A Brief Primer on the Basics of Groundwater Flow Modeling as a Tool to Aid in Evaluation of Water-Supply Alternatives and their Effects on Sustainable Yield

prepared by United Water Conservation District (United), Water Resources Dept. staff, August 2020

Introduction

As requested by Gina Bartlett/CBI West, United's Water Resources Department staff prepared this brief primer on how models can be applied to evaluate water-supply alternatives, with specific focus on model input requirements and the information provided as output. But first, it's important to clarify which steps in the process of evaluating potential water-supply alternatives actually consist of modeling:

1. Develop assumptions about future conditions: not modeling
2. Select criteria for evaluating water-supply project success/failure: not modeling
3. Run model to forecast effects of pumping scenarios and projects: ***modeling***
4. Compare forecasted effects to evaluation criteria, then rank projects based on effectiveness, cost, and other factors: not modeling
5. Proceed to design and implementation: some modeling may be performed to refine design

Model Input

Information must be provided about the physical properties and stresses affecting groundwater flow, and assumptions made about potential future conditions in order to run a model to forecast potential effects of different future pumping scenarios, as follows:

- **Physical parameters:** These mostly consist of the basic properties of aquifers (resulting from geologic factors), such as depth, thickness, and hydraulic conductivity. These input parameters are largely determined during model calibration, although they should be updated as new information becomes available.
  - Generally, post-calibration updates to physical parameters can be expected to have a minor impact on overall water balance.
  - However, certain changes to physical parameters (e.g., adding or removing a fault) can potentially change model-forecasted groundwater levels or underflows in specific local areas of interest, which in turn could have a positive or negative impact on achievement of one or more sustainability criteria in that area.
- **Aquifer stresses (inflows and outflows):** When modeling basins that are highly developed (in terms of groundwater use), assumptions about future pumping and recharge rates typically have a much larger influence on forecasted regional groundwater levels and flow directions than do aquifer physical parameters. Note that some groundwater inflows and outflows are ***not*** input to the model, but are instead calculated by the model (i.e., seawater flux, stream-channel recharge/discharge, and groundwater underflows between basins).
  - <u>*Inflows applied to model:*</u>
    - Artificial recharge by United is, by far, the largest single inflow component to the principal aquifers of the Oxnard basin. Historical artificial recharge rates are well documented. United has developed forecasts of future artificial recharge volumes that are largely based on assumed future monthly rainfall amounts, but are also partly based on other factors (e.g., groundwater conditions in upstream basins, discharges from WWTPs, SWP availability, quantities delivered to PTP

and PVP for conjunctive use, and regulatory requirements for stream diversions).

- Direct infiltration/recharge of rainfall—provides inflow chiefly to the semi-perched aquifer. The primary variable for this inflow component is rainfall, although local factors can have some influence on how much rainfall infiltrates the soil and past the root zone of plants to become recharge.
- Mountain-front recharge along the periphery of the basins—this inflow is directly proportional to rainfall.
- Agricultural return flows—provides inflow mostly to the semi-perched aquifer. Inversely related to rainfall (less irrigation is assumed in rainy months). Relies partly on groundwater, surface-water, and recycled-water deliveries from multiple sources.
- Municipal return flows—provides inflow mostly to the semi-perched aquifer. Consists of leakage from water-supply pipelines and return flows from irrigation of lawns/landscaping. Assumed to be a portion of total water used by cities/communities (not directly dependent on rainfall). Relies largely on groundwater and imported-water deliveries for M&I use.
- Percolation of treated wastewater at WWTPs without ocean outfalls—this provides a small amount of recharge, mostly to the semi-perched or shallow aquifer systems.
- Parameters that influence stream-channel recharge—Although stream-channel recharge is calculated by the model (not a direct input parameter), it is dependent on streamflow input to the model. Model-input streamflow is based partly on rainfall and partly on assumed future WWTP discharges, especially those in Santa Clarita, Thousand Oaks, Simi Valley, and Moorpark.
- Surface flows from upstream basins (outside of the model domain)—some examples include flows in the Santa Clara River, Sespe Creek, and Calleguas Creek as those streams enter the Piru, Fillmore, and Pleasant Valley basins, respectively.
- Hydraulic heads in adjacent basins (outside of the model domain) and hydraulic conductance values across the model boundary—these input parameters are used to simulate groundwater underflow into (or, occasionally, out of) the active model domain from adjacent basins and from the Pacific Ocean.

o *Outflows applied to model:*

- Groundwater pumping from wells is, by far, the largest single outflow component from the principal aquifers of the Oxnard and Pleasant Valley basins. Historical pumping rates are well documented starting in 1985, although some concerns have been raised regarding the potential for past under- or non-reported pumping. Pumping rates can be forecasted partly as a function of annual rainfall (i.e., pumping is assumed to be greater during months with little to no rainfall, and less during months with significant rainfall). Availability of other sources (e.g., surface water, imported water, or recycled water) can also affect annual pumping volumes at wells located on properties that have access to these alternative sources of supply. Wells are typically located near the point of use of groundwater (e.g., agricultural-supply wells are generally located on or adjacent to irrigated land). Screened depths of wells (which aquifers are pumped) have historically been selected by drillers in the shallowest aquifer system that provides groundwater of adequate quantity and quality for the intended use or crop (e.g., Lower Aquifer System [LAS] in Pleasant Valley basin, and the Upper Aquifer System [UAS] in western Oxnard Plain). However, pumping was intentionally shifted from the UAS to the LAS in the pumping-trough area of the Oxnard Plain during the 1980s as an initial response by United, FCGMA, and farmers to seawater intrusion in the UAS. Future shifts in well locations and screened depths may help optimize sustainable yield of the basin.

- Hydraulic parameters for stream channels are input to the model—although discharge of groundwater to streams is calculated by the model, it is influenced by the hydraulic parameters input to the model for stream channels. In the Oxnard and Pleasant Valley basins, most discharge of groundwater to streams occurs from the semi-perched aquifer in the lower reaches of the Santa Clara River.
- Hydraulic parameters for evapotranspiration (ET) are also input to the model—similar to groundwater discharge to streams, key parameters that influence ET are input to the model (e.g., extinction depth and maximum ET rate). Actual ET rates are calculated by the model, and vary as calculated hydraulic heads change throughout the simulation period. In the model, ET removes a modest quantity of groundwater mostly from the semi-perched aquifer in coastal wetland areas and along some streams.

Model Output

Each simulation (model run) produces output files that include numerical values representing groundwater hydraulic pressure (“head”) and flow into or out of each of the six faces of every model grid cell in each layer of the model. These numerical values can be processed to:

- Produce contour maps and hydrographs of water-table (or potentiometric-surface) elevations,
- Summarize flow directions and rates between adjacent groundwater basins or between aquifers,
- Estimate magnitude of groundwater/surface-water interactions,
- Estimate groundwater fluxes across a stretch of coastline where seawater intrusion is of concern, and
- Determine potential pathways that solutes in groundwater (e.g., chloride from seawater intrusion, or nitrate in the Forebay) may follow in the future and their approximate rates of migration.
    - Note that some of the processes that influence seawater intrusion and contaminant transport (e.g., density-driven flows or chemical dispersion/diffusion) are not currently incorporated into United’s model. Addition of density-driven flow and dispersion/diffusion transport modeling is being considered by United—these processes will require additional input parameters and assumptions, as well as significantly adding to the time required to run each model scenario and interpret results.

By comparing the processed model output listed above with sustainability goals and criteria set by stakeholders, the following can be determined:

- The relative effectiveness of each action being considered to achieve the sustainability goals (which action or scenario is “most likely to succeed”).

- Locations where, or times when, achievement of sustainability goals will be most difficult or uncertain, and further action or monitoring may be warranted.

Final Thoughts

A well-calibrated model (like United's regional groundwater flow model) can be used to forecast groundwater elevations and flows at specific locations and times. However, great care must be taken by those professionals and stakeholders responsible for providing the basic assumptions about future aquifer stresses (e.g., pumping or recharge rates) that will subsequently be used to develop model input files. Assumptions about future stresses are typically a greater source of uncertainty in model predictions than are physical input parameters (e.g., hydraulic conductivity of aquifer materials).

During initial modeling of scenarios developed for comparing the relative effectiveness of different optimization and water-supply projects, much of the uncertainty about future conditions can be eliminated as a variable if the model runs are conducted over a historic (1985-2015) period. Use of a historic period as the baseline for comparison would also have the advantages of: being conceptually simpler in terms of developing climatic input data, eliminating potentially contentious debate about the myriad factors affecting future water-supply conditions, and requiring significantly shorter timeframes for preparing and conducting each model simulation. After this initial modeling effort is complete and favorable projects are identified, then a few selected project scenarios can be simulated over the 50-year future period considered in the GSPs. This goal of this follow-up modeling effort would be to forecast potential impacts of the most effective project alternatives on groundwater conditions, specifically comparing them to sustainability goals for the Oxnard and Pleasant Valley basins.