THE Water Research FOUNDATION

Identifying the amount of wastewater that is available and feasible to recycle in California

WRF 4962 / Preliminary Findings

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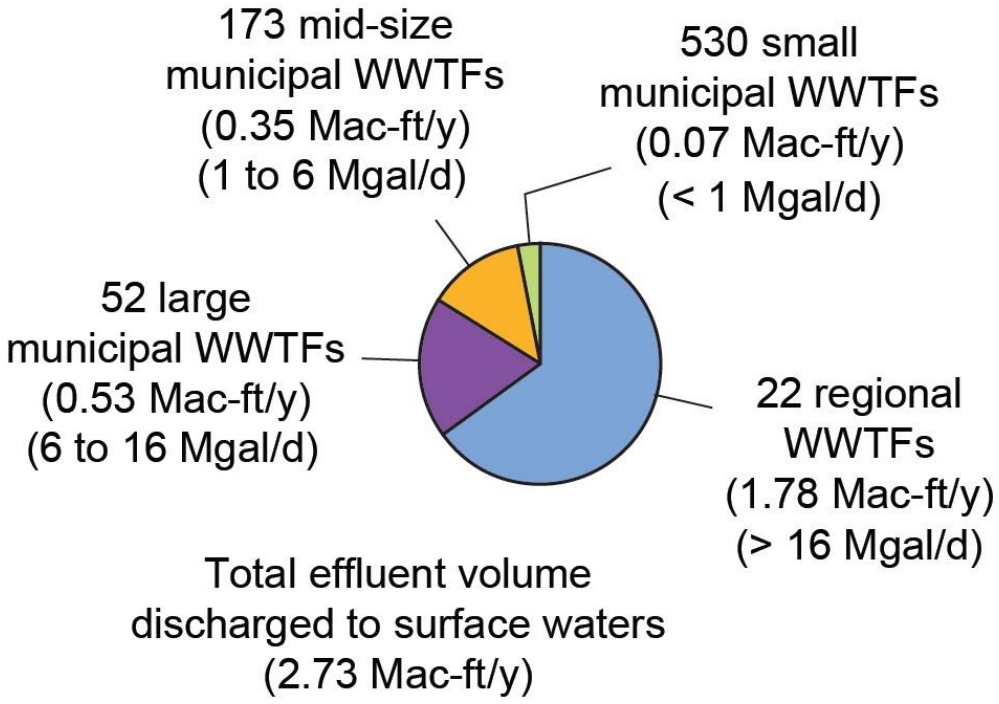
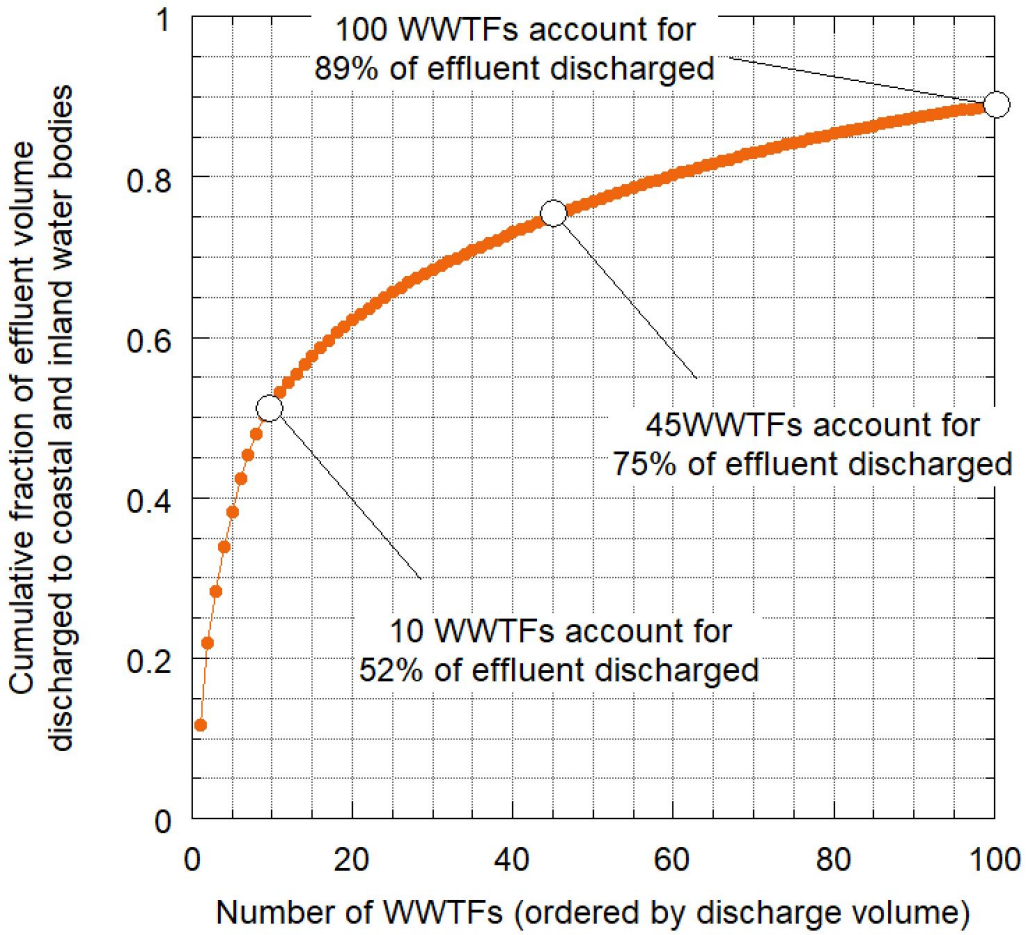
Topics

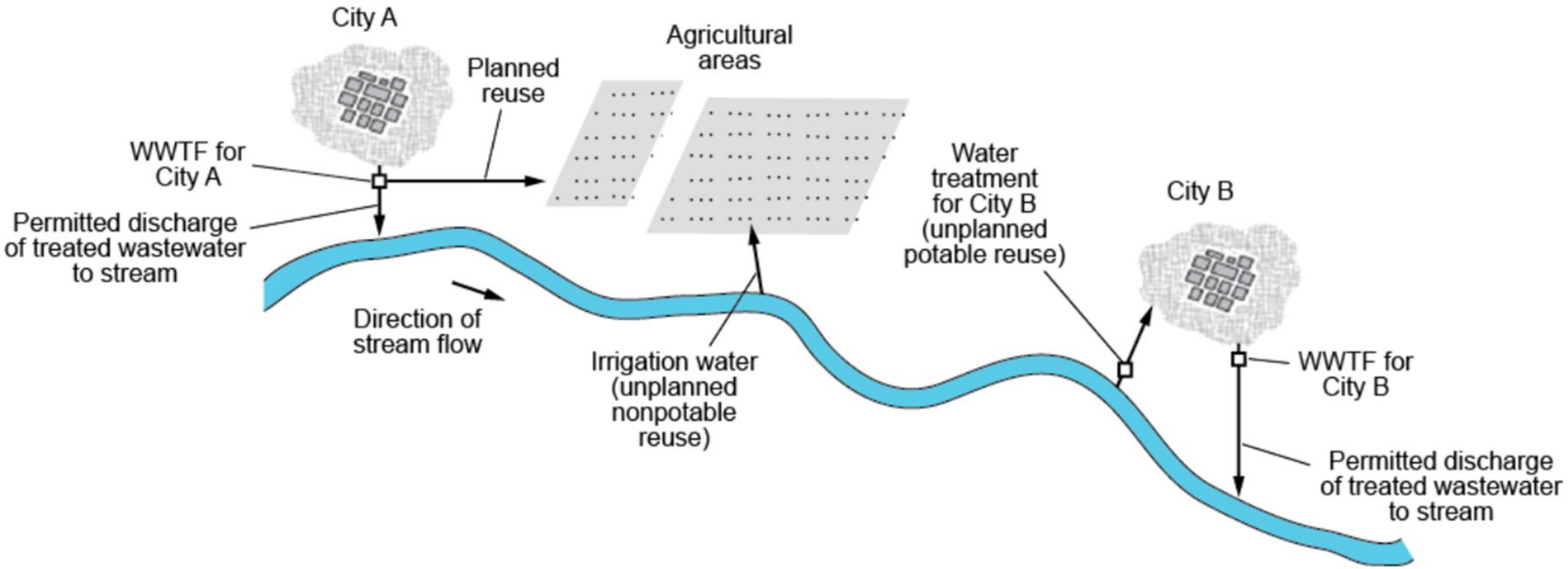
- Wastewater Management in CA
- Water Reuse in CA
- Obstacles to Water Reuse
- Approach for Modeling Feasibility of Water Reuse
- Spatial modeling of path to potential reuse sites
- Cost model for alternative water reuse projects
- Regional distribution of total cost results

Wastewater Management in CA

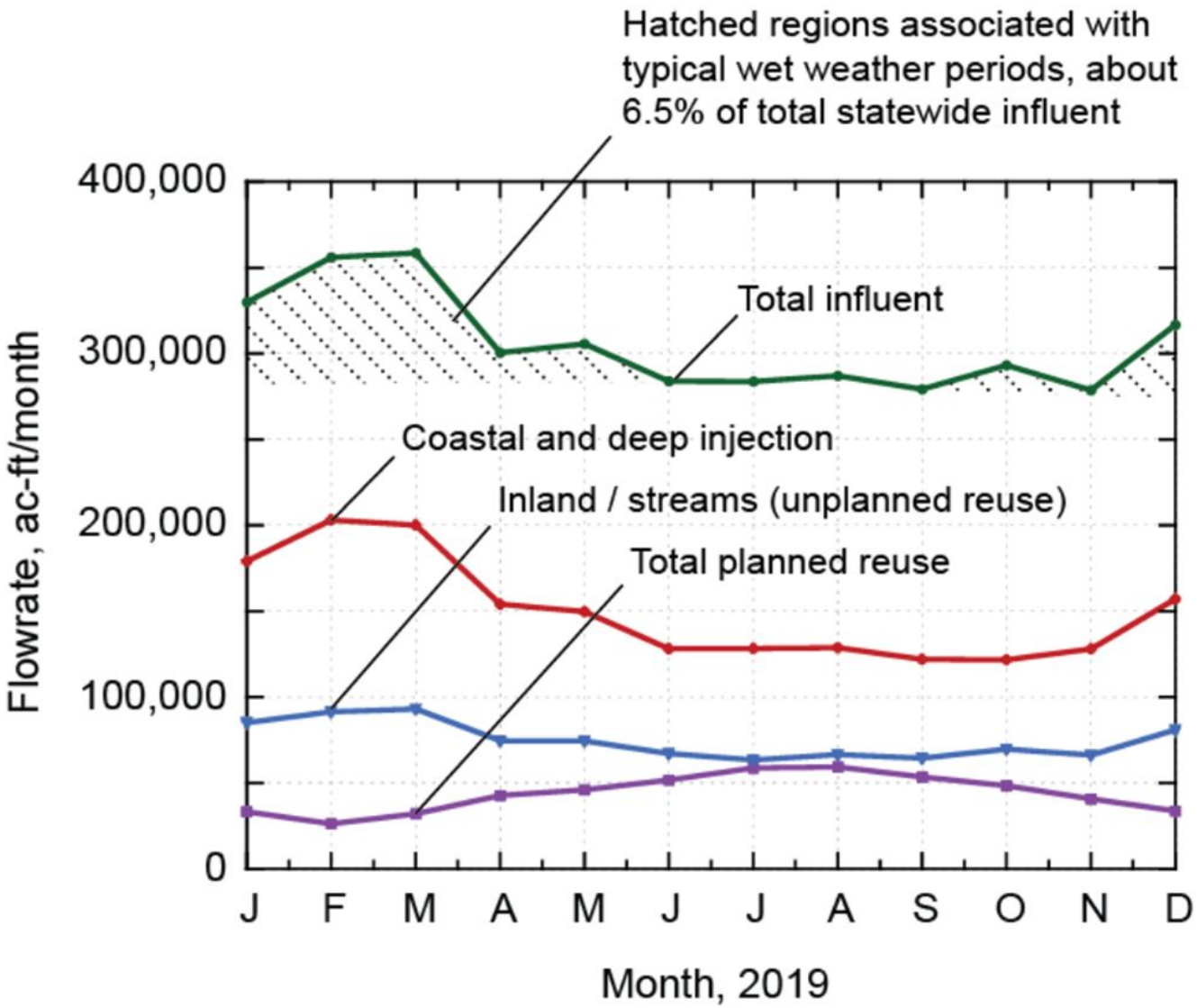


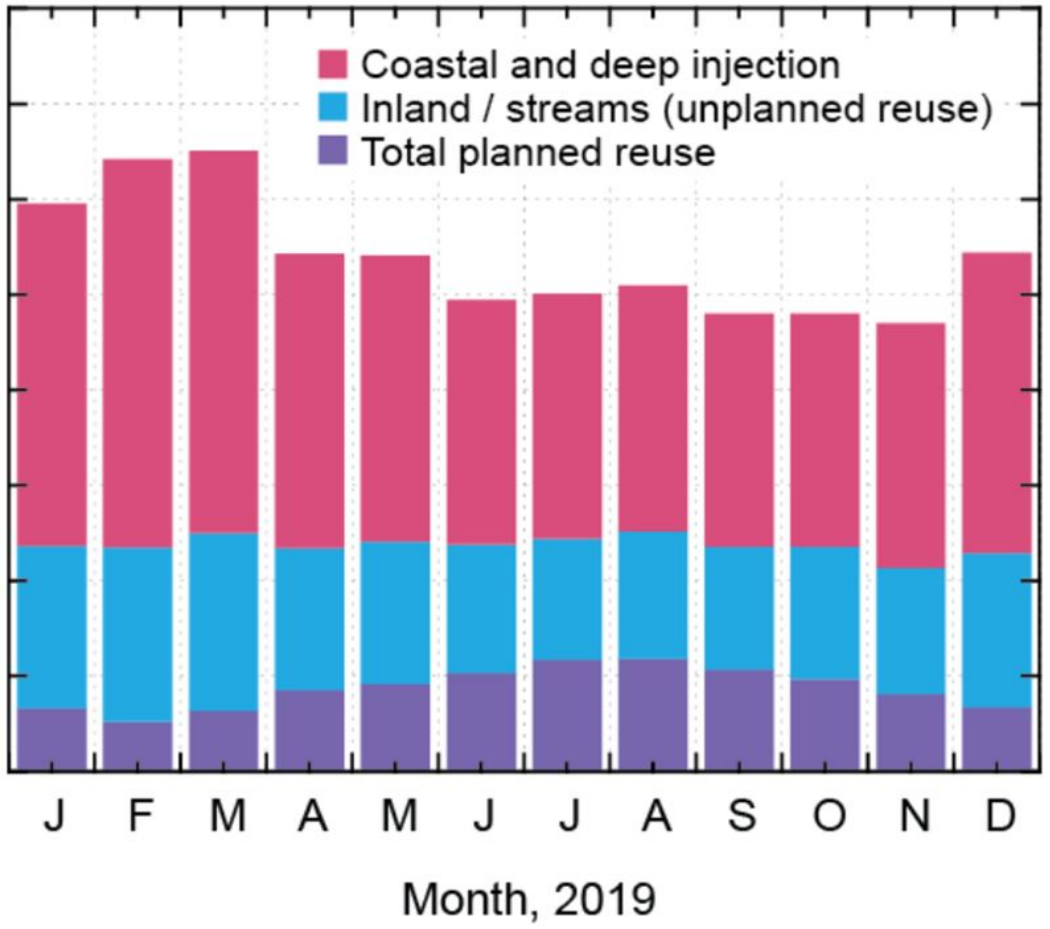


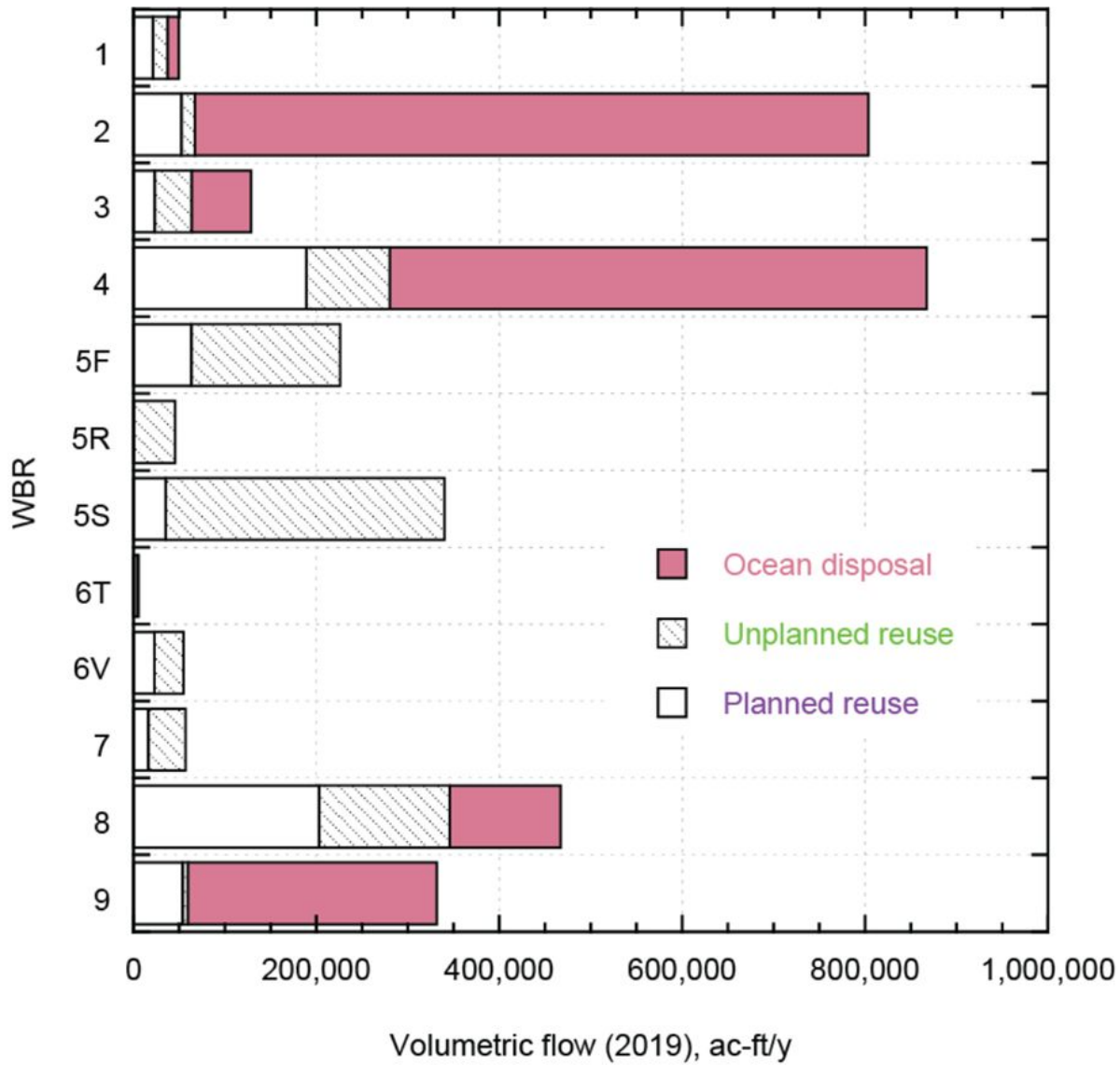
CURRENT [INLAND] EFFLUENT DISPERSAL PRACTICE:
de facto indirect reuse



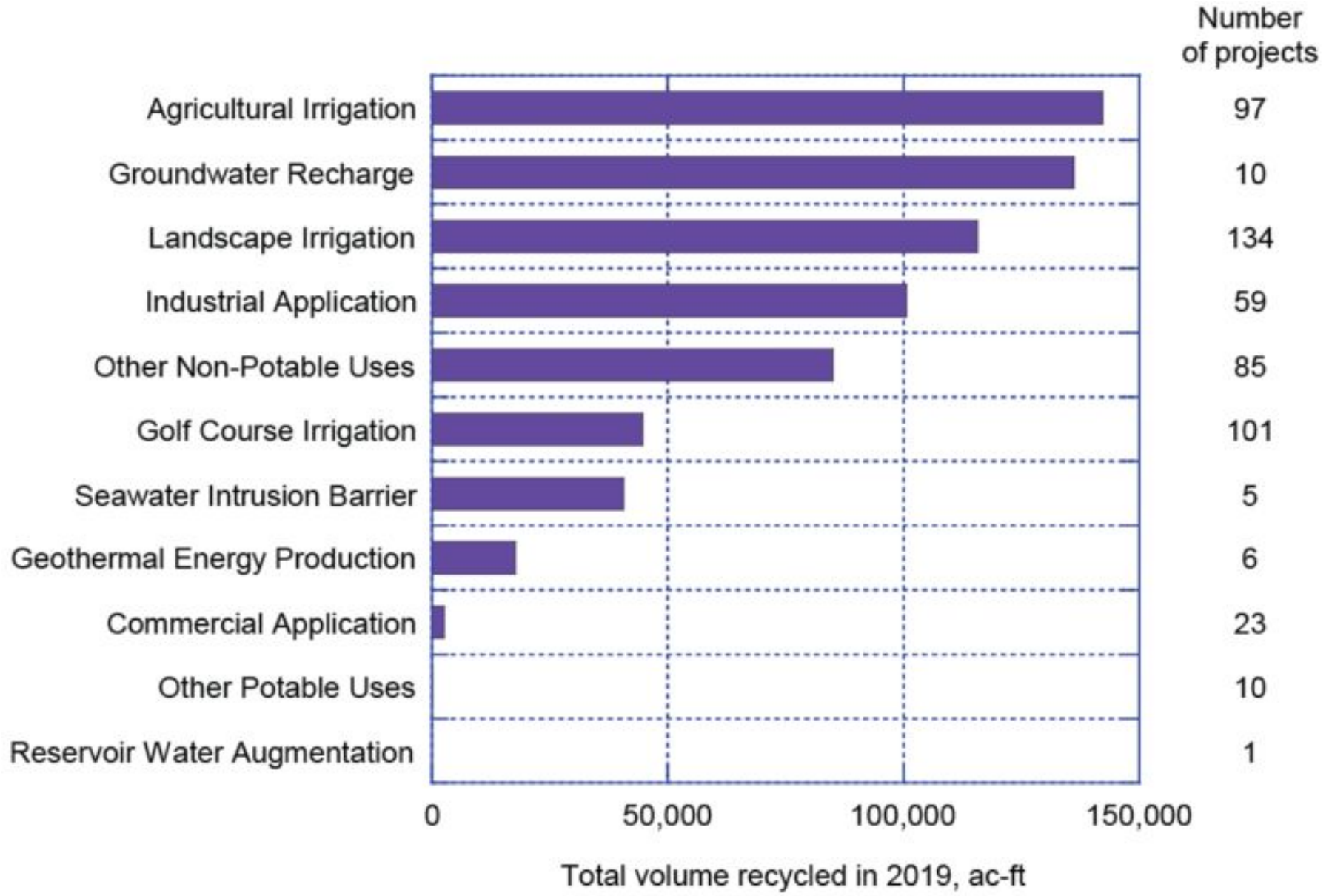
Summary of effluent management in CA



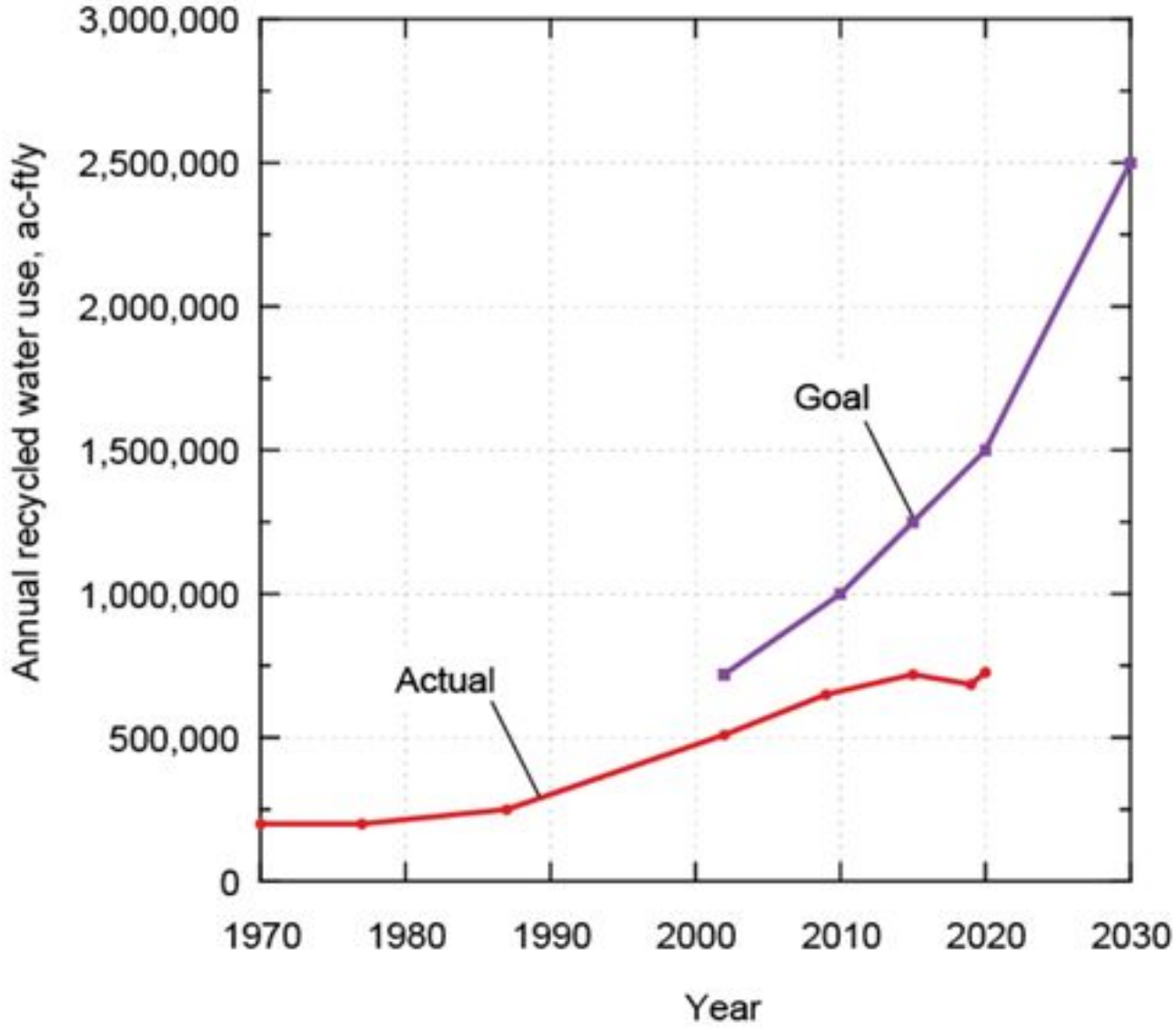



WBR
1
2
3
4
5F
5R
5S
6T
6V
7
8
9
0
200,000
400,000
600,000
800,000
1,000,000
Volumetric flow (2019), ac-ft/y
Ocean disposal
Unplanned reuse
Planned reuse

Overview of Water Reuse in CA



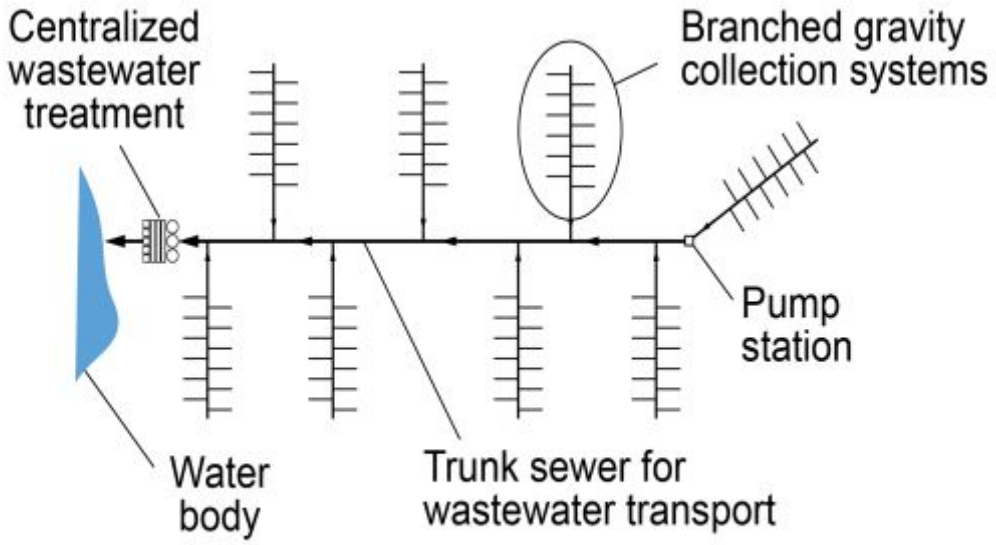
Views on Water Reuse in CA



Some Obstacles to Water Reuse

- Unintended consequences of past decisions
  - 20th century infrastructure
- Dynamic conditions
  - Impacts on water supply from drought
  - Changes in population
  - Changes in indoor water use
- Cost
  - Capital, operations, and permit compliance
- Lack of perceived threat to existing water supplies

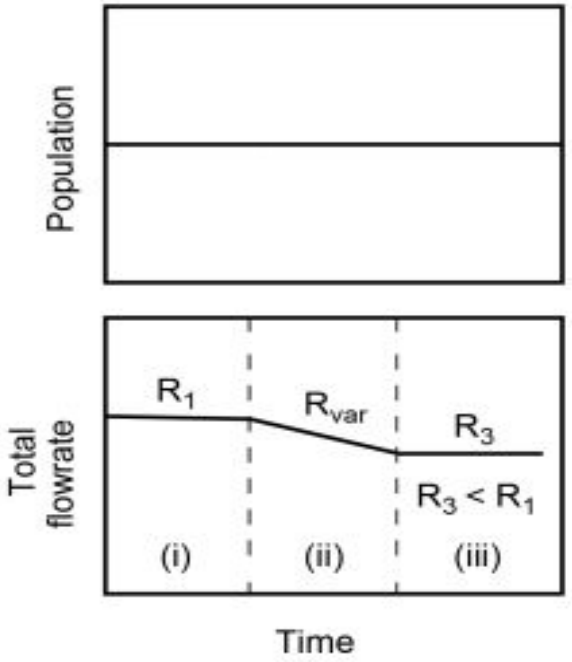
20th Century Infrastructure



Conventional wastewater infrastructure

Conventional wastewater infrastructure
- Not well adapted to low flow scenarios
- Vulnerabilities with climate change
- Limits some water reuse opportunities

Changing Patterns in Water Use



(i) Pre-1992

(ii) Improved water conservation

(iii) Maximum water conservation

Use	Flow, gal/capita•d					
	2015		2020		2030	
	Range	Typical	Range	Typical	Range	Typical
Domestic						
Indoor use	40 - 80	60	35 - 65	55 (50)	30 - 60	40 (35)
Outdoor use	16 - 50	35	16 - 50	35	16 - 50	35
Commercial	10 - 75	40	10 - 70	35	10 - 65	30
Public	15 - 25	20	15 - 25	18	15 - 25	15
Loss and waste	15 - 25	20	15 - 25	18	15 - 25	15
Total	96 - 255	175		161		135

Changing Wastewater Constituent Concentrations

Constituent	Unit	Typical value	Concentration, mg/L	
			Volume, L/capita•d (gal/capita•d)	
			380 (100)	190 (50)
BOD_5	g/capita•d	76	199	400
COD	g/capita•d	193	507	1016
TSS	g/capita•d	74	195	389
TKN as N	g/capita•d	13.2	35	70
Total P as P	g/capita•d	2.1	5.6	11
Potassium	g/capita•d	6.1	16	32
Oil and grease	g/capita•d	29	76	153

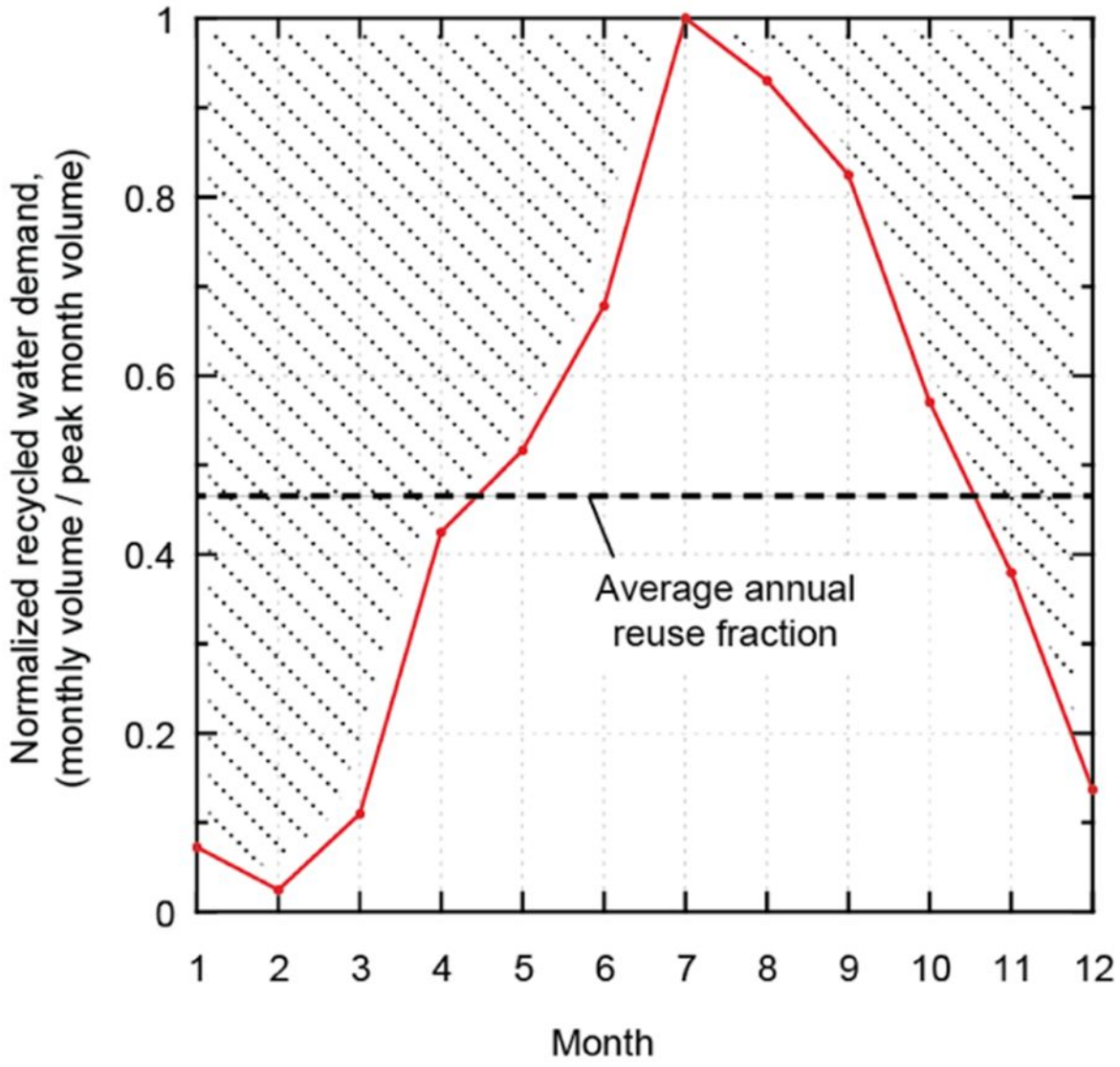
Approach for Modeling Feasibility of Expanded Water Reuse

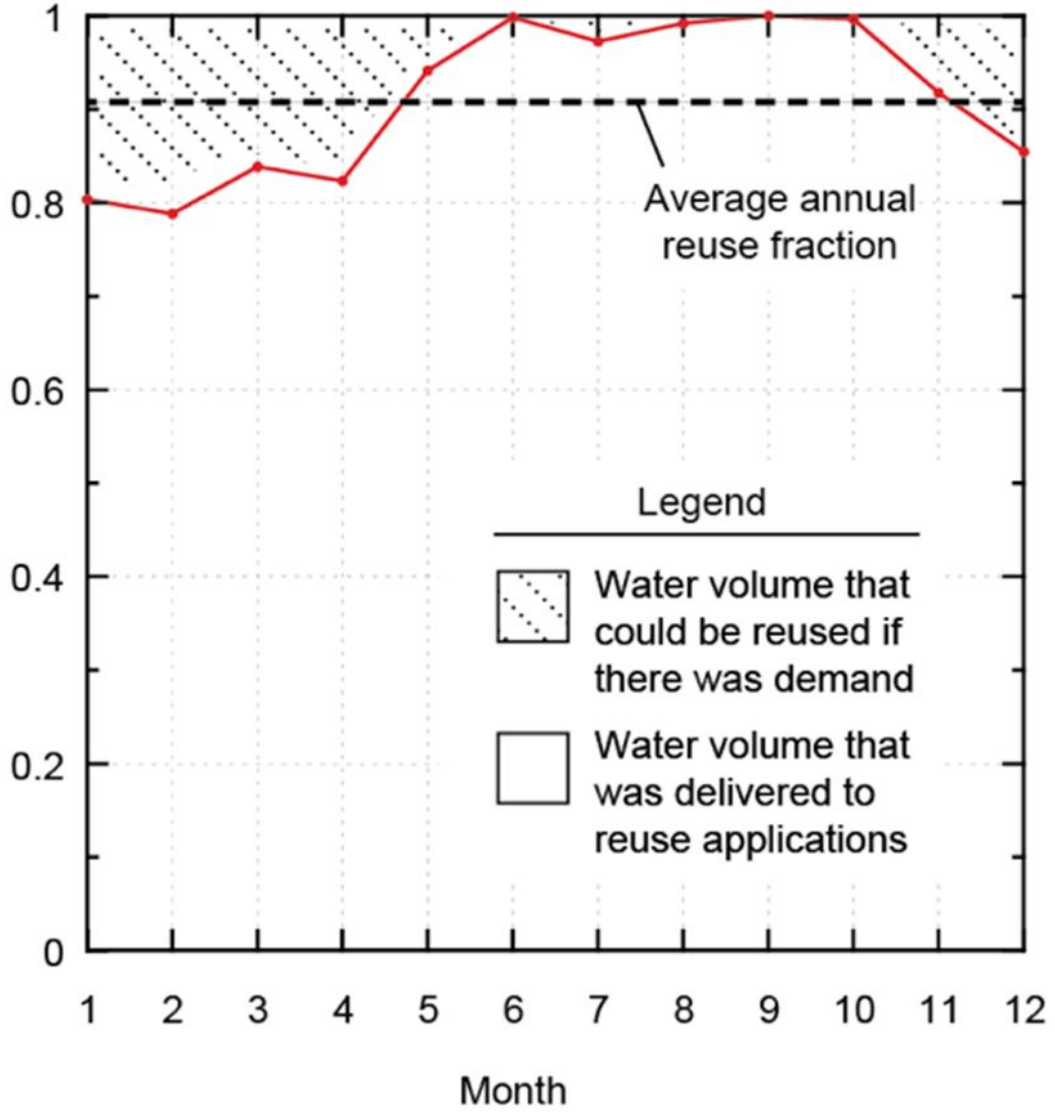
- Selected WWTFs with available flows >4 Mgal/d
- Adjustments for future water volumes for reuse
- Database with potential sites for water reuse
- ArcGIS model to determine least cost pipeline from effluent source to reuse site
- Economic model to estimate cost to upgrade water quality and deliver water
- Distribution of costs in terms of $/ac-ft

Flow balance corrections

- Dry weather flows estimated from 2019 Volumetric Annual Report
- Regional population changes and expected changes in indoor water use
- Water loss with solids
- Correction for water loss with concentrate management
- Water reuse specific usage factors

Flow balance corrections

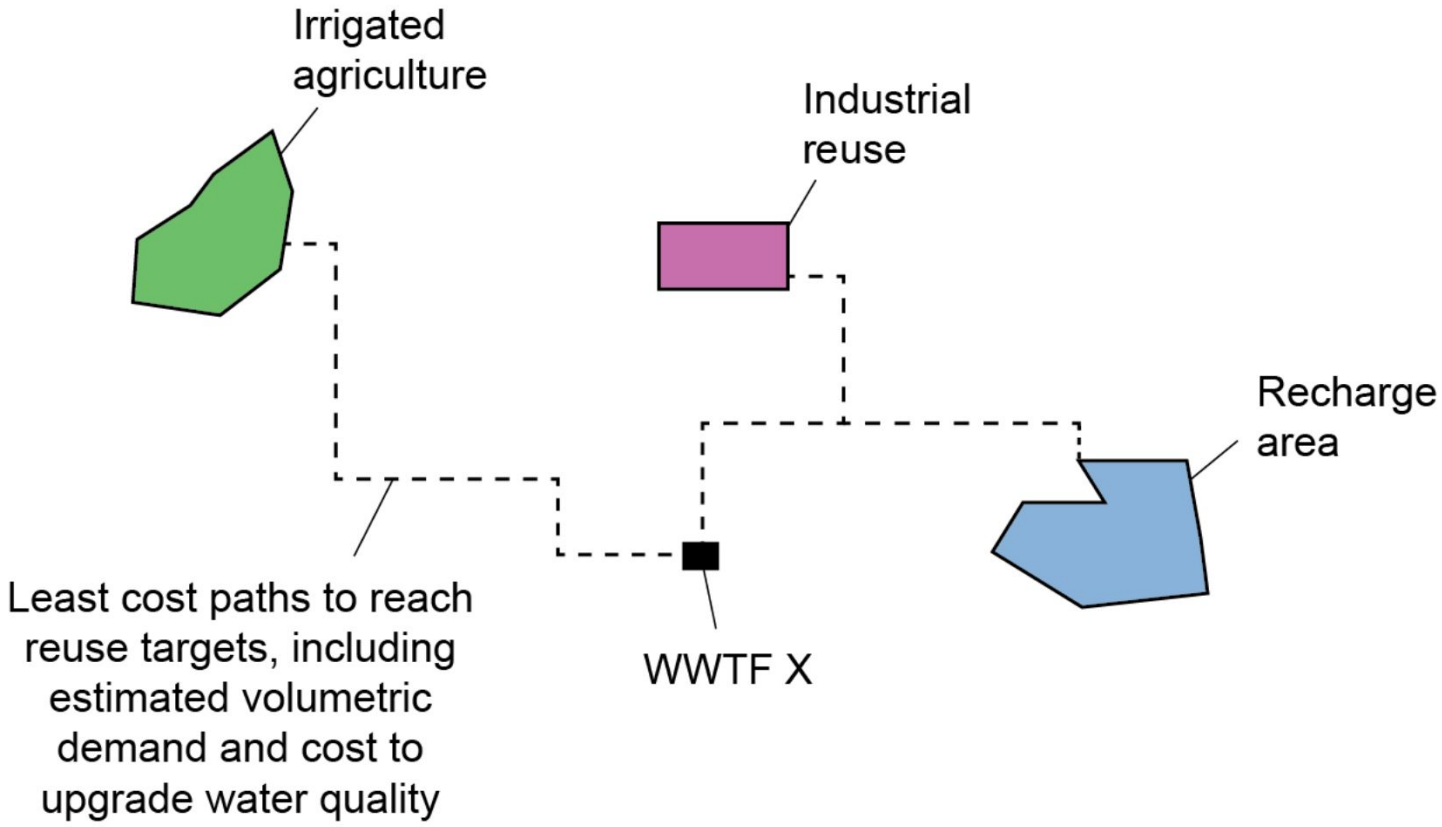


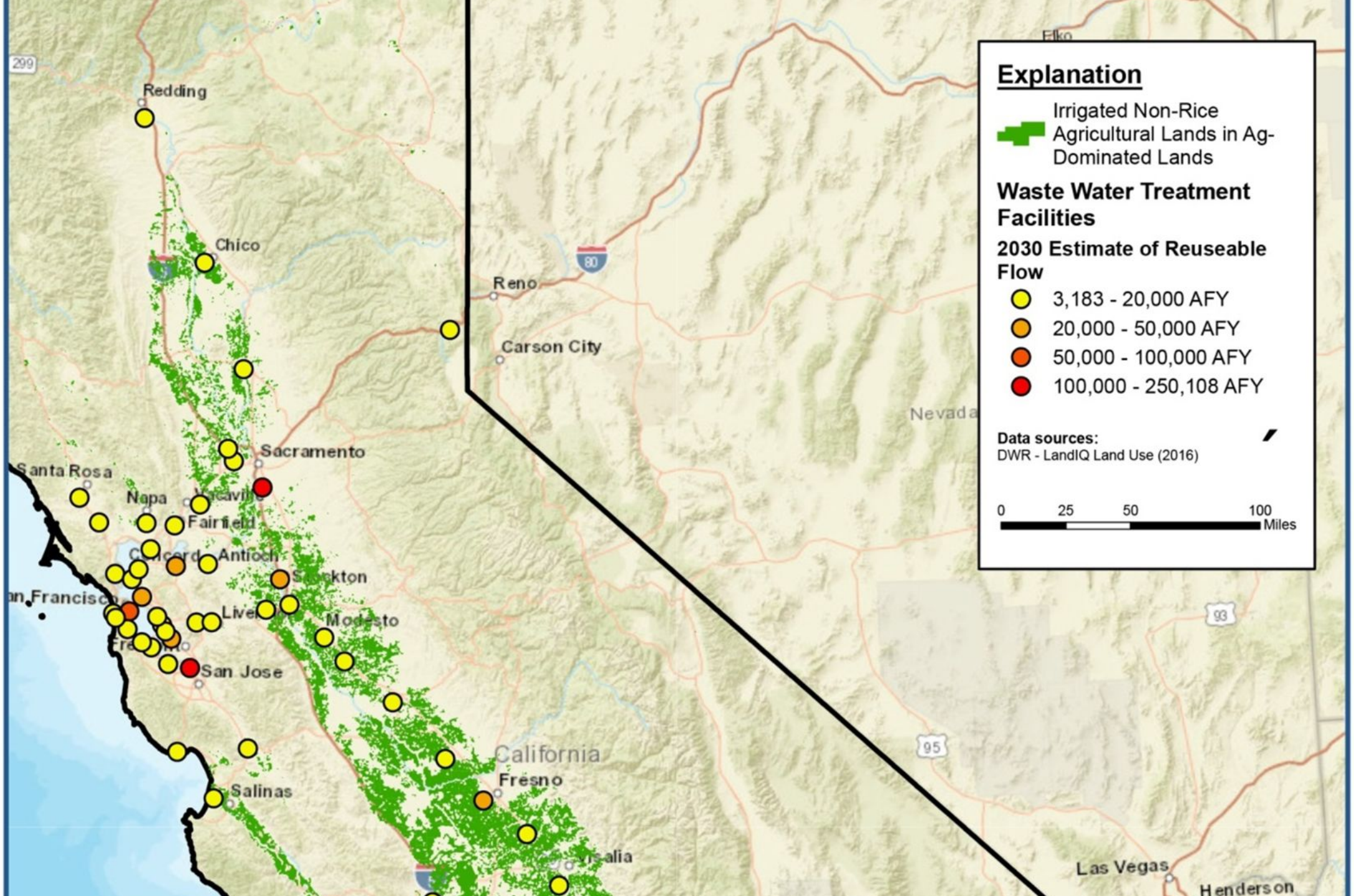


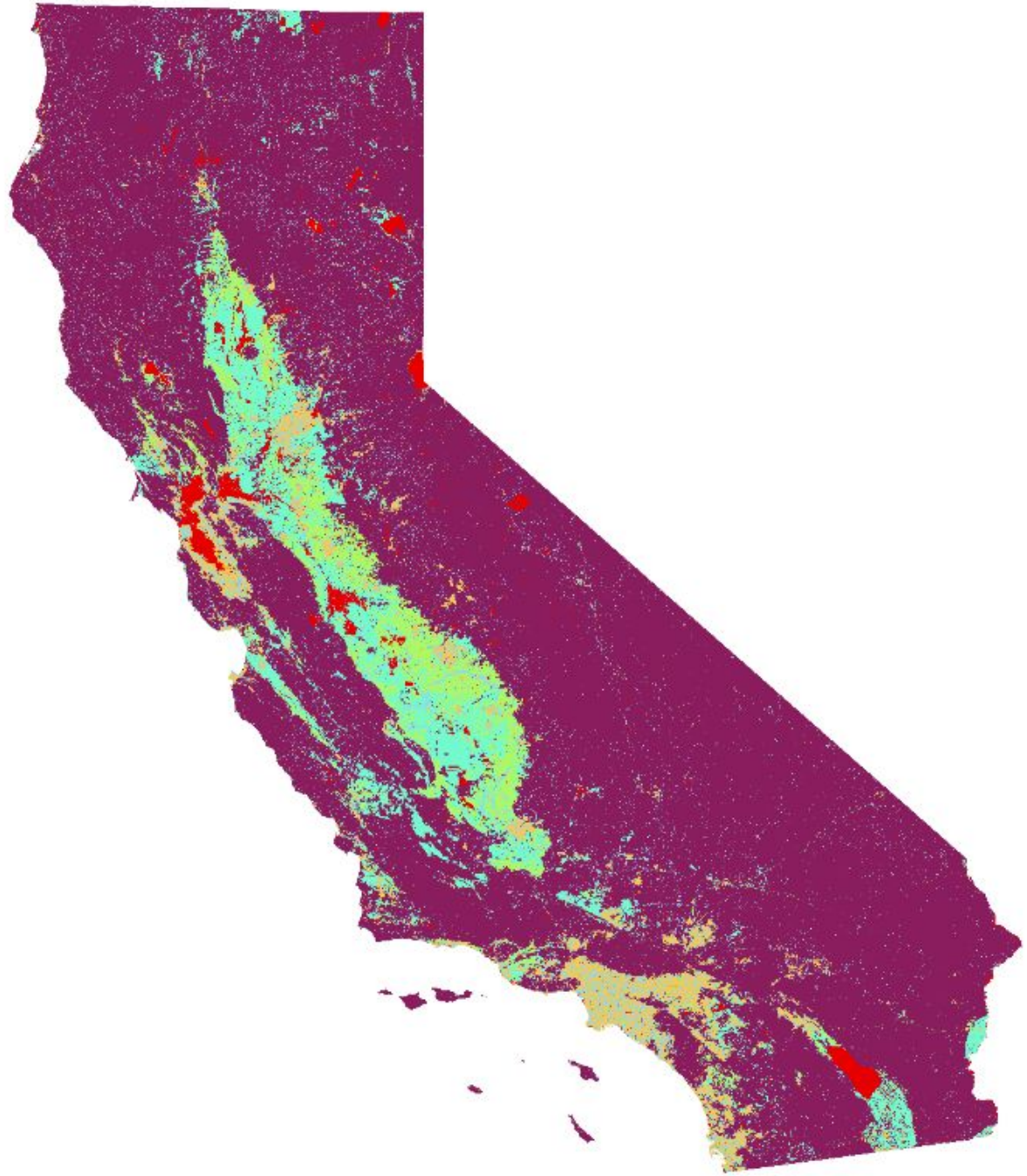
Locating Targets for Water Reuse

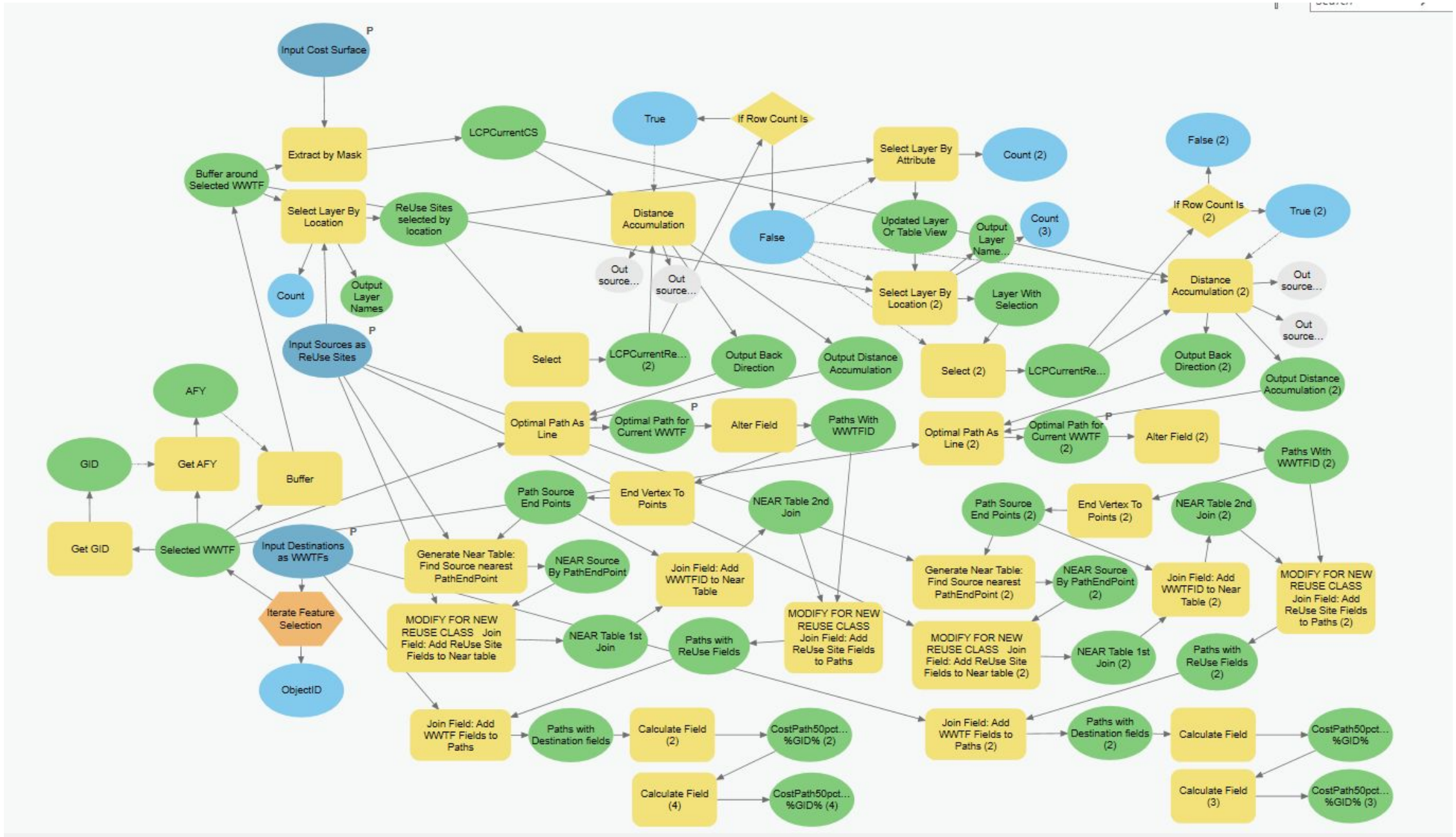
Potential reuse site database/methodology:

- Agricultural reuse
- Commercial and industrial non-potable sites
- Groundwater recharge (surface infiltration)
- Groundwater recharge (injection)
- Water supply reservoir locations
- Direct raw water and potable water augmentation

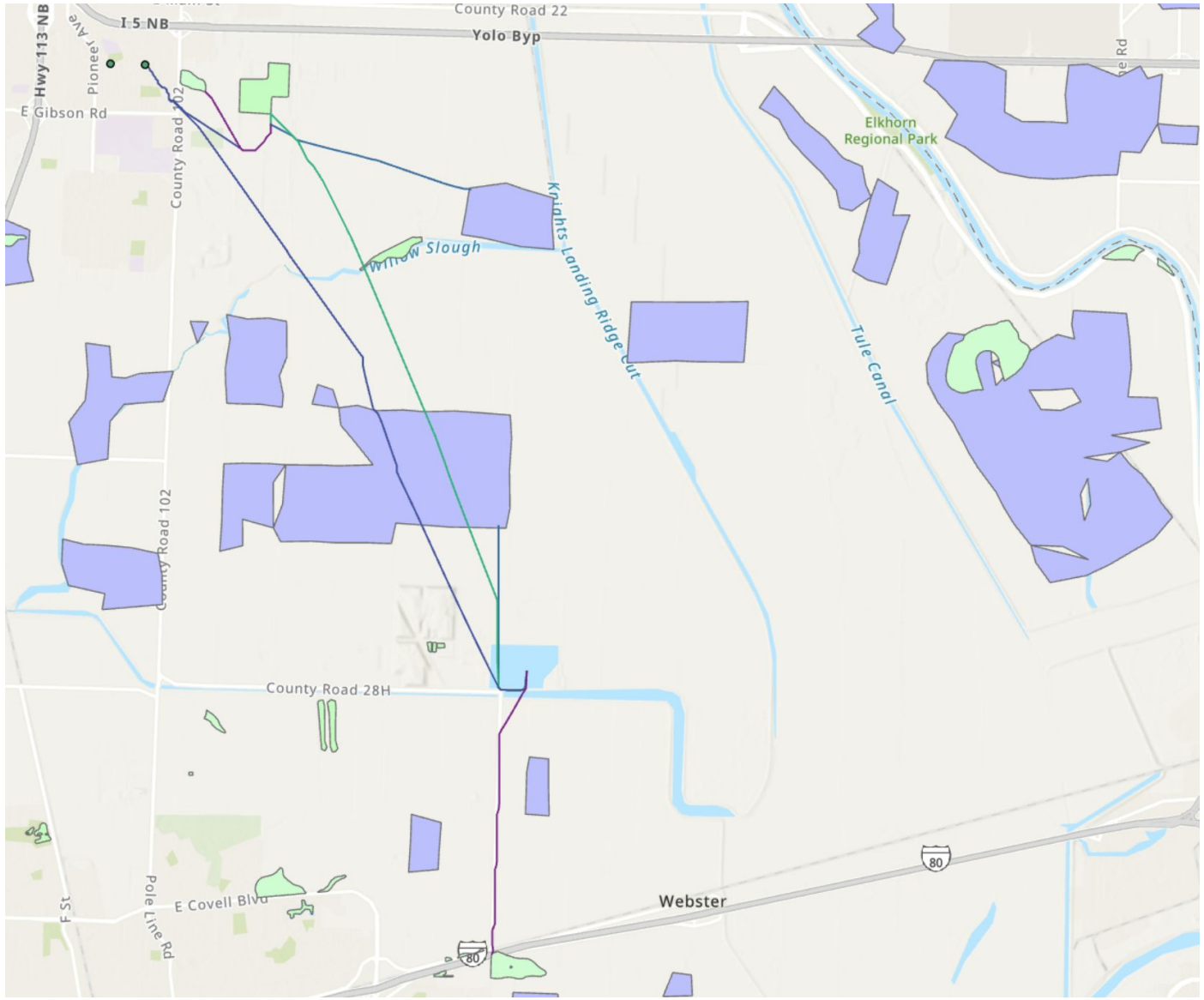



Explanation
Irrigated Non-Rice Agricultural Lands in Ag-Dominated Lands
Waste Water Treatment Facilities
2030 Estimate of Reuseable Flow
3,183 - 20,000 AFY
20,000 - 50,000 AFY
50,000 - 100,000 AFY
100,000 - 250,108 AFY
Data sources:
DWR - LandIQ Land Use (2016)
0 25 50 100 Miles
Redding
Chico
Reno
Carson City
Nevada
Sacramento
Santa Rosa
Napa
Fairfield
Antioch
Stockton
Modesto
San Jose
Salinas
California
Fresno
Las Vegas
Henderson
299
80
95
93

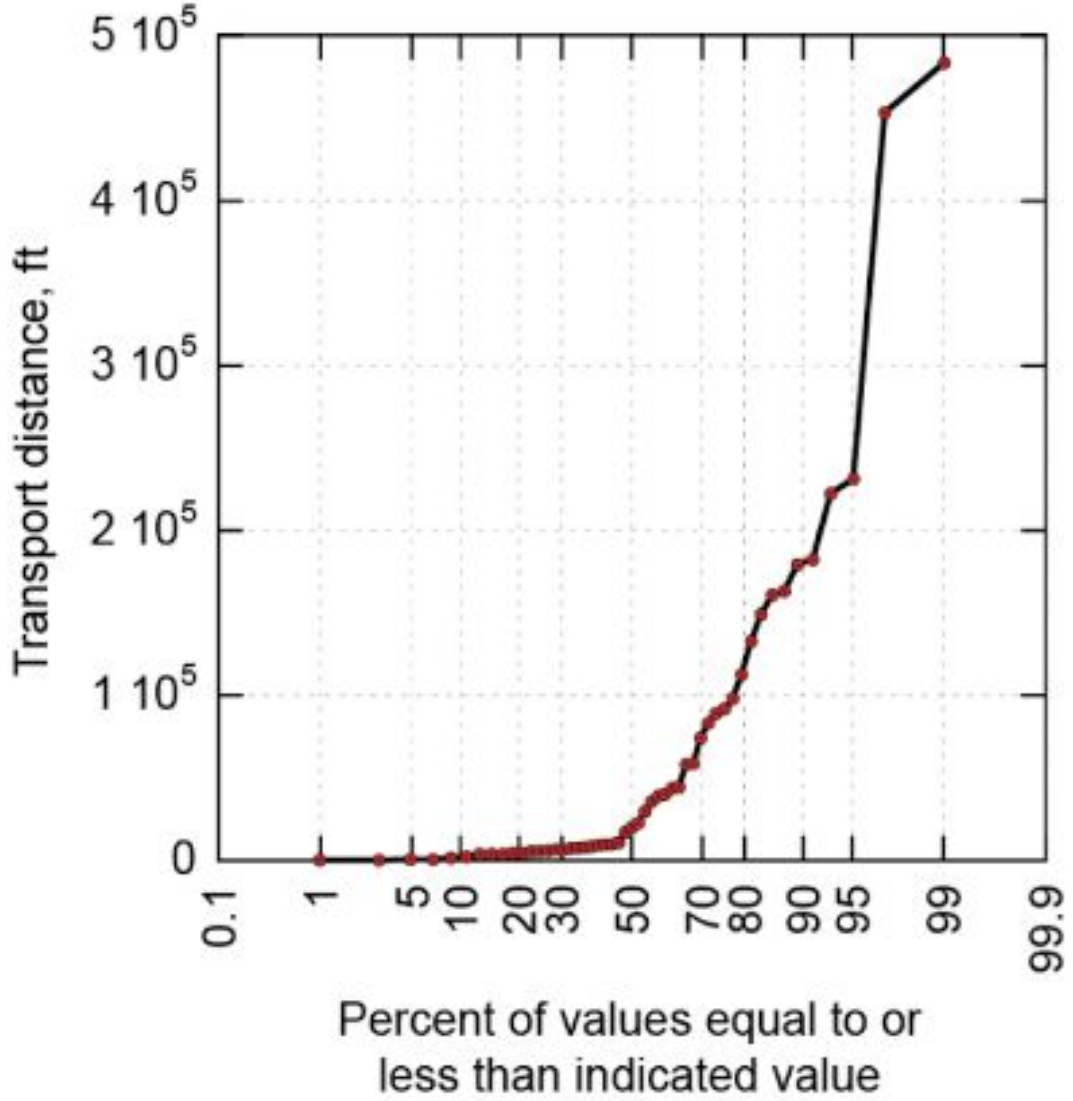


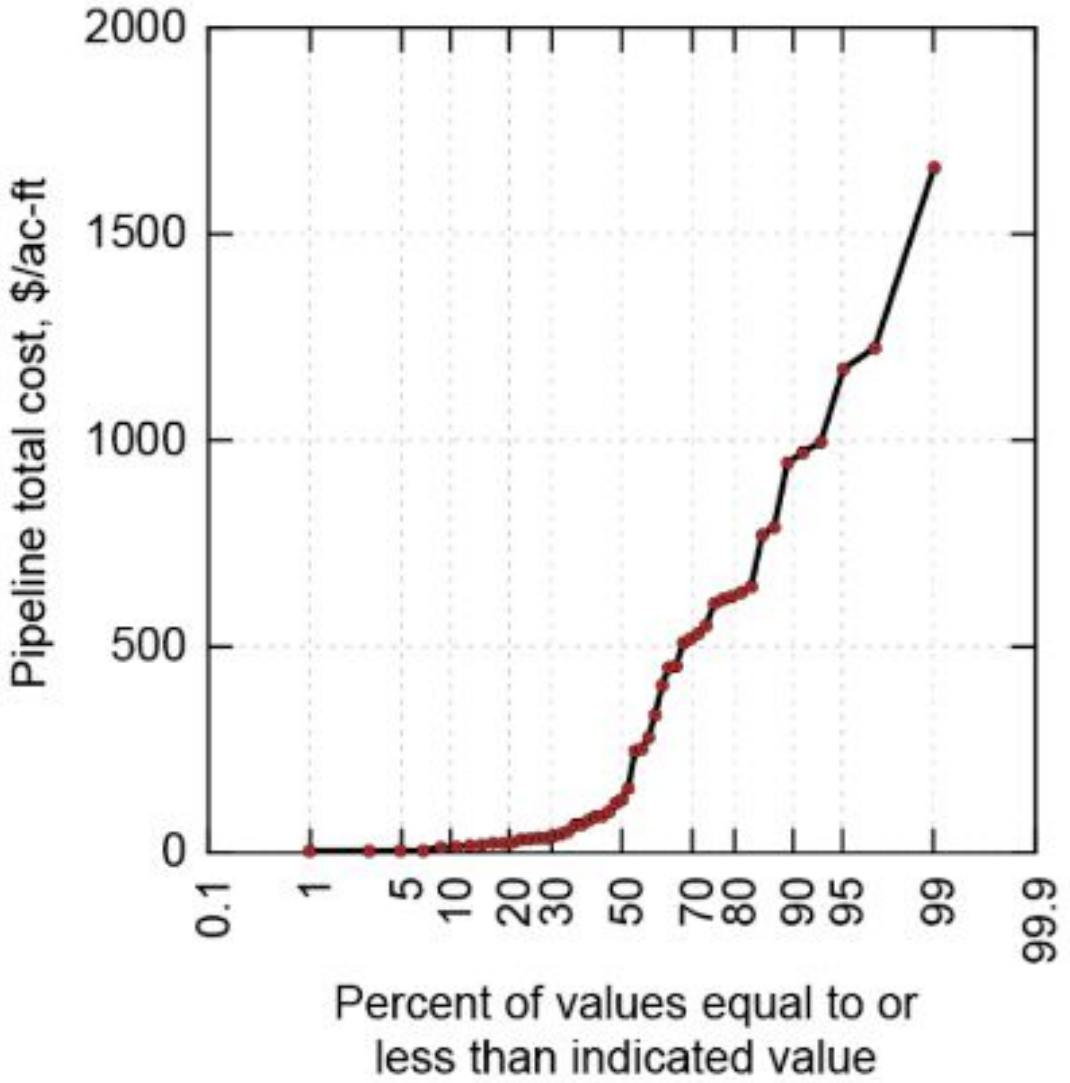

Input Cost Surface
Extract by Mask
LCPCurrentCS
Buffer around Selected WWTF
Select Layer By Location
ReUse Sites selected by location
Count
Output Layer Names
Input Sources as ReUse Sites
True
If Row Count Is
Distance Accumulation
False
Out source...
Out source...
Select Layer By Attribute
Count (2)
Updated Layer Or Table View
Output Layer Name...
Count (3)
Select Layer By Location (2)
Layer With Selection
Select
LCPCurrentRe... (2)
Output Back Direction
Output Distance Accumulation
Select (2)
LCPCurrentRe...
False (2)
If Row Count Is (2)
True (2)
Distance Accumulation (2)
Out source...
Out source...
Output Back Direction (2)
Output Distance Accumulation (2)
AFY
GID
Get AFY
Buffer
Optimal Path As Line
Optimal Path for Current WWTF
Alter Field
Paths With WWTFID
Optimal Path As Line (2)
Optimal Path for Current WWTF (2)
Alter Field (2)
Paths With WWTFID (2)
Path Source End Points
End Vertex To Points
NEAR Table 2nd Join
Path Source End Points (2)
End Vertex To Points (2)
NEAR Table 2nd Join (2)
Get GID
Selected WWTF
Input Destinations as WWTFs
Iterate Feature Selection
ObjectID
Generate Near Table: Find Source nearest PathEndPoint
NEAR Source By PathEndPoint
Join Field: Add WWTFID to Near Table
MODIFY FOR NEW REUSE CLASS Join Field: Add ReUse Site Fields to Near table
NEAR Table 1st Join
Paths with ReUse Fields
MODIFY FOR NEW REUSE CLASS Join Field: Add ReUse Site Fields to Paths
Generate Near Table: Find Source nearest PathEndPoint (2)
NEAR Source By PathEndPoint (2)
Join Field: Add WWTFID to Near Table (2)
MODIFY FOR NEW REUSE CLASS Join Field: Add ReUse Site Fields to Paths (2)
MODIFY FOR NEW REUSE CLASS Join Field: Add ReUse Site Fields to Near table (2)
NEAR Table 1st Join (2)
Paths with ReUse Fields (2)
Join Field: Add WWTF Fields to Paths
Paths with Destination fields
Calculate Field (2)
CostPath50pct... %GID% (2)
Calculate Field (4)
CostPath50pct... %GID% (4)
Join Field: Add WWTF Fields to Paths (2)
Paths with Destination fields (2)
Calculate Field
CostPath50pct... %GID%
Calculate Field (3)
CostPath50pct... %GID% (3)

LCP output for potential reuse sites

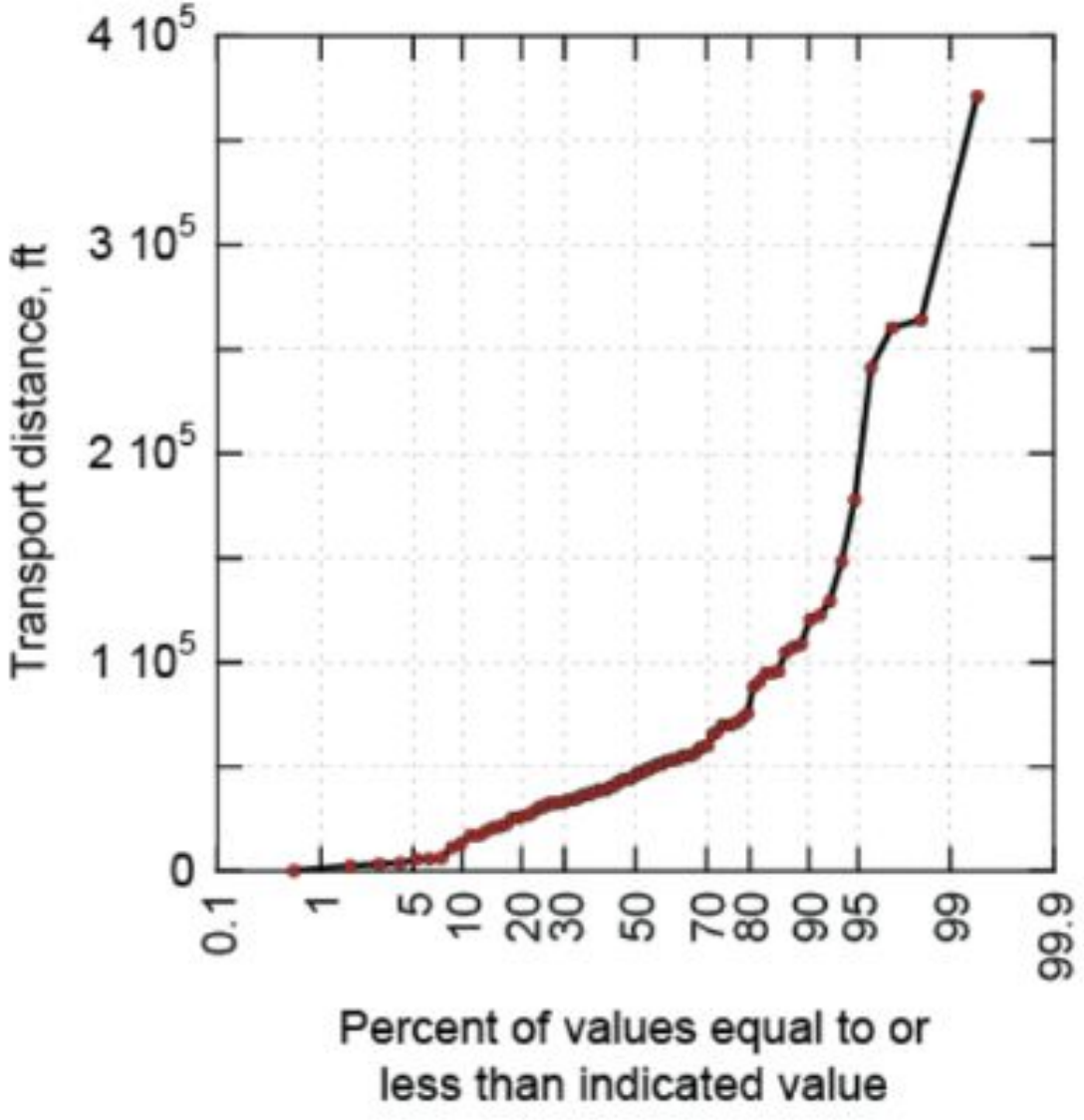


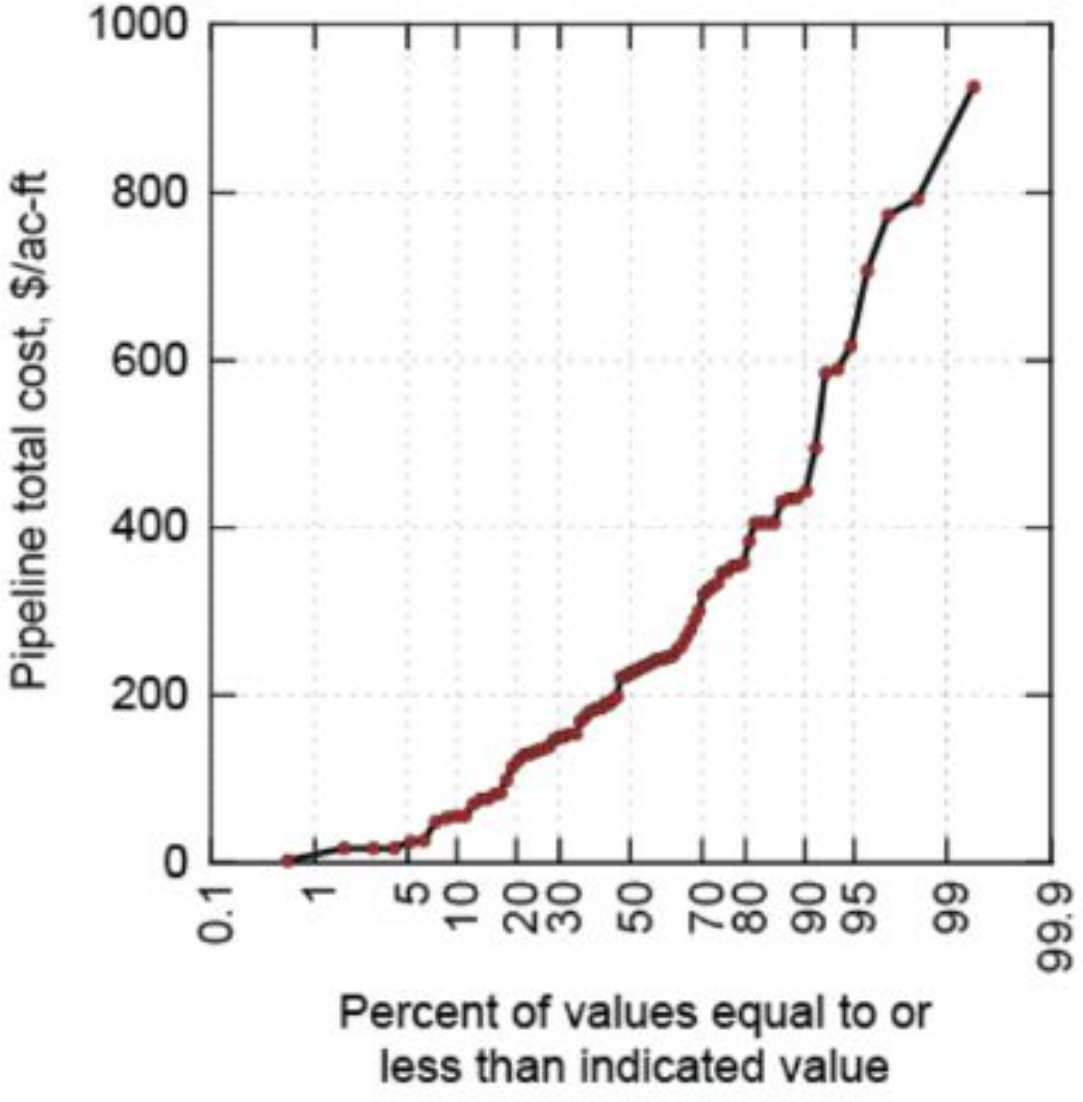
Conveyance to Agricultural Reuse Sites



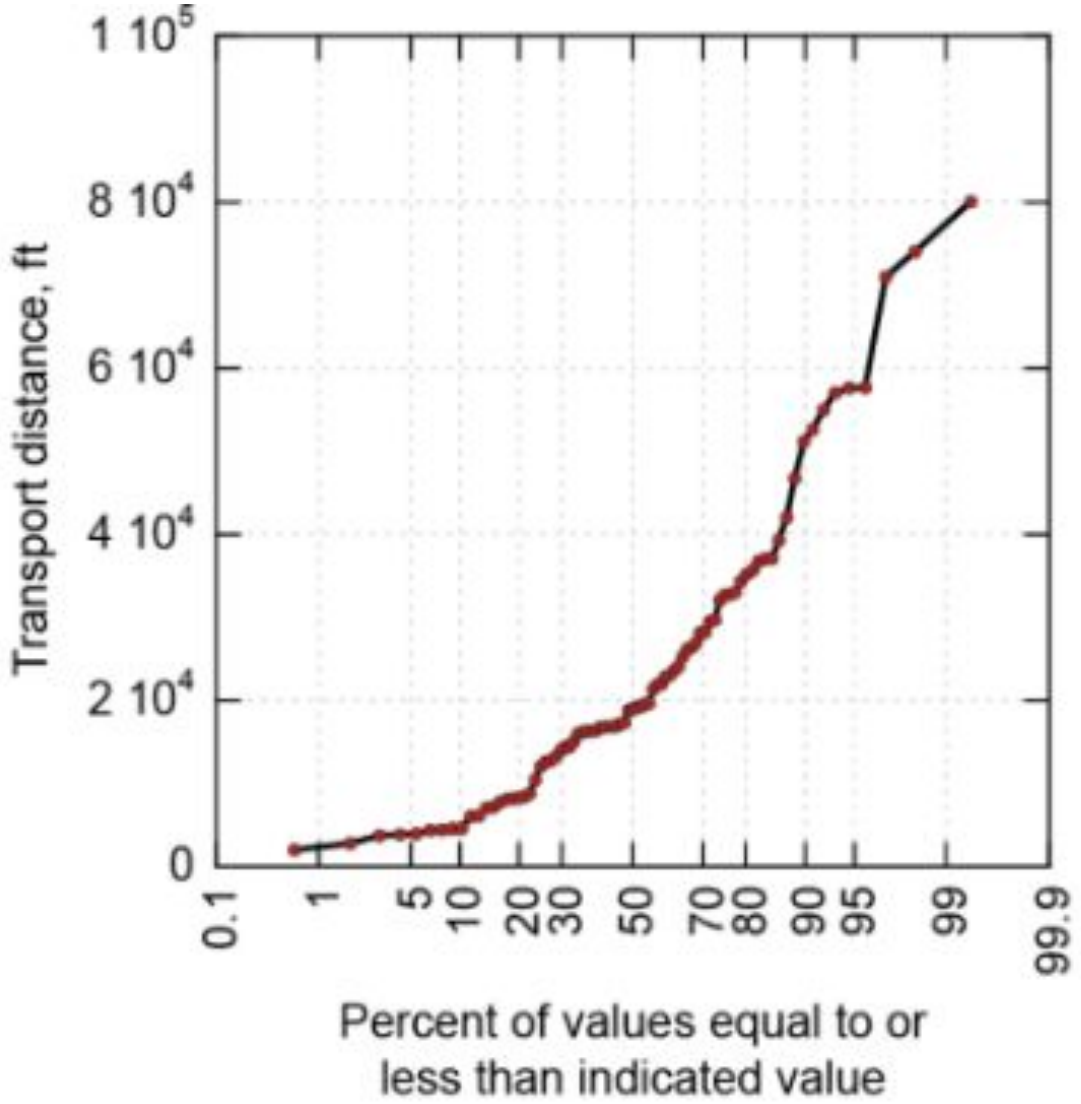


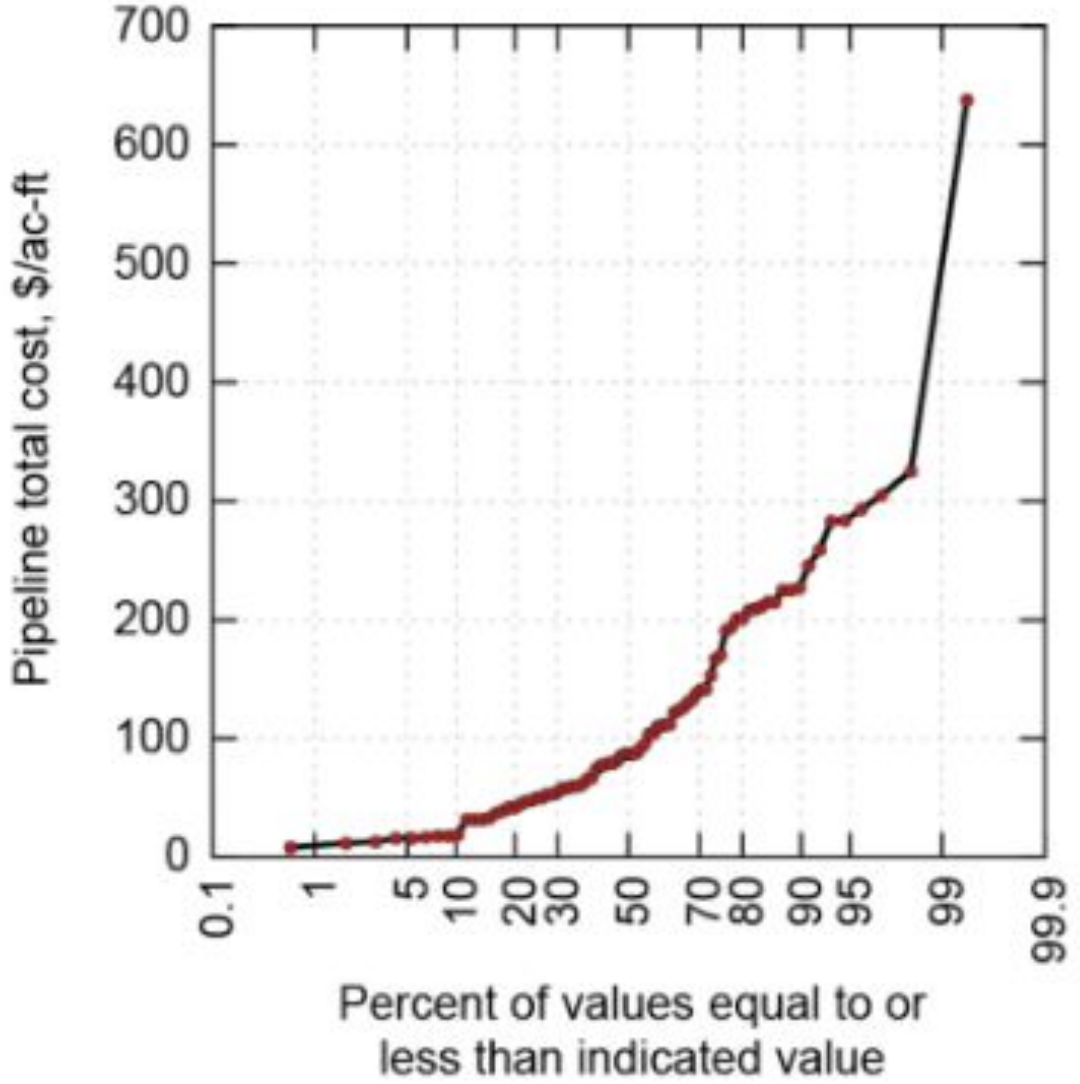
Conveyance to Reservoir Augmentation Sites





Conveyance to Raw Water Augmentation Sites





Recycled Water Production Cost Matrix

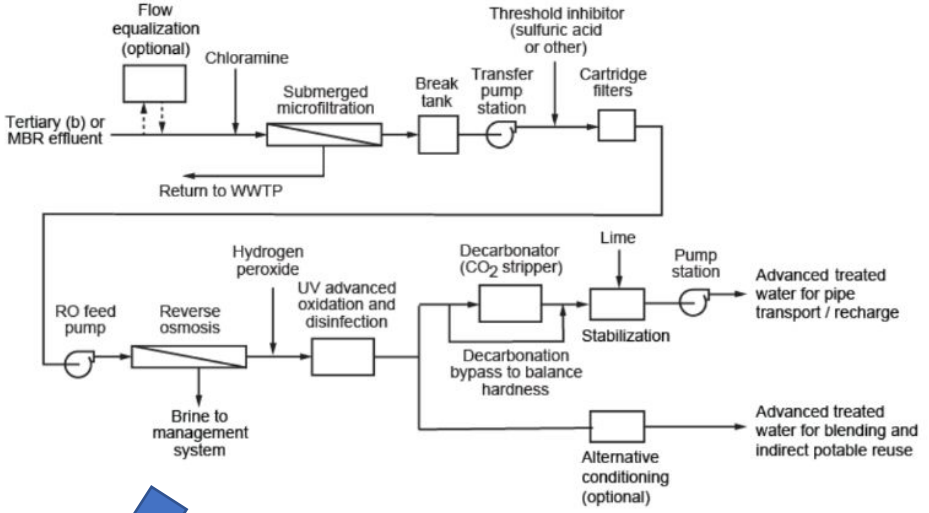
Establish a simplified matrix for a magnitude-of-order estimate

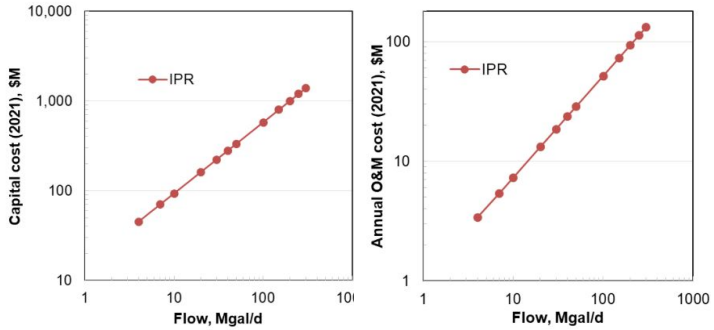
- Treatment levels associated with end use categories

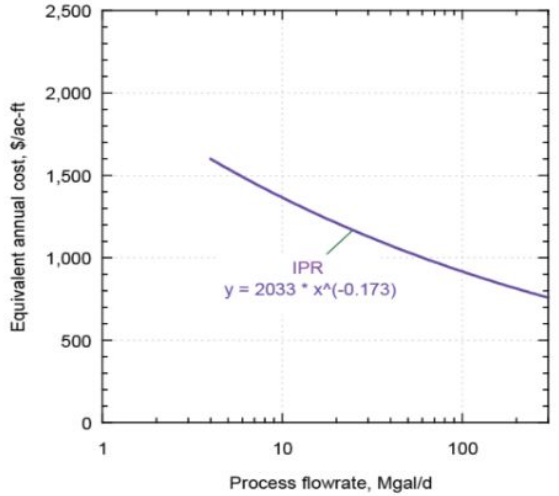
Existing Treatment Plant	A. Unrestricted Non-potable Reuse	B. Indirect Potable Reuse	C. Direct Potable Reuse
Secondary + Disinfection	Filtration + enhanced disinfection	Advanced treatment + environmental buffer	Enhanced advanced treatment + enhanced monitoring
Disinfected tertiary	No modification	Advanced treatment + environmental buffer	Enhanced advanced treatment + enhanced monitoring
Advanced treatment for IPR	No modification	No modification	Enhanced advanced treatment + enhanced monitoring
Advanced treatment for DPR	No modification	No modification	No modification

Developing Cost Curve for Treatment: Approach

- Identify unit processes to add to produce recycled water
- Use previously published cost curves, adjusting to year 2021
- Add up the costs to generate treatment cost for the system, in annualized $/AF
- Apply the cost model to CA treatment plants



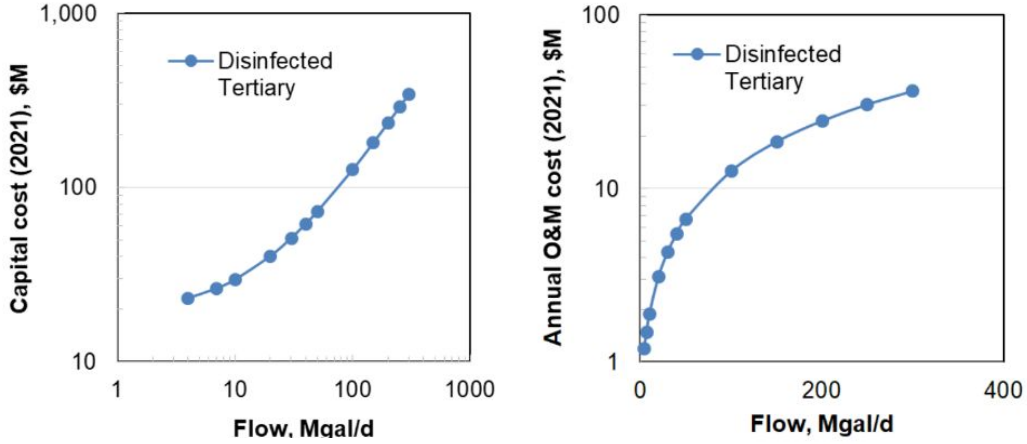


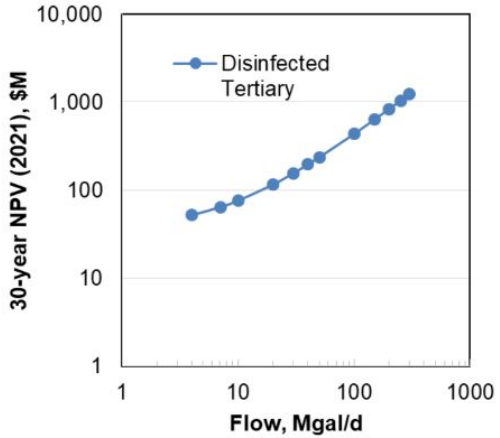


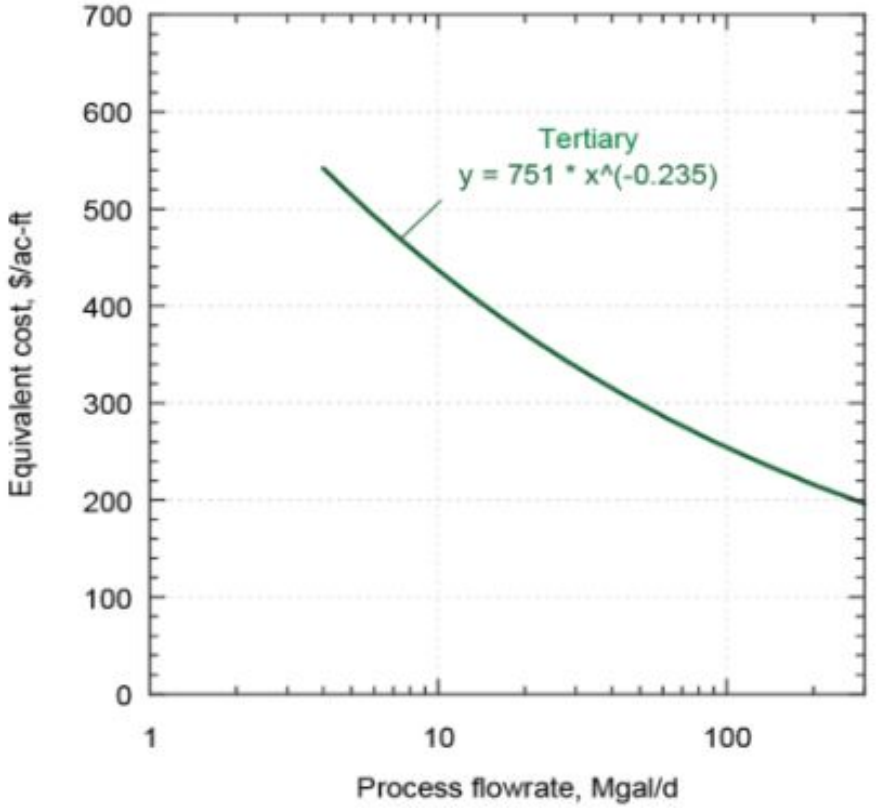
Note: No Site-Specific Restrictions were considered in cost curve development

Upgrade from Secondary to Disinfected Tertiary

- Construction Cost, $M = 0.793216 x (Flow rate, Mgal/d) + 13.838165
- O&M Cost, $M/y = 0.087594 x (Flow rate, Mgal/d) + 0.0517849







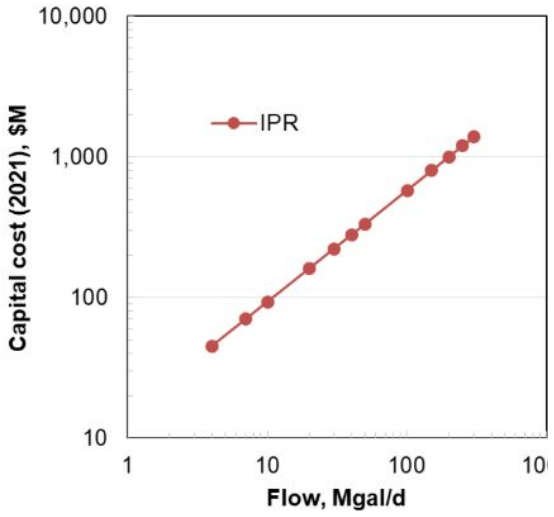
Upgrade from Secondary to Advanced Treatment IPR

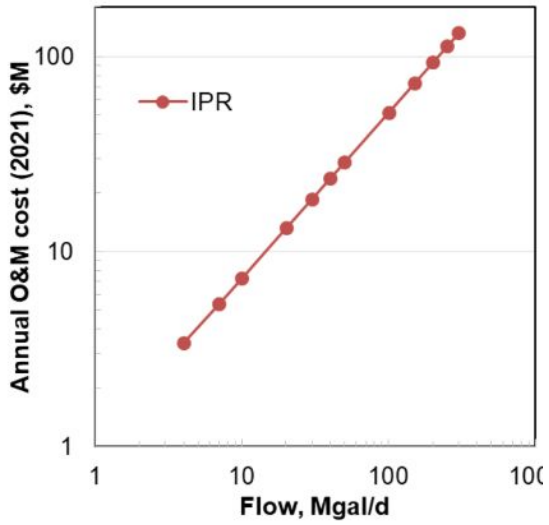
- MF/UF: Capital cost, $M/(Mgal/d) = 3.57 x (plant capacity, Mgal/d)$^{-0.22}$

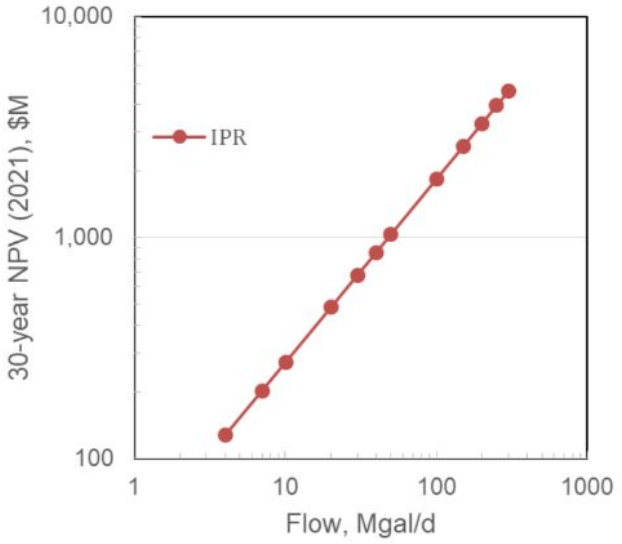
  O&M cost, $M/(Mgal/d)/y = 0.30 x (plant capacity, Mgal/d)$^{-0.22}$
- RO: Capital cost, $M/(Mgal/d) = 7.14 x (plant capacity, Mgal/d)$^{-0.22}$

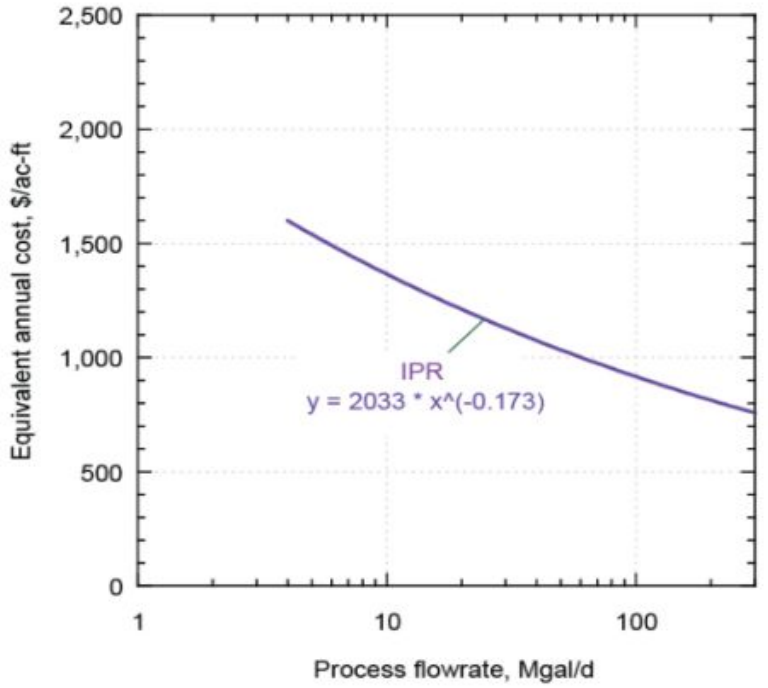
  O&M cost, $M/(Mgal/d)/y = 0.44 x (plant capacity, Mgal/d)$^{-0.13}$
- AOP: Capital cost, $M/(Mgal/d) = 0.474 x (plant capacity, Mgal/d)$^{-0.056}$

  O&M cost, $M/(Mgal/d)/y = 0.038 x (plant capacity, Mgal/d)$^{-0.052}$







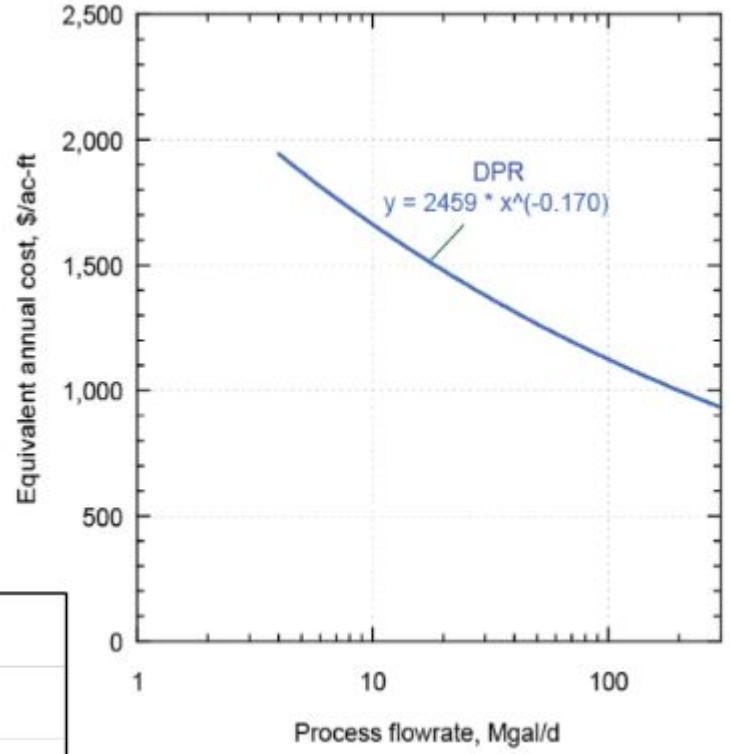


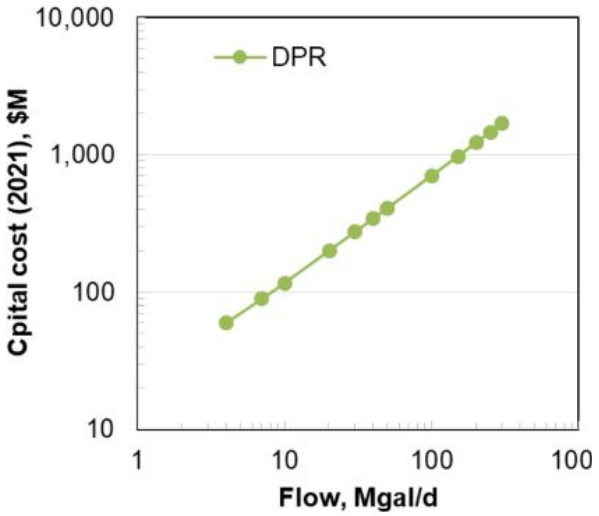
Upgrade from Secondary to Advanced Treatment DPR

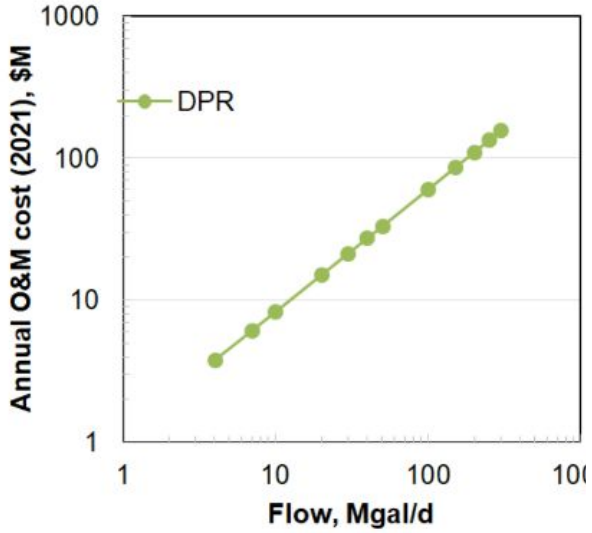
- All cost for IPR upgrade
- O3: Capital cost, $M/(Mgal/d)= 2.26 x (plant capacity, Mgal/d)$^{-0.54}$

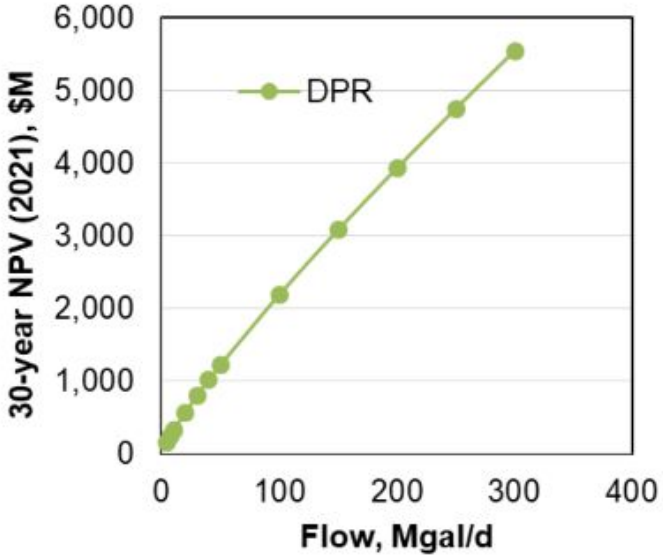
  O&M cost, $M/(Mgal/d)/year = 0.0068 x (plant capacity, Mgal/d)$^{-0.051}$
- BAC: Capital cost, $M/(Mgal/d)= 3.03 x (plant capacity, Mgal/d)$^{-0.48}$

  O&M cost, $M/(Mgal/d)/year = 0.085 x (plant capacity, Mgal/d)$^{-0.16}$









Model Output: Treatment Cost

Observation/Limitation:

- $/AF will be lower at larger plants
- Not including concentrate management (highly site-specific)
- Not including distribution system (counted with GIS-based analysis)

Annualized project cost per acre foot for various treatment process upgrades as a function of treatment capacity

Flow, Mgal/d	Cost, $/ac-ft		
	Secondary to disinfected	Secondary/tertiary to	Secondary/tertiary to DPR
4			
7			
10			
20			
30			
40			
50			
100			
150			
200	231	815	1006
250	229	786	973
300	228	763	946

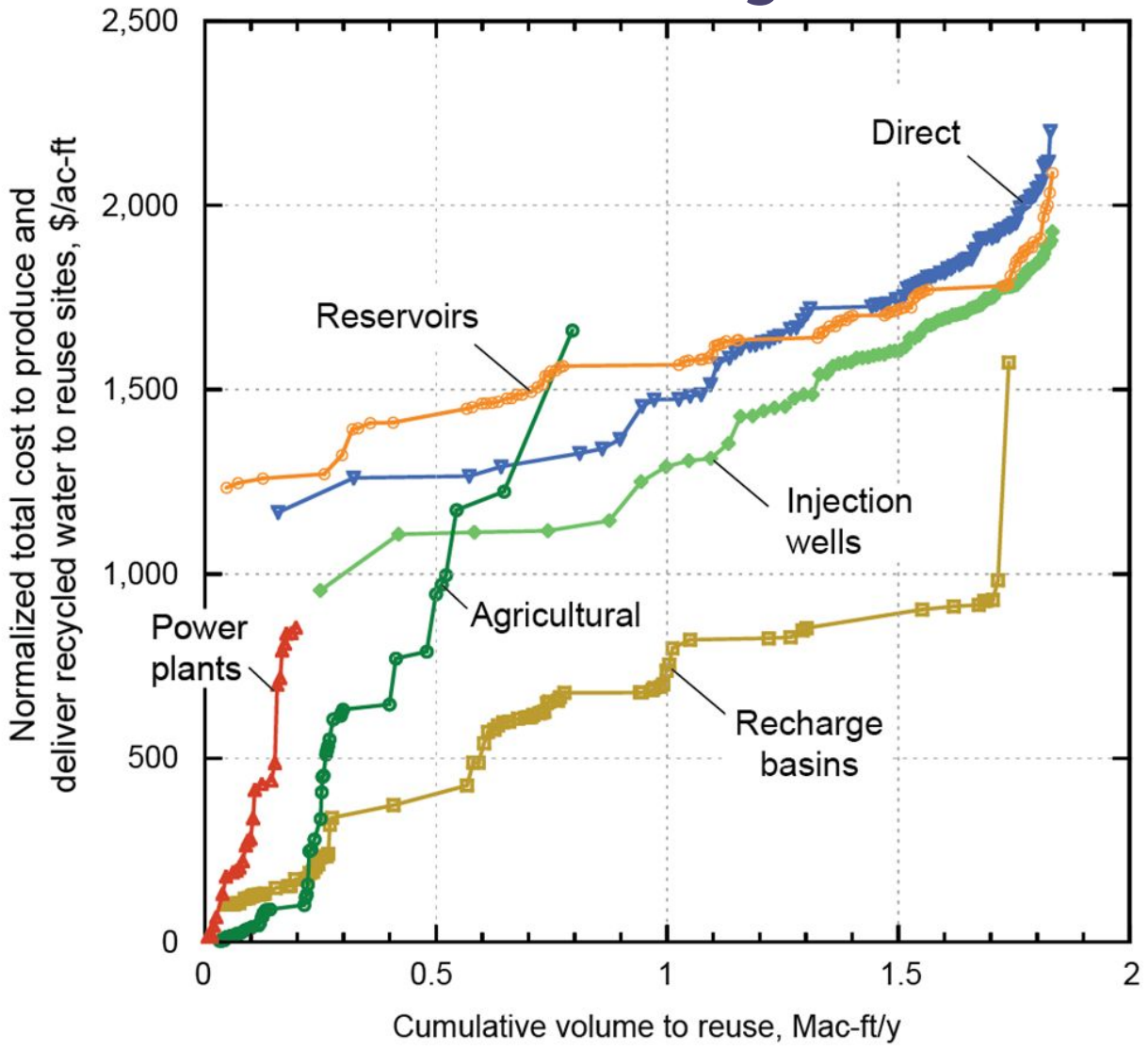
Estimated cost of concentrate management (Raucher and Tchobanoglous, 2014)

Option	Cost, $/af	
	Range	Typical
Deep well injection	60-80	70
Evaporation ponds	140-175	155
Land application	130-160	140
Zero liquid discharge	600-750	700
Line to ocean	100 - 150	115

Total Cost of Water Reuse Projects

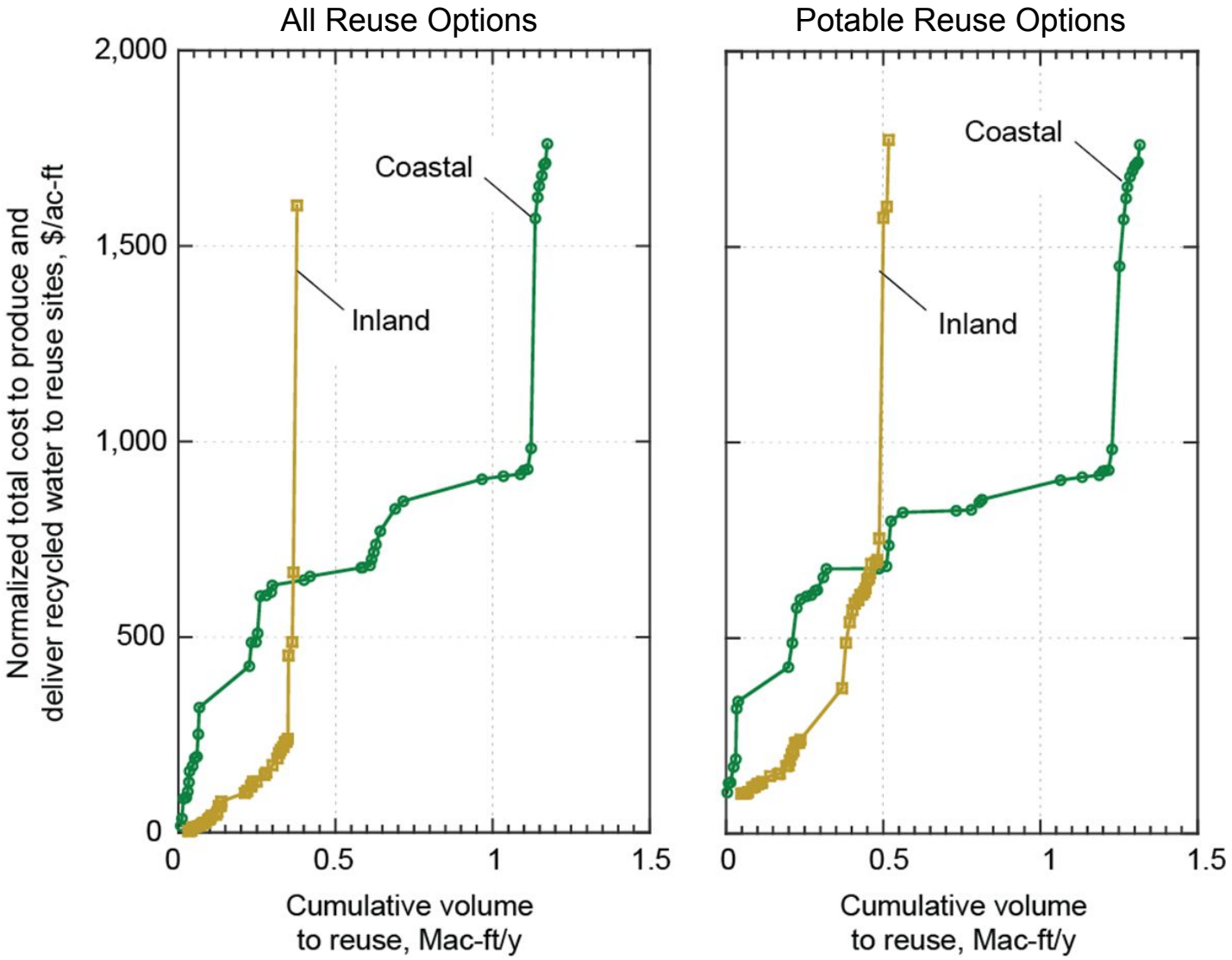
Cost of Treatment + Conveyance

- Smaller volume could be reused at lower cost by non-potable reuse
- IPR and DPR become more plausible options when targeting higher total reuse volume
- Concentrate management cost may affect total cost significantly



Coastal vs Inland

- Greater potential volume of water for reuse in coastal areas, but cost for water reuse in coastal sites is higher
  - Greater transport distances
  - Relatively greater flow volumes
  - Challenges with reaching potential reuse sites



Preliminary Findings

- Total water reuse rate ~50%, consisting of 22% permitted, and 28% unplanned reuse, with balance discharged to coastal waters.
- Unplanned water reuse needs to be acknowledged for environmental, habitat, and psychological benefits.
- Permitted non-potable reuse options are lower cost than DPR, but limited by lower volumetric demand.
- Water reuse is higher cost in coastal areas due to more limited non-potable reuse options.
- To achieve greater total reuse volume, IPR and DPR options may be preferred but at higher cost.

Study Limitations

- While there are many unknowns, site specific factors not considered in this study include:
  - Concentrate management
  - Facility siting
  - Purple-pipe urban distribution
- The study was not based on actual water reuse projects
- Therefore, the costs estimated in this study are representative of minimum costs for typical water reuse projects
- Discharge requirements for instream flows will need to be determined on a case-by-case basis where there is a habitat or environmental concern with effluent diversion
- Future changes in population and indoor water use are unknowns

Questions or contributions?

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