GUADALUPE WATERSHED MODEL PHASE I: HYDROLOGY MODEL

RMP Pilot Study
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Background

High levels of PCBs and mercury (Hg) have been detected in the Guadalupe River. The Regional Water Quality Control Board (RWQCB), San Francisco Estuary Institute (SFEI) and other agencies have developed an extensive database of concentration of contaminants in water, sediment, and fish tissues in the Guadalupe River watershed. In part based on these data, the Guadalupe River Watershed TMDL identifies mercury fish targets, bed and suspended sediment targets for runoff from mining areas, and load allocations from urban areas. The Bay Hg TMDL calls for Guadalupe River watershed load reductions of 98% and the Bay PCB TMDL calls for load reductions of greater than 95% for urban areas. In response to these regulations on Hg and PCB levels, managers in the Guadalupe River have begun implementing management actions to mitigate contaminant effects. Currently there is no validated linkage between management measures and changes in watershed loading through time.

Objectives

The aim of the Guadalupe Watershed Model project is to understand the source, release, and transport of constituents to San Francisco Bay from the Guadalupe Watershed. Accordingly, a numeric model is being developed to simulate the movement of constituents through the Guadalupe River Watershed. Ultimately the model will be used to assess the effects of best management practices (BMPs) on water quality in the Guadalupe River and San Francisco Bay. This multi-year study has the following key objectives:

Year 1 Develop, calibrate, and validate hydrologic model of Guadalupe Watershed

Year 2 Extend model to include sediment and contaminants (Hg and PCBs)

Year 3 and beyond Model Usage

- Estimate/confirm Hg and PCB loads
- Determine proportional loads
  - when, and from where, are constituents transported
- Refine assumptions of the Hg TMDL
- Assess potential effects of BMPs

Model Selection

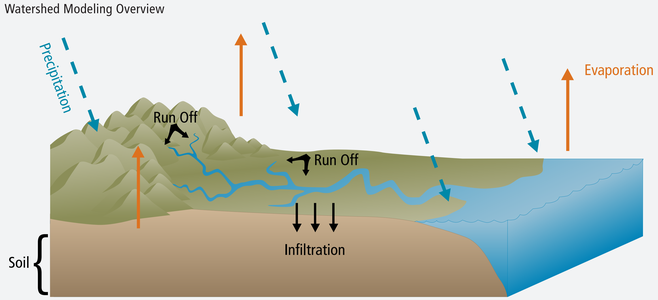
Chosen software:

Hydrological Simulation Program – FORTRAN (HSPF)

Why?

- Represents key watershed and stream processes (Figure 1)
- Includes water quality modules
- U.S. EPA and USGS approved
- Widely used
- Public domain (freely available)

Figure 1.
Watershed Modeling Overview



Model Setup

The entire Guadalupe River Watershed consists of approximately 172 sq. miles in Santa Clara County (Figure 2). The modeled portion is the downstream two-thirds of the overall watershed (103 sq. miles subset). The modeled watershed extends from the set of reservoirs in the San Jose foothills, north though San Jose, to drain into Lower South San Francisco Bay. The watershed is highly gauged for both precipitation (Figure 3) and streamflow (Figure 4).

The process of watershed segmentation divides the modeled area into logical segments, called subbasins (Figure 4), based on topography, drainage patterns, meteorological variability, soil types, land cover and land use (Table 1). Other boundary considerations for subbasins include locations of dams/reservoirs and flow gauges, as well as model objectives, e.g. delineating particular areas of interest for model usage. The purpose of segmentation is to allow for parameterization and model output of local conditions within a watershed. The segmentation process also includes assigning precipitation stations to regions of the model (Figure 3).

GIS Coverage / Map	Source	Comment
Digital Elevation Model (DEM)	USGS	National Elevation Dataset (NED)
Hydrography/Stream Network	USGS	National Hydrographic Dataset (NHD-Plus)
Catchments	USGS	National Hydrographic Dataset (NHD-Plus)
Stormdrain catchments	WLA	Catchment boundaries incorporating stormdrains
Land use	ABAG	ABAG 2000 Existing Land Use data set
Hydrologic soil groups map	SCVWD	based on USDA SCS map
Meteorological stations	SCVWD	-
Streamflow gauges	SCVWD, USGS	-
Reservoirs	SCVWD	-

WLA: William Lettis & Associates, Inc.
ABAG: Association of Bay Area Governments

Table 1.
Data used for watershed segmentation

Figure 2.
Guadalupe Watershed Location

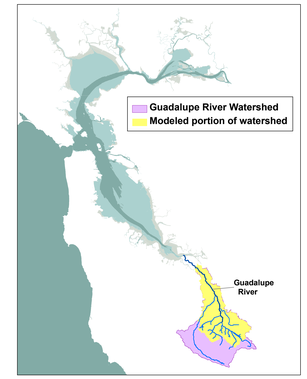


Figure 3.
Precipitation Gauges and Model Segmentation

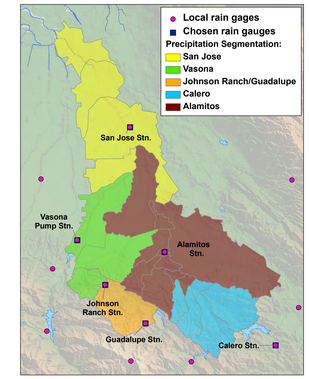
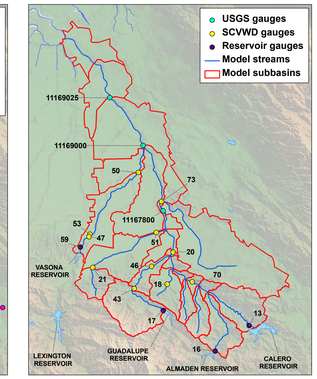


Figure 4.
Streamflow Gauges and Model Setup



Calibration and Validation

Calibration generally involves adjusting soil moisture storage parameters and evapotranspiration parameters until the simulated flow matches the observed flow. However, calibration can also require more major changes such as re-evaluating the model segmentation (e.g. is the appropriate precipitation gauge assigned to a watershed region) or tracking down a diversion removing water from the system being modeled. The validation process evaluates the calibrated model by seeing how well the model performs on data that it was not calibrated to.

The model was calibrated to several upstream locations (data not shown) before being calibrated to the most downstream gauge (USGS #11169025) for WY2003-2005 (Figure 5), followed by validation at the same gauge for WY2006-2007 (Figure 6). The model performs reasonably well for storm events, but underestimates during periods of low flow. The lack of simulated baseflow is more apparent in the flow duration curves (Figure 7 and 8).

The model is underestimating annual flow volumes, especially in drier years such as 2004 and 2007 (Table 2). This overall underestimation of flow volumes is consistent with the underprediction of baseflow.

Calibration				
Water Year	Alamitos Stn. Precipitation (in)	Sim. Flow Volume (10^8 *cf)	Obs. Flow Volume (10^8 *cf)	% Difference
2003	17.6	20.423	21.478	-4.90%
2004	13.2	14.389	18.72	-23.10%
2005	20.5	24.311	25.904	-6.60%
Average	15.2	19.708	22.034	-10.60%

Validation				
Water Year	Alamitos Stn. Precipitation (in)	Sim. Flow Volume (10^8 *cf)	Obs. Flow Volume (10^8 *cf)	% Difference
2006	16.3	43.713	44.735	-2.30%
2007	7.2	8.704	12.595	-30.90%
Average	11.8	26.209	28.665	-8.60%

Table 2.
Annual Simulated and Observed Flow Volumes for Calibration and Validation for Guadalupe River and Annual Precipitation for Alamitos Rain Gauge

Figure 5.
Calibration period (WY2003-2005): Observed and Simulated Flow for Guadalupe River (US GS #11169025) and Alamitos Station Precipitation

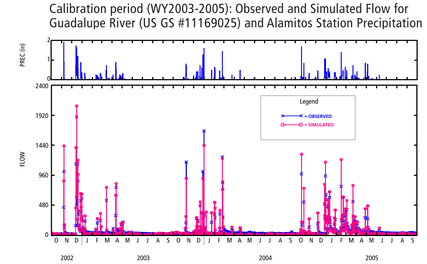


Figure 6.
Validation period (WY2006-2007): Observed and Simulated Flow for Guadalupe River (USGS #11169025) and Alamitos Station Precipitation

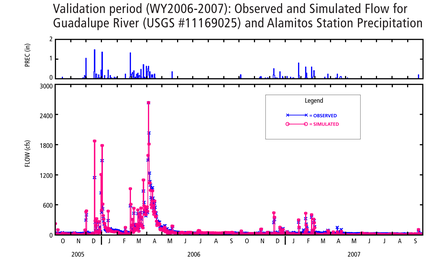


Figure 7.
Calibration period (WY2003-2005): Flow Duration Curve for Observed and Simulated Flow for Guadalupe River (USGS #11169025)

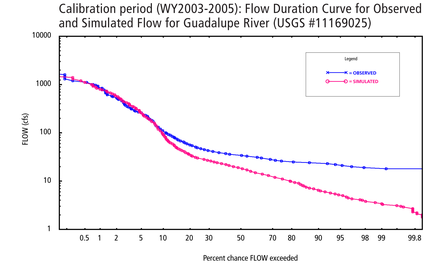
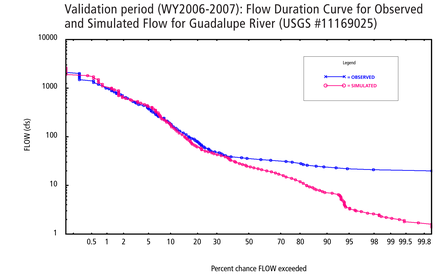


Figure 8.
Validation period (WY2006-2007): Flow Duration Curve for Observed and Simulated Flow for Guadalupe River (USGS #11169025)



Next Steps

While the model performs well for storm events in terms of both timing and flow magnitude, it is not adequately capturing total flow volume or baseflow. The underprediction of annual flow volumes suggests that sources of water have not been incorporated into the model.

The most likely source for the missing flow in the model is urban irrigation. Irrigation impacts in urban environments are usually evident at low flows, and the associated effects are shown as an increased baseflow component of the overall water balance (AQUA TERRA Consultants, 2006). Another factor that strongly influences baseflow is the amount of impervious surface – as imperviousness increases, the amount of soil present to contribute to baseflow decreases. The imperviousness estimates currently used by the model are 50% impervious for developed land and 0% impervious for undeveloped land, but higher resolution estimates exist for specific land uses (e.g. 30% for low-density residential land).

Before extending the model to include sediment and contaminants, imperviousness estimates will be re-evaluated, urban irrigation will be added and the model will be re-calibrated.

Acknowledgements

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References

AQUA TERRA Consultants, 2006. Hydrologic Modeling of the Castro Valley Creek and Alameda Creek Watersheds with the U.S. EPA Hydrologic Simulation Program - FORTRAN (HSPF). Final Report. Prepared for Alameda Countywide Clean Water Program, Hayward CA. January 20, 2006.

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