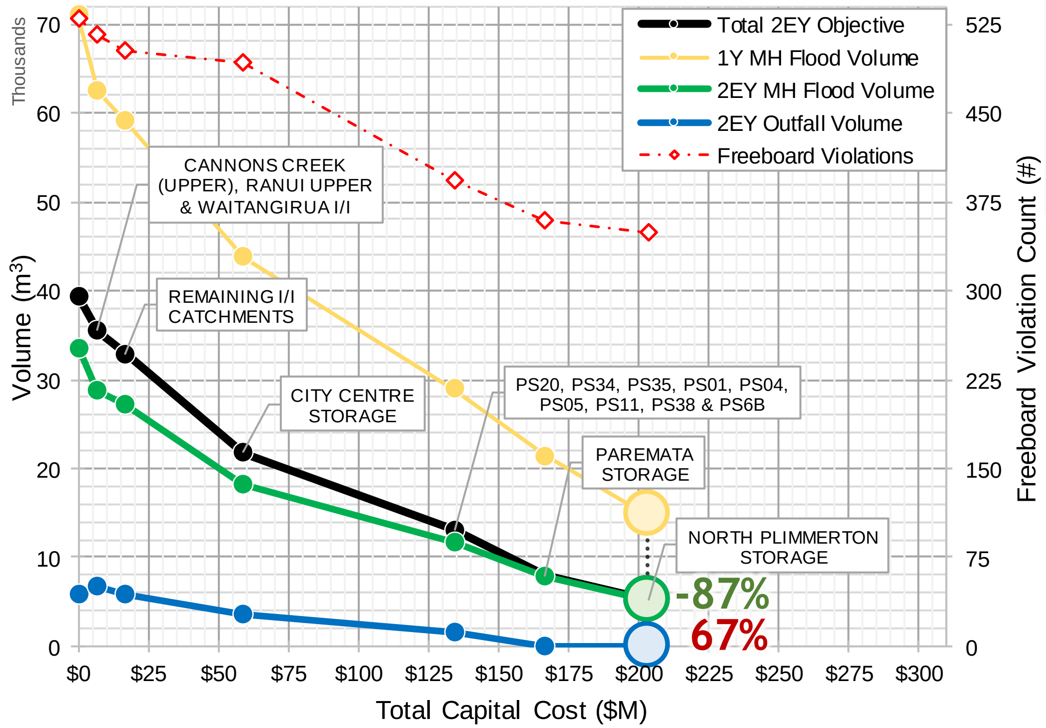
PORIRUA PRIORITIZATION
(Priority 6)

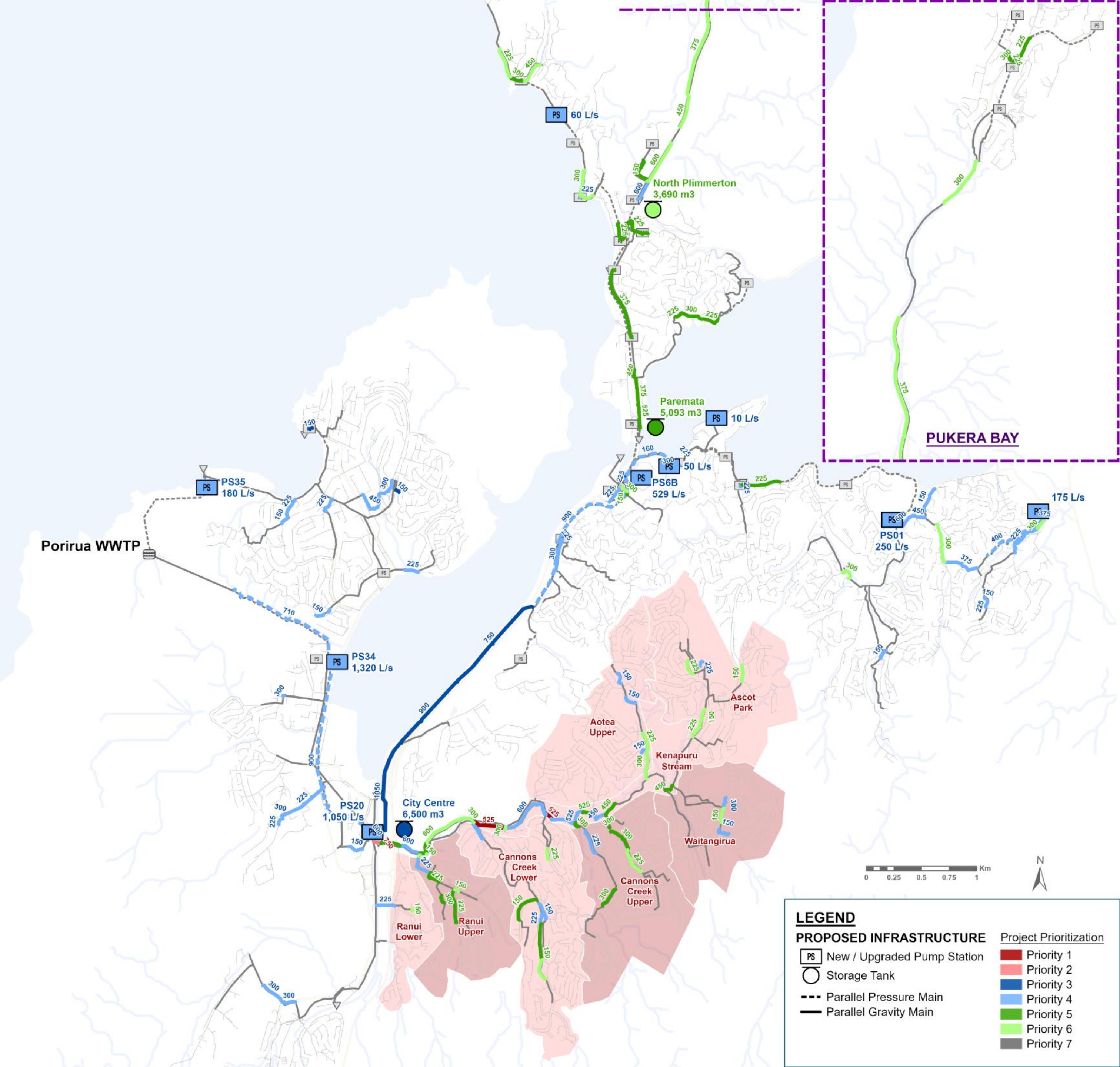
Capital Cost - $195.7 M

Cost Item	Cost ($M)
Gravity Sewer Upgrades	$67.2
Pumping Station & Pressure Main Upgrades	$50.7
Storage Facilities	$63.4
Treatment Plant Upgrade	
Inflow and Infiltration Reduction	$14.4
Total Capital Cost	**$195.7**

Manhole Flood Volume (2EY Design Storm):	**5,130 m3**
Outfall Volume (2EY Design Storm):	**78 m3**
Manhole Flood Volume (1-yr Design Storm):	**14,762 m3**
Freeboard Violations (1-yr Design Storm):	**349**

Return on Investment (ROI) Curves - Cost vs Objectives





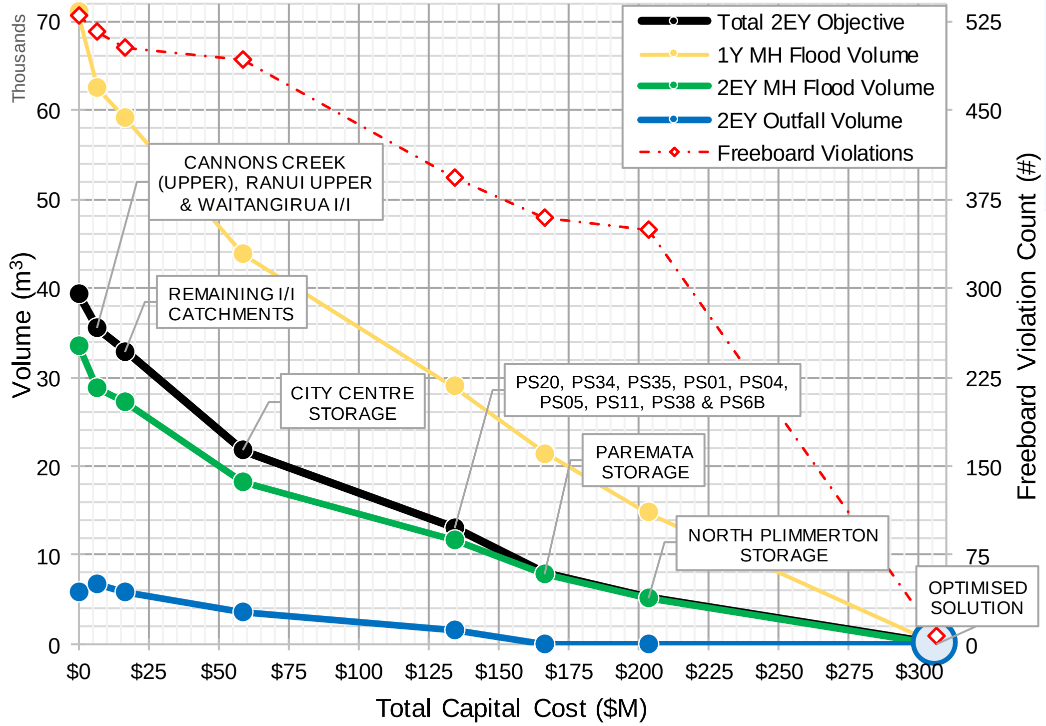
PORIRUA PRIORITIZATION
(Priority 7)

Capital Cost - $293.7 M

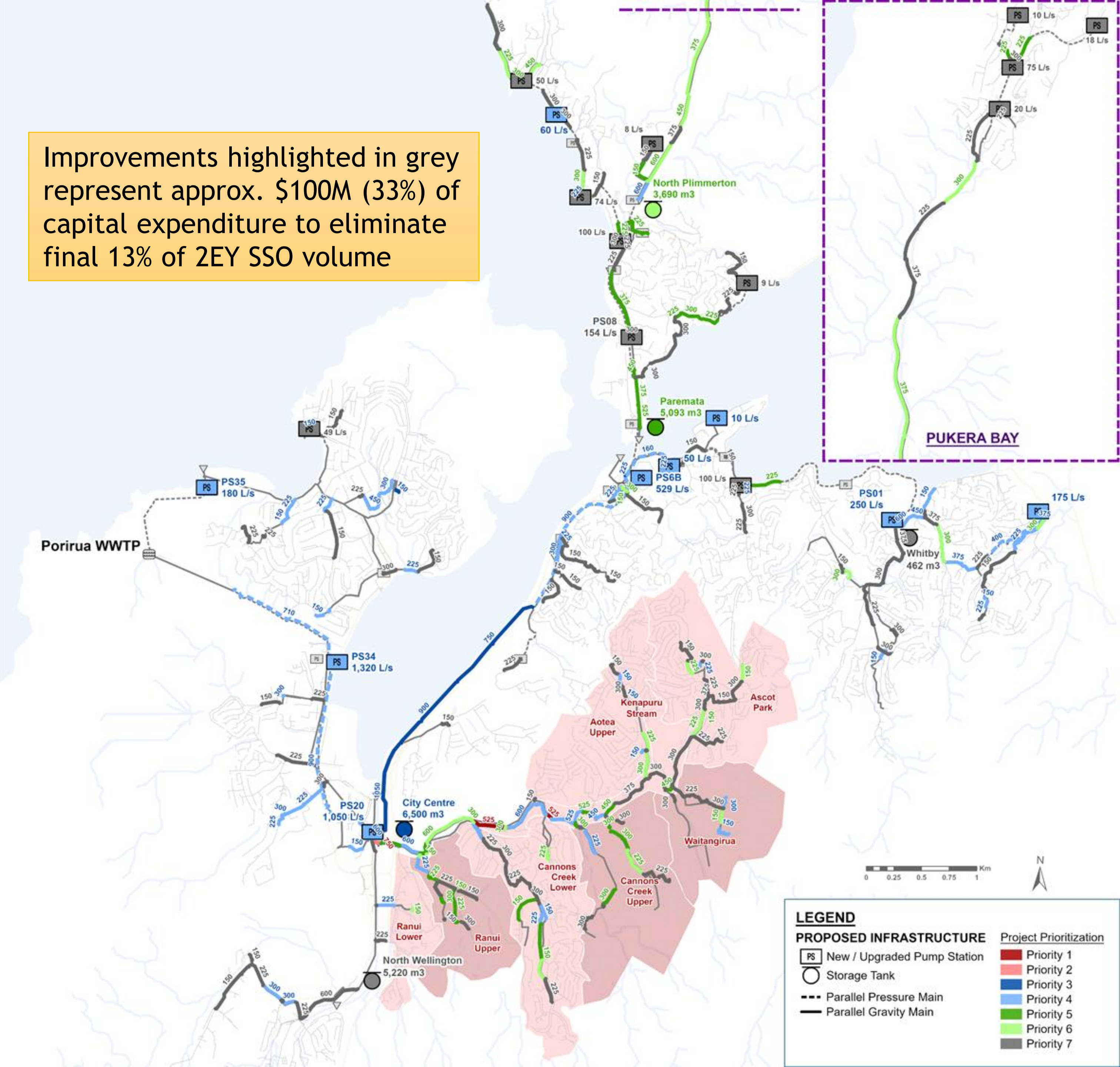
Cost Item	Cost ($M)
Gravity Sewer Upgrades	$132.3
Pumping Station & Pressure Main Upgrades	$57.3
Storage Facilities	$88.7
Treatment Plant Upgrade	
Inflow and Infiltration Reduction	$15.5
Total Capital Cost	**$293.7**

Manhole Flood Volume (2EY Design Storm):	**0 m3**
Outfall Volume (2EY Design Storm):	**0 m3**
Manhole Flood Volume (1-yr Design Storm):	**0 m3**
Freeboard Violations (1-yr Design Storm):	**7**

Return on Investment (ROI) Curves - Cost vs Objectives

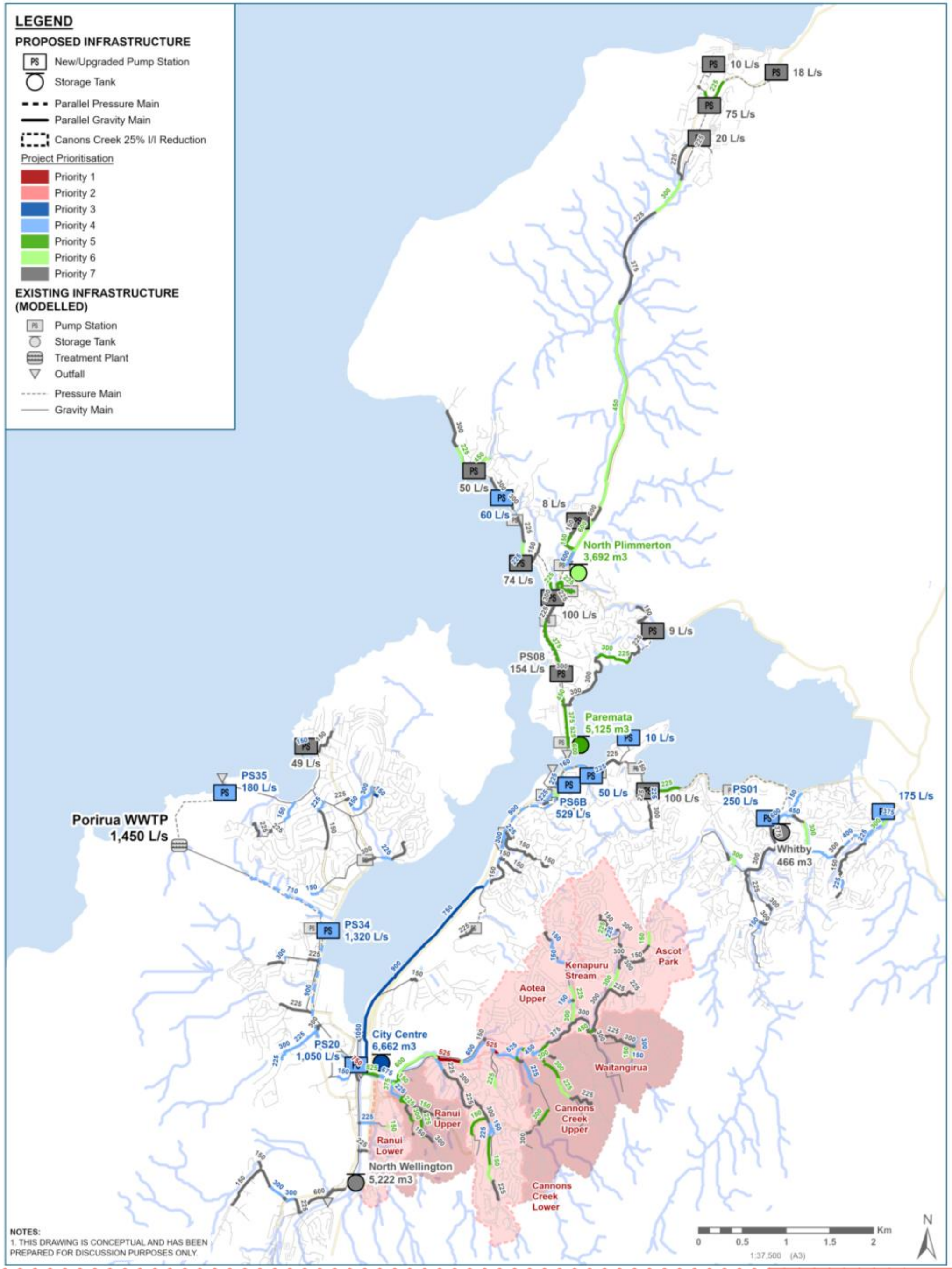


Improvements highlighted in grey represent approx. $100M (33%) of capital expenditure to eliminate final 13% of 2EY SSO volume



Prioritized Capital Works Program

	CAPITAL COST ($M)						
Cost Item	Priority 1	Priority 2	Priority 3	Priority 4	Priority 5	Priority 6	Priority 7
Gravity Sewer Upgrades	$1.1	$2.3	$17.7	$37.9	$48.2	$67.2	$132.3
Pumping Station & Pressure Main Upgrades				$50.7	$50.7	$50.7	$57.3
Storage Facilities			$25.5	$25.5	$46.8	$63.4	$88.7
Treatment Plant Upgrade							
Inflow and Infiltration Reduction	$5.7	$15.5	$15.5	$15.5	$15.5	$15.5	$15.5
Total Capital Cost	**$6.8**	**$17.8**	**$58.7**	**$129.6**	**$161.1**	**$196.7**	**$293.7**
Total 2EY SSO Volume (m^3)	**35,503**	**32,910**	**21,777**	**13,051**	**7,971**	**5,207**	**0**
% Cost of Preferred Solution	**2%**	**6%**	**20%**	**44%**	**55%**	**67%**	**100%**
% Reduction from Existing	**10%**	**16%**	**45%**	**67%**	**80%**	**87%**	**100%**



Project Outcomes

- A cost-optimal capital works program that meets pragmatic network service targets and provides benefits to the community and environment.
- Increased confidence in capital works program with multiple sensitivity analyses conducted.
- Prioritization results enable Wellington Water to maximize return on its investment as it stages improvements.
- Ability to readily and easily revisit optimization & prioritization of capital improvements as network model is upgraded or re-calibrated in the future.

THANK YOU

Questions?

Andrew Faulkner
Andrew.Faulkner@wcsengineering.com

WCS ENGINEERING