The South Orange County, California Flow Ecology Study: Part 1, Watershed Hydrology

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Highlights

- A watershed model was created and calibrated for the entirety of the annual hydrograph, including winter runoff and baseflow, spring recession, and summertime base flows.
- For baseflow analysis, it specifically focused on the relative contributions of groundwater and imported water, which was calibrated using stable isotope data.
- Based on the calibrated model, three scenarios were evaluated, including non-anthropogenic reference condition, climate change projections, and water conservation projections.

Introduction

The Public Works department of Orange County, California, on behalf of a group of municipal stormwater permittees in the southern half of the county, is conducting a “Flow Ecology Special Study” for six watersheds in the South OC Watershed Management Area (WMA). Its goals are the quantification of unnatural flows and development of relationships between levels of flow alteration and in-stream beneficial uses (or ecological condition). This will inform prioritization and design of flow management and stream rehabilitation projects. The study aims to develop tools and datasets to support future projects, including (1) recovery of stream ecosystems from negative impacts of urbanization and (2) increased resilience of ecological communities during a drier future. This study was divided into two parts: watershed hydrology and flow ecology approaches for flow management prioritization. This presentation will focus on watershed hydrology modeling, and a companion, “Part 2” presentation will focus on the flow ecology components of the study.

Methodology

A continuous simulation Loading Simulation Program in C++ (LSPC) model was developed and calibrated for the San Juan Hydrologic Unit in Southern Orange County, California. This hydrologic unit includes several major streams, including San Juan Creek, Trabuco Creek, Oso Creek, Aliso Creek, Laguna Canyon Creek, Salt Creek, and Segunda Deshecha Creek. For modeling purposes, this area was divided into about 80 subwatersheds and stream segments, including areas that are heavily urbanized and areas that remain mostly natural. Calibration and analysis focused on the more urbanized land areas and stream reaches of these watersheds.

Model Forcing and Parameterization

Present-day conditions were simulated for 1993-2019 using LSPC. The model was forced by 16 continuous, hourly precipitation records and 2 continuous, hourly evapotranspiration records that spanned 1989-2019. Land use was assigned in LSPC as “hydrologic response units” (HRUs), which are unique combinations of land use, soil type, land slope, and perviousness. Characteristics of stream reaches were assigned using LiDAR data sets, and major impoundments were included in the model after examination of available as-built or design drawings. Flow diversions were modeled based on data provided by local water utilities. Outdoor water usage (i.e., landscape irrigation) was estimated based on water usage and sanitary return flow data from 2015-2019, which accounts for current levels of water efficiency measures.

Model Calibration

Three types of data were used during model calibration. Stream gauging records were available during substantial portions of the simulated period for upper Aliso Creek, lower Aliso Creek, lower Oso Creek, and lower Trabuco Creek. Where gauging data were not available, monthly dry-weather measurements conducted manually by OC staff wading into stream channels were used. The period 2015-2019 was used as a calibration period for all reaches because it includes dry weather runoff reductions achieved through municipal water conservation efforts.

Additionally, understanding the source of dry season streamflow (and matching this in the calibration) was important to assess how conditions may change in a future with less outdoor water use and potentially less rainfall. This aspect of the calibration was aided by in-stream stable isotope data that were compared to rainfall and groundwater end-member samples to understand the source of streamflow (e.g., rainwater or imported water used in irrigation).

Model Scenarios

Three scenarios were simulated with the calibrated model. First, a pre-development “Reference Condition” scenario allowed assessment of the degree of current hydrologic alteration. While reestablishing flow regimes to pre-development conditions is not the end goal, this helped determine locations where streams may now support different ecosystems compared to conditions prior to development. These augmented systems may now support valuable ecosystems but may also be more vulnerable to impacts associated with future changes. To understand in more detail the hydrology upon which future projects will rely, two future scenarios were simulated. A future Climate Change scenario evaluated how ecological flow metrics may change based on an ensemble of four climate change projections using the RCP8.5 pathway for the periods 1975-2005 and 2030-2060. A Water Conservation Scenario was developed by consulting with a local water supply district and determining that a likely future scenario involved a 14% reduction in irrigation water application in the model.

Results and Discussion

Model Calibration

Model performance relative to calibration targets is shown for the lower Aliso Creek gauge in Table 1. The calibration was also reasonable at other locations. Stable isotope data revealed that groundwater comprises a significant portion (65-80%) of dry weather flow in most stream reaches, and so model parameterizations of groundwater infiltration and storage were adjusted to match these observations from field samples. Because groundwater infiltration in the rainy season supplied a notable fraction of summertime base flow, calibration of dry-weather streamflow required calibration of the entire yearly hydrograph, including A) high flows during wet periods, B) base flow during wet periods, C) recession following winter storms, D) springtime recession, and, most importantly for this study, E) dry summertime conditions. This calibration is shown graphically as a time series (Figure 1).

Table 1. Statistical targets and hydrologic model performance at the lower Aliso Creek gauge

Constraint	Target	Model Performance[a]	Assessment
Streamflow composition	25-35% imported water in July	32%	Pass
Nash-Sutcliffe Efficiency (NSE)	> 0.5	0.97	Pass
Logarithmic NSE	> 0.5	0.73	Pass
Root-Mean-Squared Error	≤ 0.7	0.18	Pass
Percent bias	± 25	4.1%	Pass

[a] Each statistic was calculated for daily average flow rates.

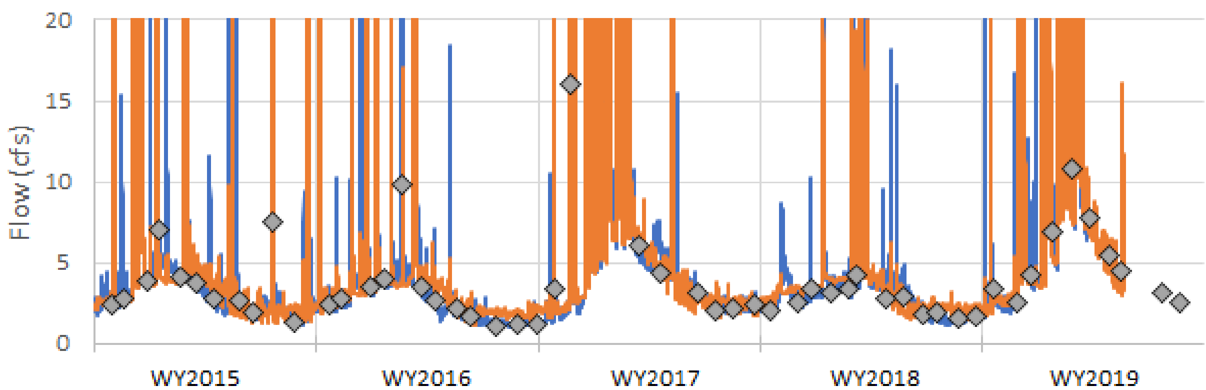

Figure 1. Comparison of observed (blue) and modeled (orange) flow time series at the lower Aliso Creek gauge between 1 October 2014 and 20 May 2019. Model output is shown as a 24-hour moving average. Gray symbols depict monthly flow measurements assessed manually by wading.

Model Scenarios

The Reference Condition Scenario simulated lower streamflows during all months due to greater infiltration and absence of irrigation flows. Due to a wide range in the forecasted impact of climate change on precipitation in Southern California, results of the Climate Change Scenario were highly variable, with average annual discharge volume changing by -28% to 21% (mean = -1%) and median summer stream flow changing by -25% to 14% (mean = -3%). The Water Conservation Scenario led to an 8% reduction in average annual runoff volume and a 31% reduction in median summer flow rate.

Conclusions and Future Work

The creation and calibration of a watershed hydrology model for South Orange County, California revealed the importance of both unnatural dry-weather flows (i.e., landscape irrigation) and natural groundwater seepage on summertime stream flows in coastal streams. The study methods used to characterize this condition may be transferable to other watersheds impacted by urban irrigation runoff. Scenario analyses demonstrated the importance of anthropogenic influences in the watershed management area on stream flows, the ambiguity of future climate change on stream flows in this region, and the relevance of planned water conservation efforts for summertime stream flows. Model results allow a quantitative analysis of ecological flows in this region, which is the focus of the second part of this two-part series.