Process and Decision Support Tools for Evaluating Flow Management Targets to Support Aquatic Life and Recreational Beneficial Uses of the Los Angeles River

Los Angeles River Environmental Flows Project

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Southern California Coastal Water Research Project

SCCWRP Technical Report #1196

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Executive Summary

Increasing potable water scarcity associated with population growth, drought, climate change, regulatory/legal policy, and protection of endangered species has led to expanded efforts to conserve and reuse wastewater and other discharges, particularly in drier regions of California, such as the greater Los Angeles area. Water reuse is encouraged by the State's recycled water policy which calls for diversification of local water supplies to mitigate the effects of short-term drought and long-term climate change through the safe use of recycled water from wastewater sources. The state policy also requires that reuse programs ensure the protection of existing water rights and beneficial uses.

The State Water Resources Control Board (State Water Board), in coordination with City of Los Angeles, Los Angeles County Department of Public Works, and Los Angeles County Sanitation Districts, initiated *the Los Angeles River Environmental Flows Project* (Project) to provide a toolset to evaluate a series of flow reduction scenarios for the LA River. These tools will be used to inform development of flow management targets that sustain specific species, habitats, and beneficial uses. This toolkit may be used to develop policies on how to balance the need for local water supply and still support beneficial uses. In the near term, the outcomes of this analysis can inform decisions associated with proposed wastewater change petitions and stormwater management programs. In the longer term, the outcomes could inform decisions regarding the ability to support beneficial uses not currently supported, in combination with broader restoration planning efforts.

The intent of this analysis is to evaluate whether proposed management actions would influence flow conditions that could potentially support beneficial uses, recognizing that there are many other factors that currently affect the ability to support these uses (e.g., channelization, lack of vegetative cover, lack of suitable substrate, mechanical channel maintenance). This analysis is based on existing channel geometry and existing substrate, vegetation, and channel roughness with a focus on changes to flow. Channel modification or potential restoration are not evaluated in this report.

The study area for the project includes the mainstem of the LA River (from the DC Tillman water reclamation plant to the Pacific Ocean), plus two LA River tributaries (Rio Hondo and Compton Creeks; Figure ES-1). The goals of the project are to:

- Develop a process for evaluating flow management targets.
- Apply the process to provide example flow management targets in the LA River (ultimate goals or recommendations will result from negotiations between regulatory and discharger agencies).
- Produce tools and approaches to help evaluate how potential modified flow regimes in the LA River may affect the likelihood of supporting aquatic life and recreational beneficial uses.

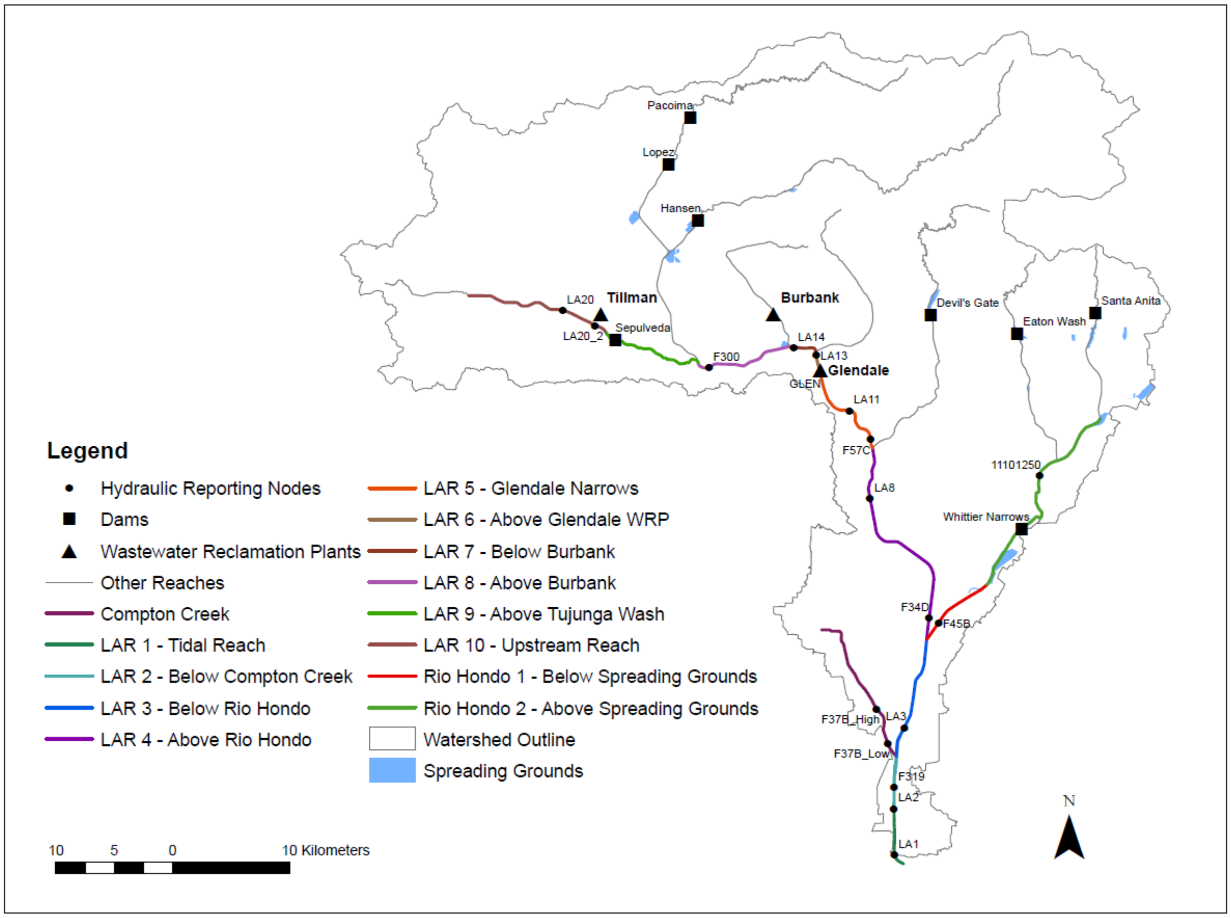

Figure ES-1. Project study area showing the major study reaches, locations of major dams and wastewater reclamation plants (WRPs). Hydraulic reporting nodes (circles) represent locations where the effect of various discharge scenarios on instream flows were evaluated.

Previous reports detail development, calibration, and validation of the hydrologic (rainfall-runoff), hydraulic (instream flow properties), temperature, water quality, and ecological response models used to support the environmental flows analysis (Stein et al. 2021). Existing aquatic life use (Stein et al. 2021) and non-aquatic life use (Stein and Sanchez 2019) have also been previously assessed and reported.

This report builds on the previous efforts to provide ranges of flows (or hydraulic conditions) associated with the support of existing, potential, or possible future beneficial uses. The tools provided in this report can be used to inform flow management decisions. To that end, we also provide a series of curves that relate potential changes in discharge from water reclamation plants or stormdrains to changes in flow in the LA River at various locations.

The central research questions that are addressed using the data, tools, and approach developed in this report include:

1. What are some of the flow ranges associated with the support of specific beneficial uses?
2. What are the potential effects of changes in WRP and stormdrain discharge relative to in-river flow range targets?

3. How can potential changes in discharge from WRPs and opportunities to increase local water supply be balanced while supporting beneficial uses?

Flow evaluations were conducted by coupling hydrologic/hydraulic and temperature modeling with a series of ecological response models (to relate flow conditions to beneficial uses). Hydrologic, hydraulic, temperature, and water quality models were created for the LA River Basin. Ecological response models were created for key species in six identified habitat types within the banks of the channel using data from the LA River and other similar river systems in the region. The model outputs were used to calculate flow metrics that relate probability of species occurrence to different management scenarios (Figure ES-2). Details on the modeling approach and development are provided in Stein et al. (2021).

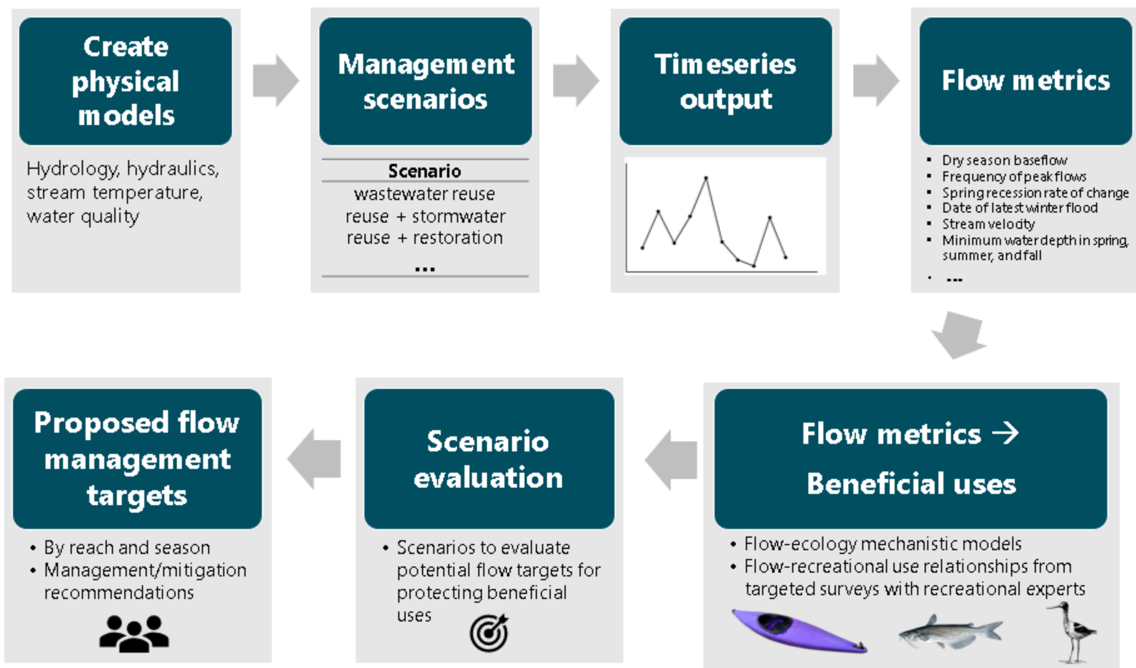

Figure ES-2. Process used to develop flow management targets.

Flow ranges associated with designated existing and potential uses and possible future beneficial uses were developed based on needs of the associated focal species (and life stages) and recreational uses for each relevant location along the river (Table ES-1). Relationships between focal species and beneficial uses were developed in consultation with the project's Technical Advisory Committee. Although cold freshwater habitat (COLD) is not currently a designated beneficial use in the mainstem of the LA River, one goal of this study is to evaluate whether proposed management actions could influence flow conditions that have the potential to support non-designated beneficial uses, such as COLD, in the future.

Table ES-1. Focal species associated with beneficial uses. Highlighted species do not currently occur in the mainstem of the LA River. Cold freshwater habitat (COLD) is currently not a designated beneficial use for any LA River reach covered by this study.

Focal Species	Beneficial Uses						
	WARM[1]	EST[2]	WILD[3]	RARE[4]	MIGR[5]	SPWN[6]	COLD[7]
Santa Ana Sucker				x		x	x
Unarmored threespine stickleback				x		x	x
Steelhead/Rainbow trout		x		x	x		x
Cladophora spp		x	x				
Typha			x				
Duckweed			x				
Black Willow			x	x			
African clawed frog	x						
Mosquitofish	x						

[1]WARM: Warm freshwater habitat
[2]EST: Estuarine habitat
[3]WILD: Wildlife habitat
[4]RARE: Rare, threatened, or endangered species
[5]MIGR: Migration of aquatic organisms
[6]SPWN: Spawning, reproduction, and/or early development
[7]COLD: Cold freshwater habitat

The draft flow ranges table organized by species for all modeled stream reaches can be viewed at: https://sccwrp.sharepoint.com/:x:/s/LARiverEflowsStudy/EVoSEKZ6EBdKh2sqcsahoZsBmA_jj1hmdh4WWxyddvgd3w?e=cALJ4U.

Additionally, the draft flow range table for species life stages, recreational uses, and current flows and beneficial uses by location can be viewed at: https://sccwrp.sharepoint.com/:x:/s/LARiverEflowsStudy/EXe7HmwHbgpFn5qhgFjAb7gBGQoCvaaB1ZYoyMg72B_18Q?e=Jsctsl.

Beneficial use definitions and water body designations can be found in the Los Angeles Regional Water Quality Control Board Basin Plan: https://www.waterboards.ca.gov/losangeles/water_issues/programs/basin_plan/basin_plan_documentation.html

Given the extensive set of flow ranges for multiple species and locations, a process was developed to synthesize flow ranges into more integrative flow management targets based on a series of decisions (ES-3).

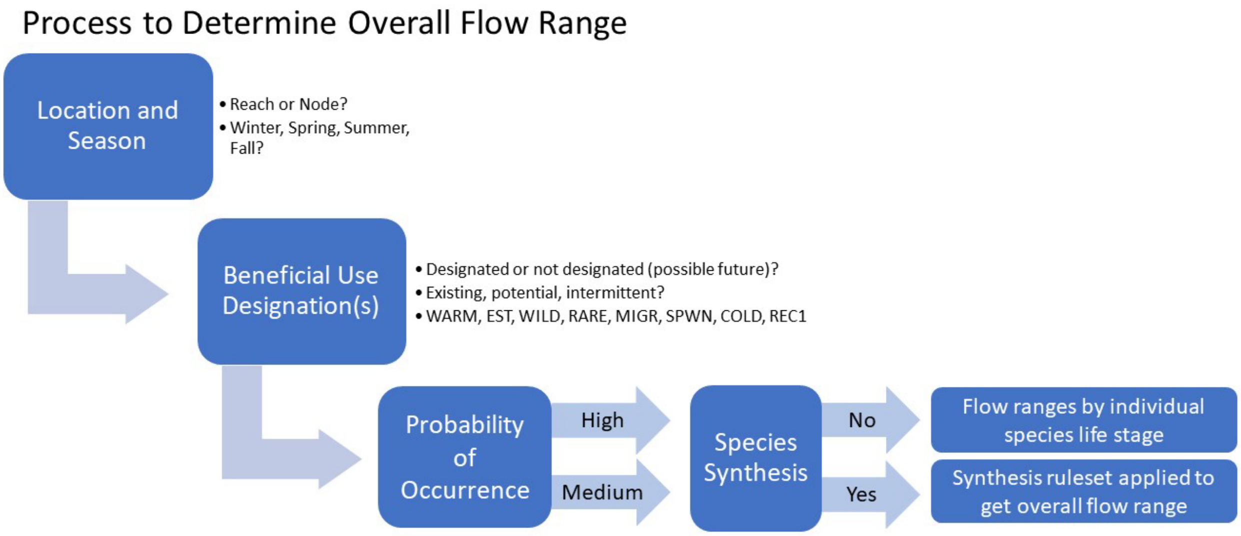

Figure ES-3. Proposed process for synthesizing and interpreting flow ranges to develop overall flow management target. Medium probability is defined as 50% of the maximum probability of occurrence; high probability is defined as 75% of the maximum probability of occurrence. Low probability was determined to not be a desirable management goal.

Potential changes to wastewater discharge, stormwater management, and dry weather stormdrain discharge were simulated using a "sensitivity curve" approach that relates discharge to instream flow conditions as measured by functional flow metrics. Instead of identifying a finite set of scenarios, sensitivity curves allow for consideration of a broad range of management options based on the amount of discharge to the river. Wastewater discharge scenarios were based on a Monte Carlo simulation[1] which evaluated the effects of 500 randomly selected scenarios ranging from 0-100% of current discharge, representing multiple combinations of potential WRP discharge reductions from each plant. Sensitivity curves for stormwater management and dry weather stormdrain scenarios were simulated using a series of discrete scenarios representing a range of Best Management Practices (BMPs) implementation. Ranges of BMP implementation scenarios were derived from the City of Los Angeles Stormwater Capture Master Plan (SCMP), and the watershed management program plans for the Upper and Lower LAR, LAR Upper Reach 2, and Rio Hondo/San Gabriel River.

A total of 66 flow-based sensitivity curves were developed for 13 reporting nodes along the river (see Figure ES-1), two seasonal functional flow components (wet-season baseflow and dry-season baseflow), and for multiple management scenarios (WRP discharge and dry weather stormdrain discharge scenarios). Sensitivity curves were only developed for the wet- and dry-season baseflow magnitude metrics because they were the most sensitive flow metrics to changes in WRP discharge and dry weather stormdrain reductions. A process was developed to use the flow ranges associated with different scenarios with the sensitivity curves to evaluate how much

[1] Monte Carlo simulation is a model used to predict the probability of different outcomes in the presence of random variables. Monte Carlo simulations are used to help explain the impact of uncertainty in prediction and forecasting models.

and under which scenarios flows can be reduced and still meet flow ranges that support a majority of beneficial uses for a given location along the river (Figure ES-4).

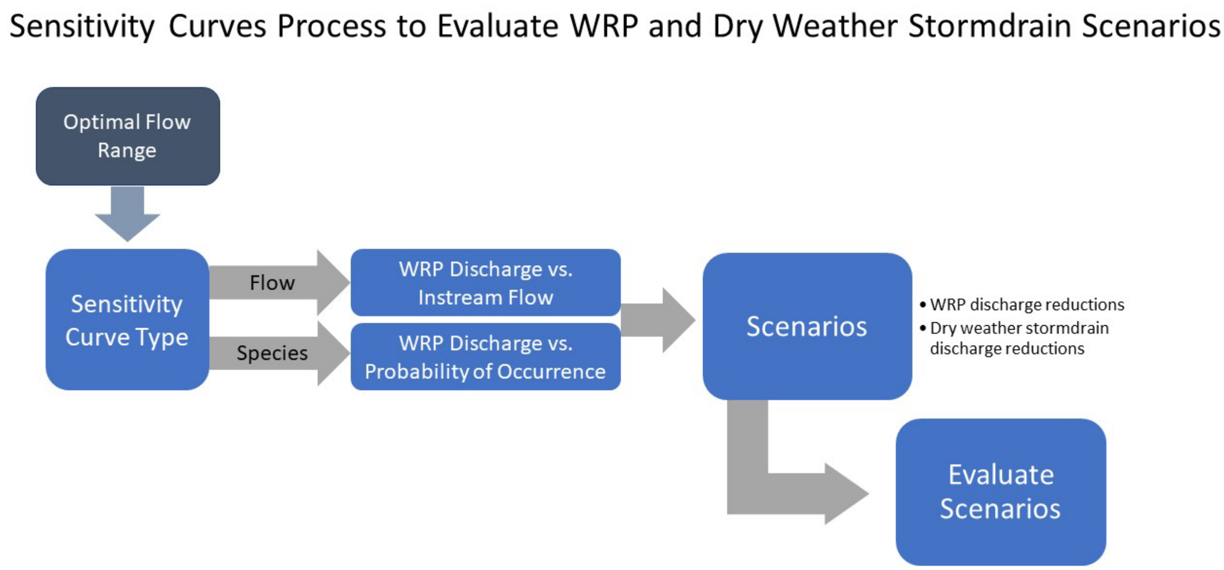

Figure ES-4. Proposed process to use optimal flow range of specific management targets with sensitivity curves to evaluate WRP and dry weather stormdrain scenarios. The optimal flow range can be derived from the process shown in Figure ES-3.

An example application of sensitivity curves at Glendale Narrows (GLEN), shows the optimal flow range for Willow and Typha plotted with the flow-based sensitivity curves representing changes in both WRP and dry weather stormdrain discharge (Figure ES-5).

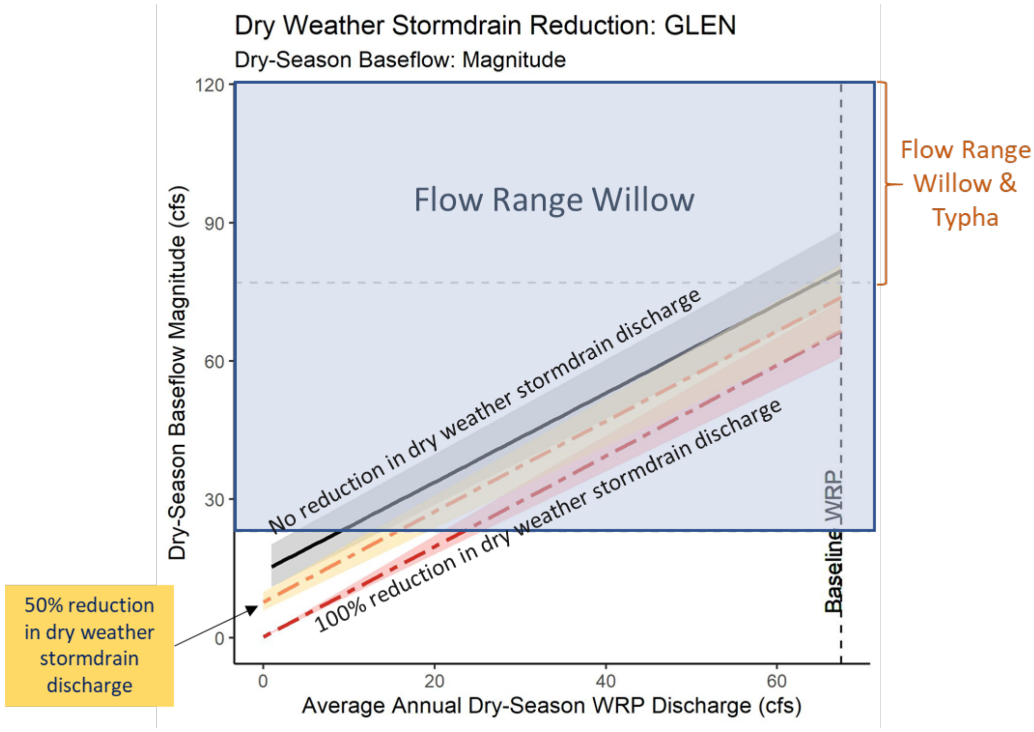

Figure ES-5. Flow-based sensitivity curves illustrating the combined effects of change in WRP discharge and 50% (yellow) and 100% reduction (red) in dry weather stormdrain discharge at GLEN reporting node. Solid and dashed lines represent median values; bounds of the gray and colored bands are the 10th and 90th percentile dry-season instream flows across the modeled period. Optimal flow range in this example is based on a 50% (medium) probability of occurrence of Willow and Typha.

Results at GLEN for all 45 scenarios that include WRP reduction, dry weather stormdrain discharge reductions, and stormwater BMPs are shown in Figure ES-6. The average annual flow volume across all simulated water years was used to compare the relative performance of all scenarios. Results at GLEN show that reductions in WRP also have a larger impact on average annual flow than reductions in dry weather stormdrain discharge. While a 100% reduction in WRP flows results in a decrease of 51,000 AF (2.223 billion cubic feet), a 100% reduction in dry weather stormdrain discharge flows only results in a decrease of 17,800 AF (0.776 billion cubic feet). However, the relative impacts of reductions in WRP and dry weather stormdrain discharge vary spatially throughout the LA River.

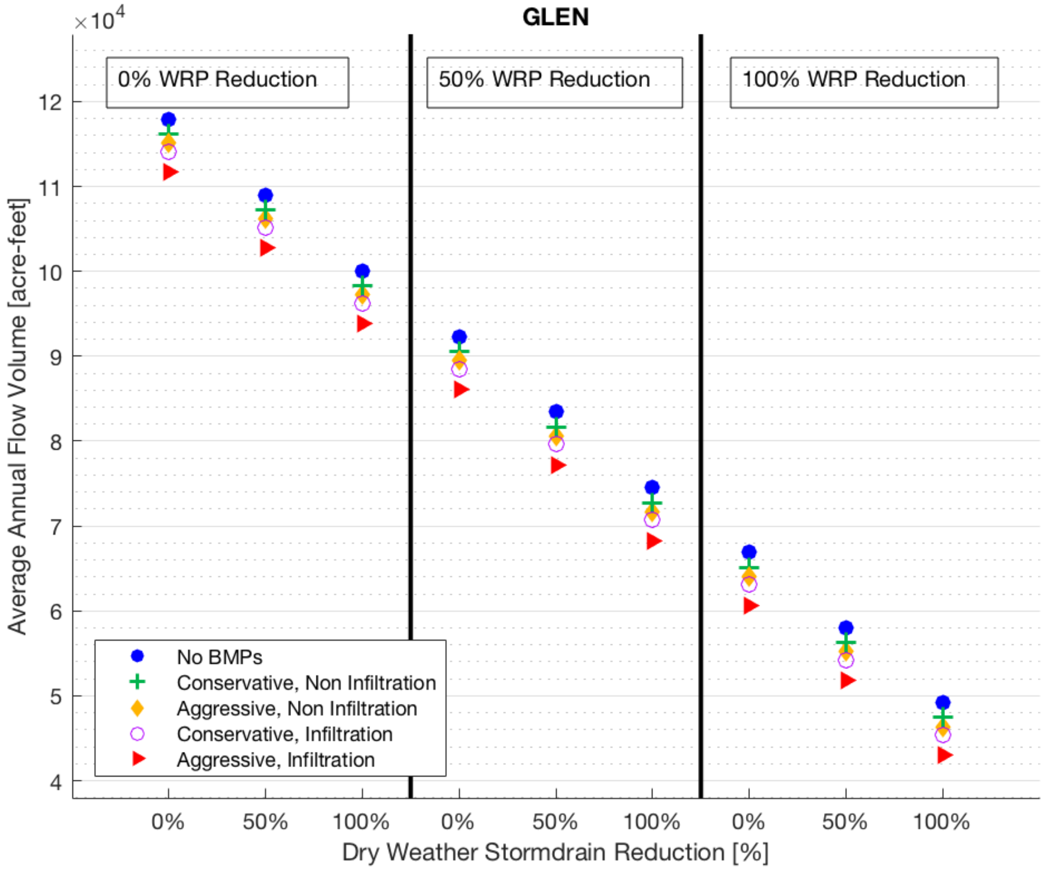

Figure ES-6. A visual comparison of average annual flow volumes (acre feet) for all 45 scenarios at GLEN.

The goal of this project was to develop a set of tools that can be used to evaluate potential effects of various changes in WRP discharge and stormdrain outflows on instream flows necessary to support beneficial uses. The goal was not to provide a definitive set of flow targets. If the State Water Board ultimately elects to adopt flow management targets, such targets will be a function of technical and policy decisions regarding beneficial use protection the LA River. The State Water Board may elect to set flow management targets that vary seasonally or be based on water year type (i.e., wet vs. dry). Once flow management targets are determined (for the existing channel morphology), various implementation scenarios and management actions can be evaluated for their ability to produce the desired in-river flows.

ACKNOWLEDGMENTS

This project was conducted through a collaboration with the State Water Resources Control Board, the Los Angeles Regional Water Quality Control Board, and local municipalities and stakeholders. Principal funding was provided by the City of Los Angeles, Department of Water and Power (DWP) and Los Angeles Sanitation and Environment (LASAN). Additional funding was provided by Los Angeles County Public Works (LADPW), Los Angeles County Flood Sanitation Districts (LACSD), the Watershed Conservation Authority (WCA), a joint powers authority between the Rivers and Mountains Conservancy (RMC) and the Los Angeles County Flood Control District, and the Mountains Recreation and Conservation Authority (MRCA), a joint power of the Santa Monica Mountains Conservancy, the Conejo Recreation and Park District and the Ranch Simi Recreation and Park District. We thank all members of the Stakeholder Working Group and the Technical Advisory Group who provided critical input, advice, and review over the course of this project. Additional project information is available at https://www.waterboards.ca.gov/water_issues/programs/larflows.html and https://www.sccwrp.org/about/research-areas/ecohydrology/los-angeles-river-flows-project/.

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INTRODUCTION AND BACKGROUND

Increasing potable water scarcity associated with population growth, drought, climate change, regulatory/legal policy, and protection of endangered species has led to expanded efforts to conserve and reuse wastewater and other discharges, particularly in drier regions of California, such as the greater Los Angeles area. Water reuse is encouraged by the State's recycled water policy which calls for diversification of local water supplies to mitigate the effects of short-term drought and long-term climate change through the safe use of recycled water from wastewater sources. The state policy also requires that reuse programs ensure the protection of existing water rights and beneficial uses.

Wastewater reclamation plants (WRPs) statewide have expanded their capabilities to treat wastewater using advanced methods that make the resulting recycled water a valuable reusable resource, including potable reuse. Recycled water has been used for irrigation and industrial applications, reducing the demand on potable water supplies. Municipalities can now use advanced treated recycled water from the WRPs to recharge groundwater basins (via injection and percolation through spreading basins) for subsequent extraction and potable reuse. Groundwater recharge serves as a management tool for basin users and managers and can allow cities to rely more on groundwater. Higher reliance on groundwater can help reduce the municipalities' demand from other over-allocated water systems, such as the Bay-Delta and the Colorado River.

As municipalities use more recycled water, the WRPs discharge less to waterways. Water conservation in the region has also reduced the volume of wastewater available for recycling. Reductions in discharges to waterways can have unintended consequences affecting fish, wildlife, or other public resources (such as access to recreation) that have come to rely on these flows. To balance these interests and minimize impacts, wastewater dischargers who want to reduce their discharges to watercourses to allow reuse and recycling of the water need approval from the State Water Board under Water Code Section 1211. The State Water Board requires that the wastewater discharger demonstrate that a change in flow will not unreasonably harm beneficial uses.

The Los Angeles (LA) River is at the forefront of the need to better understand and quantify potential impacts from changes in flow regimes. The cities of Burbank, Glendale, and Los Angeles have been beneficially reusing and recycling wastewater for decades and plan to recycle more wastewater to meet the needs of their residents and businesses. They have petitioned, or are planning to petition, the State Water Board to reduce their discharges of treated wastewater from their respective WRPs to the LA River for this purpose. The LA River also serves as an important stormwater management system. The potential reduction in wastewater discharge, along with requirements to better manage stormwater and dry weather stormdrain flows, would reduce or potentially eliminate flows in certain stretches of the LA River during the dry season. The State Water Board and Los Angeles Regional Water Quality Control Board are currently supporting the development of technical tools, including this study, to help serve as decision support tools to help municipalities balance the needs of water users and other beneficial uses.

The State Water Board, in coordination with the City of Los Angeles (through the Los Angeles Department of Water and Power and Los Angeles Sanitation and Environment), Los Angeles County Department of Public Works, and Los Angeles County Sanitation Districts, initiated *the*

Los Angeles River Environmental Flows Project (Project) to provide a toolset to evaluate a series of flow reduction scenarios for the LA River. The State Water Board may use these tools to inform the development of flow management targets that sustain specific species, habitats, and beneficial uses. The State Water Board may also use this toolkit to develop policies on how to balance the need for local water supply and groundwater recharge, and to ensure the reasonable protection of beneficial uses. In the near term, the outcomes of this analysis can inform decisions associated with proposed wastewater change petitions and stormwater management programs. In the longer term, the outcomes could inform decisions regarding the ability to support beneficial uses not currently supported, in combination with broader restoration planning efforts. The goals of the project are:

- Develop a process for evaluating flow management targets.
- Apply the process to provide example flow management targets in the LA River (ultimate recommendations will result from negotiations between regulatory and discharger agencies).
- Produce tools and approaches to help evaluate how potential modified flow regimes in the LA River may affect the likelihood of supporting aquatic life and recreational beneficial uses.

The project also serves as an important pilot application of the California Environmental Flows Framework (CEFF)[2] by demonstrating how CEFF can be applied in a highly urbanized watershed where flow alteration is primarily caused by wastewater and stormwater discharges. The outcomes of this project may also serve as an approach for assessing similar situations in other river systems.

All phases of the project, beginning with initial project scoping, have been coordinated through both a Stakeholder Working Group (SWG) and a Technical Advisory Committee (TAC). Additional project information including meeting notes and presentations are available on the project website at https://www.waterboards.ca.gov/water_issues/programs/larflows.html#background.

Intended Use and Key Assumptions

The intent of this analysis is to evaluate whether proposed management actions would influence flow conditions that could potentially support beneficial uses, recognizing that there are many other factors that currently affect the ability to support these uses (e.g., need for a local water supply, channelization, lack of vegetative cover, lack of suitable substrate, mechanical channel maintenance). The tools developed are not intended to produce specific recommendations or requirements, which would ultimately result from consideration of numerous factors, besides those modeled here, that affect the ability to support one or more beneficial uses. The intention is for dischargers to use the tools to evaluate the potential effects of various scenarios involving changes in discharge to the LA River. The tools can also be used to inform a larger process for development of flow criteria that balances water supply, flood control, specific species, habitats,

[2] The California Environmental Flows Framework provides a set of reference-based ecological flow criteria for each stream reach in the state and provides guidance for developing refined flow criteria when appropriate.

and beneficial uses. This toolkit may be used to develop policies on how to balance the need for local water supply and groundwater recharge, and still support beneficial uses.

Additional assumptions and considerations include:

- The primary intended use is to apply the tools to evaluate potential effects of changes in discharge on existing beneficial uses. The tools can be used to evaluate potential restoration of future uses, but that is not the primary objective of this study.
- The analysis assumes that the physical structure of the channel remains unchanged. In the concrete reaches, minimal changes to channel morphology will occur in the future unless physical channel modification or restoration actions are performed. In the soft bottom reaches, there will be changes to the morphology and those morphologic changes will be influenced by the flow regime and will in turn impact hydraulics. The potential effects on channel modifications on flow targets could be explored during a later phase of the study.
- The term "optimal flow" recommendation is derived based on the overlap of flow needs for different beneficial uses. The term does NOT constitute a regulatory recommendation regarding optimization.
- Confidence and resolution of flow ranges associated with species or habitat occurrences typically should be interpreted in light of the inherent uncertainty in the hydrologic, hydraulic, and ecological models limited by model resolution.

Study Area

The study area for the project includes the mainstem of the LA River (from the Donald C. Tillman WRP to the Pacific Ocean), plus two LA River tributaries, Rio Hondo and Compton Creek (Figure 1). The mainstem of the LA River is defined as the area between the concrete banks. Tributaries of the LA River above the WRPs are included in the project's hydrologic model to characterize the watershed more accurately. The models produced could be used in the upper reaches to support future studies but are not currently part of the flow-ecology analysis.

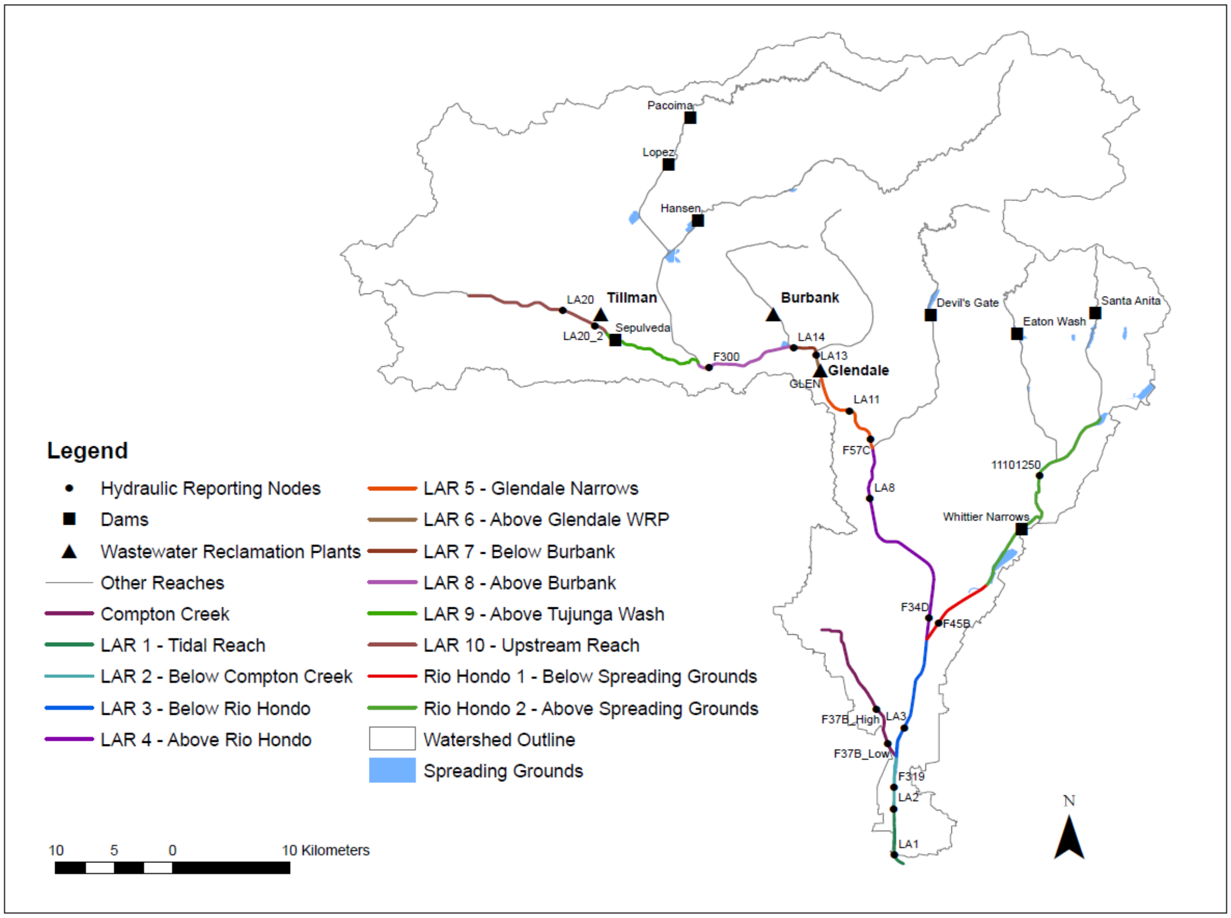

Figure 1. Project study area showing the major study reaches, locations of major dams and wastewater reclamation plants (WRPs). Hydraulic reporting nodes (circles) represent locations where the effect of various discharge scenarios on instream flows were evaluated.

Organization of this Report

The project consists of seven activities, each with a series of tasks:

- Activity 1 - Stakeholder coordination
- Activity 2 - Non-aquatic Life Use Assessment
- Activity 3 - Aquatic Life Beneficial Use Assessment
- Activity 4 - Apply Environmental Flows and Evaluate Scenarios
- Activity 5 - Monitoring and Adaptive Management Plan
- Activity 6 - Summary of results/reporting
- Activity 7 - Water Quality Assessment

Previous reports are available online and organized by activity (Table 1). These reports detail development, calibration, and validation of the hydrologic, hydraulic, temperature, water quality, and ecological response models used to support the environmental flows analysis (Stein et al. 2021). Existing aquatic life use (Stein et al. 2021) and non-aquatic life use (Stein and Sanchez 2019) have also been previously assessed and reported.

Table 1. Project reports organized by activity and available for download at https://www.sccwrp.org/about/research-areas/ecohydrology/los-angeles-river-flows-project/.

Activity	Report	Year	Summary
Activity 1	Stakeholder Working Group (SWG) and Technical Advisory Committee (TAC) Meeting Materials	2019-2021	Supporting documents from all SWG and TAC meetings
Activity 2	Review of Recreational Uses and Associated Flow Needs Along the Main-stem of Los Angeles River	2019	Evaluation of recreational uses and associated flow needs along the mainstem of the LA River
Activity 3	Assessment of Aquatic Life Use Needs for the Los Angeles River	2021	Development, calibration, and validation of the hydrologic, hydraulic, temperature, and ecological response models used to support the environmental flows analysis
Activity 4	Process and Decision Support Tools for Establishing Flow Recommendations to Support Aquatic Life and Recreational Beneficial Uses of the Los Angeles River (this report)	2021	Process and decision support tools to determine flow management targets to support beneficial uses and evaluate WRP, stormwater, and stormdrain reduction scenarios
Activity 5	Proposed Monitoring and Adaptive Management Plan	In progress	Recommended monitoring and adaptive management plan to evaluate effect of changes in flow on beneficial uses
Activity 6	Technical Study Progress Reports	2019-2021	Quarterly progress reports for the technical study
Activity 7	Water Quality Assessment and Restoration Opportunities in the LA River Watershed	In progress	Evaluation of WRP and flow management scenarios on water quality and restoration opportunities to offset potential changes in flow

This report builds on the previous efforts to provide ranges of flows (or hydraulic conditions) likely to support designated existing and potential, and possible future beneficial uses (Activity 3). The ranges provided in this report can be used to inform flow management decisions. To that end, we also provide a series of curves that relate discharge from WRPs or stormdrains to flow in the river at various locations (Activity 4).

The central research questions that are addressed using the data, tools, and approach developed in this report include:

1. What are some of the flow ranges associated with the support of specific beneficial uses?
2. What are the potential effects of changes in WRP and stormdrain discharge relative to in-river flow range targets?
3. How can potential changes in discharge from WRPs and opportunities to increase local water supply be balanced while supporting beneficial uses?

APPROACH

Flow ranges associated with designated existing and potential uses and possible future beneficial uses were developed based on needs of focal species (and life stages) and recreational uses for each relevant location along the river. Flow evaluations were conducted by coupling hydrologic, hydraulic and temperature modeling with a series of ecological response models. Hydrologic, hydraulic, temperature, and water quality models were created for the LA River Basin. Ecological response models were created for key species in six identified habitat types[3] within the banks of the channel using data from the LA River and other similar river systems in the region. The model outputs were used to calculate flow metrics that relate probability of species occurrence to different management scenarios (Figure 2). Details on the modeling approach and development are provided in Stein et al. (2021).

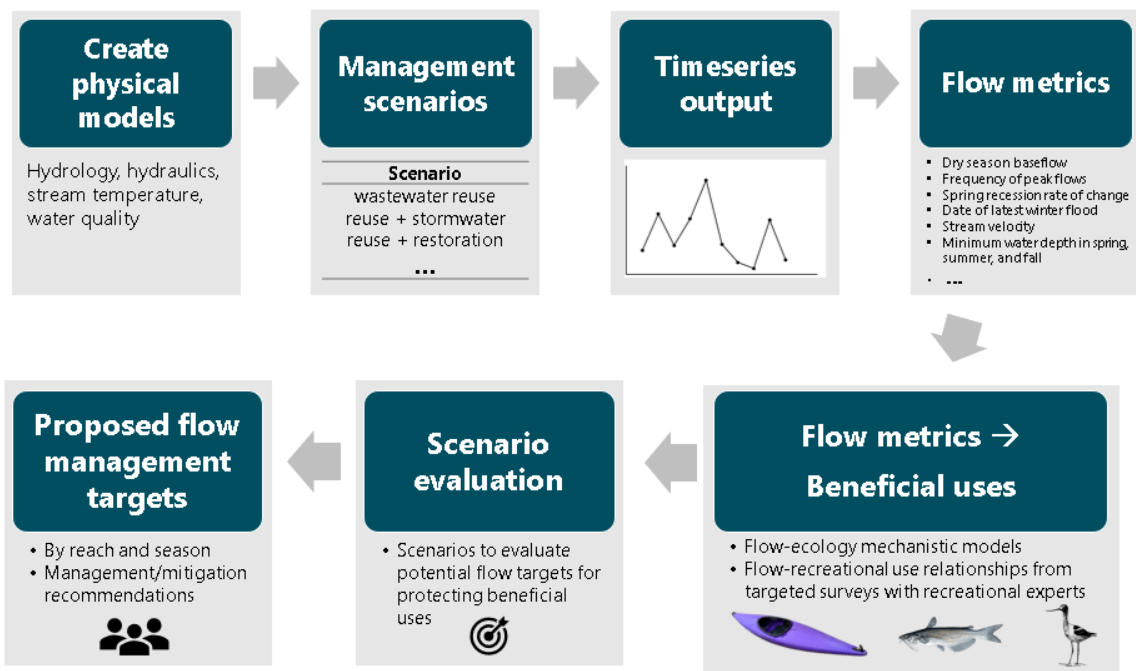

Figure 2. Process used to develop flow management targets.

Reporting Nodes

Reporting nodes were selected to represent specific reaches of the river where the effect of various discharge scenarios on instream flows were evaluated (Figure 1). The reporting nodes were selected to represent a range of different hydraulic and hydrologic conditions, prioritizing cross sections in soft-bottom reaches such as within Glendale Narrows. Hydrologic outputs were paired with hydraulic outputs for the evaluation at these nodes. The selection of the reporting nodes was reviewed and coordinated with both the project SWG and TAC.

[3] Key focal species and habitats are listed in Table ES-1 and Table 3 and described in Stein et al. 2021.

Hydrologic, Hydraulic, and Temperature Modeling

The hydrologic, hydraulic, and temperature models used in this study are described in detail in Stein et al. 2021. Briefly, we estimated flow conditions in the study area using a coupled hydrologic-hydraulic model created in EPA's Storm Water Management Model (SWMM) and the Hydrology Engineering Center's River Analysis System (HEC-RAS). Current hydrologic conditions, referred to as baseline conditions, were defined as the flows and operations that occurred during water year (WY) 2011 to 2017. This period was chosen because: (1) high-resolution (hourly) data was available for wastewater discharge, in-stream flows, dam operations, and spreading grounds, and (2) wastewater discharge during this period remained relatively constant. The baseline period is considered hydrologically dry based on precipitation (Figure 3), which occurs in the LAR basin seasonally, mostly between October and April. However, changes to WRP discharge will primarily impact the river in the dry summer months (Figure 4), when flows in the river are mainly comprised of WRP discharge and dry weather runoff, which includes irrigation return flows and other urban runoff from activities such as car-washing. Previous work has found winter and summer flows in the Los Angeles River are not strongly correlated, unlike unaltered natural hydrologic systems where groundwater storage may provide replenishment of surface waters in the drier months. Instead, summer flows are more closely related to changes in WRP discharge, irrigation, and conservation practices (Manago and Hogue 2017).

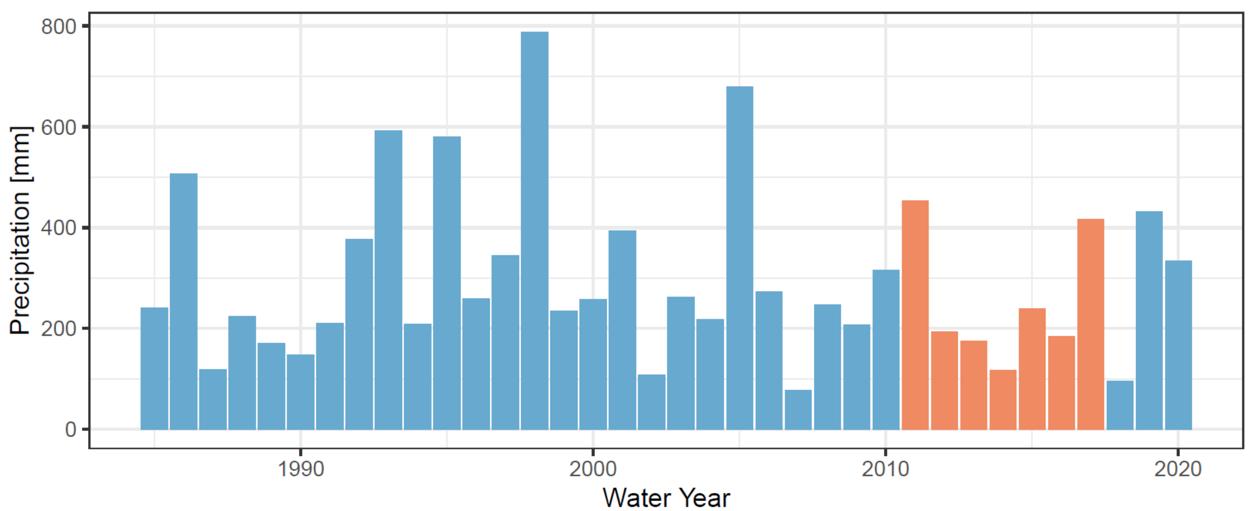

Figure 3. Water year precipitation at Los Angeles International Airport from 1985 (when D.C. Tillman started operation) to 2020. Data from the National Climatic Data Center (NCDC) Climate Data Online (Station USW00023174). Orange bars show the simulation period (WY 2011 through 2017), also referred to as the baseline condition.

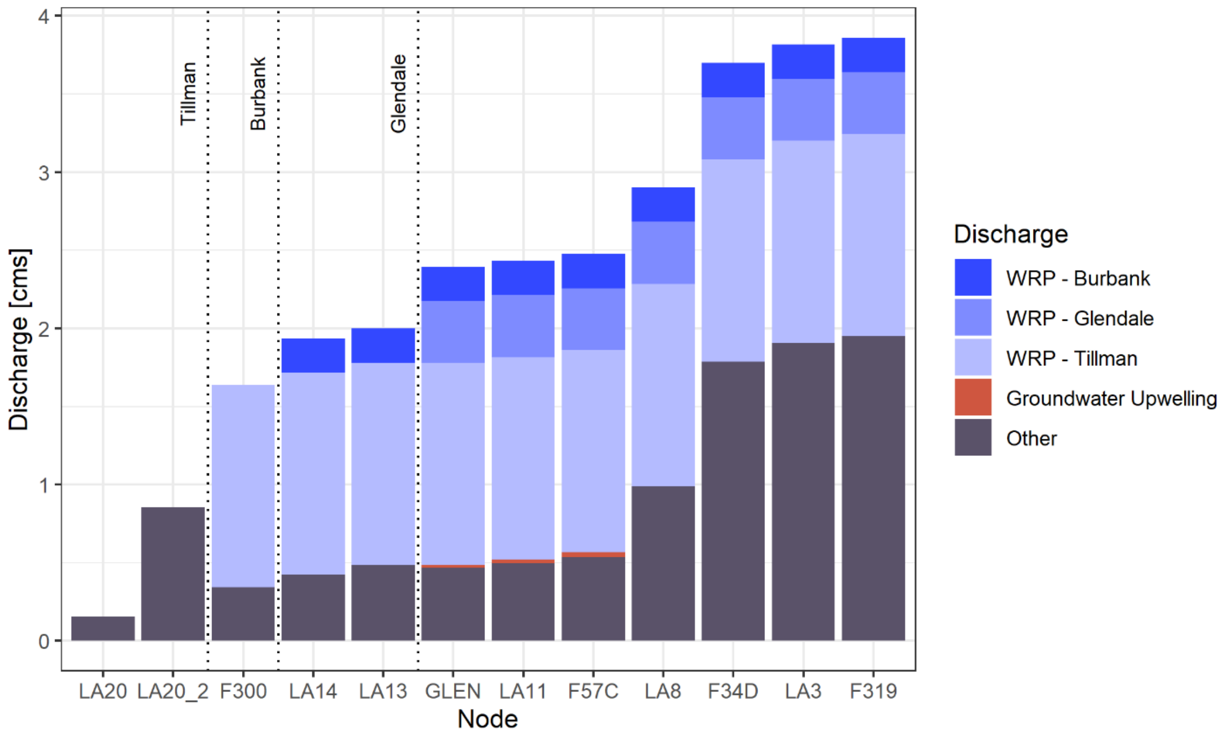

Figure 4. Contributions to discharge during the summer months (June, July, and August) across all reporting nodes in the Los Angeles River for the baseline conditions (WY 2011 through 2017). Groundwater upwelling occurs in the Glendale Narrows, contributing to overall flow/discharge. "Other" flows include dry weather stormdrain discharge, dam discharge, and industrial discharge. Vertical dashed lines show the locations of the water reclamation plants.

The hydrologic model simulates discharge on the mainstem of the LA River, Compton Creek, and Rio Hondo at an hourly time step from WY 2011 through 2017. The model was validated from WY 2011 through 2013 and calibrated from WY 2014 through 2017 at seven locations throughout the watershed (4 on the mainstem, 3 on tributaries) by comparing daily discharge values. The hydraulic model was created for a subset of this spatial domain—specifically the mainstem of the LA River from Sepulveda Basin to the outlet to the harbor, and for Compton Creek and Rio Hondo (Figure 5).

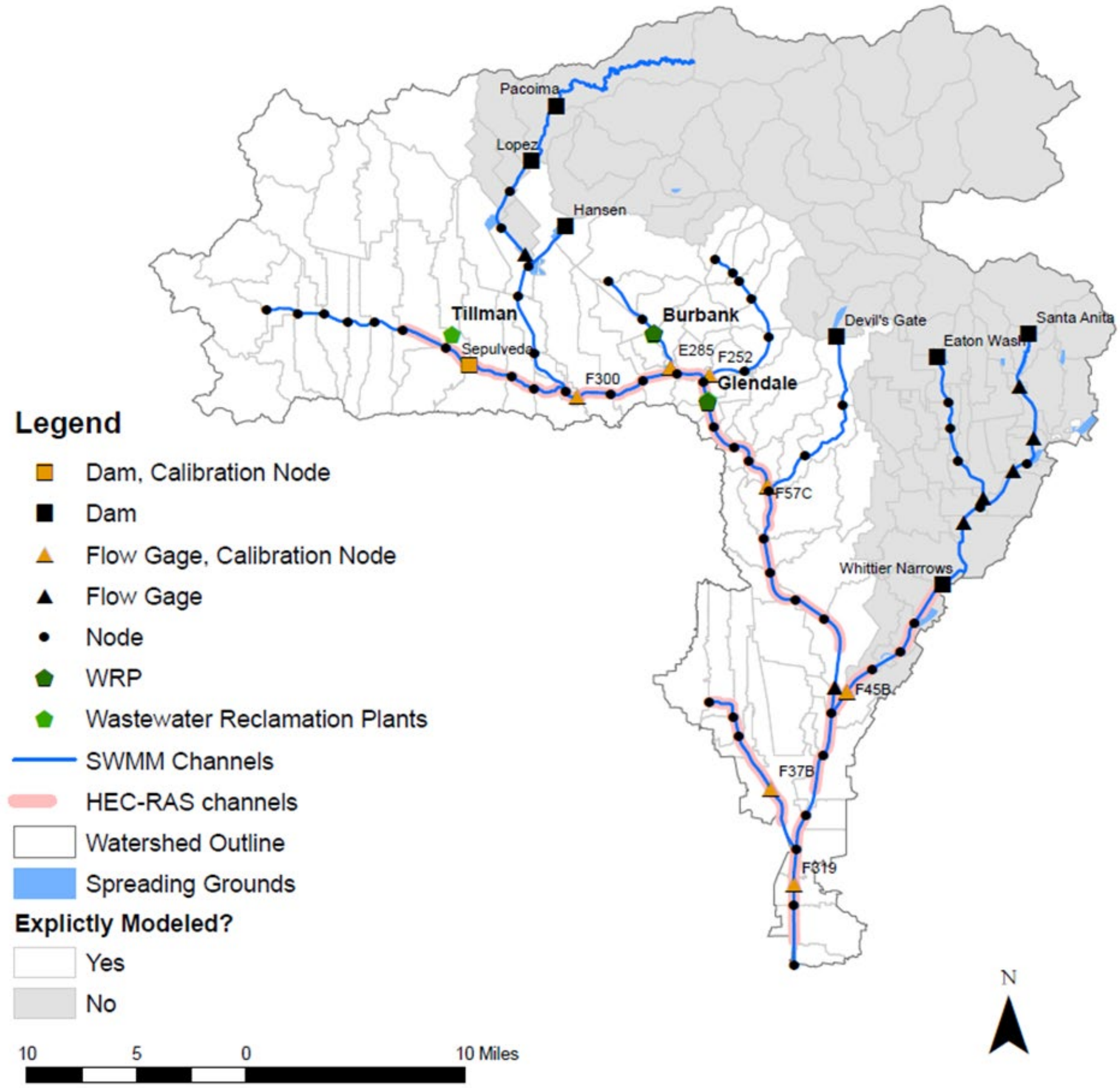

Figure 5. Hydraulic and hydrologic model domain. The hydraulic model was developed in HEC-RAS and paired with a hydrologic model created in EPA SWMM.

The one-dimensional hydraulic model was created by combining existing HEC-RAS models for the LA River and updating channel geometry and Manning's roughness[4] based on field observations and calibration. The hydraulic model was run under steady-state conditions, which were used to develop rating curves to apply to the simulated hydrographs, producing time series hydraulic data for velocity, maximum channel depth, and shear stress. Field observations showed that the rating curves created for the reporting node within Sepulveda Basin (LA20_2) were inaccurate as the basin acts as a storage instead of a conveyance feature. To account for the storage behind Sepulveda Dam, a static level of 1.34 m (4.39 feet) was added to the depth rating

[4] Manning's roughness represents the friction in the channel associated with substrate type, vegetation, etc. The 'roughness' affects hydraulic properties such as velocity.

curve for LA20_2 such that observed flows in July 2020 (about 0.85 cms [30 cfs]) matched the observed depths of about 1.5 m in the basin.

The final SWMM model included 77 catchments, and 78 channels. The final HEC-RAS model contained over 1,600 cross sections. Please see Stein et al. 2021 for results from the calibration and validation for both the hydrologic and hydraulic models. The coupled hydrologic-hydraulic model was used as a base for the temperature model, created in i-Tree Cool River (see Stein et al. 2021 for details) and the water quality model, created using EPA SWMM. All models were calibrated and validated using local data sources from a variety of ongoing monitoring programs.

Dry Weather Stormdrain Discharge

We modeled stormdrains that discharge directly to the LA River. Dry weather stormdrain flows were isolated for the whole modeled time period from the SWMM model using a water budget approach (Table 2). The total simulated flows (Q_{tot_sim}) were composed of storm runoff (Q_{storm_runoff}), urban baseflow ($Q_{baseflow}$), and dam discharge (Q_{dam}; Eq. 1) where urban baseflow is defined as the sum of discharge from WRPs (Q_{WRP}), groundwater upwelling that occurs in Glendale Narrows ($Q_{upwelling}$), industrial discharges ($Q_{industrial}$), and non-storm runoff ($Q_{non-storm\,runoff}$; Eq. 2). In the mass balance model, dam discharge may be positive or negative, as the dams in the system provide storage, which change the timing and peak of the river hydrograph. Storm runoff is surface runoff due to precipitation events whereas non-storm runoff is defined as flows resulting from other activities that create urban runoff such as irrigation and car-washing. *Dry weather stormdrain discharge* is defined as industrial discharges ($Q_{industrial}$) and non-storm runoff ($Q_{non-storm\,runoff}$) discharged through stormdrains to the river (Eq. 3).

$$Q_{tot\_sim} = Q_{storm\_runoff} + Q_{baseflow} - Q_{dam} \quad \text{(Eq. 1)}$$

$$Q_{baseflow} = Q_{WRP} + Q_{upwelling} + Q_{industrial} + Q_{non-storm\,runoff} \quad \text{(Eq. 2)}$$

$$Q_{dry\_weather\_stormdrain\_discharge} = Q_{industrial} + Q_{non-storm\,runoff} \quad \text{(Eq. 3)}$$

Table 2. Summary of Water Budget Components

Mass Balance Component	Method of Estimation
Storm runoff	Nonlinear reservoir routing (EPA SWMM)
Dam operations	Observed discharge data
Groundwater upwelling	Assumed constant at 3,000 acre-ft/yr (0.12 cms)
WRP discharges	Observed discharge data
Dry weather stormdrain discharge	Water budget approach

Tidal Model

The LA River below Willow St. is tidally influenced (Everest International Consultants, Inc. 2017) and supports wading shore birds. For the tidal area, a separate one-dimensional HEC-RAS model was created. The model was run in unsteady-state conditions, with the simulated hydrographs as an upstream boundary condition at Wardlow Rd (F319, 1.8 km upstream of

Willow St.) and tidal water surface elevation data as a downstream boundary condition, to directly output the timeseries of hydraulic data. Hourly water levels relative to mean sea level were extracted from NOAA (Gauge 9410660) for the tidal data (CO-OPS 2021). Two reporting nodes fall within the estuary portion of the river, LA2 and LA1. While both nodes demonstrate that water in the channel is affected by the tides, model outputs show that the upstream reporting node LA2 is primarily influenced by the inflows from the LA River while the downstream node LA1 is primarily influenced by the tides. Timeseries results from the tidal model were used as inputs to the scenario analysis as described below. Reductions in flows throughout the LA River (WRP, storm flow, or dry weather stormdrain discharge) resulted in greater tidal effects at both nodes.

Flow Ecology Modeling

Aquatic life beneficial uses in the LA River are defined based on the ability of the river and its tributaries to support characteristic aquatic plant and animal communities (Table 3). The overarching goal of this project is to provide tools to evaluate the potential effects of reduced WRP discharge and increased stormwater capture on existing beneficial uses. Through discussions with the TAC, that goal was expanded to also consider possible future beneficial uses. Therefore, our analysis included characterizing species and habitats that currently occur and those that could potentially occur in the future (based on a comparison to similar southern California watersheds). Current beneficial use designations for the mainstem of the LA River, Compton Creek, and Rio Hondo are set forth in the *Los Angeles Region Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties*, and adopted by the Los Angeles Regional Water Quality Control Board (https://www.waterboards.ca.gov/losangeles/water_issues/programs/basin_plan/). Our analysis focuses on the current beneficial uses but may also be used to consider support for species and habitats that are not currently supported in study area. The intent of considering potential future conditions is to extend the utility of the decision support tool described in this report to allow evaluation of proposed management actions that may influence flow conditions that could potentially support other beneficial uses in the future (e.g., Cold Freshwater Habitat [COLD], Migration of Aquatic Organisms [MIGR]). We recognize that there are many other factors that currently limit or preclude the ability to support these uses (e.g., local water supply needs, channelization, lack of vegetative cover, lack of suitable substrate, mechanical channel maintenance). Although this report provides examples of how changes to flow may influence current and potential future beneficial uses, we do not intend to propose management recommendations for beneficial uses not currently designated. More detailed modeling of micro-habitats and specific hydraulic conditions would be necessary to support restoration efforts for species not currently supported.

Table 3. Habitats and representative focal species. Shaded cells represent habitats and species not currently supported in the entire mainstem LA River, Compton Creek, or Rio Hondo.

Habitat	Focal Species	Description
Cold water habitat	Santa Ana Sucker (SAS)	Not currently present
	Unarmored threespine stickleback	
Migration habitat	Steelhead/Rainbow trout	Currently, MIGR[1] is only designated for LA River Reach 1. Overlays with other habitats
Wading shorebird habitat	Cladophora spp	Green algae to support prey of wading birds
Freshwater marsh habitat	Typha	
	Duckweed	
Riparian habitat	Black Willow	
Warm water habitat	African clawed frog	Surrogate for invasive spp. habitat
	Mosquitofish	

[1]MIGR: Migration of aquatic organisms

We determined the flow conditions likely necessary to support the life history needs of each focal species using readily available species and habitat data from a variety of sources including literature, surveys in the LA River and other similar watersheds and species/habitat databases. We then used these relationships to create ecological response curves or models relating key hydrologic, hydraulic, and temperature conditions to the probability of occurrence for each focal species life stage at each reporting node (Figure 3). The ecological response curves were then used to identify flow ranges likely to support each focal species for different life stages at different habitat locations in the river and time periods associated with certain life history phases such as breeding or growth (please see Stein et al. 2021 for full description of species habitat and ecological response curves). Critical life stages and habitat requirements were identified in coordination with the project TAC and used to develop a series of example flow recommendations for each reporting node in the study area (see below). Given the channelized nature and predominantly concrete substrate of the LA River, there are limited opportunities to modify flows in a way that reduces suitability for invasive species while still providing sufficient flows for native species. Therefore, we did not provide management targets aimed at reducing habitat for invasive warm water species.

Example flow management targets were determined based on the thresholds of probability of occurrence from each species ecological response curve, i.e., medium (50% of maximum probability of occurrence) and high (75% of maximum probability of occurrence[5]). Each ecological response curve was related to the flow at several cross-sectional positions at each node and by applying the rating curve describing the relationship between the hydraulic variable in the ecological response curve and flow in the stream (see example in Figure 6). The flow associated with the hydraulic value for each probability threshold was determined for each node, cross section position, species life stage and hydraulic variable to create a target flow range for that species. Hydraulic flow ranges for each species life stage were combined for each node and cross section position to develop example ranges of integrative flow management targets for each species life stage (i.e., growth and adult).

[5] Based on input from the TAC, we did not consider management targets aimed at achieving a low probability of occurrence (i.e., less than 50% probability of occurrence) for the focal species.

Most hydraulic flow ranges overlapped and therefore were intuitive to combine. However, on the occasions where flow ranges did not overlap, the range of the most limiting hydraulic factor was used. "Limiting hydraulic factor" is defined as the variable least supported by the current flow range. The depth and wetted width corresponding to specific flows in the LA River can be visualized using a beta R Shiny App (https://mohammap.shinyapps.io/LAVIS/). Figure 7 illustrates the dry season baseflow range for willow adult on the channel cross-sectional plot at GLEN adapted from the R Shiny App.

Caution must be used when interpreting and making decisions about appropriate flow ranges for some species and reaches given the limitations of applying a one-dimensional hydraulic model using existing channel morphology compared to a two-dimensional, spatially continuous model. In the concrete reaches, there are strengths in using a one-dimensional model of current morphology as there will be minimal changes to the morphology in the future, unless channel modifications or restoration actions are performed. However, there may be model limitations in the soft-bottom reaches, given that there will be changes to the morphology and those morphologic changes will be influenced by the flow regime and will in turn impact hydraulics. The potential effects of channel modifications on flow targets could be explored during a later phase of the study. In addition, the ecological model was built from a combination of data from the LA River and other watersheds and input from the TAC, which introduce some uncertainty in interpretation of the model results. Due to the large scale of our analysis, as well as multiple species and scenarios being evaluated, we used a nodal approach that considers the cross-sectional area at each node split into three sections (i.e., main channel and overbanks or depositional areas within the concrete banks of the river) to evaluate hydraulic conditions and associated flow ranges necessary to support the selected focal species. Using this approach may be more appropriate for the stationary focal species such as the Willow, Typha, or Cladophora which are more dependent on conditions at a given location. However, this still neglects factors such as availability of suitable substrate and presence of adequate subsurface moisture conditions.

The model may pose additional limitations for evaluation of reintroduction efforts of fish species. One-dimensional models can miss the complexity of microhabitats, such as edgewater areas and vernal pools, that species can use as refugia both longitudinally and laterally across the cross-section. For example, for potential future support of steelhead migration, we are using an average velocity across the main channel to evaluate if conditions are suitable for in-migration. Although the average velocity in the main channel may be unsuitably high for migration, velocity in the edgewater may be suitable. Additionally, flow requirements for steelhead must be considered in the context of channel hydraulics, seasonal hydrology, swimming performance, availability of cover and velocity refugia, and other factors.

Longitudinally, although flow and hydraulic conditions may be suitable at a given node, there may be locations along the reach where conditions are unsuitable, which may pose a barrier to re-establishing migration. In addition, the nodal approach does not account for conditions between nodes, e.g., velocity, that may affect suitability for some focal species. For example, under a future restoration scenario, certain velocities may limit the ability for steelhead to migrate from node to node due to exhaustion, particularly when microhabitats and refugia do not exist in uniform concrete reaches. Therefore, a "low probability" of occurrence does not necessarily preclude the ability of a species to persist in the actual, or potential future conditions in the river, similarly a “high probability” of occurrence does not confirm that a fish would persist or successfully migrate upstream.

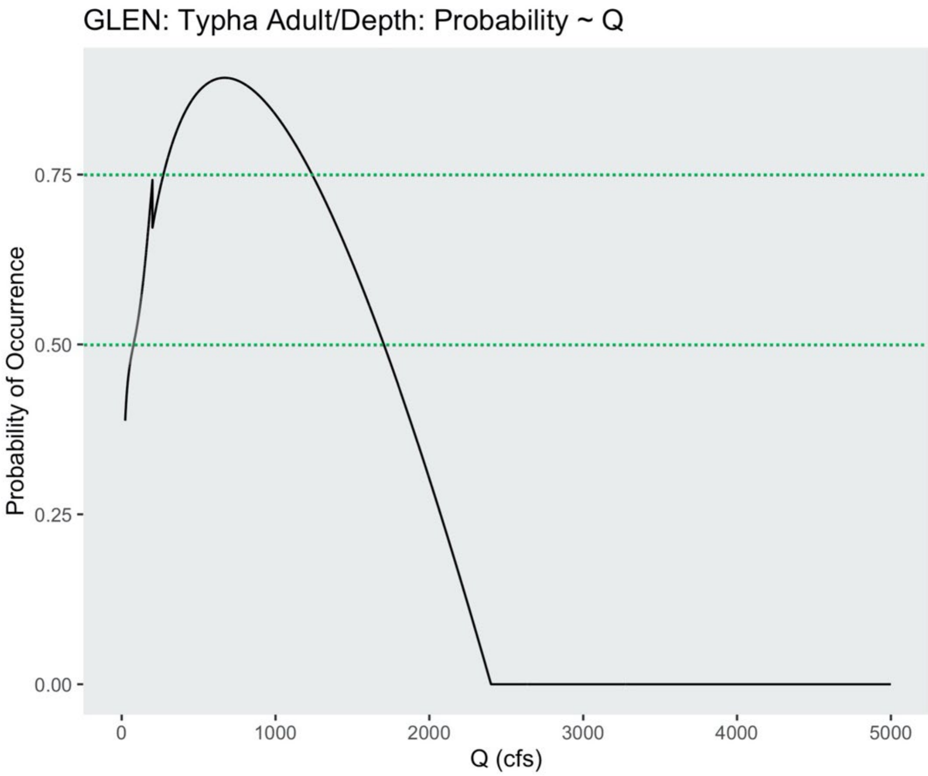

Figure 6. Typha adult patch probability of occurrence at node GLEN. Probability of occurrence related to flow at the node from the Typha adult patch ecological response curve though depth vs. flow rating curve. Dotted green lines show medium (0.5: 50% of maximum probability of occurrence - flow range 77-1704 cfs) and high (0.75: 75% of maximum probability of occurrence - flow range 271-1238 cfs) probability thresholds.

Figure 7. Dry-season flow range for willow adult at GLEN plotted on the channel cross section to visualize corresponding depth and wetted width of the upper and lower limits adapted from the beta R Shiny App (https://mohammap.shinyapps.io/LAVIS/).

Non-aquatic Life Uses

Example flow management targets to support non-aquatic life uses were not based on empirical observations, but instead were based on input obtained through a series of workshops and targeted interviews. Recreational use experts[6] were asked to identify key uses associated with different reaches of the river and the associated flows, depths or velocities needed to support those uses (see Stein and Sanchez 2019 for details). Key uses that could be affected by changes in flow included fishing, kayaking, wading, and other educational and community events. Recreational experts provided their best professional judgement on flow needs associated with recreational uses relative to those proposed for supporting aquatic life. Based on this input, the flow ranges associated with at least 0.9–1.5 ft (0.27-0.5 m) depth of water at the deepest part of the channel were used for kayaking and 1–2 ft (0.3-0.6 m) for fishing were incorporated into the tools used to develop example flow management targets. Recreational experts also noted that deeper pools (depth range of 3–8 ft or 0.9-2.4 m) were important for fishing. However, the cross sections at representative nodes may not capture these pools. Nodes that may support priority recreational uses are in Sepulveda Basin (LA20_2), at or near Glendale Narrows and Elysian Park (LA14, GLEN, LA11, F57C), and the Long Beach Estuary (LA1 and LA2).

[6] Recreational use experts consisted of local community docents, non-governmental organization representatives, local land conservancy representatives, and concessionaires who conduct recreational tours along the river.

Scenario Analysis

Wastewater discharge, stormwater management, and dry weather stormdrain discharge scenarios were simulated using the developed models. Wastewater discharge scenarios were simulated using a "sensitivity curve" approach. Instead of identifying a finite set of scenarios, sensitivity curves allow for consideration of a broad range of management options based on the amount of discharge to the river. Stormwater management and dry weather stormdrain scenarios were simulated as discrete scenarios due to model complexity and simulation time.

Wastewater Discharge

Potential wastewater discharge scenarios were selected using a Monte Carlo approach. Discharge timeseries from the WRPs from WY 2011 to 2017 were randomly scaled by 0 to 100% for 500 scenarios, representing multiple combinations of potential WRP discharge reductions from each plant. Two types of sensitivity curves were developed: flow-based and species-based. Seasonal average annual WRP discharge was calculated for both the wet- and dry-season for each scenario. Only the WRP's that contribute flow to each node were used for the seasonal WRP calculation. For example, at LA14, a node upstream of the Glendale WRP, the average annual discharge was calculated from Burbank and Tillman only. Annual functional flow metrics were calculated across the simulation period, WY 2011 to 2017, for each of the 500 WRP scenarios.

Flow-based sensitivity curves were developed that relate changes in WRP discharge to in-stream flow conditions (i.e., functional flow metrics). For each scenario, the range of flow metric values from the 10^{th}, 50^{th}, and 90^{th} percentiles were plotted against the average seasonal WRP discharge to account for the variability in flow metric values from each scenario across the period of record. Curves were developed for the dry-season baseflow (50^{th} percentile of flow during the dry-season) and wet-season baseflow (10^{th} percentile of flow during the wet-season) magnitude metrics, as they were the most sensitive to changes in WRP discharge. The wet-season metrics, baseflows from the start of the storm season to the start of the dry-season, and dry-season metrics, baseflows from the start of the dry-season to the start of the following wet-season, are calculated on an annual basis. Typically, the start of the wet-season is between November to January and the start of the dry-season is between May to July depending on the climatic conditions for a given water year. Curves were not developed for the upstream node in Rio Hondo (11101250) and Compton Creek (F37B and F37B), locations not impacted by potential changes in WRP discharge. Sensitivity curves were also not developed for LA1 and LA2 (tidal reach) because the tidal model yielded negative flow values indicating flow moving in the upstream direction due to the influence of tides. Therefore, functional flow metrics could not be calculated for the tidally influenced reach.

Species-based sensitivity curves were also developed that relate changes in WRP discharge directly to probability of species occurrence. For each scenario and relevant reporting node where the species are likely to be supported, the average probability of occurrence during the life stage critical period were plotted against average seasonal WRP. The average probabilities for species habitat models were calculated directly from the predictive models (e.g., Willow seedling, Typha Adult). For species habitat models that were based on thresholds, the average probabilities were calculated on the likelihood of the flow timeseries providing suitable flow based on the threshold values (e.g., Willow adult, Steelhead migration). For Santa Ana sucker, the maximum probability of occurrence was 0.4, therefore, the curves were rescaled to a 0-1 range to promote comparison between species.

Stormwater and Dry Weather Stormdrain Discharge

In addition to the WRP sensitivity curves, discrete scenarios were run to assess the impacts of reducing dry weather stormdrain discharge and capturing storm flows with distributed stormwater treatment (also known as best management practices (BMPs)). Unlike the WRP scenarios where we modeled 500 scenarios to develop the sensitivity curves, for the stormdrain analysis, we developed three discreet scenarios representing a range of BMP implementation and created a sensitivity curve using only those. In this study, dry weather stormdrain discharge is defined as any flows running off the land surface and into the LA River that are not a result of a precipitation event (i.e., irrigation, car wash return-flows, or shallow groundwater dewatering operations) as well as industrial discharges. Storm flows are defined as urban runoff due to precipitation events.

The EPA's System for Urban Stormwater Treatment and Analysis IntegratioN (SUSTAIN) (Shoemaker et al. 2009) was used to simulate dry weather stormdrain discharge reduction and storm flow capture. SUSTAIN was chosen as it simulates BMPs on an aggregate level which is appropriate for a watershed-scale analysis, it can be modified to simulate underground BMPs such as infiltration galleries, and it uses timeseries from hydrologic models, such as SWMM, to drive the BMP simulation module. First, hydrologic timeseries from the calibrated and validated SWMM model were isolated as three timeseries, storm flows, dry weather stormdrain discharge flows, and all other flows (Figure 8). Refer to the *Dry Weather Stormdrain Discharge* section above for details on the water balance approach used to isolate flows. *All other flows* include model inputs and outputs such as WRP flows, groundwater upwelling, evapotranspiration, and dams. The three timeseries for each node were set as inputs to the SUSTAIN model. Scenarios were run with 0%, 50%, and 100% of historic WRP flows combined with 0%, 50%, and 100% of dry weather stormdrain discharge flows, plus five stormwater management scenarios, for a total of forty-five discrete scenarios (3 x 3 x 5 = 45; Figure 8).

Stormwater planning documents for the LA River basin were reviewed, including the City of Los Angeles Stormwater Capture Master Plan (SCMP) (LADWP 2015), and the watershed management program plans for the Upper and Lower LAR, LAR Upper Reach 2, and Rio Hondo/San Gabriel River (Tetra Tech 2018; CWE 2015; Hunters 2017; Ch2m, Paradigm Environmental, and Black & Veatch 2016). The documents reviewed discuss a range of distributed and regional stormwater capture practices for each jurisdiction as well as projected ranges of BMP implementation; some estimates include total structural capacity, catchment prioritization indexes (based on land use), and pollutant source control. All the plans consider infiltration and non-infiltration based structural BMPs such as infiltration basins, bioretention systems, and vegetated swales. Modeling efforts in this project were consolidated to one methodology by adapting strategies from the five stormwater planning documents listed above.

First, a representative group (six BMPs identified in the SCMP) that were consistent across all five stormwater planning documents were chosen for modeling. Two BMP types were chosen for this analysis, infiltrating and non-infiltrating, to assess the impacts of stormwater management on flows and water depth in the LA River. Infiltrating BMPs simulated in SUSTAIN include porous pavement, bioretention, and underground infiltration structures while non/low-infiltrating BMPs include detention pond, vegetated swales, and underground detention structures. SUSTAIN simulates BMPs as an aggregate, meaning storm flow runoff from an entire subwatershed is routed to a set number of BMP units that are simulated in parallel. Thus, the area of land to be routed to BMPs is required.

The SCMP was used as a guide to estimate the total potential area of land that may be treated with BMPs. The SCMP outlines conservative and aggressive approaches[7] that provide a feasible range of BMP implementation rates (by the year 2095) that could be uniformly applied to the whole watershed. The conservative and aggressive rates were estimated by considering the social, financial, and political barriers or opportunities that could impede or accelerate stormwater capture (LADWP 2015). These rates were used to determine the area of land in each subwatershed routed to BMPs in the SUSTAIN model (see Appendix B for more details on how land use types, geophysical categorization, and percent imperviousness were used with the implementation rates to estimate the area of land routed to BMPs). The goal of this analysis is to provide a window that specific jurisdiction implementation plans fall within. This analysis assumes all jurisdictions and subregions will implement their respective stormwater capture plans. It should be noted that meeting target capture volumes and complying with water quality regulations (such as total maximum daily loads) on a watershed level relies on the successful implementation within each jurisdiction or subregion. While the conservative implementation rate considers barriers to implementing stormwater infrastructure, collaboration across jurisdictional lines may be needed to meet county wide goals and regulations.

The resulting percent area of land from the entire LA River watershed routed to BMPs was 9.85% and 16.42% for the conservative and aggressive scenarios, respectively. This compares similarly to the values reported in the SCMP, 7.58% and 14.14% for the conservative and aggressive scenarios, respectively (LADWP 2015). Note that the SCMP only calculated these values within the City of Los Angeles Boundary while the values for SUSTAIN were calculated for the entire LA River watershed. However, estimated implementation rates for SUSTAIN are also similar to other stormwater planning documents. For example, the Lower LA River plan (Hunters 2017) predicted 803 acre-ft of runoff to be captured by BMPs, or around 34% of the entire area. The methodology used in this study estimated between 19% to 36% for the conservative and aggressive scenarios, respectively, from the lower LA River subwatersheds (F319).

Average annual flow volumes were used to compare the relative performance of all 45 management scenarios.

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[7] Conservative and aggressive approaches are defined in the SCMP based on funding availability and sociopolitical support. The conservative approach plans for up to 50% stormdrain capture; the aggressive approach plans for up to 95% stormdrain capture.

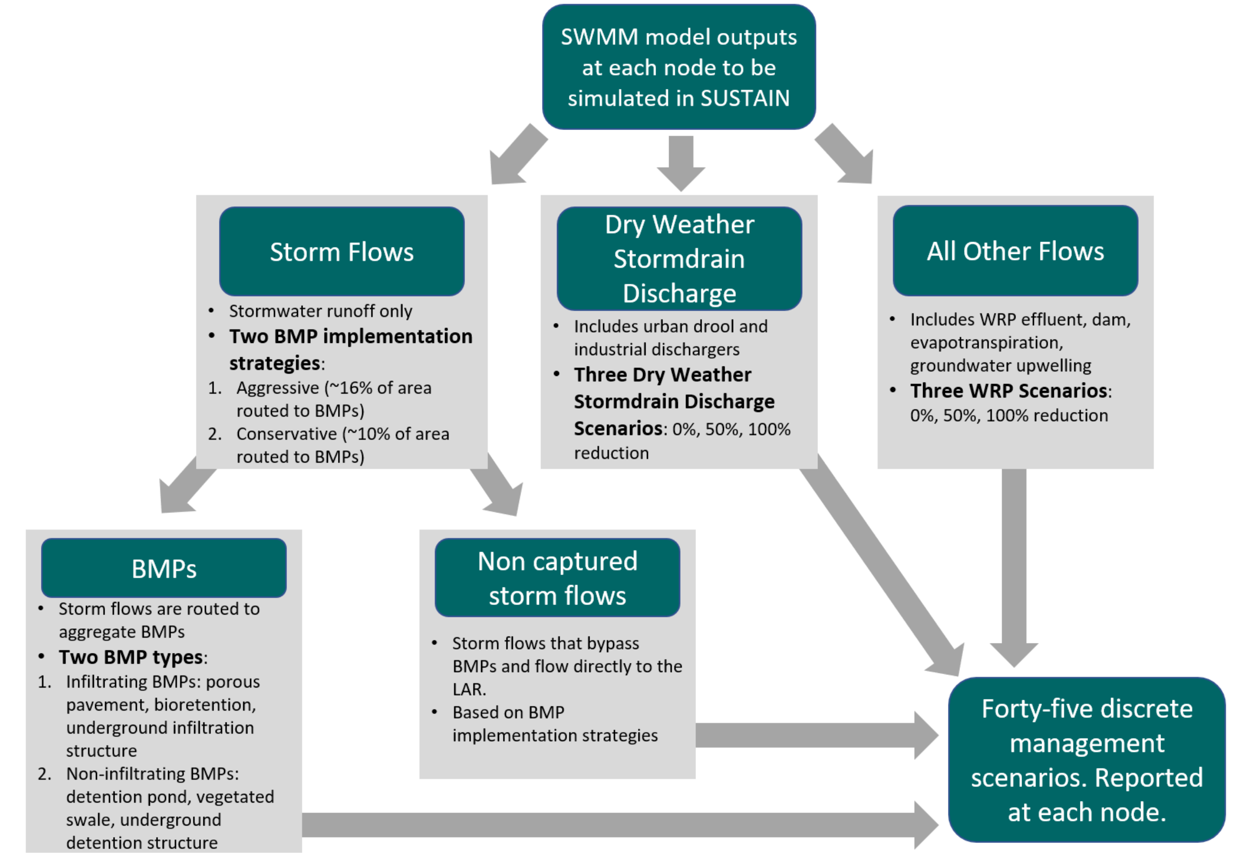

Figure 8. Conceptual model showing the forty-five management scenarios that were simulated in SUSTAIN. Scenarios included storm flow capture via infiltrating and non-infiltrating storm control measures (BMPs), dry weather stormdrain diversions, and combined effects with WRP discharge scenarios.

PROCESS FOR ESTABLISHING FLOW MANAGEMENT TARGETS

Flow ranges associated with designated existing and potential, and possible future beneficial uses were determined based on our current understanding of the needs of the associated focal species (and life stages) and recreational uses for each relevant reporting node (an example of flow recommendations for GLEN is shown in Table 4). Relationships between focal species and beneficial uses were developed in consultation with the TAC (Table 5). Although COLD is not currently a designated beneficial use in the mainstem of the LA River, Compton Creek, and Rio Hondo, one goal of this study is to extend the utility of the tools to evaluate flow conditions that have the potential to support non-designated beneficial uses, such as COLD, in the future. In many cases, additional management or restoration actions may be necessary to fully support focal species (e.g., substrate modifications, creation of refugia and resting habitat). Furthermore, current augmented non-storm flows and elevated temperatures provide conditions conducive for invasive species which may outcompete or predate native species. Management actions to reduce invasive species would be a necessary as part of any strategy aimed at restoring habitat for native cold-water species.

The flow ranges table is organized by individual species and is separated into two life stages: growth and adult. Growth is defined as any life stage describing early life history before reaching adult maturity (e.g., seedling, juvenile, smolt). The flow ranges are organized by node, within its associated reach. The current suitability is defined as described in Stein et al. (2021). Critical cross section is defined as the most suitable area of cross section for that species e.g., riparian willow would be suited to overbanks, fish species suited to active main channel. In cross sections where the active main channel is not mid-channel due to a sand bar e.g., GLEN, the sand bar is designated as an overbank and the deepest part of the channel designated as the active main channel.

Table 4. Example flow ranges by focal species' life stage or recreational uses for reporting node GLEN. Color coding: green; flow conditions currently supported, red; flow conditions not currently supported: grey; flow ranges not applicable, white: flow ranges not available. The current flow range represents the 10th and 90th percentile of flow observed during the dry season across the baseline period.

Species (habitat)	Life Stage	Reporting Node	Reporting Reach	Current suitability	Critical Cross section position	Dry-Season Baseflow			
						Current flow range (cfs)	Optimal Flow Range (cfs, Medium Probability – 50%)	Optimal Flow Range (cfs, High Probability – 75%)	Duration
Willow (riparian birds)	Growth	GLEN	LAR 5	Partial	Overbank	72-89	> 23	> 23	April-September
Typha (Freshwater marsh)	Growth	GLEN	LAR 5	Partial	Overbank	72-89	> 23		April - September
Typha (Freshwater marsh)	Adult	GLEN	LAR 5	Partial	Overbank	72-89	> 77	> 270	Annual
Willow (riparian birds)	Adult	GLEN	LAR 5	High	Overbank	72-89	>23		Annual
SAS (Coldwater fish)	Growth	GLEN	LAR 5	Partial	Main Channel	72-89	> 34	> 149	March-July
SAS (Coldwater fish)	Adult	GLEN	LAR 5	Partial	Main Channel	72-89	> 34	> 149	Annual
Steelhead (Migration)	Adult (Prolonged)	GLEN	LAR 5	High	Main Channel	72-89	> 23		April - June
Steelhead (Migration)	Adult (Burst)	GLEN	LAR 5	High	Main Channel	72-89	> 23		April - June
Steelhead (Out-Migration)	Smolts	GLEN	LAR 5	High	Main Channel	72-89	> 23		April - June
Kayaking		GLEN	LAR 5		Main Channel	72-89	65-253		May - September
Fishing		GLEN	LAR 5		Main Channel	72-89	96-447		May - September

Flow ranges associated with species/habitat occurrence are separated by season and associated flow metric (i.e., dry-season baseflow, wet-season baseflow, and wet-season peak flows) to account for seasonal differences in flow condition. The following adjustments were made to the flow ranges:

- When channel hydraulics resulted in the modeled upper baseflow tolerances being substantially above current baseflow ranges in the main channel, we relied on the lower flow limit and include a separate upper (peak flow) limit above which high flow conditions are expected to result in a low probability of occurrence.

- For some species (i.e., Willow Adult, Steelhead burst swimming and Cladophora Adult) the upper hydraulic limit corresponded to flows that overtop the concrete banks. In these instances, wet-season peak flow limits were not reported.

- Adult willows require flows to inundate the overbank area seasonally, but these areas should not remain inundated for prolonged periods that may result in mortality or impaired growth. In these cases, we identify a lower limit necessary to maintain flow in the river, and an upper limit that would completely inundate the overbank area (and thereby potentially results in unsuitable conditions)

The current flow range of each flow metric represents the range in flow metric values from the 10^{th} percentile to the 90^{th} percentile calculated from mean daily flow across the baseline condition (WY 2011-2017). For both dry-season and wet-season baseflow, the low magnitude values are presented in Table 4. The flow ranges for each flow metric are given for both medium and high probability thresholds, except in cases where threshold values (vs. probabilities) were used in the species habitat model (e.g., willow adult, steelhead migration and recreational uses); in these cases, only one flow value (the threshold) is presented. Flow duration is the critical time period for each species and the start date of that period denotes the timing during which flow conditions should be met to meet the beneficial use needs. Flow ranges are color coded to show whether the current flow ranges support the recommendations: green; flow ranges currently supported, red; flow ranges not currently supported: gray; flow recommendations not applicable, white; flow recommendations not available. Note that although current flow ranges may be outside of the flow range associated with a medium or high probability of species/habitat occurrence, this does not guarantee that focal species or recreational uses cannot be supported. For example, although the current dry season baseflow magnitude in the main channel of GLEN is lower than the flow range associated with fishing, fishing could be supported in pools that may be upstream or downstream of the reporting node.

The draft flow ranges table organized by species for all relevant nodes can be viewed at: https://sccwrp.sharepoint.com/:x:/s/LARiverEflowsStudy/EVoSEKZ6EBdKh2sqcsahoZsBmA_jj1hmdh4WWxyddvgd3w?e=cALJ4U. Additionally, the draft flow range table for species life stages, recreational uses, and current flows and beneficial uses by location can be viewed at: https://sccwrp.sharepoint.com/:x:/s/LARiverEflowsStudy/EXe7HmwHbgpFn5qhgFjAb7gBGQoCvaaB1ZYoyMg72B_18Q?e=Jsctsl.

Table 5. Focal species associated with beneficial uses. Highlighted species do not currently occur in the mainstem of the LAR. Cold freshwater habitat (COLD) is currently not a designated beneficial use for any LA River reach covered by this study. Beneficial use definitions and water body designations can be found in the LA Regional Water Quality Control Board Basin Plan (https://www.waterboards.ca.gov/losangeles/water_issues/programs/basin_plan/basin_plan_documentation.html).

Focal Species	Beneficial Uses						
	WARM[1]	EST[2]	WILD[3]	RARE[4]	MIGR[5]	SPWN[6]	COLD[7]
Santa Ana Sucker				x		x	x
Unarmored threespine stickleback				x		x	x
Steelhead/Rainbow trout		x		x	x		x
Cladophora spp		x	x				
Typha			x				
Duckweed			x				
Black Willow			x	x			
African clawed frog	x						
Mosquitofish	x						

[1]WARM: Warm freshwater habitat
[2]EST: Estuarine habitat
[3]WILD: Wildlife habitat
[4]RARE: Rare, threatened, or endangered species
[5]MIGR: Migration of aquatic organisms
[6]SPWN: Spawning, reproduction, and/or early development
[7]COLD: Cold freshwater habitat

Given the extensive set of flow ranges for multiple species and locations, a process was developed to synthesize flow ranges into overall flow management targets based on a series of decisions (Figure 9). Additionally, a user-friendly application is being developed that interactively identifies potential flow management targets based on the decision process. The process includes determining which location and seasons are of interest and depending on the location, either designated or non-designated beneficial uses and the related focal species from Table 5 can be evaluated. Next, flow ranges for the focal species life stages can be obtained based on the probability of species occurrence (i.e., high [75%] or medium [50%]) or defined thresholds. Based on the decisions made, overall flow management targets can be developed by using a ruleset to synthesize flow ranges across multiple species life stages. The ruleset includes the following steps:

1. Find the overlap across all species life stages.
2. If no overlap across all species life stages, find the flow range that satisfies the most species life stages.
3. Or decision can be based on agreed upon management priorities.

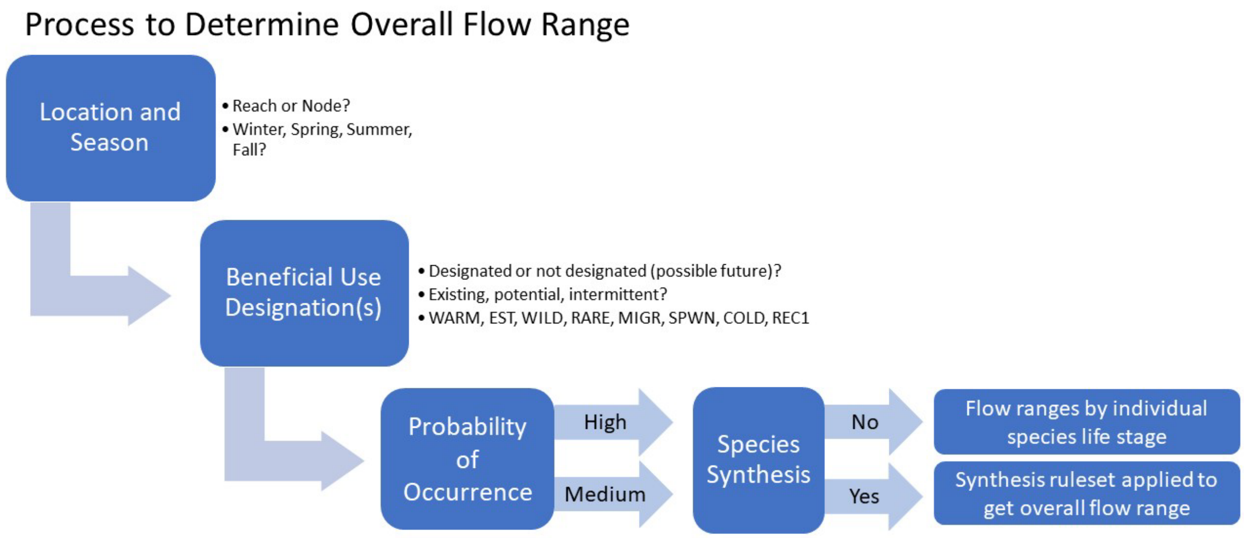

Figure 9. Proposed process for synthesizing and interpreting flow ranges to develop overall flow management targets. Medium probability is defined as 50% of the maximum probability of occurrence; high probability is defined as 75% of the maximum probability of occurrence. Low probability was determined to not be a desirable management goal.

Flow management targets can be developed for individual life stages, individual species, or across multiple species at a node. For example, in Glendale Narrows (reporting node GLEN), flow management targets for the designated beneficial use WILD can be developed for individual species, Willow and Typha, by finding the overlap between the flow ranges for adult and growth life stages (Figure 10a). If overall flow management targets across multiple species are desired, the flow range that satisfies the most species life stages can be utilized (Figure 10b).

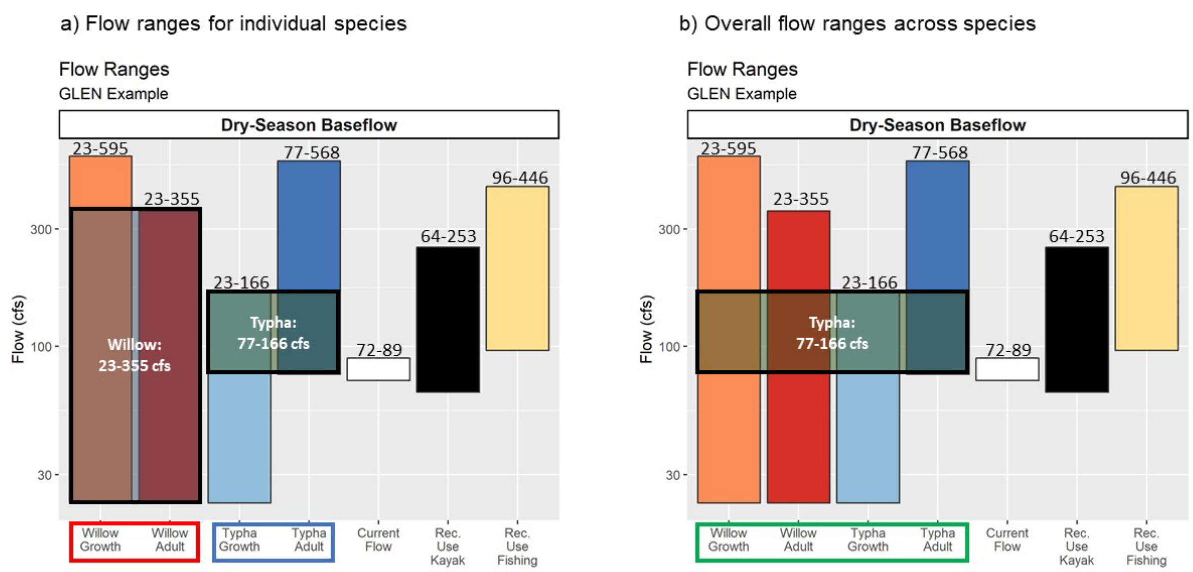

Figure 10. Illustration of synthesizing flow ranges for: (a) individual species, Willow and Typha, and (b) overall flow ranges across multiple species. This example is using flow ranges for medium probability of occurrence.

The overall flow range being considered as a potential management target can be plotted on an annual hydrograph to evaluate when instream flows are outside of this range. For example, the wet-season peak flow limit and baseflow lower limit for Willow and Typha at GLEN were plotted on the annual hydrograph for WY 2015 (Figure 11). In WY 2015, the dry season baseflow is near the lower limit for Willow and Typha. In contrast, wet season baseflow following large storm events were typically higher than the lower limit. Therefore, there may be additional opportunities for WRP reuse to occur during and after large storm events. This is particularly relevant because suggested flow ranges are averaged over time relative to species/habitat needs. Because WRP discharge typically varies diurnally (and day-to-day), there could be opportunities for discharges to vary between day and night and maintain overall flow levels supportive of beneficial uses.

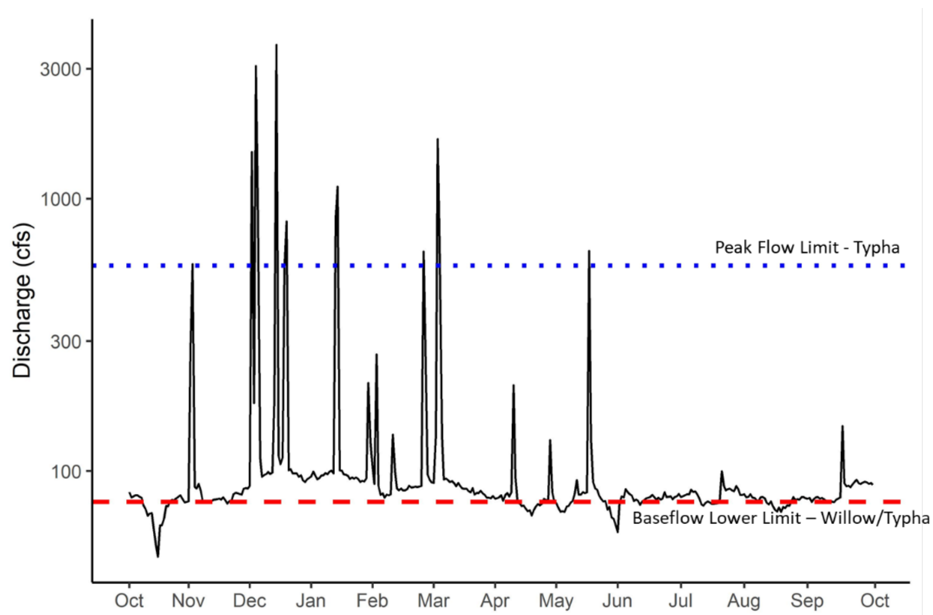

Figure 11. Modelled annual hydrograph from Glendale Narrows (GLEN) for water year 2015 with the wet-season peak flow limit for Typha (blue dotted line) and baseflow lower limit for Willow and Typha (dashed red line). Note that the y-axis is in log scale.

Depending on the decisions made, an output summary table can be downloaded from the user-interface (Table 6). The table includes the current and optimal flow ranges and additional details on timing and duration.

Table 6. Example summary output table based on decision process

Example In-River Flow Management Targets
Location: GLEN
Beneficial Use: Existing, WILD
Synthesis: Multiple Species (Willow, Typha)
Probability: Medium (50%)

Dry-Season Baseflow			Wet-Season Baseflow			Wet-Season Peak Flow	
Current flow range (cfs)	Optimal flow range (cfs)	Duration	Current flow range (cfs)	Optimal flow range (cfs)	Duration	Current Annual Peak Q range[1] (cfs)	Optimal flow range (cfs)
72-89	77-166	April - September	82-130	77-355	October - March	8,188-32,608	< 568

[1] Current annual peak Q range represents the 10^{th} and 90^{th} percentile of annual peak discharge calculated from the hourly flow timeseries period of record (WY 2011-2017)

Relationship to the California Environmental Flows Framework

The California Environmental Flows Framework (CEFF) is a unified approach that provides management guidance to develop ecological flow criteria and environmental flow recommendations statewide[8]. This framework uses a functional flows approach that focuses on key aspects of the natural flow regime that sustain ecological, geomorphic, or biogeochemical functions and that support the specific life history needs of native aquatic and riparian-dependent species (Yarnell et al. 2015). Ecological flow criteria, or natural ranges of key functional flow metrics that must be maintained instream to support natural functions of healthy ecosystems, can be quantified and serve as a management goal to preserve stream health. However, in highly modified systems such as the LA River, mediating factors, including the physical form and structure of the stream channel, impairments to water quality, and biological interactions among species, may alter the relationship between flow and ecology, limiting the ability of natural flows to support desired ecosystem functions. Because the LA River is a highly engineered channel with water quality impairments, reference functional flows would likely not support the existing species and recreational uses of the river. For example, historically, sections of the LA River were naturally intermittent and supported species adapted to thrive under seasonal flow conditions. Such conditions rely on natural floodplain morphology and substrate (in addition to natural flows) to provide the broad suite of ecological functions. Restoring such natural conditions is not realistic in the short term given the highly urbanized setting. Consequently, for this study, we do not identify natural functional flow ranges (CEFF Section A), instead, we consider the current engineered channel morphology to identify ranges of functional flow metrics needed to support the life history needs of a suite of focal species representative of various habitat types and beneficial uses (CEFF Section B). However, achieving flow ranges necessary

[8] The terms ecological flow criteria and environmental flow recommendations as used here are defined in the CEFF (https://ceff.ucdavis.edu/).

to support focal species alone does not ensure persistence of those species. Habitat restoration would need to be coupled with flow management to provide resilient conditions for native species and habitats.

Although we are using a species-based approach to identify functional flow ranges, we have cross-walked our focal species analysis with key functions identified in CEFF (Table 7). Some functions are not expected to be supported in the LA River given the engineered nature of the channel and therefore we do not capture that representation in the analysis. Furthermore, certain functional flow components are not always well represented in flashy systems in semi-arid portions of the state, such as the LA River. Pronounced spring recession flows are often absent in the LA River due to the lack of snowmelt runoff, lack of strong groundwater influence, and channelized nature of the river which hastens “draining” of the system following storms. Although they are an important part of the hydrograph for steelhead migration, current functions of the LA River are not heavily dependent on spring recession flows. Similarly, fall pulse flows can be important for initial flushing of fine sediments and “priming” of the system for subsequent winter storms. However, in the LA River, such flows seldom support current functions because of the lack of natural substrate, stochastic nature of early season storms, and the fact the first storms of the season are often captured for water quality purposes.

Table 7. Relationship between focal species flow ranges and the supported ecosystem functions by functional flow component. Red ○'s indicate that flow ranges for focal species were not developed for the given flow component and ecosystem functions may not be fully supported.

Functional Flow Component	Type of Ecosystem Function	Supported Ecosystem Function	Associated Flow Characteristic	Willow	Typha	Cladophora	Steelhead Migration	Santa Ana Sucker
Fall Pulse Flow	Physical	Flush fine sediment and organic material from substrate	magnitude					
		Increase longitudinal connectivity	magnitude, duration				○	
		Increase riparian soil moisture	magnitude, duration	○				
	Biogeochemical	Flush organic material downstream and increase nutrient cycling	magnitude, duration	○				
		Modify salinity conditions in estuaries	magnitude, duration			○		
		Reactivate exchanges/connectivity with hyporheic zone	magnitude, duration					○
		Decrease water temperature and increase dissolved oxygen	magnitude, duration					
	Biological	Support fish migration to spawning areas	magnitude, timing, rate of change				○	
Wet-season Baseflow	Physical	Increase longitudinal connectivity	magnitude, duration				X	
		Increase shallow groundwater (riparian)	magnitude, duration	X				
	Biogeochemical	Support hyporheic exchange	magnitude, duration					
	Biological	Support migration, spawning, and residency of aquatic organisms	magnitude				X	X
		Support channel margin riparian habitat	magnitude	X				X
Wet-season Peak Flows	Physical	Scour and deposit sediments and large wood in channel and floodplains and overbank areas. Encompasses maintenance and rejuvenation of physical habitat.	magnitude, duration, frequency	X				
		Increase lateral connectivity	magnitude, duration					
		Recharge groundwater (floodplains)	magnitude, duration	X				
	Biogeochemical	Increase nutrient cycling on floodplains	magnitude, duration	X				

		Increase exchange of nutrients between floodplains and channel	magnitude, duration	X				
	Biological	Support fish spawning and rearing in floodplains and overbank areas and/or adult migration	magnitude, duration, timing				○	X
		Support plant biodiversity via disturbance, riparian succession, and extended inundation in floodplains and overbank areas	magnitude, duration, frequency	X	X			
		Limit vegetation encroachment and non-native aquatic species via disturbance	magnitude, frequency	X				
Spring Recession Flow	Physical	Sorting of sediments via increased sediment transport and size selective deposition	magnitude, rate of change				○	
		Recharge groundwater (floodplains)	magnitude, duration	X				○
		Increase lateral and longitudinal connectivity	magnitude, duration				○	
	Biogeochemical	Decrease water temperatures and increase turbidity	duration, rate of change			○		○
		Increase export of nutrients and primary producers from floodplain to channel	magnitude, duration, rate of change					
	Biological	Provide hydrologic cues for fish outmigration and amphibian spawning; support juvenile fish rearing	magnitude, timing, rate of change				○	
		Increase hydraulic habitat diversity and habitat availability resulting in increased algal productivity, macroinvertebrate diversity, arthropod diversity, fish diversity, and general biodiversity	magnitude, timing, rate of change, duration			○		○
		Provide hydrologic conditions for riparian species recruitment (e.g., cottonwood)	magnitude, timing, rate of change, duration	X				
		Limit riparian vegetation encroachment into channel	magnitude, rate of change					
	Physical	Maintain riparian soil moisture	magnitude, duration	X				

Dry-season Baseflow		Limit longitudinal connectivity in ephemeral streams; limit lateral connectivity to disconnect floodplains	magnitude, duration, timing					
		Maintain longitudinal connectivity in perennial streams	magnitude				○	
	Biogeochemical	Maintain water temperature and dissolved oxygen	magnitude, duration			**X**		**X**
	Biological	Maintain habitat availability for native aquatic species (broadly)	magnitude, timing, duration		**X**	**X**	○	**X**
		Condense aquatic habitat to limit non-native species and support native predators	magnitude, duration					**X**
		Support algal growth and primary producers	magnitude			**X**		**X**

SCENARIO RESULTS

Wastewater Discharge

A total of 66 flow-based sensitivity curves were developed for 13 reporting nodes, two seasonal functional flow components (wet-season baseflow and dry-season baseflow), and for multiple management scenarios (WRP discharge and dry weather stormdrain discharge scenarios). Sensitivity curves were only developed for the wet- and dry-season baseflow components because they were the most sensitive flow components to changes in WRP discharge and dry weather stormdrain reductions—other flow components, such as spring recession and peak flows, were insensitive to the change scenarios. Two types of sensitivity curves were developed: flow-based curves that predict changes in instream flow conditions (functional flow metrics) associated with varying amounts of discharge or "capture" and species-based curves that predict changes in probability of species occurrence. All links to access flow-based and species-based sensitivity curves developed can be found in Appendix A.

A process was developed to use the flow ranges associated with medium and high probability of species occurrence along with the sensitivity curves to evaluate how much and under which scenarios flows can be reduced and still meet the optimal flow ranges (Figure 12). This process will also be incorporated into the online tool being created, which will allow users to interactively view and evaluate sensitivity curves for different scenarios. There are two starting perspectives when determining which type of sensitivity curve to use: (1) protecting the species or beneficial use at the location using the optimal flow range and (2) evaluating how much WRP discharge can be reduced before seeing an effect. For (1), use the flow-based sensitivity curves to evaluate the scenarios that meet the optimal flow range. For (2), use the species-based sensitivity curves to evaluate the effect on the species probability of occurrence.

Caution must be taken when using the curves to evaluate future scenarios given the previously discussed model uncertainties. Although a reduction in WRP discharge may lead to predicted instream flows that satisfy the optimal flow range, it does not guarantee that associated beneficial uses will be supported. Likewise, the probability of species occurrence does not guarantee that the species can be supported. There may be other limiting factors such as substrate, temperature, water quality, or mechanical channel maintenance activities that can impact the potential for species support.

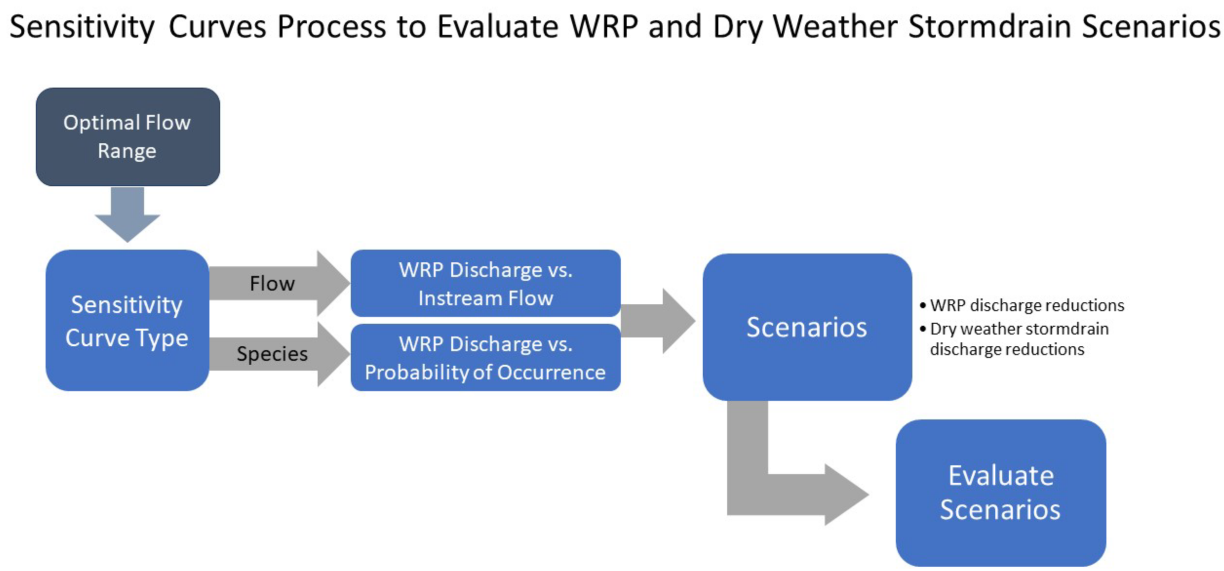

Figure 12. Proposed process to use optimal flow range of specific management targets with sensitivity curves to evaluate WRP and dry weather stormdrain scenarios.

An example application of sensitivity curves at GLEN shows the optimal flow range for Willow and Typha plotted with the flow-based sensitivity curve (Figure 13). The overlap between the optimal flow range and the sensitivity curve indicates scenarios where the optimal flow range is likely achieved. In this example, the median dry season baseflow magnitude reduced by 81%, from 79 cfs under baseline conditions to 15 cfs under 100% reduction in WRP discharge. Under baseline conditions with no change in WRP discharge, some water years had flow within the optimal range and some water years had flow lower than the optimal flow range. At GLEN, there may be more flexibility in terms of reductions in WRP discharge if managing for flows supportive of Willows only. In contrast, if managing flows for both Willow and Typha, there may be limited opportunities for reductions in WRP discharge during the dry season.

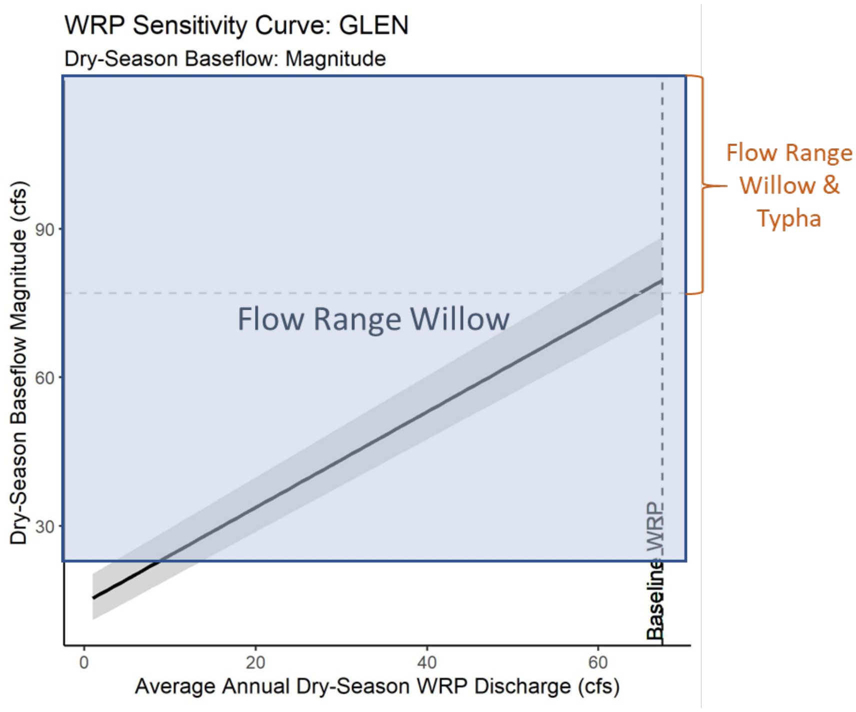

Figure 13. WRP sensitivity curve for dry season baseflow magnitude and optimal flow range for Willow (blue box) based on a 50% (medium) probability of occurrence at GLEN reporting node. Solid line represents median values; bounds of the gray band are the 10th and 90th percentile dry season flows across the modeled period. Optimal flow range for supporting both Willow and Typha is from 77 to 166 cfs.

The combined effects of changes in WRP discharge and dry weather stormdrain discharge can also be evaluated using the dry weather stormdrain sensitivity curves (Figure 14). Under baseline WRP discharge and 50% and 100% reduction in dry weather flows at GLEN, dry season baseflow magnitude only reduces by ~6 cfs and 13 cfs, respectively. However, the combined effects of 100% removal of both WRP discharge and dry weather stormdrain discharge results in an elimination of nearly all instream flows. In contrast, for the downstream most gage on the mainstem, Wardlow (F319), the relative impact of dry weather stormdrain discharge reduction was larger than the reductions at GLEN. Under baseline conditions at Wardlow, dry season baseflow magnitude reduces from 124 cfs to 62 cfs with 100% reduction in dry weather discharge and no changes to WRP discharge (Figure 15).

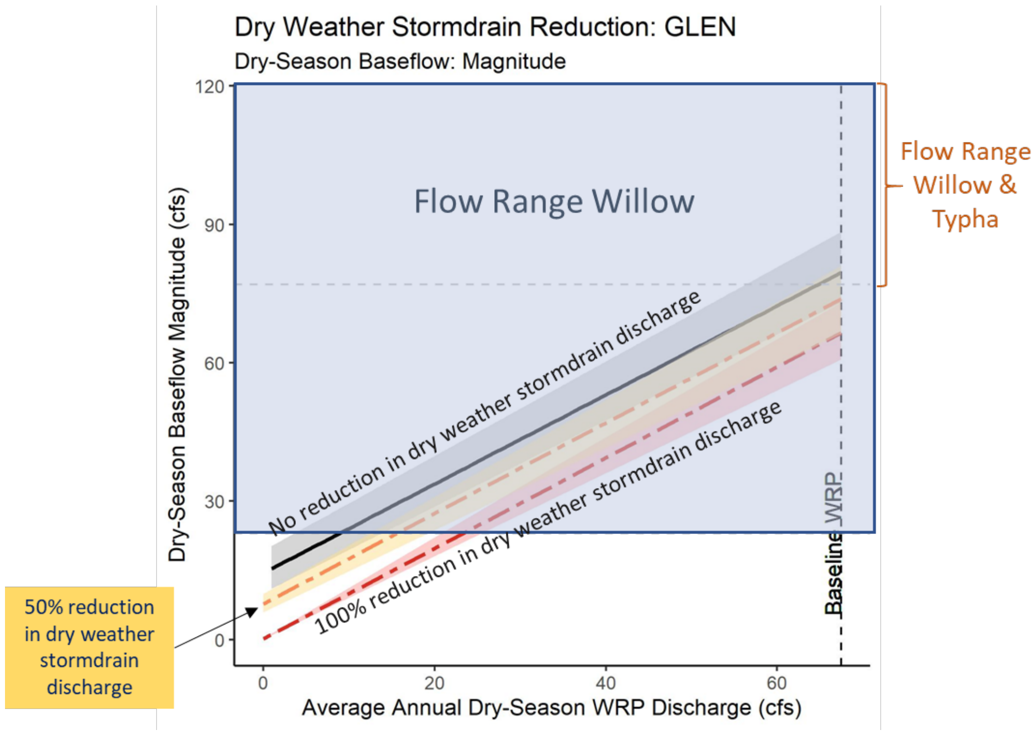

Figure 14. Flow-based sensitivity curves illustrating the combined effects of change in WRP discharge and 50% (yellow) and 100% reduction (red) in dry weather stormdrain discharge at GLEN reporting node. Solid and dashed lines represent median values; bounds of the gray and colored bands are the 10th and 90th percentile dry-season instream flows across the modeled period. Optimal flow range in this example is based on a 50% (medium) probability of occurrence of both Willow and Typha.

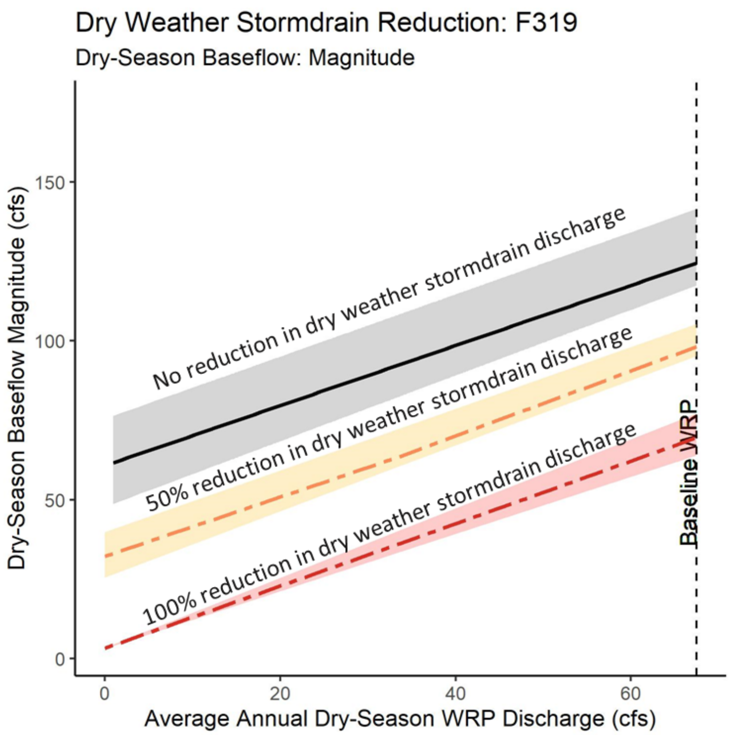

Figure 15. Flow-based sensitivity curves illustrating the combined effects of change in WRP discharge and 50% (yellow) and 100% reduction (red) in dry weather stormdrain discharge at the downstream most gage on the mainstem, Wardlow (F319). Under baseline conditions with no change in WRP discharge, dry season baseflow reduces from 124 cfs to 62 cfs with 100% reduction in dry weather discharge. Solid and dashed lines represent median values; bounds of the gray and colored bands are the 10th and 90th percentile flows across the modeled period.

Species-based sensitivity curves can be used to evaluate the relative impact of reductions in WRP discharge on specific focal species life stages (Figure 16). At GLEN, under baseline conditions in the dry season, average annual probability of occurrence for Typha adult is approximately 50%. Any reductions to WRP discharge will cause a decline in probability of occurrence. If using species-based sensitivity curves, managers need to determine the probability thresholds to aim for (e.g., 52% to 48% probability) and the range in seasonal WRP discharge associated with those thresholds. Alternatively, the proposed change in WRP discharge could be used to determine the change in probability of occurrence, for example reducing the WRP discharge by half would reduce the probablity of occurrence from 51% to 46%. In this example a 50% reduction in WRP flows would result in a change of less than 10% in the probability of occurrence. Web links to all species-based sensitivity curves can be found in Appendix A and a user-friendly application is being developed to evaluate sensitivity curves based on the proposed decision processes.

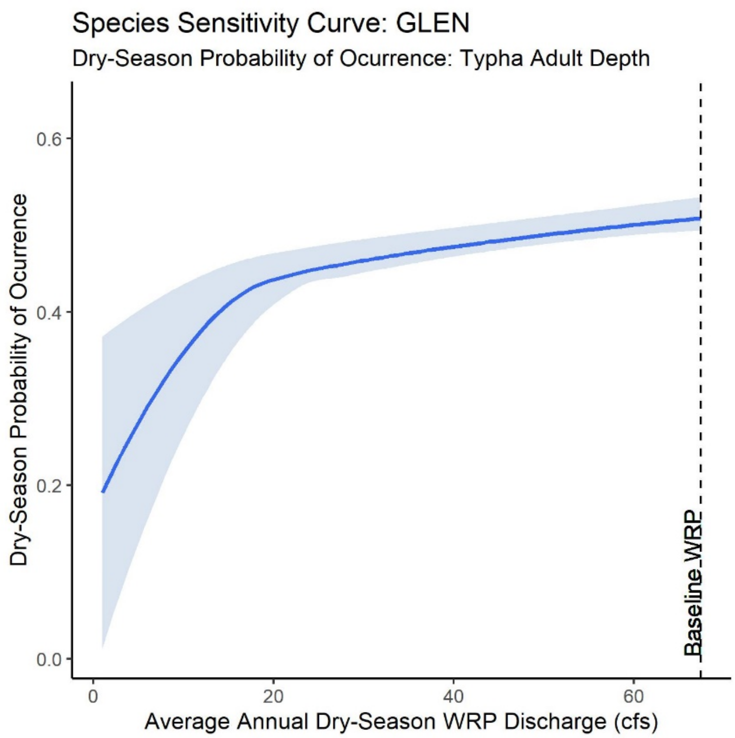

Figure 16. Species-based sensitivity curve relating changes in average annual dry-season WRP discharge with Typha adult habitat suitability at GLEN reporting node. The limiting hydraulic factor for Typha adult at GLEN during the dry season was depth. Solid line represents the median habitat suitability; blue band is the 10th and 90th percentile of habitat suitability across the modeled period.

Stormwater and Dry Weather Discharge

The effects of changes to WRP discharge as well as reductions in dry weather stormdrain discharges is illustrated at GLEN for water year 2012 (Figure 17). Results show that reductions in WRP flows have a larger impact on overall discharge than reductions in dry weather stormdrain discharge. The baseline (no reductions), 100% reduction in dry weather stormdrain discharge, 100% reduction in WRP flows, and 100% reduction in both sources of flow have median daily flow values of 96 cfs, 76 cfs, 21 cfs, and 1.3 cfs, respectively. Thus, while reductions in WRP flows lowers the median flow in 2012 by around 75 cfs, reductions in dry weather stormdrain discharge lowers the median flow by only 20 cfs. The implications of combining multiple management types across varying sources of flows may need to be considered when assessing the impact on species.

Peaks that are greater than ~100 cfs are considered storm flows. Managing storm flows with BMPs does not have an impact on inter-storm flows, which are driven by WRP and dry weather stormdrain discharge.

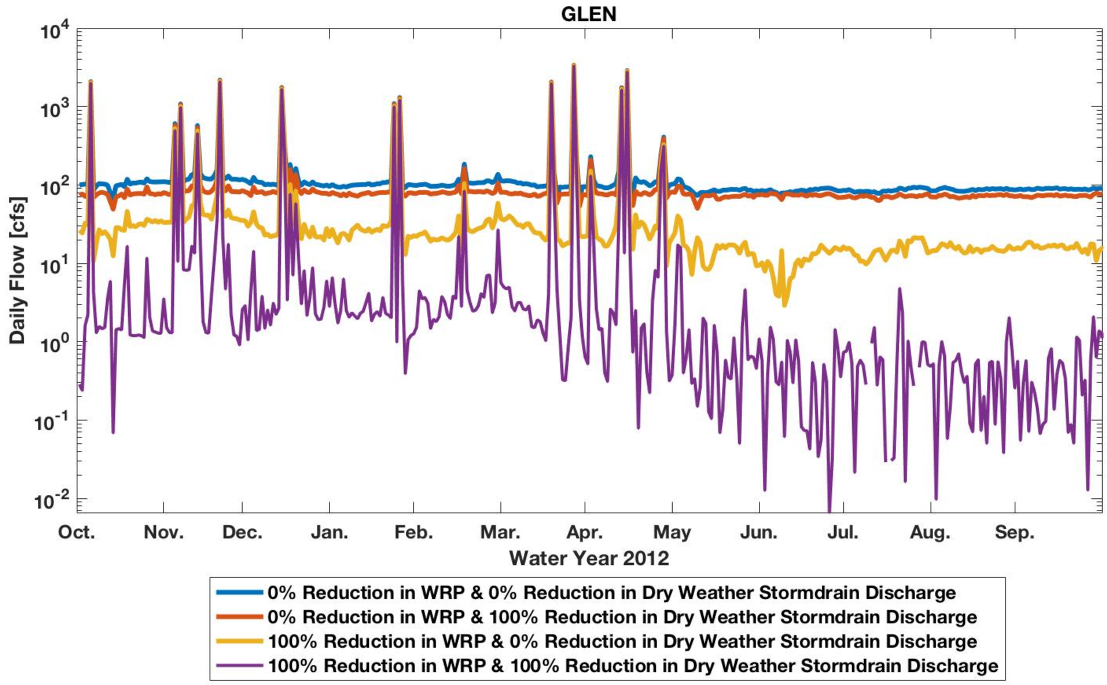

Figure 17. Example of combined impacts of reduction in WRP and dry weather stormdrain discharge flows. Order of lines within the plot (top to bottom) correspond to the order of lines in the legend. Note the log scale.

Results at GLEN for all 45 discrete scenarios that include WRP discharge reductions, dry weather stormdrain discharge reductions, and stormwater BMPs are shown in Figure 18 and Table 8. The average annual flow volume across all simulated water years was used to compare the relative performance of all scenarios. The WRP, dry weather stormdrain discharge, and BMP scenarios are applied independently in the model (Figure 8). For example, 100% reduction in dry weather stormdrain discharge with no BMPs and 0% reduction in WRP shows the volume of water that is reduced due to removing only dry weather inter-storm runoff (not storm) and industrial discharges. Similarly, the aggressive infiltration BMP scenario with 0% reduction in WRP and 0% reduction in dry weather stormdrain discharge shows the volume of water that is reduced by only capturing storm flows under the aggressive BMP implementation rate with infiltration based BMPs.

Results at GLEN show that reductions in WRP also have a larger impact on average annual flow than reductions in dry weather stormdrain discharge. While a 100% reduction in WRP flows results in a decrease of 51,000 AF (2.223 billion cubic feet), a 100% reduction in dry weather stormdrain discharge flows only results in a decrease of 17,800 AF (0.776 billion cubic feet). However, the relative impacts of reductions in WRP and dry weather stormdrain discharge vary spatially throughout the LA River. Results at LA20 (Appendix C) show that reductions in discharge are solely due to reductions in dry weather stormdrain discharge as there are no WRP discharges upstream of LA20. Results at F319 (Appendix C and Table 9) demonstrate that various combinations of discharge management (WRP and dry weather stormdrain discharge) will achieve similar average annual flow volume goals. For example, 100% reduction in WRP and 0% reduction in dry weather stormdrain discharge, 50% reduction in WRP and 50%

reduction in dry weather stormdrain discharge, and 0% reduction in WRP and 100% reduction in dry weather stormdrain discharge all have an average annual flow volume value close to seven billion cubic feet per year.

Results at GLEN demonstrate that varying BMP management scenarios will achieve similar average annual flow volume goals (Figure 18 and Table 8). For example, under 0% WRP reduction the 100% dry weather stormdrain discharge reduction without BMPs scenario has a similar average annual flow volume value as 50% reduction in dry weather stormdrain discharge with infiltration based BMPs and an aggressive BMP implementation plan (100,000 and 103,000 AF, respectively). BMP scenarios perform relatively the same with non-infiltration based BMPs and a conservative BMP implementation plan removing the lowest volume of water relative to baseline (no BMPS) and infiltration based BMPs with an aggressive BMP implementation plan removing the largest volume of water relative to baseline. This is seen across all WRP and dry weather stormdrain discharge reduction scenarios as well as at every reporting node.

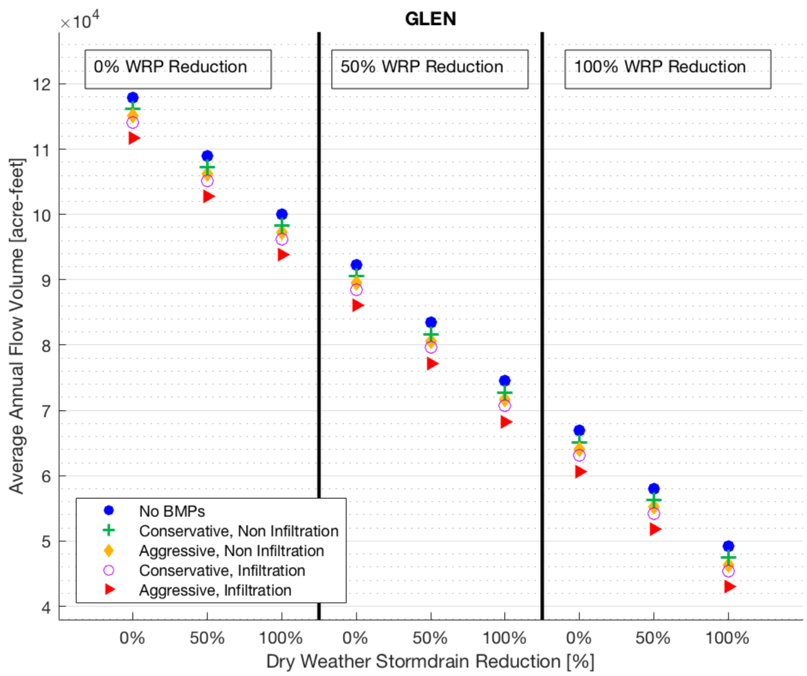

Figure 18. A visual comparison of average annual flow volumes (acre-feet) for all 45 discrete scenarios at GLEN.

Table 8. Average annual flow volumes values for all 45 discrete scenarios in acre-feet at GLEN.

WRP Reduction		0% WRP Reduction			50% WRP Reduction			100% WRP Reduction		
Dry Weather Stormdrain Reduction		0%	50%	100%	0%	50%	100%	0%	50%	100%
Average Annual Flow Volume (acre-feet)	No BMPs	117,932	108,997	100,062	92,321	83,416	74,511	66,890	58,040	49,190
	Conservative, Non-Infiltration	116,196	107,261	98,327	90,583	81,681	72,776	65,154	56,304	47,454
	Aggressive, Non-Infiltration	115,104	106,169	97,234	89,493	80,588	71,683	64,051	55,211	46,364
	Conservative, Infiltration	114,123	105,188	96,254	88,513	79,608	70,703	63,081	54,233	45,383
	Aggressive, Infiltration	111,713	102,778	93,845	86,102	77,197	68,294	60,673	51,823	42,975
	Color Coding	Higher Average Annual Flow Volume			<------------------------------->			Lower Average Annual Volume		

Table 9. Average annual flow volume values for all 45 discrete scenarios in acre-feet at F319.

WRP Reduction		0% WRP Reduction			50% WRP Reduction			100% WRP Reduction		
Dry Weather Stormdrain Reduction		0%	50%	100%	0%	50%	100%	0%	50%	100%
Average Annual Flow Volume (acre-feet)	No BMPs	211,302	186,364	161,440	185,698	160,802	135,889	160,262	135,400	110,558
	Conservative, Non Infiltration	206,451	181,497	156,566	180,831	155,923	131,015	155,395	130,533	105,696
	Aggressive, Non Infiltration	203,306	178,352	153,421	177,686	152,778	127,870	152,250	127,388	102,544
	Conservative, Infiltration	200,871	175,919	150,827	175,253	150,345	125,434	149,817	124,954	100,108
	Aggressive, Infiltration	194,078	169,123	144,192	168,458	143,549	118,641	143,021	118,173	93,317
	Color Coding	Higher Average Annual Flow Volume			<---------------------------------->			Lower Average Annual Volume		

CONCLUSIONS AND NEXT STEPS

The goal of this project was to develop a set of tools that State and local water managers can use to evaluate potential effects of changes in WRP discharge and stormdrain outflows on instream flows and the potential effect on support of currently designated and possible future beneficial uses based on current channel morphology. The relationship between flow and beneficial uses does not account for the effect of factors such as substrate, temperature, water quality, or mechanical channel maintenance activities, and therefore flow management alone may not support the focal species even if the calculated optimal flows were to exist. For example, actions to reduce invasive species in the LA River would be an important element of any plan aimed at supporting native species and habitats.

The goal of this project was not to provide a definitive set of flow targets, but to provide tools that can be used by managers and stakeholders to evaluate potential effects of future changes in flow. Staff in the State Water Board's Division of Water Rights may use the tools developed by this study as non-binding guidance to inform the processing of future Water Code section 1211 wastewater change petitions. This may include evaluating different flow scenarios and proposed reductions due to recycling and how those changes impact beneficial uses. If the State Water Board ultimately elects to adopt flow management targets, such targets may be the subject of a future rulemaking. As part of a possible future rulemaking, the State Water Board may elect to set flow management targets that vary seasonally or be based on water year type (i.e., wet vs. dry) that could be achieved through various combinations of management actions that collectively produce the desired in-river conditions. Flow management targets developed using the tools created through this process would be one component of a larger evaluation considering all aspects of a proposed project that would ultimately set flow criteria in consideration of multiple management objectives for the LA River.

Moving forward, additional work is ongoing by the study team to assess potential water quality implications of changes in discharges and effects of potential restoration actions. This study assumed no changes to the physical condition of the river; however, future phases can further explore the relationship between changes in discharge and proposed restoration actions, such as creation of in-channel pools or other refugia, changing roughness, etc. Future work will also investigate opportunities to use habitat restoration in tributaries to the LA River to offset potential adverse effects of changing flow on habitats in the mainstem of the river. Such restoration opportunities may allow for provision of beneficial uses in areas where they can be supported in a more sustainable manner and could be used to demonstrate opportunities to restore sections of the watershed to more natural conditions and support the need for local water supply and groundwater replenishment. Finally, we plan to develop a monitoring and adaptive management program that can be used to assess the effects of changes in discharge on instream beneficial uses.

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Appendix A. Flow-based and Species-based Sensitivity Curves

A suite of flow-based and species-based sensitivity curves were developed for the WRP and dry weather stormdrain discharge scenarios.

WRP Discharge Scenarios

A total of 22 flow-based sensitivity curves for the WRP scenarios for wet-season baseflow magnitude (wet-season 10th percentile flow magnitude) and dry-season baseflow magnitude (dry-season 50th percentile flow magnitude) were developed and will be available through the Shiny App. Solid lines represent median percentile flows; bounds of the grey and colored bands are the 10th and 90th percentile baseflows across the modeled period. The plots are also available at: https://sccwrp.sharepoint.com/:f:/s/LARiverEflowsStudy/EgJAr4I0Yu5HoD37ICJRvV0BcG9d1JJO6HPe8VGdKwIcyg?e=seYqq3

A total of 83 species-based sensitivity curves for the WRP scenarios for wet-season habitat suitability and dry-season habitat suitability were developed and will be available through the Shiny App. Solid lines represent median habitat suitability; bounds of blue are the 10th and 90th percentile habitat suitability across the modeled period. The plots are also available at:

https://sccwrp.sharepoint.com/:f:/s/LARiverEflowsStudy/En0e0gVemzRGhoqK4AycdcgBrWuiQXcFYD8TECIOsE6ajg?e=iLw7i8

Dry Weather Stormdrain Scenarios

A total of 44 flow-based sensitivity curves illustrating the combined effects of change in WRP discharge (gray) and 50% (yellow) and 100% reduction (red) in dry weather stormdrain discharge for wet-season and dry-season baseflow magnitude were produced and will be available through the Shiny App. Solid and dashed lines represent median baseflow values; bounds of the grey and colored bands are the 10th and 90th percentile baseflows across the modeled period. For Santa Ana sucker, the maximum probability of occurrence was 0.4, therefore, the curves were rescaled to a 0-1 range to promote comparison between species. The plots are also available at:

https://sccwrp.sharepoint.com/:f:/s/LARiverEflowsStudy/EqKjLBIvbDxBrzVvtShU5SwBYLAa4_Mf_l6Opv5QMPEeMQ?e=7R0bgn

A total of 83 species-based sensitivity curves illustrating the combined effects of change in WRP discharge (blue) and 50% (yellow) and 100% reduction (red) in dry weather stormdrain discharge for wet-season and dry-season habitat suitability were produced and will be available through the Shiny App. Solid and dashed lines represent median habitat suitability; bounds of the grey and colored bands are the 10th and 90th percentile habitat suitability across the modeled period For Santa Ana sucker, the maximum probability of occurrence was 0.4, therefore, the curves were rescaled to a 0-1 range to promote comparison between species. The plots are also available at:

https://sccwrp.sharepoint.com/:f:/s/LARiverEflowsStudy/EiWEN6KGP55FheaipWdixs8BKdjA7YTOwb86t7Qi1ChbzA?e=bMHtW8

APPENDIX B. STORMWATER MANAGEMENT METHODS

BMP Implementation rates (LADWP 2015) were used to determine the area of land routed to BMPs in SUSTAIN for each watershed. Table B-1 displays implementation rates across varying land use types and geophysical categories for the conservative and aggressive scenarios. The conservative and aggressive BMP implementation rates are based on political, financial, and social opportunities or boundaries that shape future potential stormwater capture.

Table B-1. Implementation rates used to determine the area of land routed to BMPs in SUSTAIN.

	Conservative Scenario			Aggressive Scenario		
Geophysical Category	A	B	C	A	B	C
High Density Single-family	35%	25%	15%	50%	40%	30%
Low Density Single-family	30%	20%	10%	40%	30%	20%
Multi-family	35%	25%	15%	50%	40%	30%
Commercial	37%	27%	17%	55%	45%	35%
Institutional	57%	47%	37%	95%	85%	75%
Industrial	50%	40%	30%	80%	70%	60%
Transportation	52%	42%	32%	85%	75%	65%
Secondary Roads	47%	37%	27%	75%	65%	55%

To calculate the area of land routed to BMPs (Eq. B-1) under the conservative and aggressive approach, geophysical categorization, land use area, and percent imperviousness spatial data is needed for each subwatershed within the SUSTAIN model. Subwatersheds for SUSTAIN were first delineated based on reporting nodes (Figure B-1).

$$Area\ routed\ to\ aggregate\ BMP_{i,k} = \sum(A_{i,j} * Imp_{i,j} * Rate_{i,j,k}) \qquad \text{(Eq. B-1)}$$

Where:

A = Land use area

Imp = Percent Imperviousness

Rate = Geophysical Category Implementation Rate

i = SUSTAIN reporting node subwatershed

j = Applicable land use type

k = Conservative and Aggressive Scenario

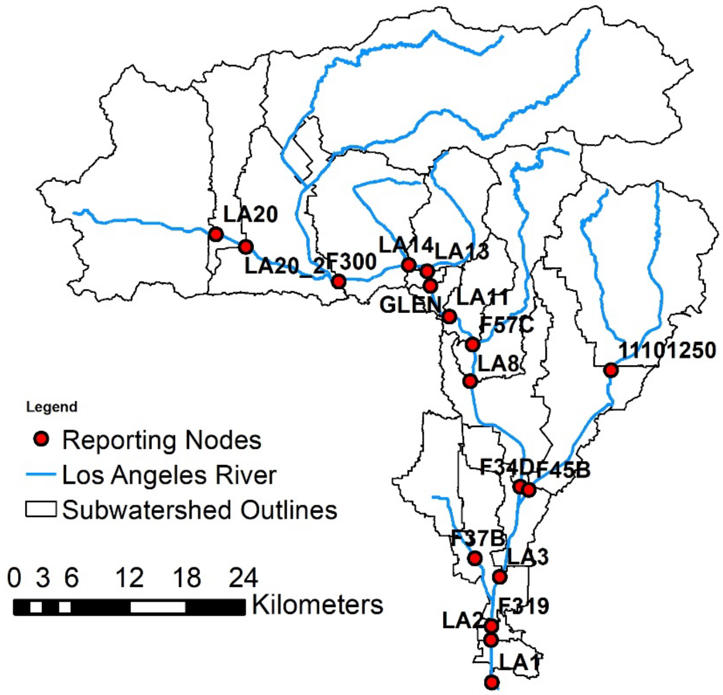


Figure B-1. SUSTAIN model domain. Subwatersheds were delineated in respect to reporting nodes.

Geophysical categories (A, B, C in Table B-1) are based on the infiltration potential of the area based on geophysical obstacles and aquifer class (LADWP 2015). Each subwatershed was assigned one geophysical categorization (A, B, or C). The geophysical categorization map was acquired from the California Department of Water Resources GIS Data Portal and loaded into ArcMap (DWR Atlas 2015). The geophysical category for each subwatershed was determined by overlaying the geophysical categorization GIS layer with the SUSTAIN subwatershed delineation map (Figure B-2A) and identifying the dominant geophysical category in each subwatershed (Figure B-2B). As the SCMP only includes the area within the LA City Boundaries, SUSTAIN subwatersheds that exist outside these boundaries were defaulted to the medium geophysical category, B.

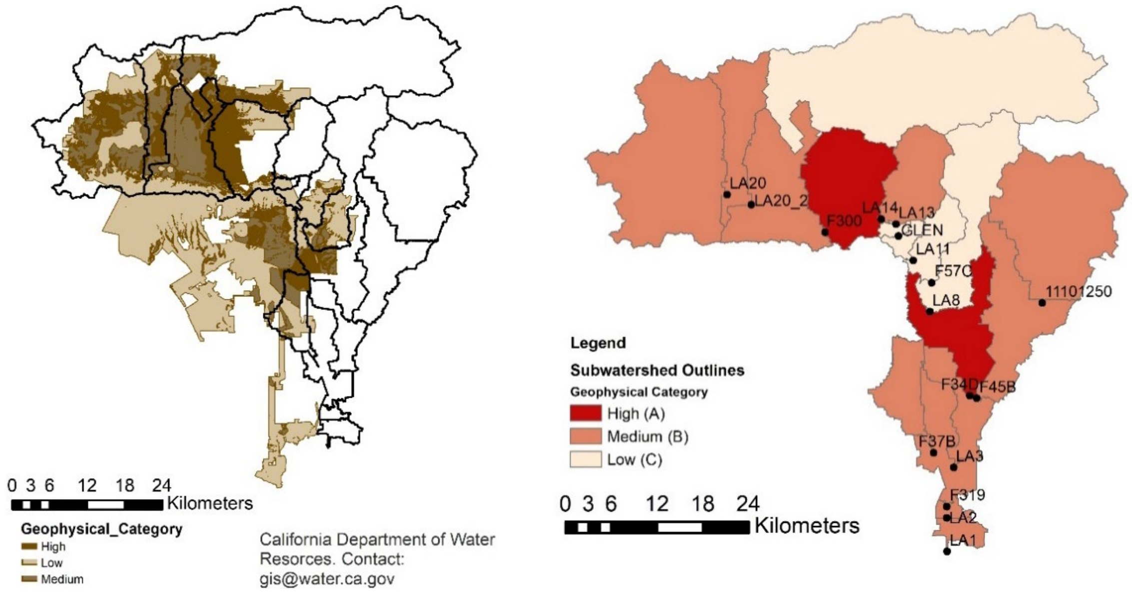


Figure B-2. A (left) shows the SCMP geophysical category map with the delineated SUSTAIN reporting node subwatersheds. B (right) shows the dominant geophysical category within each subwatershed. Subwatersheds that do not overlap were automatically set to medium.

Land use data (2016) from Southern California Association of Governments was used in GIS to calculate the area of each land use type within each subwatershed (SCAG 2016). Applicable land use types from SCAG include those that overlap with Table B-1 . An impervious cover layer developed for the Watershed Management Modeling System (WMMS) model was used to calculate the total area of impervious cover within each applicable land use type (Los Angeles County Flood Control District 2020). See Figure B-3 for an example of the land use and impervious cover data for reporting node LA20 subwatershed.

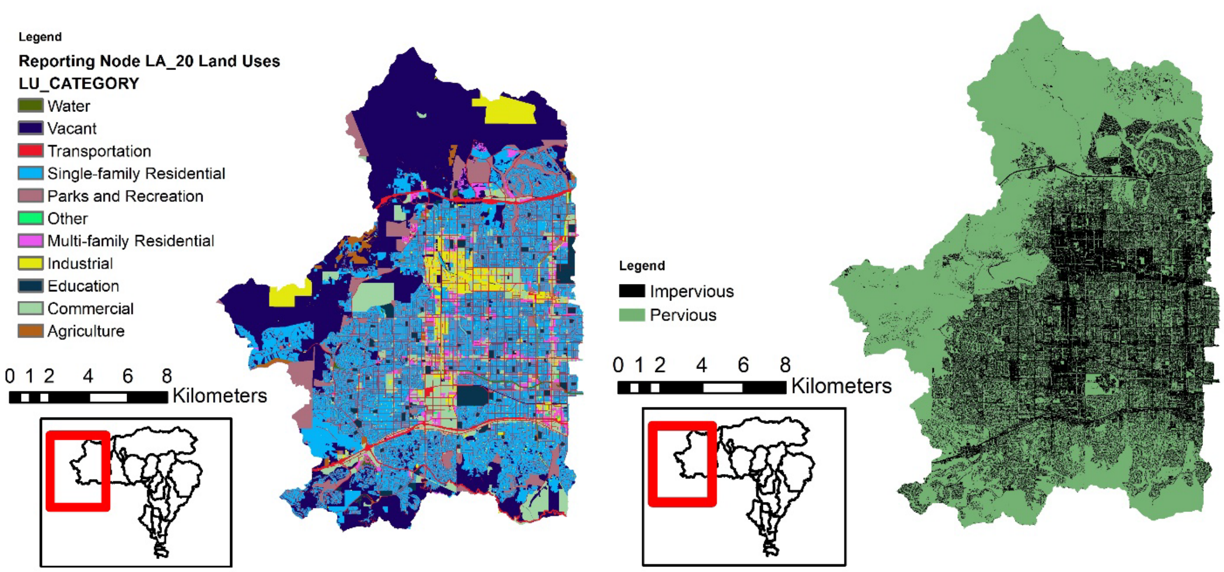
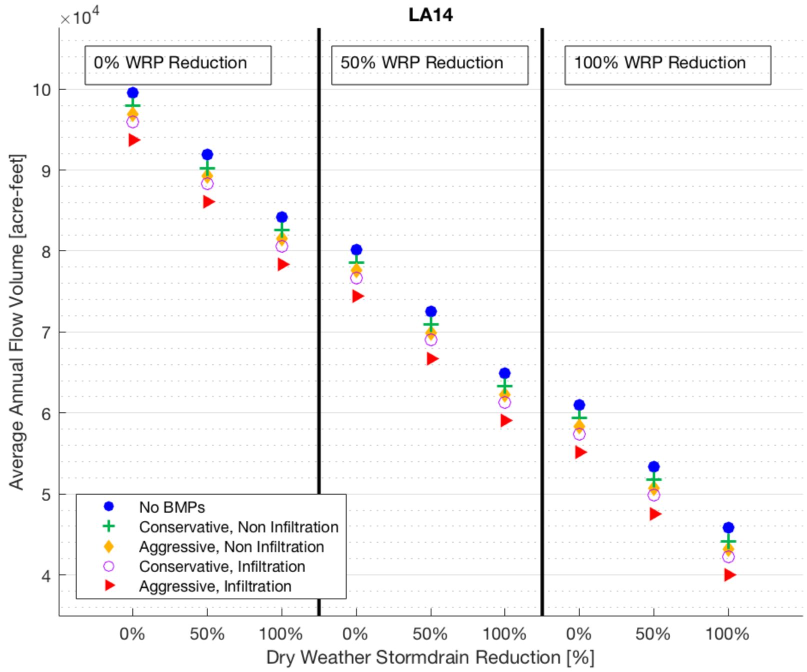
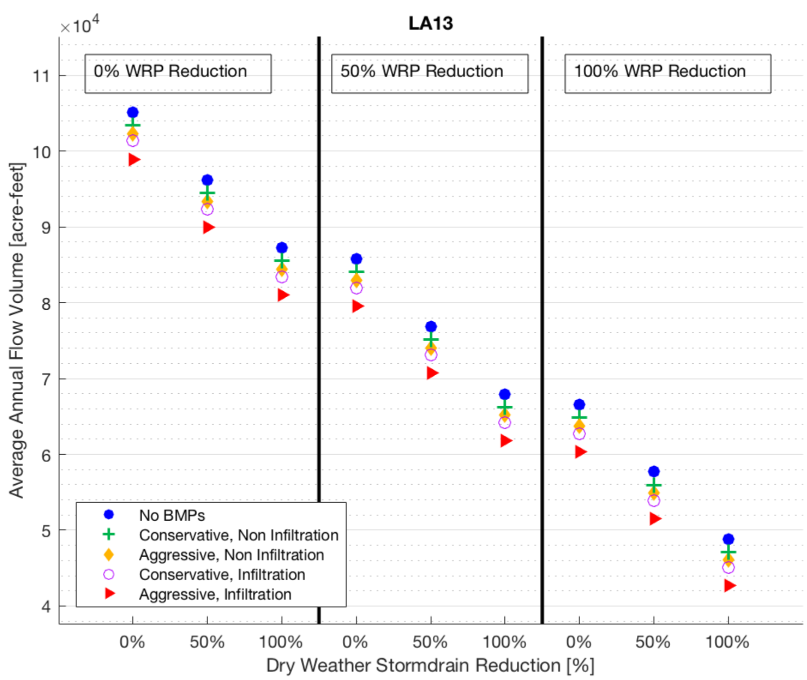
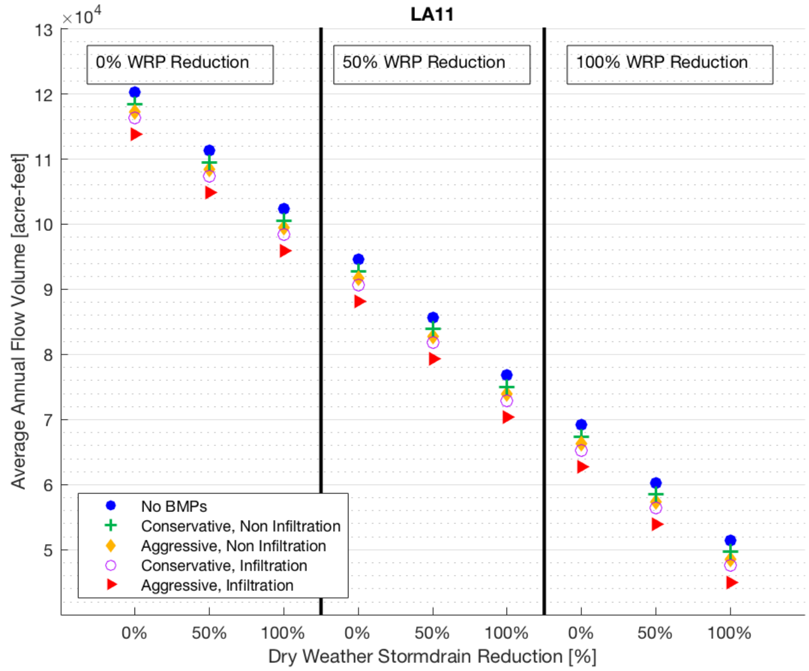


Figure B-3. A (left) shows an example of the SCAG land use data set in the LA20 subwatershed. B (right) shows an example of the WMMS impervious surface data set in the LA20 subwatershed.

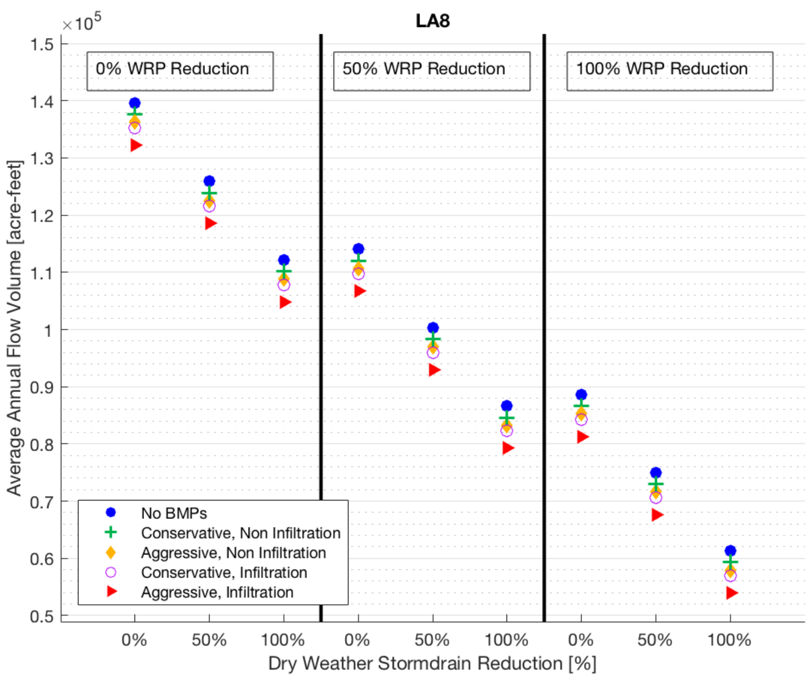
APPENDIX C. STORMWATER AND DRY WEATHER DISCHARGE PLOTS



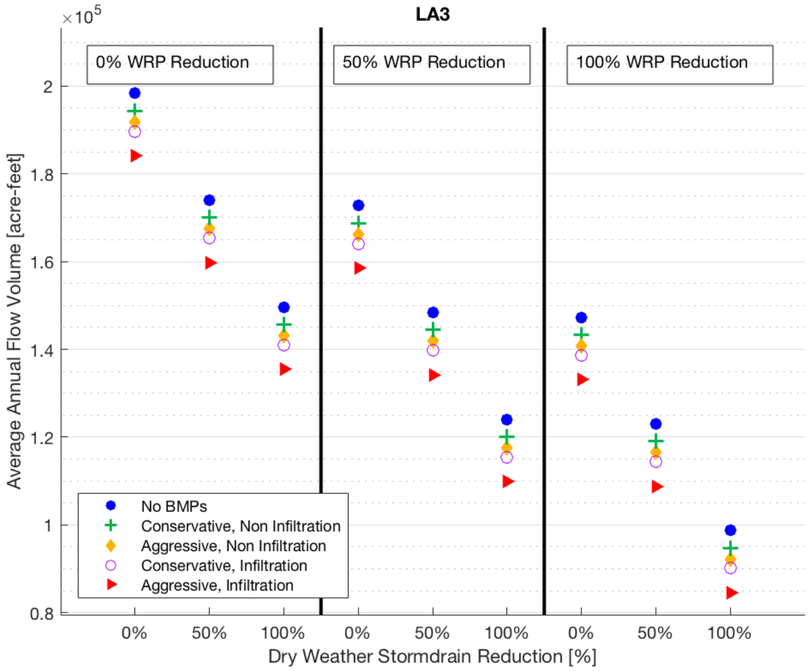




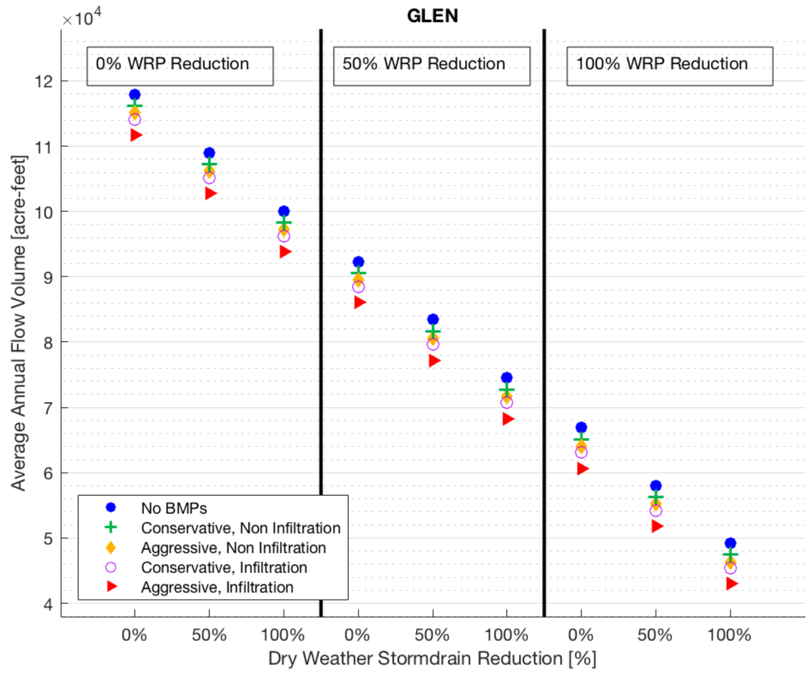
LA11
×10^4
0% WRP Reduction
50% WRP Reduction
100% WRP Reduction
Average Annual Flow Volume [acre-feet]
13
12
11
10
9
8
7
6
5
No BMPs
Conservative, Non Infiltration
Aggressive, Non Infiltration
Conservative, Infiltration
Aggressive, Infiltration
0%
50%
100%
0%
50%
100%
0%
50%
100%
Dry Weather Stormdrain Reduction [%]



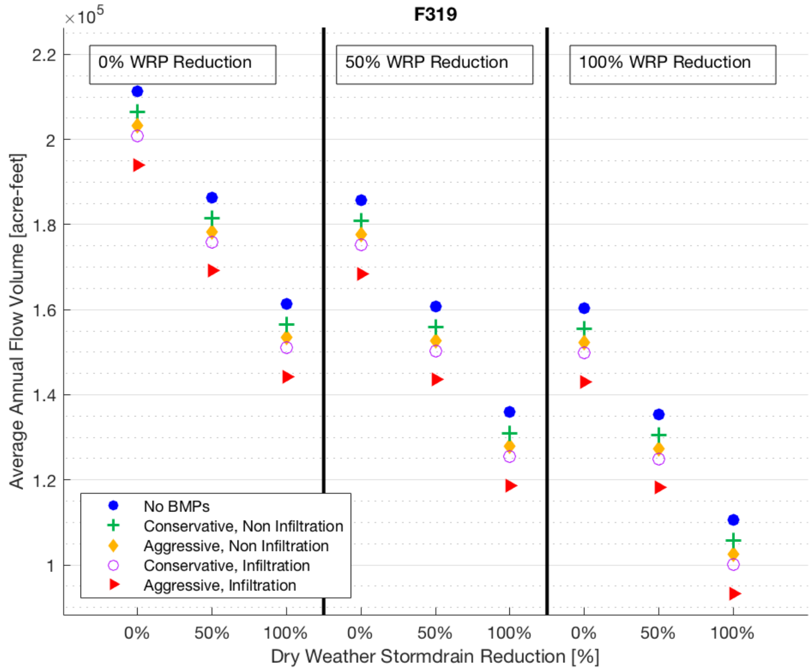
LA8
×10^5
0% WRP Reduction
50% WRP Reduction
100% WRP Reduction
Average Annual Flow Volume [acre-feet]
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
No BMPs
Conservative, Non Infiltration
Aggressive, Non Infiltration
Conservative, Infiltration
Aggressive, Infiltration
0%
50%
100%
0%
50%
100%
0%
50%
100%
Dry Weather Stormdrain Reduction [%]



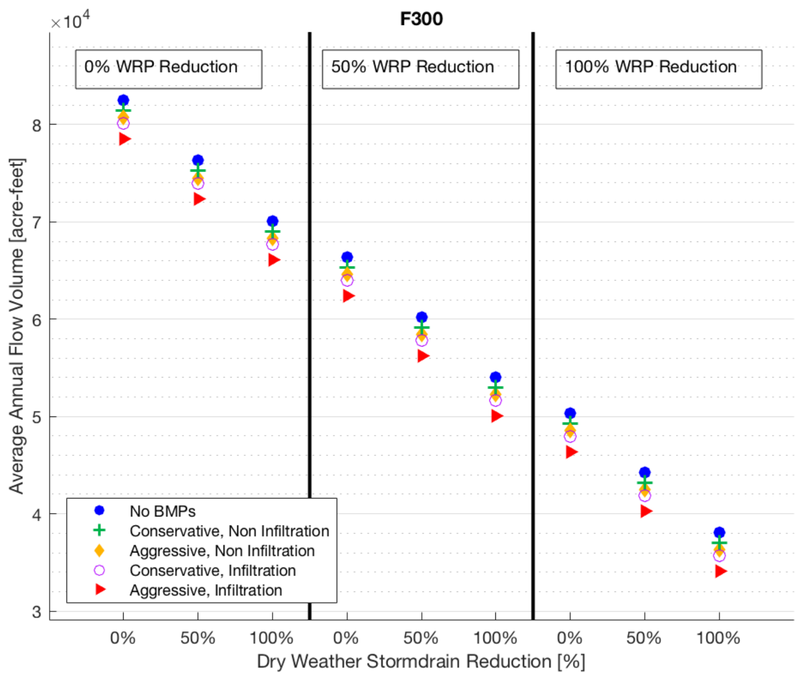
×10^5
LA3
0% WRP Reduction
50% WRP Reduction
100% WRP Reduction
Average Annual Flow Volume [acre-feet]
2
1.8
1.6
1.4
1.2
1
0.8
No BMPs
Conservative, Non Infiltration
Aggressive, Non Infiltration
Conservative, Infiltration
Aggressive, Infiltration
0% 50% 100% 0% 50% 100% 0% 50% 100%
Dry Weather Stormdrain Reduction [%]



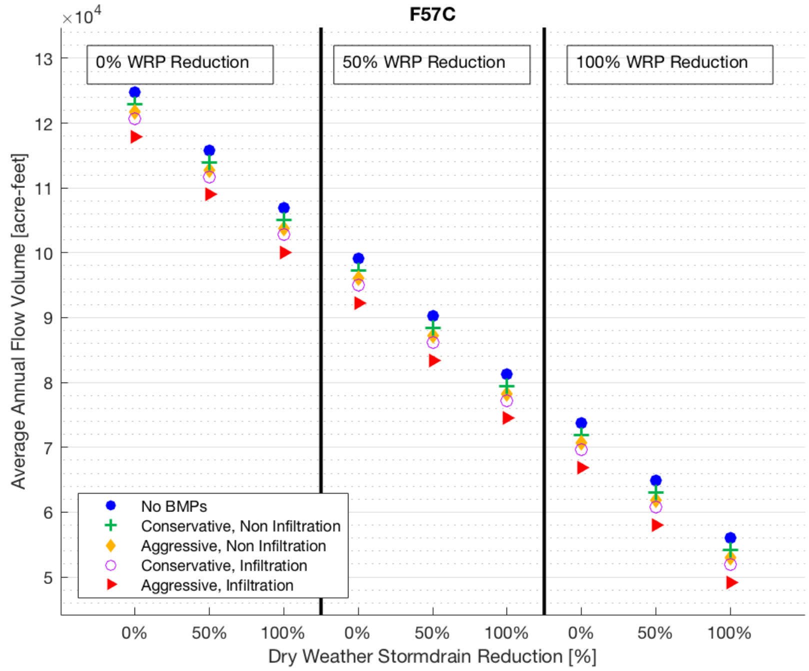
×10^4
GLEN
0% WRP Reduction
50% WRP Reduction
100% WRP Reduction
Average Annual Flow Volume [acre-feet]
12
11
10
9
8
7
6
5
4
No BMPs
Conservative, Non Infiltration
Aggressive, Non Infiltration
Conservative, Infiltration
Aggressive, Infiltration
0% 50% 100% 0% 50% 100% 0% 50% 100%
Dry Weather Stormdrain Reduction [%]



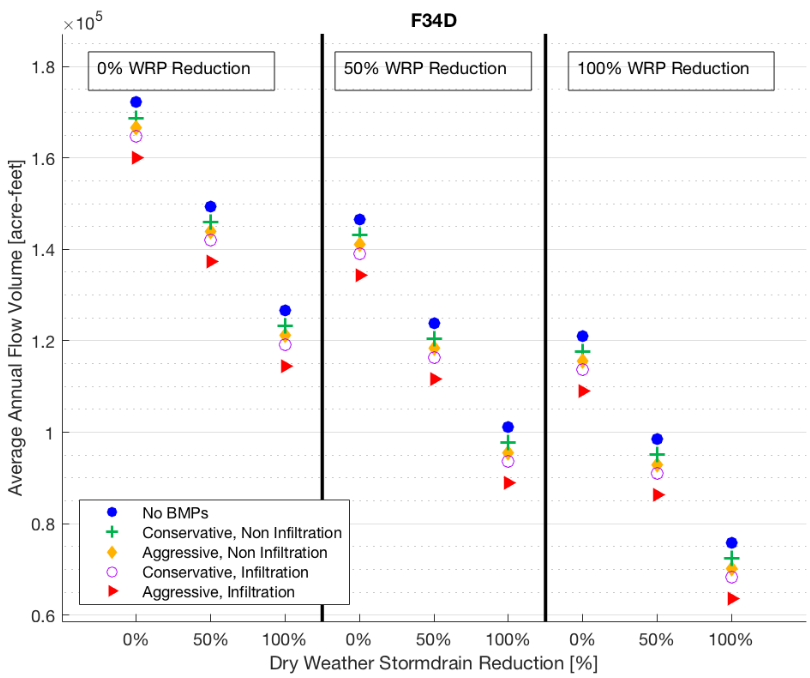
F319
×10^5
0% WRP Reduction
50% WRP Reduction
100% WRP Reduction
Average Annual Flow Volume [acre-feet]
2.2
2
1.8
1.6
1.4
1.2
1
No BMPs
Conservative, Non Infiltration
Aggressive, Non Infiltration
Conservative, Infiltration
Aggressive, Infiltration
0% 50% 100% 0% 50% 100% 0% 50% 100%
Dry Weather Stormdrain Reduction [%]



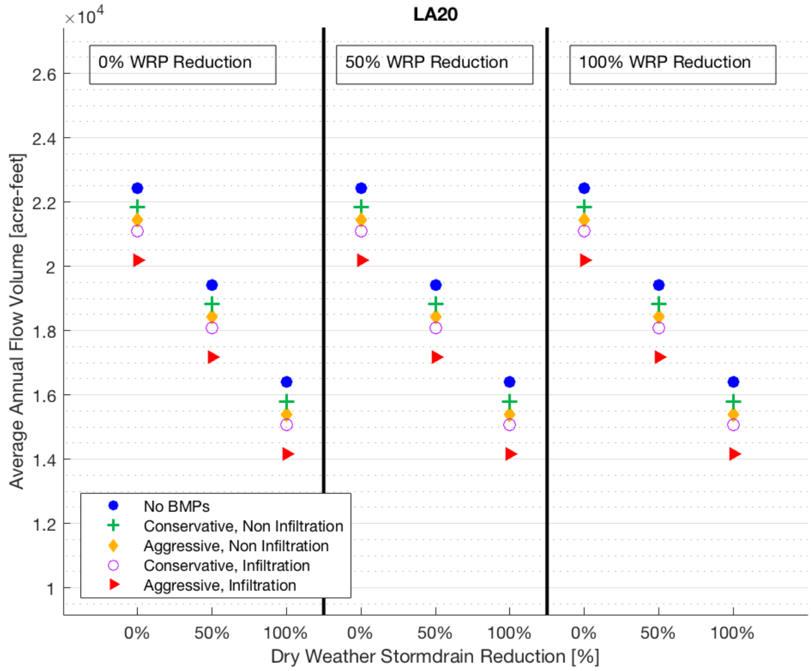
F300
×10^4
0% WRP Reduction
50% WRP Reduction
100% WRP Reduction
Average Annual Flow Volume [acre-feet]
8
7
6
5
4
3
No BMPs
Conservative, Non Infiltration
Aggressive, Non Infiltration
Conservative, Infiltration
Aggressive, Infiltration
0% 50% 100% 0% 50% 100% 0% 50% 100%
Dry Weather Stormdrain Reduction [%]



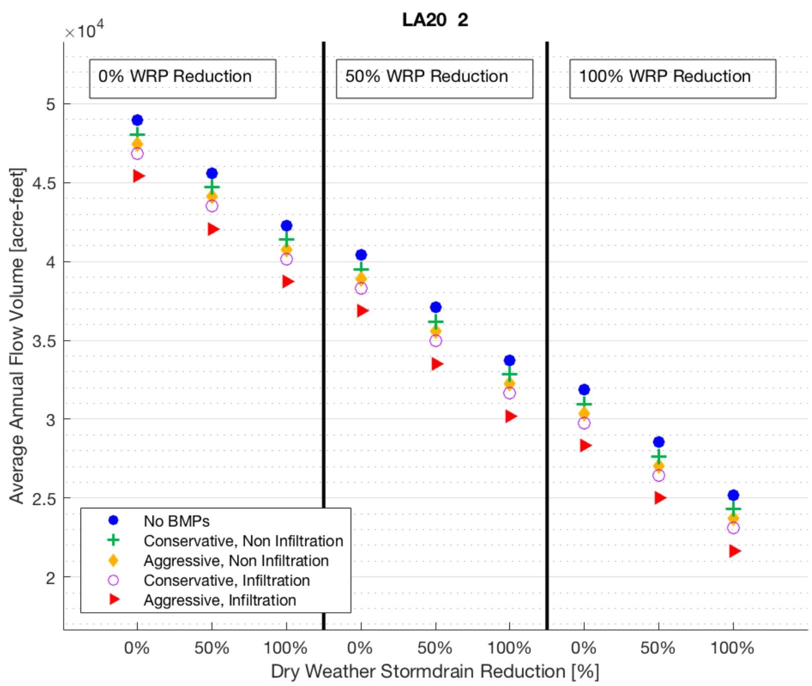
F57C
×10^4
0% WRP Reduction
50% WRP Reduction
100% WRP Reduction
Average Annual Flow Volume [acre-feet]
13
12
11
10
9
8
7
6
5
No BMPs
Conservative, Non Infiltration
Aggressive, Non Infiltration
Conservative, Infiltration
Aggressive, Infiltration
0% 50% 100% 0% 50% 100% 0% 50% 100%
Dry Weather Stormdrain Reduction [%]



F34D
×10^5
0% WRP Reduction
50% WRP Reduction
100% WRP Reduction
Average Annual Flow Volume [acre-feet]
1.8
1.6
1.4
1.2
1
0.8
0.6
No BMPs
Conservative, Non Infiltration
Aggressive, Non Infiltration
Conservative, Infiltration
Aggressive, Infiltration
0% 50% 100% 0% 50% 100% 0% 50% 100%
Dry Weather Stormdrain Reduction [%]



LA20
×10^4
0% WRP Reduction
50% WRP Reduction
100% WRP Reduction
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
Average Annual Flow Volume [acre-feet]
No BMPs
Conservative, Non Infiltration
Aggressive, Non Infiltration
Conservative, Infiltration
Aggressive, Infiltration
0%
50%
100%
0%
50%
100%
0%
50%
100%
Dry Weather Stormdrain Reduction [%]



LA20 2
×10^4
0% WRP Reduction
50% WRP Reduction
100% WRP Reduction
5
4.5
4
3.5
3
2.5
2
Average Annual Flow Volume [acre-feet]
No BMPs
Conservative, Non Infiltration
Aggressive, Non Infiltration
Conservative, Infiltration
Aggressive, Infiltration
0%
50%
100%
0%
50%
100%
0%
50%
100%
Dry Weather Stormdrain Reduction [%]