Application of Meta-Heuristic Algorithm to Optimize Recycled Water Injection – Finding the most cost effective well locations for injecting ATW

California Water & Environmental Modeling Forum

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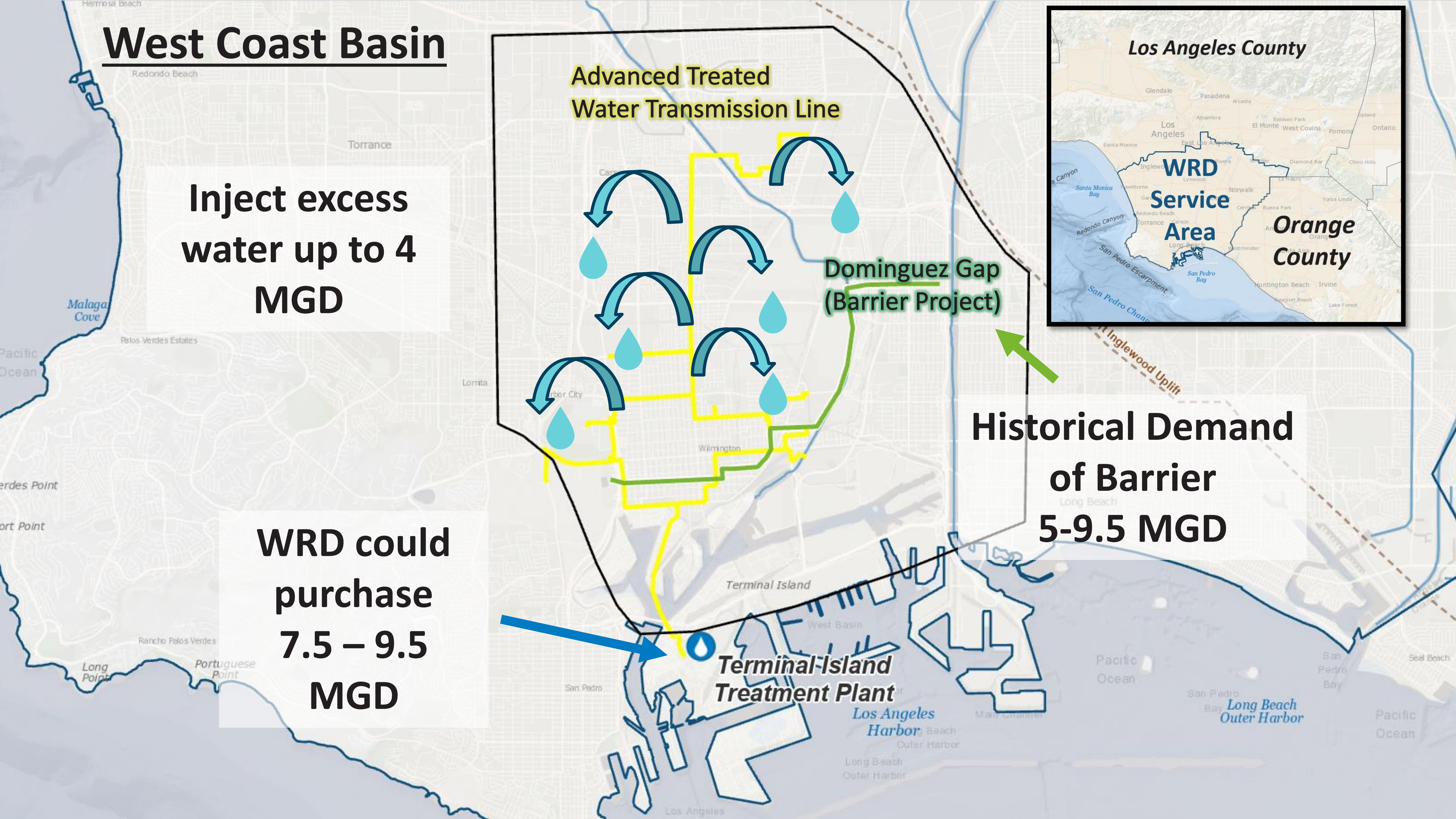
Water sustainability has become critical in Southern California and use of ATW for MAR is a very important part of the water portfolio


West Coast Basin
Advanced Treated Water Transmission Line
Inject excess water up to 4 MGD
Dominguez Gap (Barrier Project)
Historical Demand of Barrier 5-9.5 MGD
WRD could purchase 7.5 – 9.5 MGD
Terminal Island Treatment Plant
Terminal Island
Los Angeles Harbor
Long Beach Outer Harbor
Los Angeles County
WRD Service Area
Orange County
Inglewood Uplift
Hermosa Beach
Redondo Beach
Torrance
Malaga Cove
Palos Verdes Estates
Pacific Ocean
Lomita
Wilmington
Rancho Palos Verdes
Long Point
Portuguese Point
San Pedro
West Basin
Long Beach
Pacific Ocean
Seal Beach
San Pedro Bay

Challenges

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- Limited feasible areas for siting injection well
- Well injection capacity
- Impacts on municipal wells
- Impacts on contaminated sites
- Impacts on salt barrier
- Need to have well redundancy to allow down-time for maintenance
- Lowest Cost

Objective Function: (1) Lowest Cost

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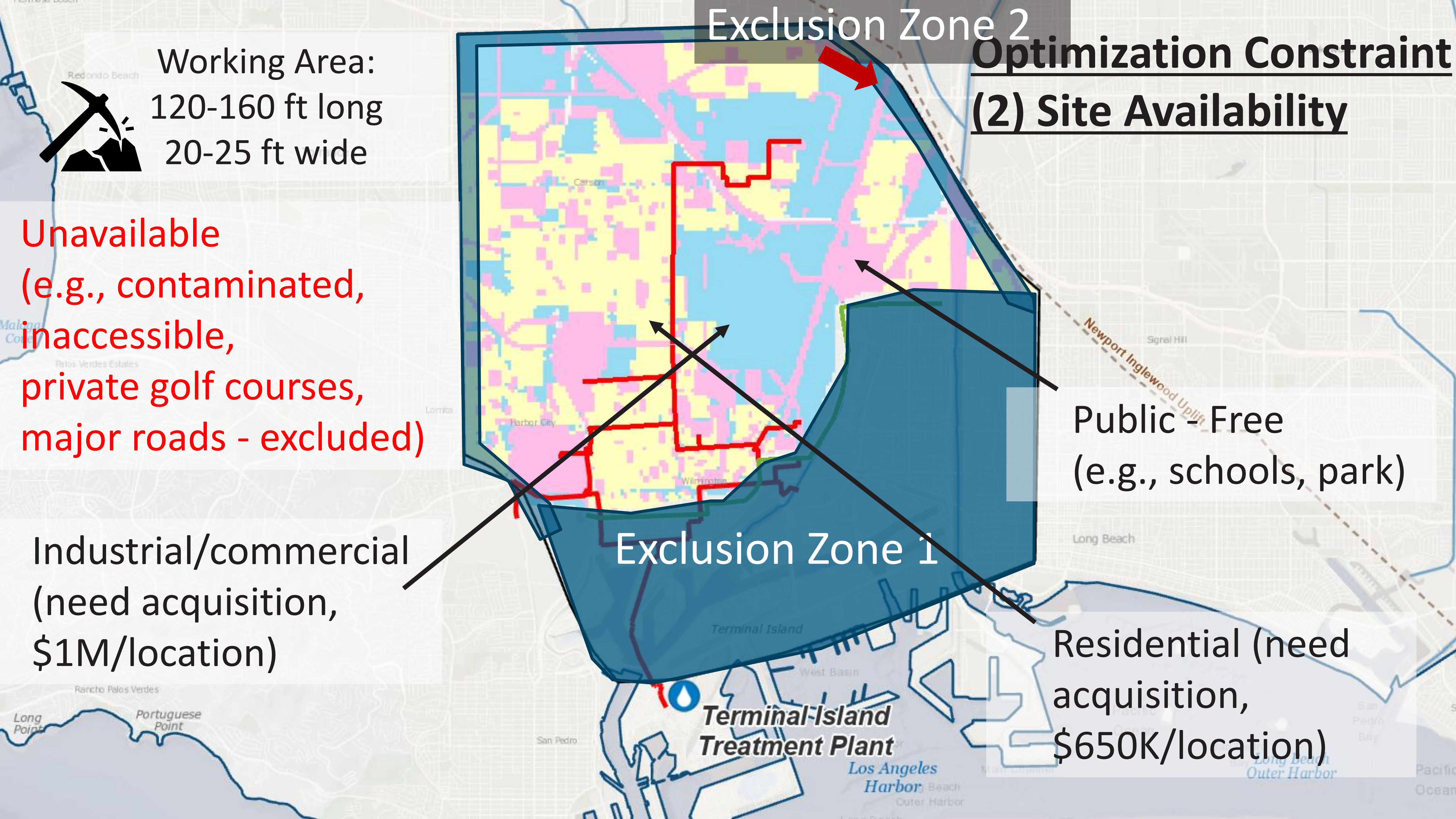
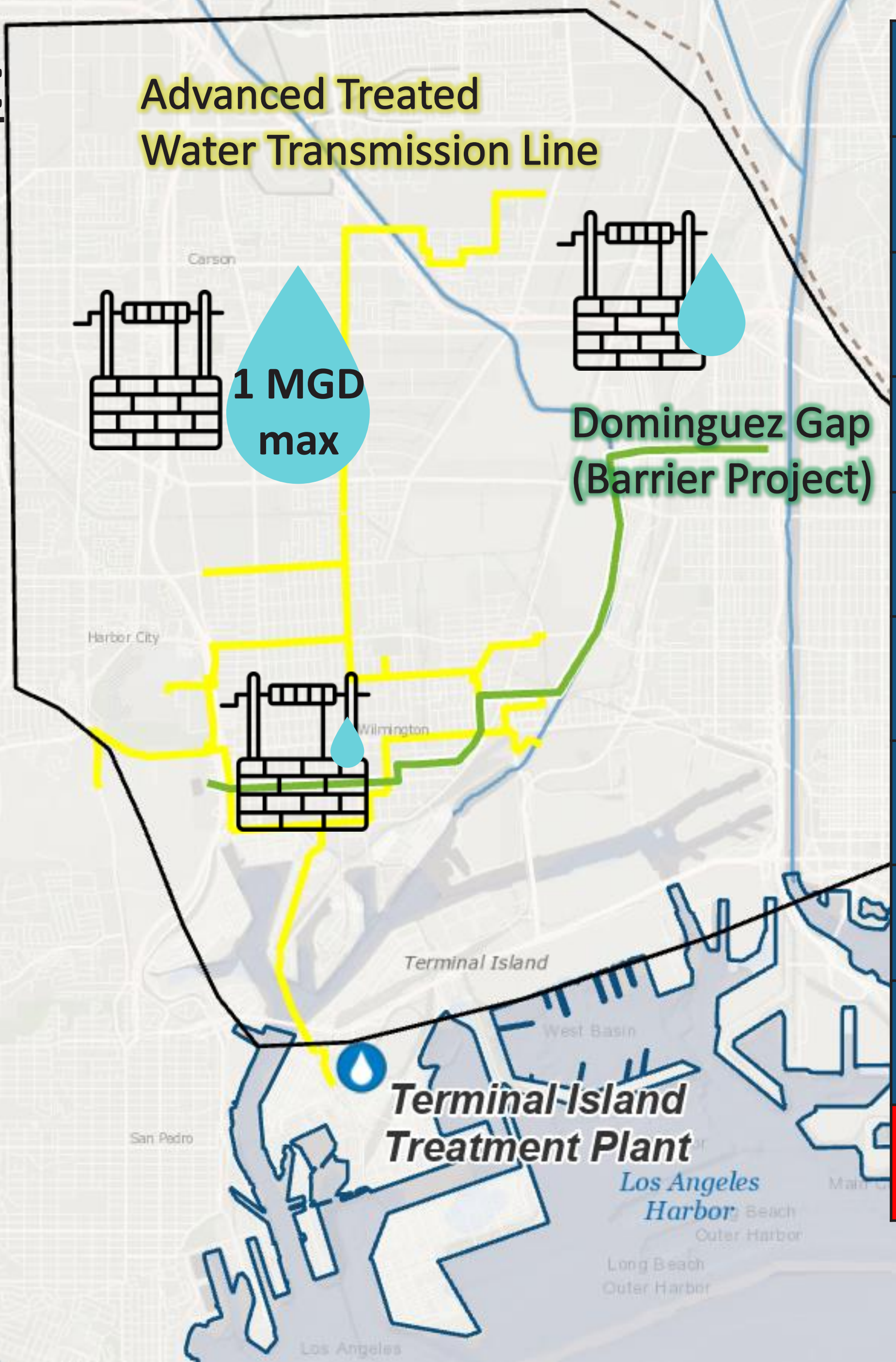
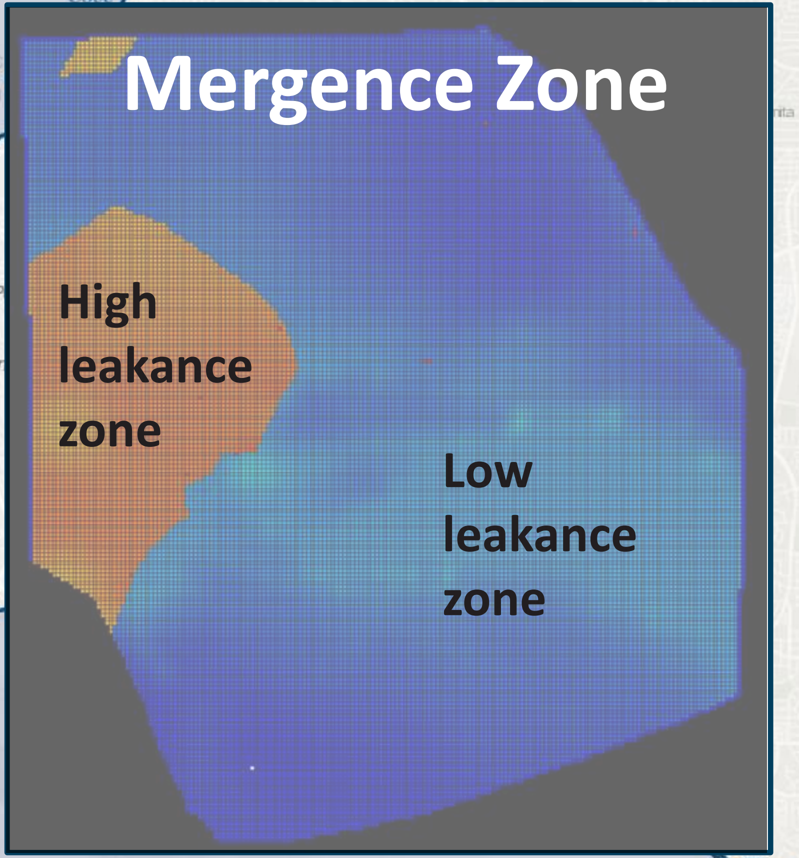
- Objective Function = Minimize Rough-Order-of-Magnitude (ROM) Comparative Costs
  - Land – if land acquisition is needed
  - Length of pipelines
  - # of pipeline connections
  - Well construction (injection + 1 monitoring well pair) – no. of wells, depths, sizes
- We evaluated this for injecting 1, 2, 3 and 4 MGD of excess advanced treated water

Optimization Constraint (2) Site Availability



Optimization Constraint
(3) Injection Capacity

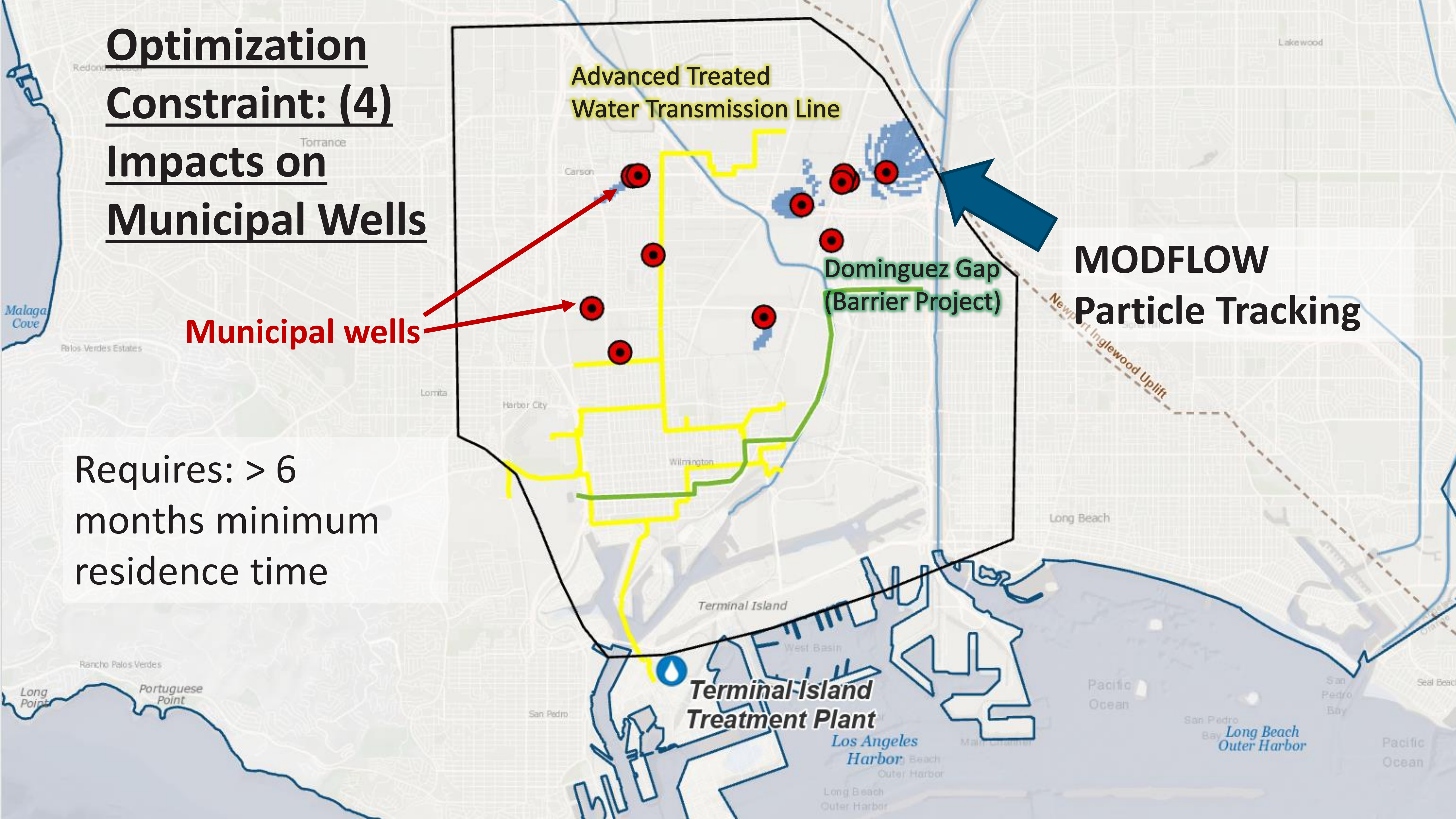




- Layer 1 (Bellflower Aqtd)
- Layer 2 (Gaspur Aqfr)
- Layer 3 (Bellflower Aqtd, Gasper-Gage Mergence Zone)
- Layer 4 (Gage Aquifer)
- Layer 5 (Confining unit, Gage-Lynwood Mergence Zone)
- Layer 6 (Lynwood Aqfr and Low K zone)
- Layer 7 (Confining unit, Lynwood-Upper Silverado Mergence Zone)
- Layer 8 (Upper Silverado Aqfr)
- Layer 9 (Confining Unit, Lower-Upper Silverado Mergence Zone)
- Layer 10 (Lower Silverado Aqfr)

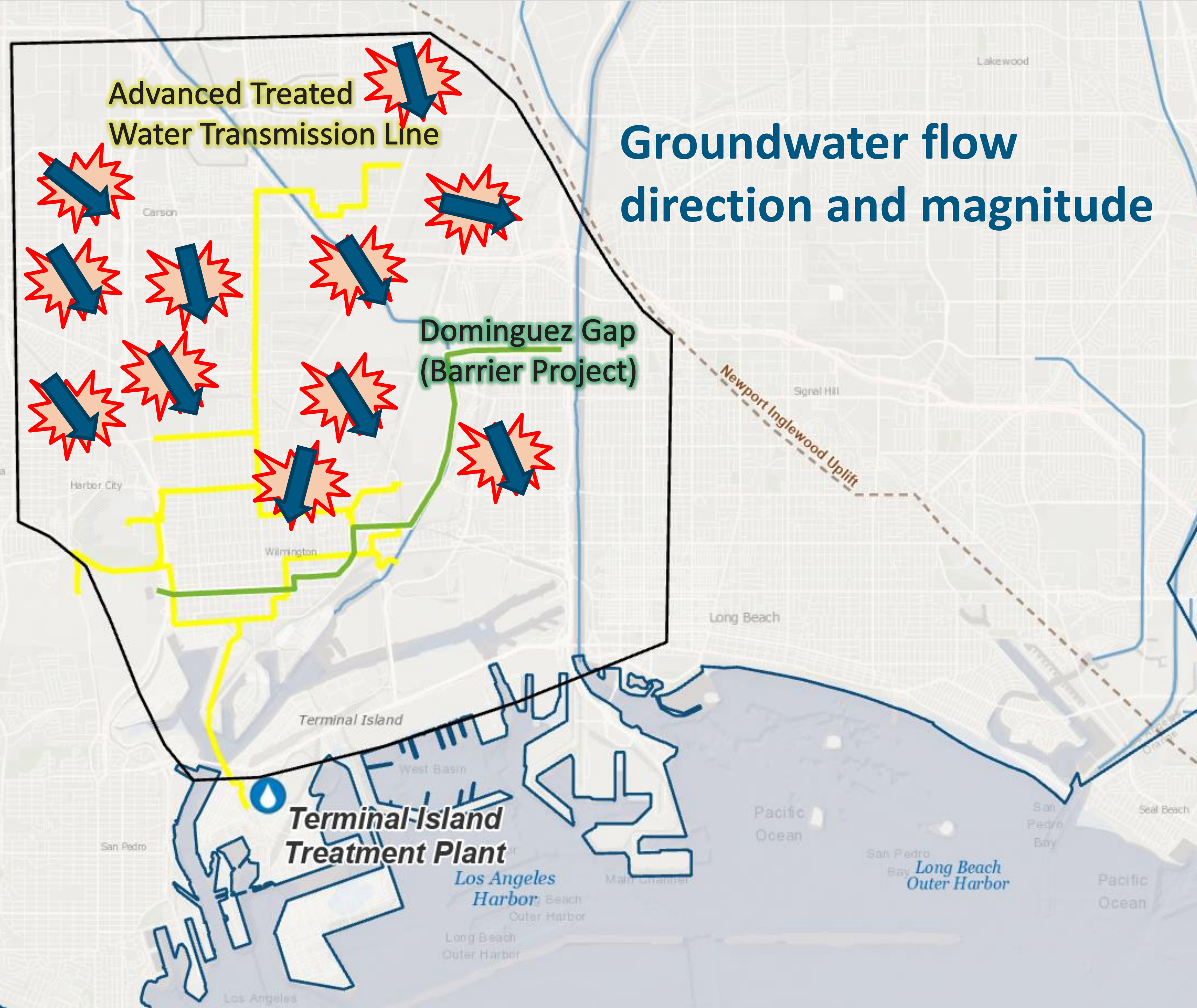
Optimization Constraint: (4) Impacts on Municipal Wells

Requires: > 6 months minimum residence time



Optimization Constraint: (5) Impacts on Environmental Sites

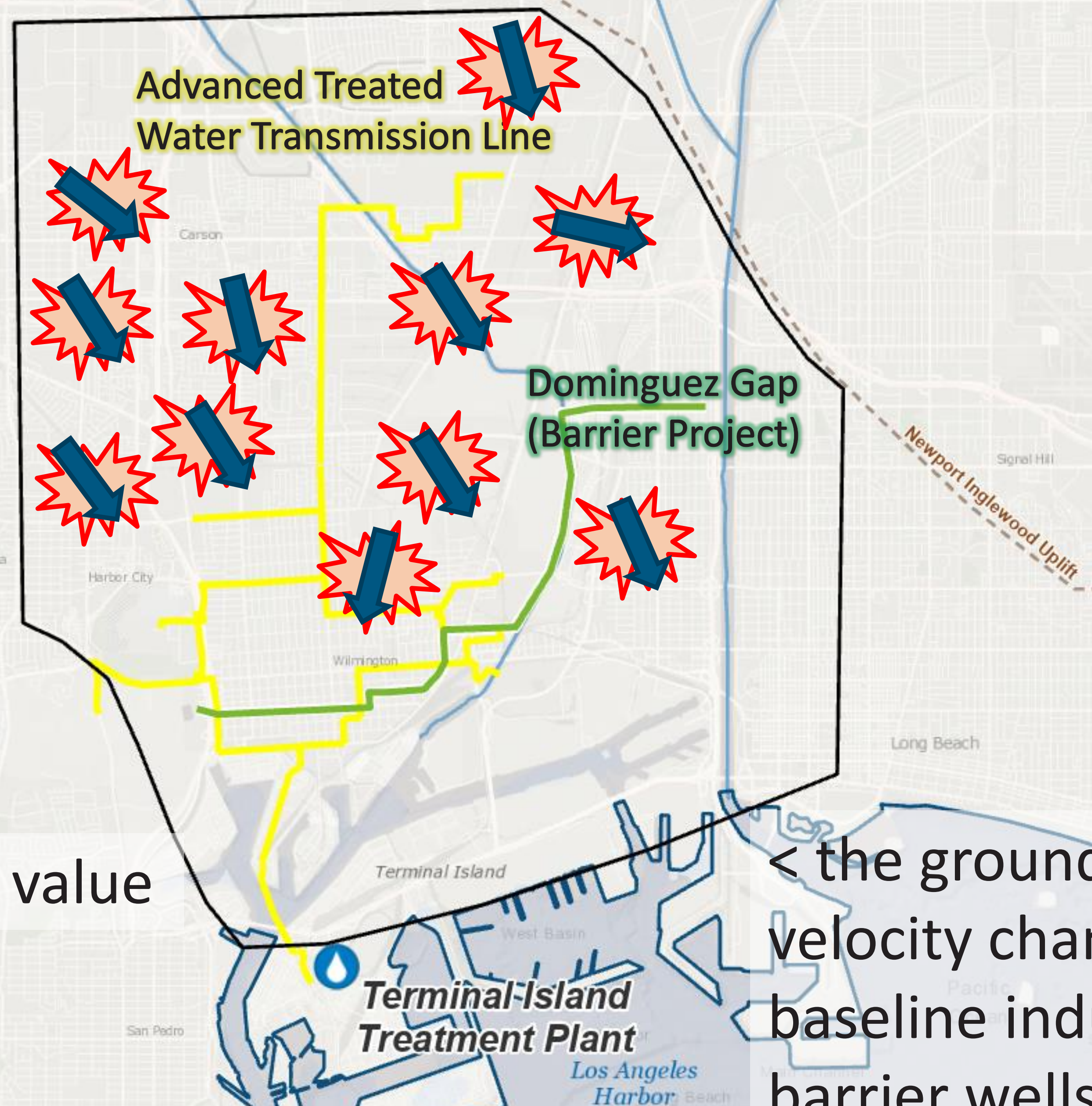
Identify environmental sites



Optimization Constraint: (5) Impacts on Environmental Sites

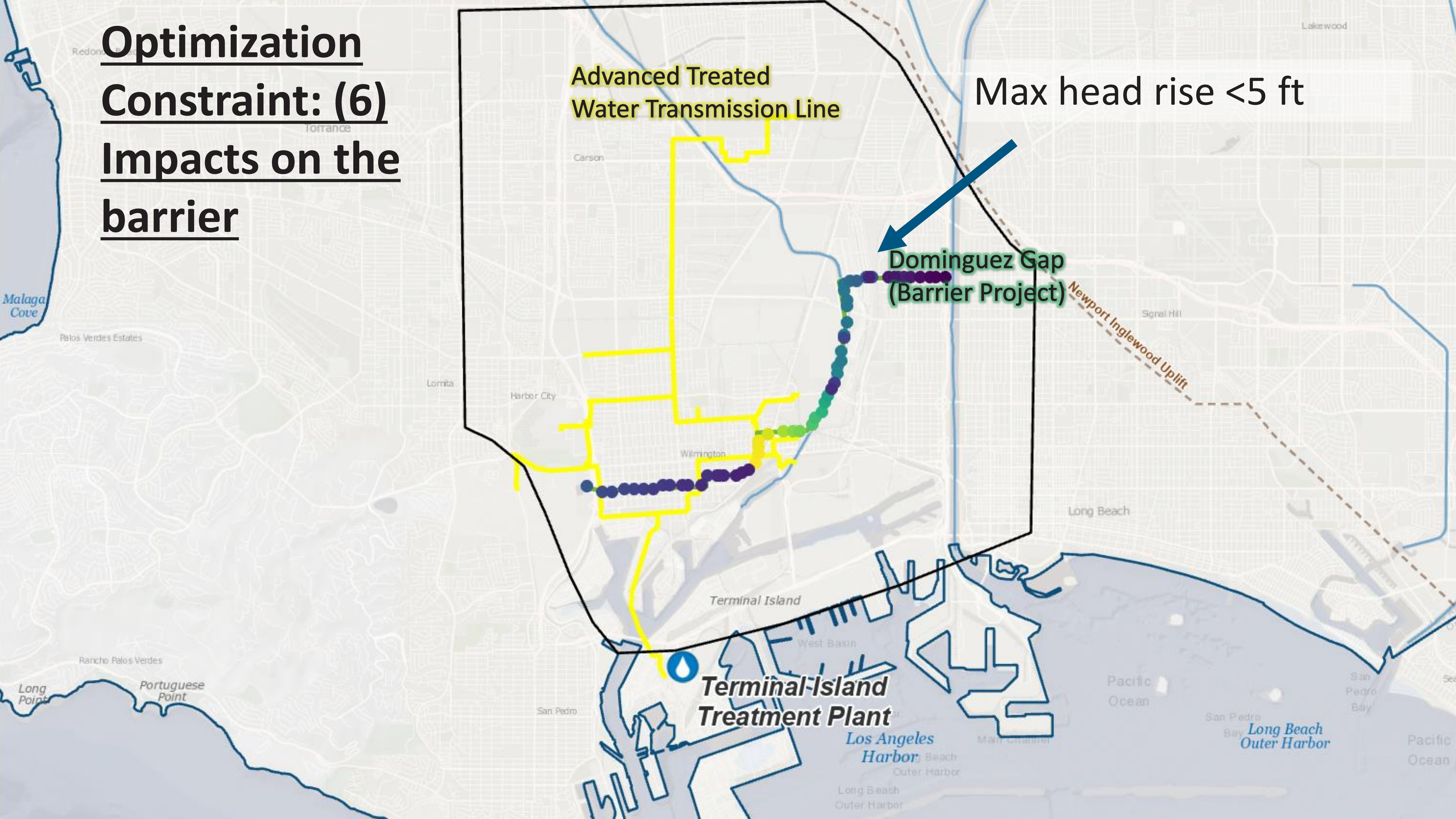
Identify environmental sites

< 20% of the absolute value

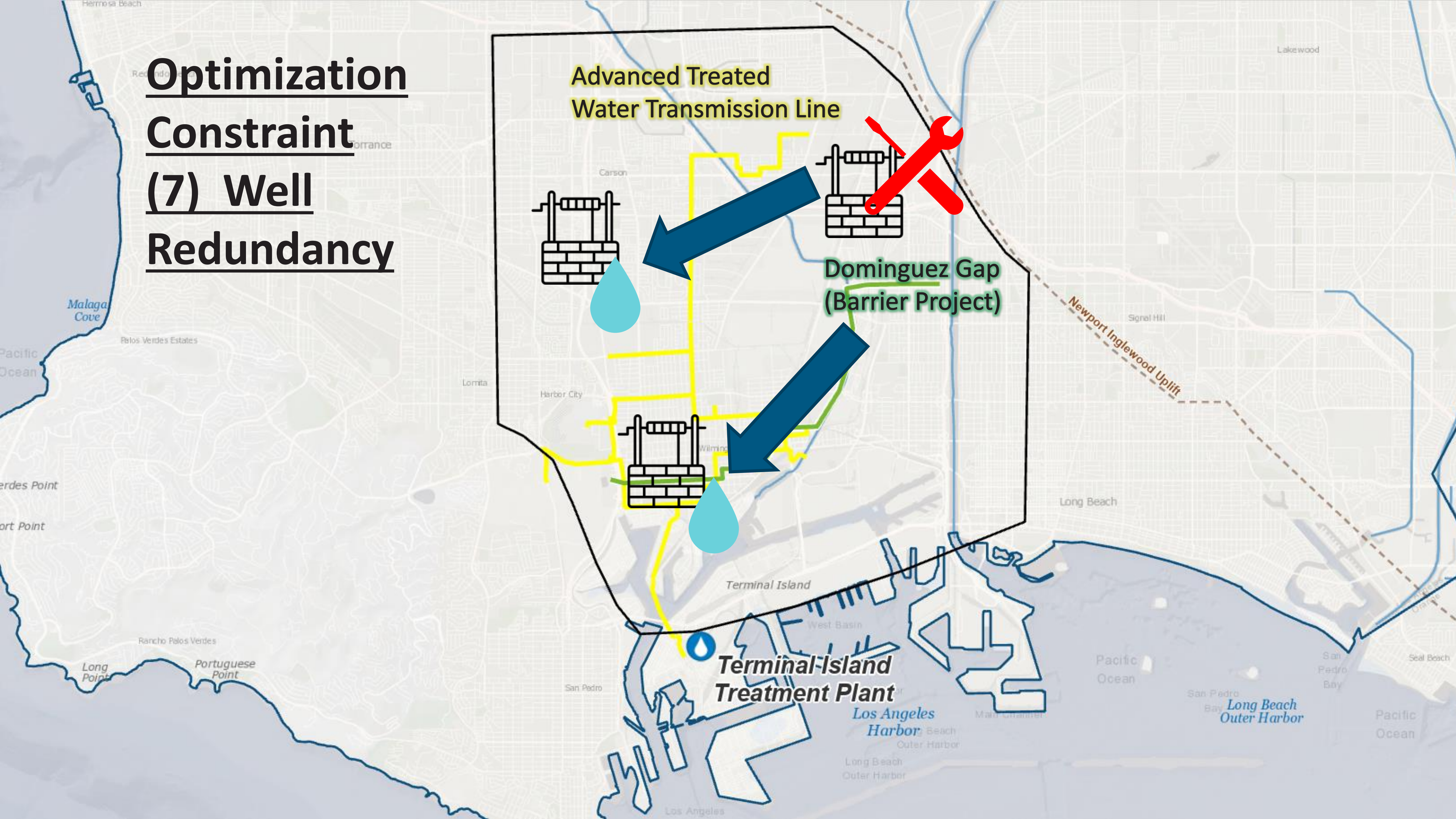


< the groundwater velocity change over the baseline induced by the barrier wells

Optimization Constraint: (6) Impacts on the barrier



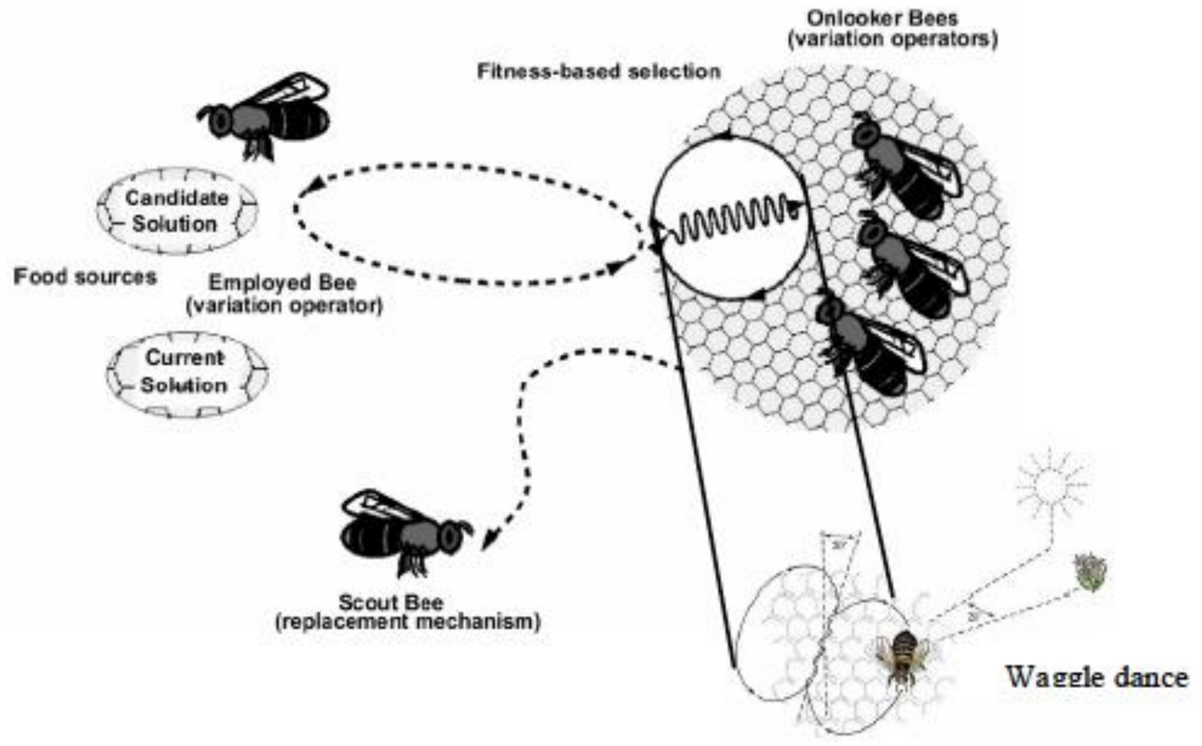
Optimization Constraint (7) Well Redundancy



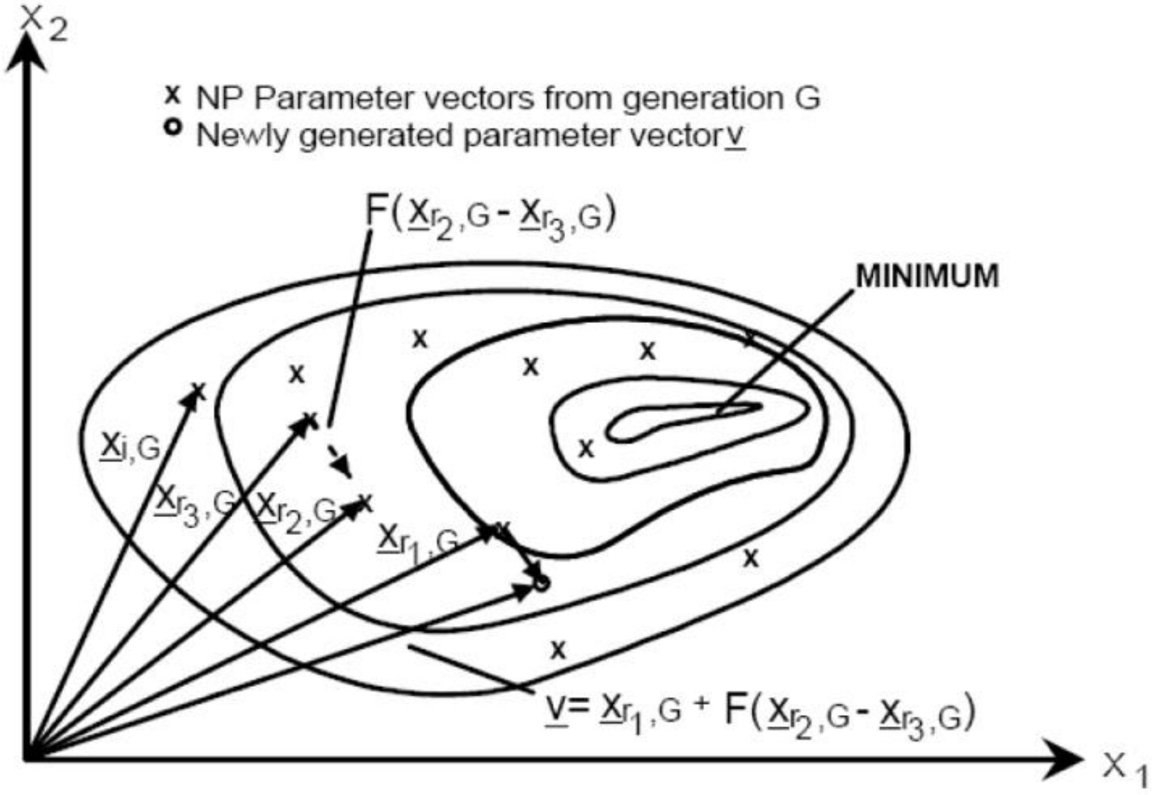

So much to take care of….

Meta Heuristic Optimization Methods

Artificial Bee Colony (ABC)



Differential Evolution (DE)



Optimize on Cost, satisfy all constraints

Optimization Flowchart

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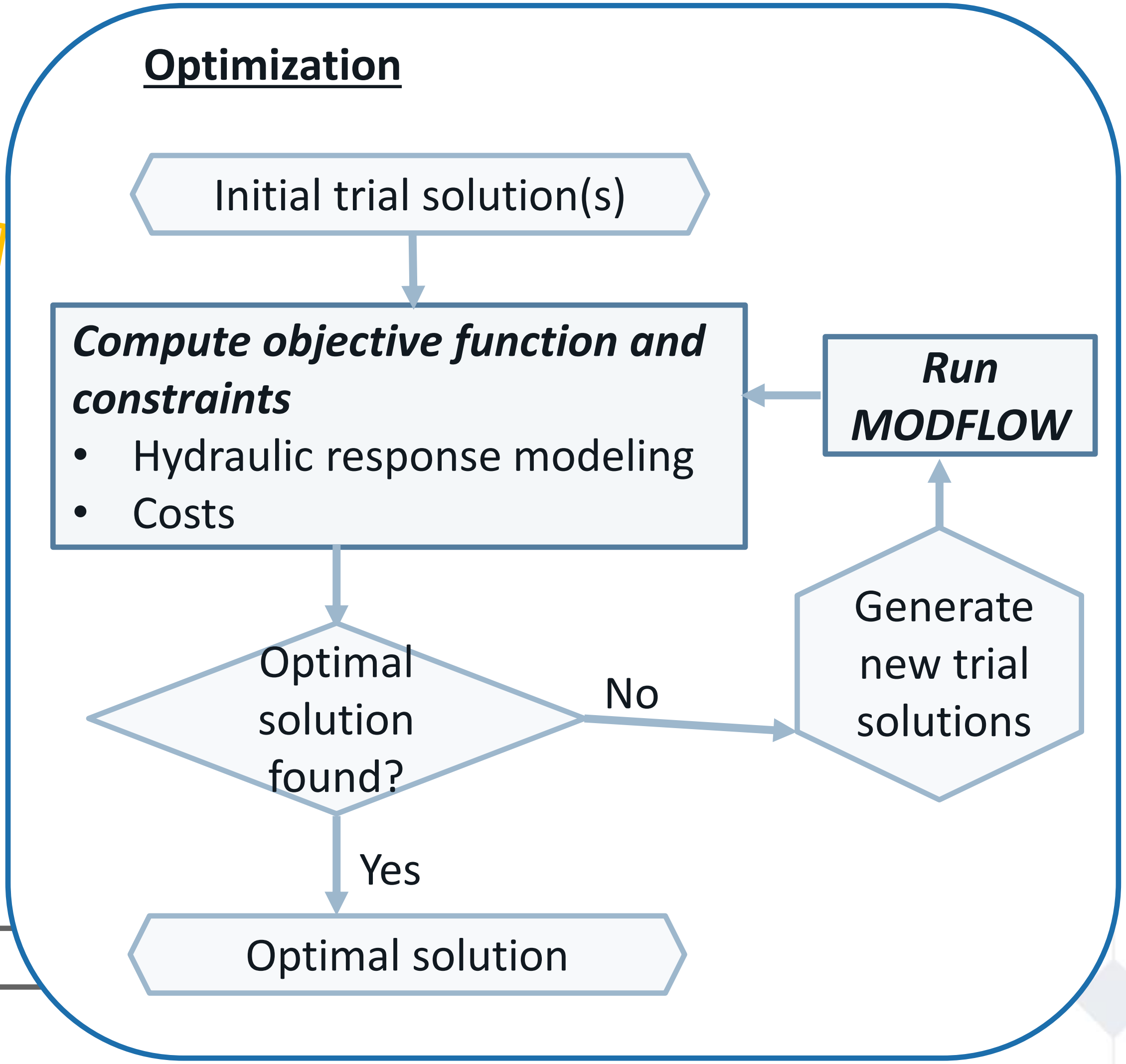
Optimization Framework Formulation

- ***Decision variables:*** number of injection wells, locations, injection rates, and injection zones
- ***Objective function:*** cost
- ***Constraints:*** impacts on barrier wells, environmental sites, municipal production wells, site availability, regulatory requirements

Inputs

- Cost components
- Hydraulic model parameters
- Existing system layout
- Environmental sites and impact on constraint criteria
- Municipal wells and impact constraint criteria
- Site Availability

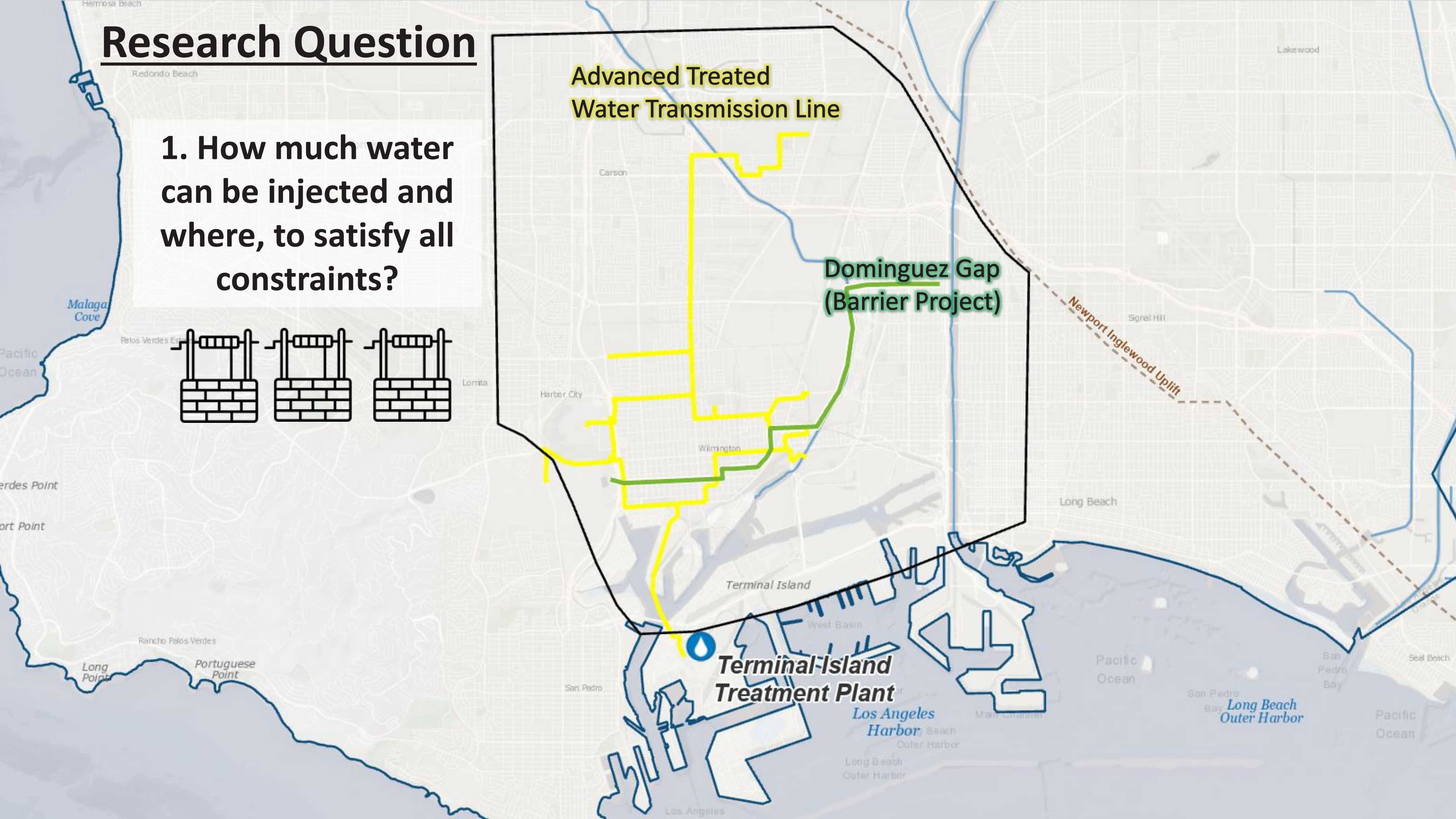


Post-optimization Processing

- Confirmatory evaluation
- Graphic display
- Data for injection well design

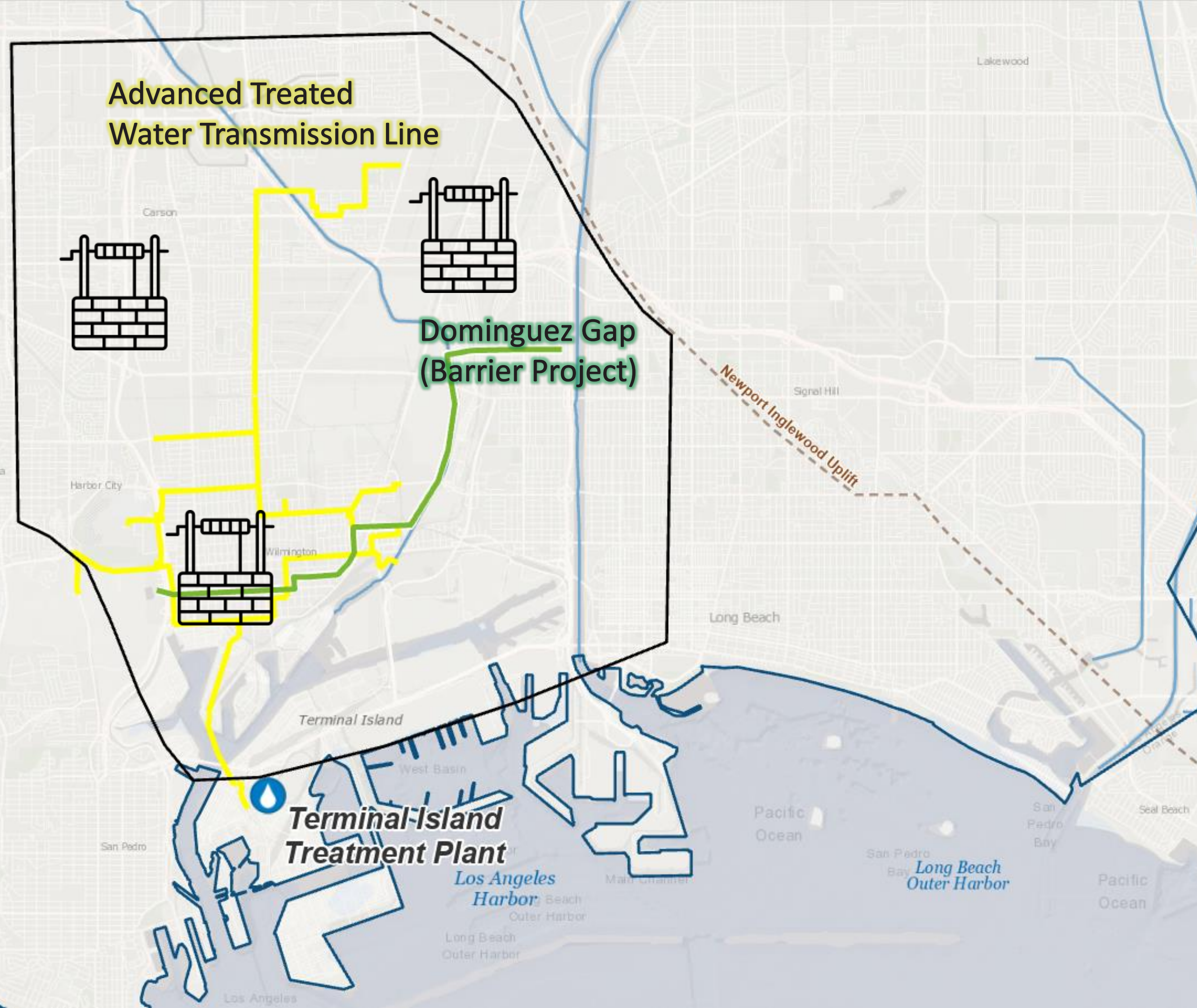
Research Question

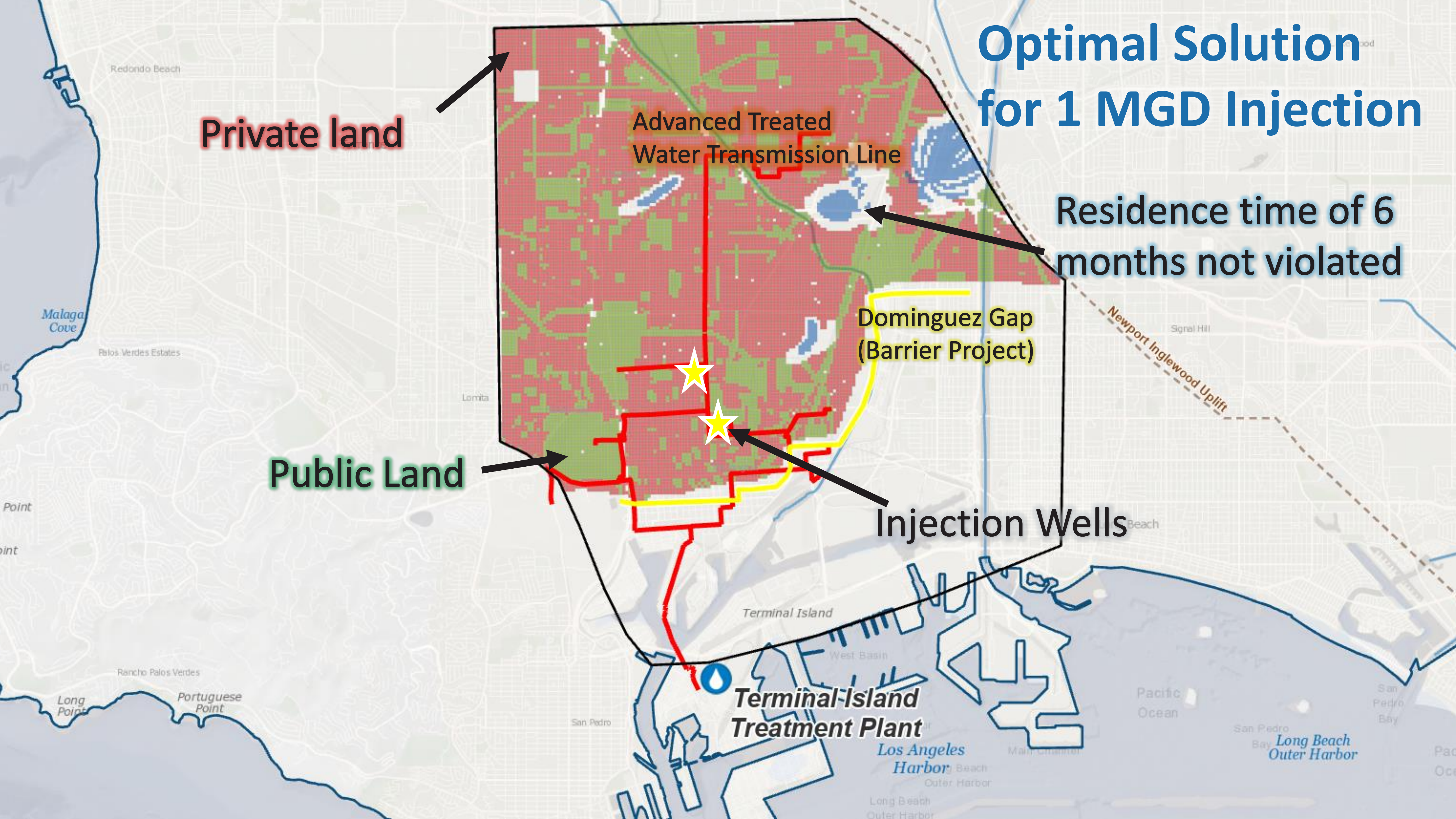
1. How much water can be injected and where, to satisfy all constraints?



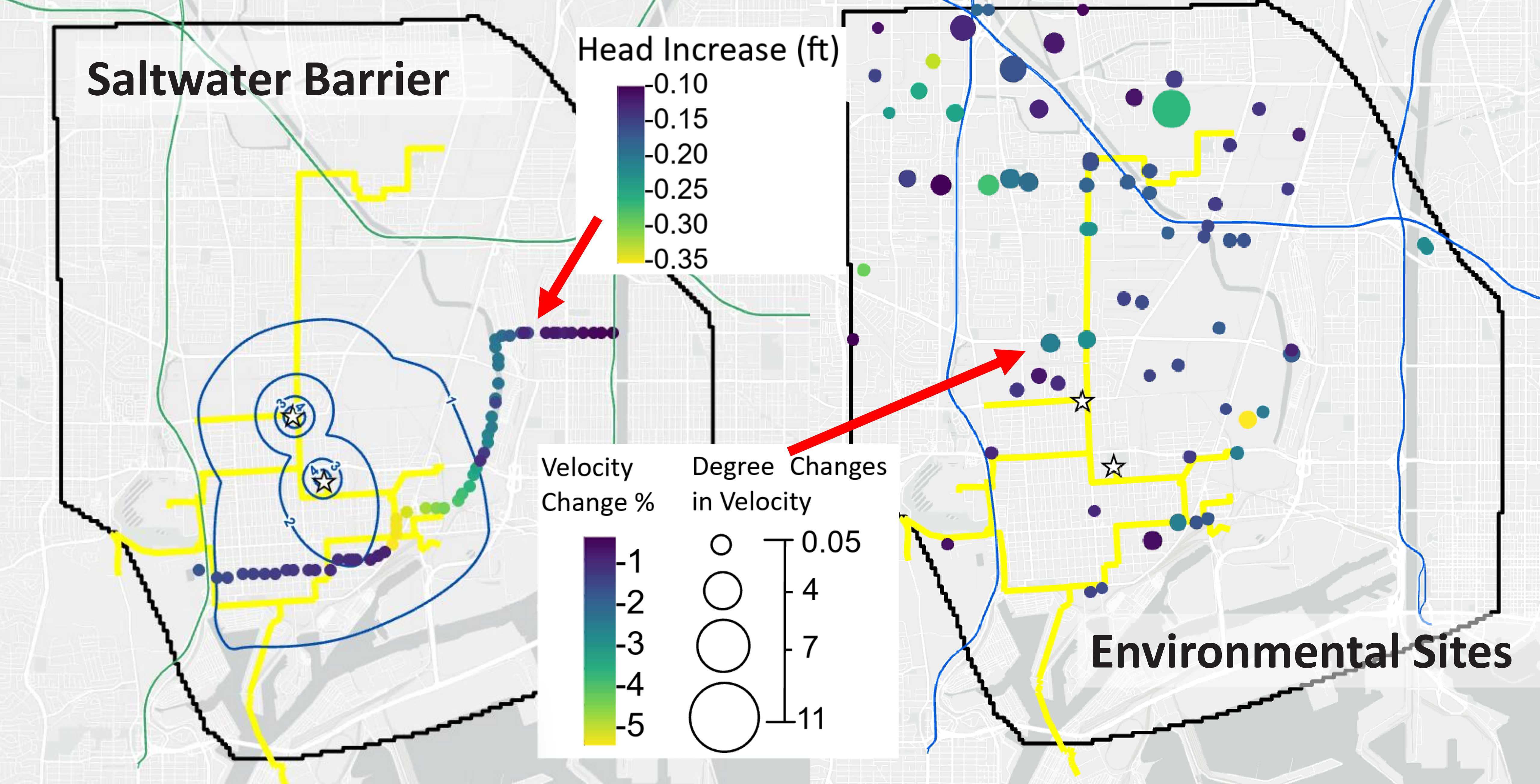
Research Question

2. Where are the injection locations that minimize cost?

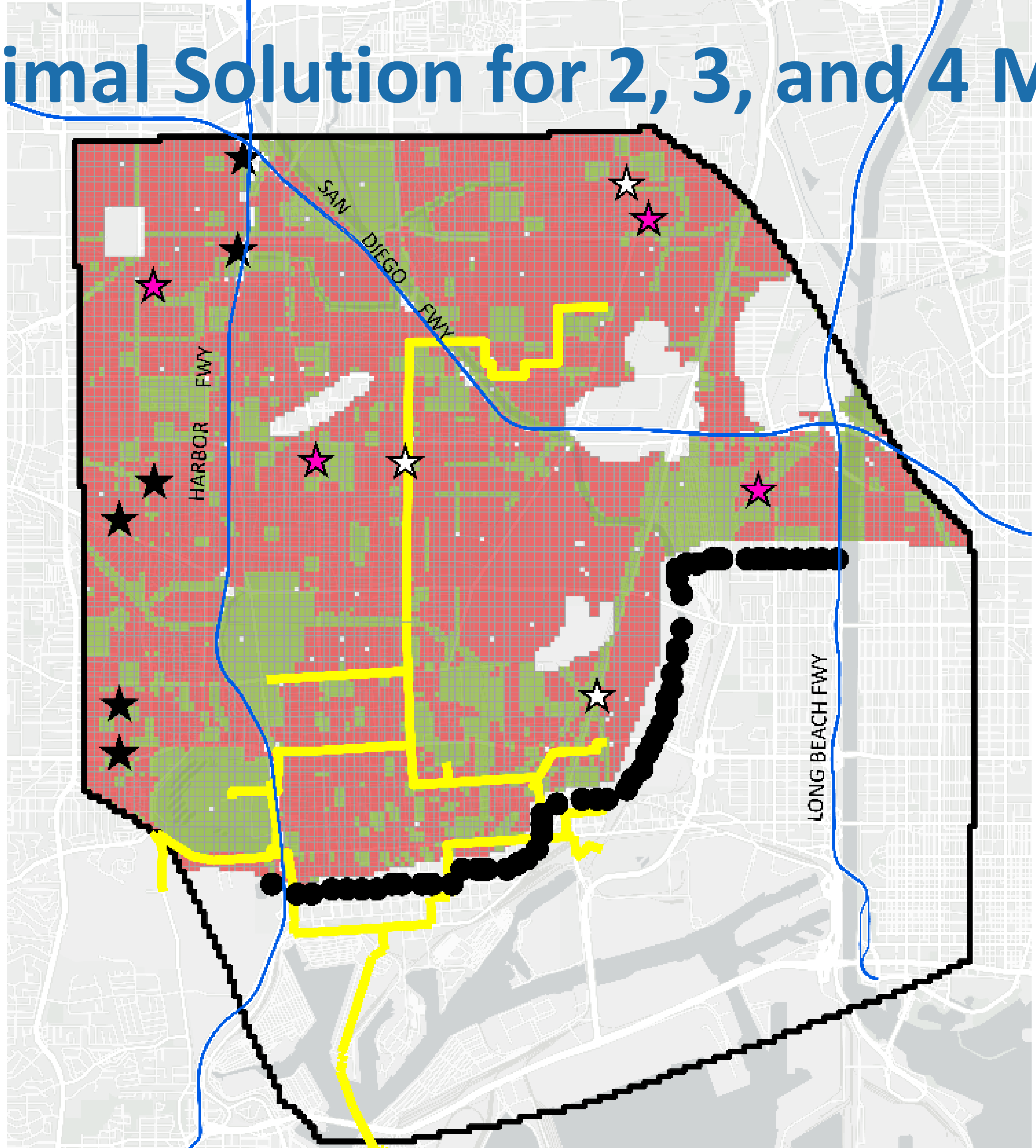



Optimal Solution
for 1 MGD Injection
Private land
Advanced Treated
Water Transmission Line
Residence time of 6
months not violated
Dominguez Gap
(Barrier Project)
Public Land
Injection Wells
Terminal Island
Treatment Plant
Redondo Beach
Malaga Cove
Palos Verdes Estates
Lomita
Signal Hill
Newport Inglewood Uplift
Terminal Island
West Basin
Rancho Palos Verdes
Long Point
Portuguese Point
San Pedro
Los Angeles Harbor
Pacific Ocean
San Pedro Bay
Long Beach Outer Harbor

Optimal Solution for 1 MGD Injection



Optimal Solution for 2, 3, and 4 MGD



Legend

- ☆ 2MGD
- ★ 3MGD
- ★ 4MGD

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Summary of Optimal Solutions for 1, 2, 3, and 4 MGD Injection Scenarios

Injection Rate (MGD)	Injection Wells	Approximate ROM Costs (millions of dollars)					Cost/ MGD
		Pipeline	Land	Well Installation	ATW Connection	Total	
1	2	$0.05	$0	$4.50	$0.50	$5.05	$5.05
2	3	$2.50	$1.30	$6.75	$0.75	$11.30	$5.65
3	4	$9.15	$0.65	$9.00	$1,00	$19.80	$6.60
4	6	$15.60	$3.95	$12.90	$1.50	$33.95	$8.49

Conclusions

- Up to 4 MGD of treated water can be injected without violating constraints.
- Locations that minimize cost were determined for injecting 1, 2, 3 and 4 MGD and costs were determined.
- Relaxing some constraints would produce lower cost solutions but come at a higher risk.
- The developed optimization program is robust and can be customized for other situations.

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