U.S. Department of the Interior
U.S, Geological Survey
California Water Science Center

Klamath Natural Flow Study
Upper Klamath Basin Groundwater Flow Model

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Model Purpose

The purpose of the Upper Klamath Basin Groundwater Flow Model (UKBGFM) is to simulate groundwater conditions in the Upper Klamath Basin under historical and predevelopment conditions. The UKBGFM quantifies estimates of and changes in groundwater levels, storage, pumping, drainage flow to tile drains, evapotranspiration, and flow between the Upper Klamath Basin and neighboring basins. The quantifications of base flow to streams and seepage to and from lakes and reservoirs can be used as inputs to the RiverWare Mass Balance Model (Zagona and others, 2001), a companion model being developed as part of the Klamath Natural Flow Study (KNFS).

Simulation Code and Data

The UKBGFM is based on the U.S. Geological Survey (USGS) groundwater flow model developed by Gannett and others (2012). The model code is being updated to MODFLOW-OWHM (Hanson and others, 2014; Boyce and others, 2020; Boyce, 2022), which was designed to simulate the conjunctive use of groundwater and surface water for various land uses per water-budget accounting units. The UKBGFM simulates the 7,600 square mile Upper Klamath Basin using 33,887 model cells that are 2,500 by 2,500 foot from October 1980 to September 2020. Recharge of precipitation is simulated using output from a surface hydrology model using the Precipitation-Runoff Modeling System (PRMS) (Regan and others, 2018) that is being developed as part of the KNFS. Evapotranspiration is simulated using datasets calculated by the Desert Research Institute (DRI) as part of the KNFS. For developed lands, the UKBGFM can use DRI's evapotranspiration, DRI's effective precipitation, and surface-water delivery datasets to estimate groundwater pumping for irrigation and recharge from irrigation return flow. Groundwater pumping for urban uses is estimated using U.S. Census population data (U.S. Census Bureau, 2021), population served data from Oregon's Drinking Water Data Online (Oregon Spatial Data Library, 2019), and per capita water-use estimates (Oregon Water Resources Department, 2021). The remaining features are simulated by various packages based on the original model (Gannett and others, 2012). For simulating the interaction between the groundwater and surface-water systems, particularly base flow, the UKBGFM uses the Stream Package (STR) (Prudic, 1989). The Drain Package (DRN) (Harbaugh and others, 2000) simulates groundwater discharge to tile drains, and the Reservoir Package (RES) (Fenske and others, 1996) simulates seepage between the groundwater system and lakes and reservoirs. The boundary flows between adjacent basins are simulated with the General Head Boundary Package (GHB) (Harbaugh and others, 2000). An example plan for the MODFLOW packages to be used for the UKBGFM is provided on the backside.

Natural Flow Representation

To simulate predevelopment conditions, the developed land can be replaced with undeveloped land use. All groundwater pumping and tile drains can be removed. Stages in the lakes and reservoirs can be modified to represent surface-water altitudes during predevelopment conditions.

Sensitivity & Uncertainty Analysis

The UKBGFM can be calibrated using a combination of trial and error and automated calibration methods to match simulated outputs with measured calibration targets. Calibration targets can include groundwater levels measured at observation wells and the estimated base-flow component of streamflow rates measured at streamflow gaging stations. Adjusted model parameters can include aquifer properties, stream and lakebed conductance, and land-use properties such as irrigation efficiency. After calibration, a sensitivity analysis can be performed to quantify the range that parameter values can be modified, while still ensuring a reasonable fit between simulated and measured values. An uncertainty analysis can be performed by using these ranges of parameter values to determine the range of reasonable outputs for key simulated outputs such as base flow.

Model Products

The UKBGFM produces daily output datasets for base flow to streams and for seepage to and from lakes and reservoirs that can inform the development of the RiverWare Mass Balance Model being developed as part of the KNFS.

Key Reference

Gannett, M.W., Wagner, B.J., and Lite, K.E., Jr., 2012, Groundwater simulation and management models for the upper Klamath Basin, Oregon and California: U.S. Geological Survey Scientific Investigations Report 2012–5062, 92 p.

Example Plan for MODFLOW Packages to be used for the Upper Klamath Basin Groundwater Flow Model