California Central Valley Groundwater Modeling Workshop

July 10 - 11, 2008

Lawrence Berkeley National Laboratory, Berkeley, CA

California's Central Valley is currently home to over 6 million people, and generates over $20 billion in agricultural crops each year. An intricate surface water distribution system routes water from surrounding watersheds to the Central Valley, the Central Coast and Southern California. The Central Valley's aquifers have historically provided water for agricultural and urban use, and are increasingly being used as a buffer for fluctuations in surface water supplies. Current scientific and management challenges include understanding the aquifer's response to drought and climate change, protecting the quality of groundwater, limiting subsidence caused by groundwater pumping, and implementing aquifer storage and recovery programs.

This workshop will be a gathering of researchers, consultants, administrators and others interested in learning about how groundwater models have been applied to address scientific and resource-management questions in the Central Valley. The workshop follows the Computational Methods in Water Resources XVI International Conference, being held in San Francisco July 6-10 (http://www-esd.lbl.gov/CMWR08/). Workshop presentations will increase our understanding of the groundwater flow system at both the local and regional scales.

The workshop will begin with a dinner gathering July 10th at Looney's Barbeque in Berkeley. Members of the original USGS Central Valley Regional Aquifer System Analysis team will give a presentation on the history of groundwater modeling in the Central Valley. The meaning of the term 'groundwater model' has changed over the years, from a set of painted wooden dowels representing well logs, to analog models created with resistors and capacitors, to the current digital computer models.

On Friday, we will meet at Lawrence Berkeley Laboratory to see twenty presentations on groundwater models developed for the Central Valley. The morning session will include four groundwater flow models in the Tulare Basin and five in the San Joaquin River Basin. The afternoon session will include four more models in the San Joaquin River Basin, three in the Sacramento River Basin, and will close with four presentations on Valley-wide modeling efforts.

Registration

The registration fee includes lunch and refreshments during the workshop.

Pre-register by June 27th for the reduced fee and a parking pass.

Pre-registrants: $75 for CWEMF members*; $125 for non-members†; $10 for students**

Late registrants: $100 for CWEMF members*; $150 for non-members†; $35 for students**

Space is limited. To register**,** please complete and submit the attached form.

Sponsors

California Department of Water Resources — U.C. Berkeley Water Center

California Water and Environment Modeling Forum

This workshop is being organized by Charlie Brush, California Department of Water Resources (cbrush@water.ca.gov) and Norm Miller, Lawrence Berkeley National Laboratory and U.C. Berkeley (nlmiller@lbl.gov).

Additional copies of this announcement are available at http://www.cwemf.org.

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California Department of Water Resources

U.C. Berkeley Water Center

California Water and Environment Modeling Forum

Registration Form

Name	
Organization	
Mailing Address	
Phone number	
Email address	
Will attend:	__ Friday 7/11 (workshop) __ Thursday evening 7/10 (dinner, appx. $15-$20, not incl. in registration fee)
Registration Fee	

	by June 27	**after June 27**
CWEMF Member*	__ $75	__ $100
Non-member†	__ $125	__ $150
Student**	__ $10	__ $35

Registration fee includes lunch and refreshments during the workshop, and the conference proceedings.

* Staff of the following have current CWEMF organizational memberships: CH_2M Hill, CCWD, EBMUD, MWDSC, CDWR, SWRCB, USBR, USACE, USFWS and USGS.

† The registration fee includes CWEMF membership until the Annual Meeting in February 2009.

** Currently enrolled in coursework at a degree-granting institution.

Mail completed form with payment to:

Central Valley Modeling Workshop
CWEMF
PO Box 488
Sacramento, CA 95812

Make checks payable to “CWEMF”

Or email the above information to GroundwaterModelingWorkshop@cwemf.org and pay at the workshop.

Additional copies of this announcement are available at http://www.cwemf.org.

California Central Valley Groundwater Conference

Draft Agenda

Looney's Barbeque, 2190 Bancroft Avenue, Berkeley, July 10, 2008

7:00 PM	**HISTORY OF GROUNDWATER MODELING IN THE CENTRAL VALLEY** Dave Prudic, Gil Bertoldi, and others (USGS)

Building 90, Room 3133, Lawrence Berkeley National Laboratory, July 11, 2008

7:30 AM REGISTRATION

8:00 AM	**OPENING**
8:00 AM	Opening remarks - Norm Miller (LBNL/UCB), Charlie Brush (DWR)
8:10 AM	Welcome - Susan Hubbard (LBNL)
8:20 AM	Introduction - Francis Chung (DWR)

8:30 AM	**TULARE BASIN**
8:30 AM	**Ground water dating and flow-model calibration in the Kern Water Bank, California** Laurent Meillier (SWRCB), Hugo A. Loaiciga and Jordan F. Clark (UCSB)
8:50 AM	**Estimation of groundwater pumping as closure to the water balance of a semi-irrigated agricultural basin: Tule River Basin** Thomas Harter (UC Davis) and Nels Ruud (Fugro West)
9:10 AM	**Numerical groundwater flow model for the Kaweah Delta Water Conservation District, southern San Joaquin Valley, California** Nels Ruud, Peter Leffler (Fugro West), and Larry Dotsun (Kaweah Delta WCD)
9:30 AM	**Integrated Modeling: An Analytical Tool for Integrated Regional Water Management Plan Development – Application to Kings Basin** Reza Namvar, Elias Tijerina, and Ali Taghavi (WRIME)

9:50 AM 20-minute break

10:10 AM	**SAN JOAQUIN RIVER BASIN - 1**
10:10 AM	**High resolution groundwater models of the San Joaquin River riparian zone for evaluation of surface water/groundwater interactions under alternate river flow regimes** Deborah L. Hathaway, Gilbert Barth, and Karen MacClune (SSPA)
10:30 AM	**Development of regional and nested local-scale ground-water models for study of the fate of agricultural nitrogen, Merced County, California** Steven P. Phillips, Christopher T. Green, Karen R. Burow, Jennifer L. Shelton, and Diane L. Rewis (USGS)
10:50 AM	**Sample travel time distributions and age tracer concentrations in an alluvial fan aquifer, San Joaquin Valley, California** Christopher Green and Barbara Bekins (USGS)
11:10 AM	**WESTSIM: Integrated groundwater/surface water, conjunctive use, agricultural srainages, and wetland return flow simulation on the west-side of the San Joaquin Valley** Nigel W. T. Quinn (LBNL) and Jafar A. Faghih (MWH Americas)
11:30 AM	**Hydrogeosphere application in multi-scale hydrological/ecological processes in San Joaquin River Basin,** and **HGS-CalSim: A tool to conjunctively and dynamically simulate hydraulic processes and multi-reservoir systems for evaluation of climate change impacts** Jeff Randall, Mary Kang, Don DeMarco (HGL), and George Matanga (USBR) / Mary Kang and Varut Guvanasen (HGL)

NOON	**LUNCH**

California Central Valley Groundwater Conference

Draft Agenda – continued

Building 90, Room 3133, Lawrence Berkeley National Laboratory, July 11, 2008

1:00 PM	**SAN JOAQUIN RIVER BASIN – 2**
1:00 PM	**San Joaquin County DYNFLOW model** Brian J. Heywood (CDM) and Brandon Nakagawa (San Joaquin Co. DPW)
1:20 PM	**City Wide Groundwater Modeling for Remediation and Management – City of Lodi** Varinder S. Oberoi, Michael Chendorain, Patrick B. Hubbard (Treadwell & Rollo), Richard Prima, Wally Sandelin, and Charles Swimley (City of Lodi)
1:40 PM	**Impact of climate change on crop water requirements, groundwater and soil salinity in the San Joaquin Valley, CA** Jan W. Hopmans (UC Davis), Edwin P. Maurer (Santa Clara University), and Gerrit Schoups (Delft Technical University)
2:00 PM	**Sustainable root zone salinity in the context of shallow perched water table, and attenuation: Land retirement demonstration project in the west San Joaquin Valley** Purnendu Singh and Wes Wallender (UC Davis)

2:20 PM	**SACRAMENTO RIVER BASIN**
2:20 PM	**Applications of the Sacramento County Integrated Groundwater and Surface Water Model** Jim Blanke, Jon Traum, and Ali Taghavi (WRIME)
2:40 PM	**Butte Basin IWFM model** Brian J. Heywood, Karilyn J. Heisen (CDM), and Kristen E. Hard (Butte Co. DWRC)
3:00 PM	**SACFEM: A Land Use Based Transient Finite-element Groundwater Flow Model of the Sacramento Valley** Peter Lawson (CH2M Hill)

3:20 PM 20-minute break

3:40 PM	**CENTRAL VALLEY**
3:40 PM	**Application of MODFLOW's Farm Process to California's Central Valley** Claudia C. Faunt, Randall T. Hanson, Wolfgang Schmid, and Kenneth Belitz (USGS)
4:00 PM	**Integrated Hydrologic Models in the Central Valley, California** Ali Taghavi (WRIME)
4:20 PM	**Simulating the historical evolution of the Central Valley hydrologic flow system with the California Central Valley Groundwater-Surface Water Model** Charles F. Brush, Emin C. Dogrul (DWR), Michael M. Moncrief (MBK, formerly DWR), Jeff Galef (DWR), Steven Shultz (CH2MHill), Matt Tonkin (SSPA), Dan Wendell (CH2MHill), Tariq N. Kadir, and Francis I. Chung (DWR)
4:40 PM	**California Central Valley Drought Scenario Sensitivity Analysis Using C2VSIM** Norman L. Miller (LBNL/UCB), Charles F. Brush (DWR), Larry L. Dale (LBNL/UCB), Sebastian Vicuna (UCB), Tariq N. Kadir, Emin C. Dogrul, and Francis I. Chung (DWR)

5:00 PM	**CLOSING**
5:00 PM	Closing remarks - Charlie Brush (DWR) and Norm Miller (LBNL/UCB)
5:10 PM	**ADJOURN**

Directions to Lawrence Berkeley Laboratory: http://www.lbl.gov/Workplace/Transportation.html
Shuttle bus from downtown Berkeley: http://www.lbl.gov/Workplace/Facilities/Support/Busses/off-site.html

Additional copies of this announcement are available at http://www.cwemf.org.

Directions

Looney's Barbeque is located at 2190 Bancroft Way, Berkeley, CA, near the corner of Bancroft and Oxford/Fulton Streets at the south-west corner of the UC Berkeley campus.
Map: http://maps.google.com/maps?q=2190%20Bancroft%20Way%2094701

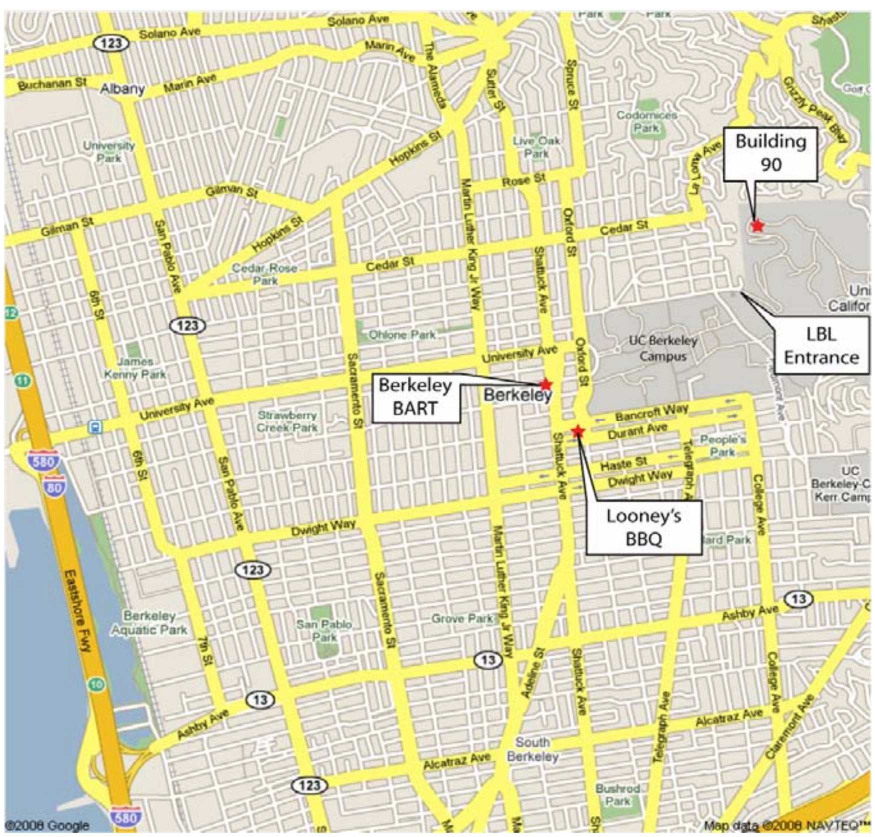
Lawrence Berkeley Laboratory is located directly east of the main UC Berkeley Campus. Parking passes will be provided to workshop participants who pre-register by June 27th. There is also a convenient shuttle from downtown Berkeley and the Downtown Berkeley BART station.

Map of LBL: http://www.lbl.gov/Workplace/lab-site-map.html
Driving directions: http://www.lbl.gov/Workplace/Transportation.html
Parking: http://www.lbl.gov/Workplace/site-access/parking/map.html
Shuttle: http://www.lbl.gov/Workplace/Facilities/Support/Busses/off-site.html

Accommodations

For those staying over Thursday night, suggested hotels in and near Berkeley include:
Holiday Inn Express, 1175 University Ave., Berkeley, CA 510-548-1700
The French Hotel, 1538 Shattuck Ave., Berkeley, CA 510-548-9930
Coral Reef Inn and Condosuites, 400 Park St., Alameda, CA (check travelocity.com)
Days Inn, 1925 Webster St., Alameda, CA 510-521-8400
Super 8 Berkeley-El Cerrito, 6009 Potrero, El Cerrito, CA 510-232-0900

Additional accommodation suggestions are posted at the Lawrence Berkeley Laboratory web site: http://www.lbl.gov/Workplace/near-our-shuttle.html



Additional copies of this announcement are available at http://www.cwemf.org.

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Abstracts of Workshop Presentations

Ground water dating and flow-model calibration in the Kern Water Bank, California

Laurent Meillier[1], Hugo A. Loáiciga[2] and Jordan F. Clark[3]

This paper describes a study of ground water characteristics and ground water dating in the Kern Water Bank, west of Bakersfield, California. The paper also presents the results of developing a calibrated ground water flow model for the Kern Water Bank's aquifer. The Kern Water Bank is one of the largest artificial storage and recovery operations in the southwestern United States. This study sheds light on the chemical characteristics of ground water, on the nature of the recharge water, on the subsequent ground water movement through the storage aquifer, and on the origin and age of ground water in the Kern Water Bank. It also produced a calibrated ground water-flow model that can be used in predicting the effects of future recharge and ground water extraction operations in the Kern Water Bank aquifer. It was determined that the chemistry of ground water in the Kern Water Bank is suitable for irrigation following additional purification. Ground water in the Kern Water Bank originates primarily from western Sierra Nevada runoff and from regional ground water accretions. Ground water age shows a clear differentiation into three age ranges. An optimal set of hydrogeologic parameters was identified, which, in conjunction with recharge data, boundary- and initial-condition data, and a hydrogeologically-based finite difference grid, were integrated into a ground water flow model useful for predicting recharge and stress impacts in the Kern Water Bank.

[1]*Regional Water Quality Control Board, San Francisco Bay Region, 1515 Clay St. Suite 1400, Oakland, CA 94612*
[2]*Department of Geography, University of California, Santa Barbara, CA 93106*
[3]*Department of Earth Science, University of California, Santa Barbara, CA 93106*

Estimation of Groundwater Pumping as Closure to the Water Balance of a Semi-Arid, Irrigated Agricultural Basin: Tule River Basin (Southern Tulare County)

Thomas Harter[1] and Nels C. Ruud[2]

Groundwater pumping is frequently the least measured water balance component in semi-arid basins with significant agricultural production. We present a GIS-based water balance model for estimating basin-scale monthly and annual groundwater pumping and apply it to a 2,300 km^2 semi-arid, irrigated agricultural area in the southern San Joaquin Valley, California (Tule River basin). Both annual groundwater storage changes and pumping are estimated as closure terms. The local hydrology is dominated by distributed surface water supplies, limited precipitation, and large crop water uses; whereas basin-scale runoff generation and groundwater-to-surface water discharges are negligible. Groundwater represents a terminal long-term storage reservoir with distributed inputs and outputs. To capture the spatio-temporal variability in water management and water use, the study area is delineated into 26 water service areas and 9611 individual fields or land units. The model computes conveyance seepage losses external to districts; seepage losses within districts; and net applied surface water of each district. For each land unit, the model calculates the applied water demand; its allotment of delivered surface water; the groundwater pumping required to meet the balance of its applied water demand; and aquifer recharge resulting from deep percolation of applied water and precipitation. These spatially distributed components are aggregated to the basin scale. Estimated annual groundwater storage changes compared well to those computed by the water-table fluctuation method over the 30-year study period, providing an independent verification of the consumptive use estimation. Pumping accounted for as much as 80% of the total applied water in 'Critical' water years and as little as 30% in 'Wet' years. Pumping estimates are most sensitive to estimation uncertainty of soil available water. They show little sensitivity to estimation errors in effective root depth, irrigation efficiencies, and intra-district seepage losses, although the cumulative sensitivity is significant. Model results also illustrate monthly field-by-field pumping and recharge rates and seasonal recharge and pumping patterns within and between irrigation and water districts.

[1] *Land, Air and Water Resources Department, University of California, Davis, CA 95616*
[2] *Fugro West, 1000 Broadway Ste. 200, Oakland, CA 94607*

Numerical Groundwater Flow Model for the Kaweah Delta Water Conservation District Southern San Joaquin Valley, California

Nels Ruud[1], Peter Leffler[2] and Larry Dotson[3]

The Kaweah Delta Water Conservation District is an intensively irrigated agricultural area located in the eastern part of the southern San Joaquin Valley. Overall, the District is approximately 340,000 acres in size; with agriculture accounting for about 285,000 acres, urbanized areas for 40,000 acres, and undeveloped lands for 15,000 acres. Many farmers in the District depend on both surface water and groundwater resources to meet their crop water needs. Urban demands are met almost entirely with groundwater. On average, the District uses approximately 880,000 acre-feet per year (afy) of surface water and groundwater with irrigated agriculture consuming about 95 percent of this total. The major sources of surface water are: 1) Lake Kaweah via the St. Johns and Lower Kaweah rivers, 2) Millerton Reservoir via the Friant-Kern Canal, and 3) Pine Flat Dam via the Kings River.

In this study, we developed a three-dimensional numerical groundwater flow model for the District. The model was based on the conceptualization of the aquifer system hydrogeology from the Water Resources Investigation (WRI) for the District (Fugro West, Inc., 2003) and the recalculation of the major recharge and discharge components of the hydrologic balance at the land unit scale of the land use survey. The groundwater model covered the same base period of 1981 to 1999 as the WRI. The objective of the calibrated model was to calculate the hydraulic head and groundwater storage changes in the aquifer system subject to historical transient groundwater recharge and pumping stresses in the District. The model was used to evaluate the potential impacts and benefits of five different future agricultural and urban water use management and supplemental water supply scenarios on the groundwater resources of the District:

Model Scenario 1 – 2 Percent Annual Urban Growth Rate: This scenario evaluated a 2 percent urban growth rate for the cities of Visalia and Tulare over a 19-year simulation period from 2000 through 2018.

Model Scenario 2 – 3 Percent Annual Urban Growth Rate: This scenario evaluated a 3 percent urban growth rate for the cities of Visalia and Tulare over a 19-year simulation period from 2000 through 2018.

Model Scenario 3 – Water Management Basins: This scenario evaluated the recharge of supplemental surface water into eight additional water management basins located predominantly east of the City of Visalia.

Model Scenario 4 – Conceptualized Delta View Improvement District: This scenario evaluated the diversion and delivery of supplemental CVP surface water supplies to the conceptual Delta View Improvement District, located within the northwestern region of the District and within the northeast region of the Kings County Water District.

Model Scenario 5 – City of Visalia Stormwater/Recharge Basins: This scenario evaluated recharge of supplemental surface water into 13 City of Visalia stormwater/recharge basins located in and around the City of Visalia.

Overall, the results demonstrate that the calibrated groundwater flow model for the District is well-suited for simulating scenarios of the geographic scope and magnitude (of changes to the hydrologic budget) implemented in this study. The model could be applied to many other such scenarios to help guide implementation of groundwater management strategies or to evaluate impacts of various patterns of urban growth. However, model limitations related to the model grid (1,000 by 1,000 foot grid squares) and large size of the model domain most likely preclude use of the model for small scale simulations such as individual residential developments or individual recharge basins. Nonetheless, smaller scale models that may be needed for particular problems may benefit by incorporating District model results into their boundary conditions.

[1]*Fugro West, Inc., 502 Giuseppe Court, Suite 11, Roseville, California 95678*
[2]*Fugro West, Inc., 1000 Broadway, Suite 440, Oakland, CA 94607*
[3]*Kaweah Delta Water Conservation District, 2975 North Farmersville Boulevard, Farmersville, CA 93223*

Integrated Modeling: An Analytical Tool for Integrated Regional Water Management Plan Development – Application to Kings Basin

Reza Namvar[1], Elias Tijerina[1], and Ali Taghavi[1]

An Integrated Groundwater and Surface water Model (IGSM) was developed as the analytical tool for development of Kings Basin Integrated Regional Water Management Plan (IRWMP). Kings Basin covers an area of about 1,600 square miles. Water use in this basin consists of approximately 2,700 TAF agricultural and 170 TAF urban water use which is met by 1,800 TAF of groundwater and 1,070 TAF of surface water. Kings River, with an average annual stream flow of 1,600 TAF, is the primary source of surface water for the basin. This analytical tool is being used to evaluate IRWMP project alternatives and water management strategies. The project alternatives include regional groundwater direct and in-lieu recharge projects and regional groundwater banking. The model development and calibration will be discussed briefly, and model past and potential future applications will be presented.

[1]*WRIME Inc., 1451 River Park Drive, Suite 142, Sacramento, CA 95815*

High Resolution Groundwater Models of the San Joaquin River Riparian Zone for Evaluation of Surface Water/Groundwater Interactions under Alternate River Flow Regimes

Deborah L. Hathaway[1], Gilbert Barth[1] and Karen MacClune[1]

Efforts are underway to evaluate and implement actions to restore 150 miles of the San Joaquin River downstream of Friant Dam and to reintroduce previously extirpated spring- and fall-run Chinook salmon. Among planned actions is the augmentation of river flow to achieve restoration hydrographs that vary in shape and volume according to a degree of “wetness” or, water year type, reflecting the basin water supply. High resolution groundwater models of the riparian zone of the San Joaquin River have been developed and applied to evaluate surface water/groundwater interactions associated with the restoration hydrographs. Model cells are approximately 250 by 125 feet in size; the shallow groundwater within about one mile to each side of the river is modeled in three layers, with boundary conditions specified to reflect deeper aquifer conditions and lateral regional boundary conditions.

Initially developed in 2000, the models for San Joaquin River Reaches 1, 2 and 4 were re-structured and re-parameterized in 2005 and used to evaluate seepage losses under a range of conditions. The Reach 1 and 2 models were re-calibrated using available flow and alluvial monitoring well data from the 2004 to 2005 period, including data collected during the large flood releases in May of 2005. The models are implemented in MODFLOW with river boundary conditions specified using HEC-2 model-generated water surface profiles. The models can evaluate near-river groundwater and groundwater/surface water interaction at a high spatial and temporal resolution.

Detailed transient modeling analyses of the riparian groundwater environment adjacent to the river indicate that numerous physical processes bear on the magnitude and timing of river seepage losses, and that the seepage losses may be impacted by changes that will be associated with river restoration. The analyses indicate that river seepage losses will vary seasonally and with flow levels as a function of regional groundwater conditions, riparian vegetation type and density, geomorphic changes affecting the hydraulic properties of the river bed and antecedent water supply conditions. Model sensitivity results illustrate the dynamic and transient nature of surface water/groundwater interactions. The models provide a platform capable of assessing the transient seepage losses under restoration conditions planned for the San Joaquin River to support water acquisition and to monitor the effectiveness of water operations in meeting the target hydrographs. The predictive accuracy of the models can be further evaluated and improved as additional data are collected through expanded monitoring programs.

[1]*S.S. Papadopulos & Associates, Inc.*

Development of Regional and Nested Local-Scale Ground-Water Models for Study of the Fate of Agricultural Nitrogen, Merced County, California

Steven P. Phillips[1], Christopher T. Green[2], Karen R. Burow[1], Jennifer L. Shelton[1], and Diane L. Rewis[1]

Regional- and local-scale models of steady-state ground-water flow were developed as part of a study of the transport and fate of nitrate from application of nitrogen fertilizers along a well-instrumented, 1-km transect near the Merced River. A three-dimensional local model (17 square km) is nested within a regional model (2,700 square km) bounded by the Stanislaus, San Joaquin, and Merced Rivers and the foothills of the Sierra Nevada in northeastern San Joaquin Valley, California. The regional model provides hydrologically reasonable boundary conditions for the nested local model; both were developed using MODFLOW-2000.

The heterogeneity of aquifer materials was incorporated explicitly into the regional and local models. Three-dimensional kriging was used to interpolate sediment texture data from about 3,500 drillers' logs in the regional model area. The resulting distribution of sediment texture was used to estimate hydraulic parameters for each cell in the 16-layer regional model. Sediment texture data within the local model domain were used to generate multiple transition-probability-based realizations of textural distributions for the 110-layer local textural and flow models, which shared the same grid. Explicit depiction of textural heterogeneity in the local model effectively incorporates macro-scale hydrodynamic dispersion into the flow model, allowing more direct comparison of particle-tracking results to tracer-derived estimates of ground-water age.

Water levels measured in multi-depth wells along the 1-km transect were used to calibrate the local model. The median error between simulated and observed values at 11 well locations was 0.12 m, less than 3 percent of the observed range along the transect. The calibration was evaluated using independent estimates of ground-water inflow to the Merced River and ground-water age estimates from concentrations of sulfur hexafluoride. The calibrated local model has been used to estimate source areas for water and nitrate sampled from the multi-depth wells, and as the basis for a reactive transport model used to better understand the transport and fate of nitrate in the aquifer system.

A report describing the development of the regional and local models can be downloaded from: http://pubs.usgs.gov/sir/2007/5009/.

[1]*US Geological Survey, Sacramento, CA*
[2]*US Geological Survey, Menlo Park, CA*

Sample travel time distributions and age tracer concentrations in an alluvial fan aquifer, San Joaquin Valley, CA

Christopher Green[1] and Barbara Bekins[1]

A calibrated model of flow and transport was used to investigate the effects of heterogeneity on travel time distribution and age tracer concentrations in ground water samples. The study site included a 1-km transect of multi-level well nests near the Merced River at Delhi, CA, installed as a part of the US Geological Survey's National Water Quality Assessment Program. The model domain included a rectangular area of 24.6 km^2 and a depth of 55 m, discretized into a domain of 140 (x) by 110 (y) by 110 (z) cells. Multiple geostatistical realizations were created of subsurface geological features in pre-holocene alluvial fans and alluvial holocene using geophysical logs, drilling cores, and published maps of geological features. The distribution of hydrofacies in each geostatistical model was used to populate the hydraulic parameters in a 3-D flow model by assigning uniform values to each sedimentary category. Using artificial constant head boundary conditions, average flow was simulated three times, one for each principal direction, for all 200 realizations. The realizations were ranked based on average flow properties across the domain in the x, y, and z-directions, and 6 realizations were selected to represent average and extreme cases of average hydraulic properties for further modeling studies.

A site-specific 3-D flow model was made using MODFLOW with boundary conditions interpolated from the results of a sub-regional model that included the transport model domain. Transport of age tracers was simulated with backward random walk particle tracking (RWHet). Using a parameter estimation routine (PEST) hydraulic conductivity, porosity, and dispersivity were calibrated in the flow and transport models to obtain a best fit between observed and modeled heads and concentrations of age tracers including sulfur hexafluoride and dichlorodifluoromethane (cfc-12). Calibrated models were used to estimate distributions of travel times in samples from existing ground water wells and to simulate concentrations of additional, hypothetical age tracers for comparison of apparent ages of multiple tracers in individual samples.

Results show that heterogeneity strongly influences the distribution of ages and the apparent ages of ground water samples. Travel time distributions were strongly skewed and often multimodal. Near-surface heterogeneity in the recharge zones strongly influenced the characteristics of travel time distributions, solute flux density in source areas, and thus the composition of the sampled water. As observed in previous studies, the apparent ages were consistently lower than the arithmetic average of the travel time distributions, and this difference increased with the age of the sample. Apparent ages based on a single solute should be used with care, as the travel time distributions underlying them are complex and depend on highly variable local geologic features. Use of multiple age tracers provides a more robust estimate of the extent of mixing in ground water samples.

[1]US Geological Survey, Menlo Park, CA

WESTSIM: Integrated groundwater/surface water, conjunctive use, agricultural drainages, and wetland return flow simulation on the west-side of the San Joaquin Valley

Nigel W.T. Quinn[1], Jafar A. Faghih[2]

WESTSIM is a detailed groundwater and surface water simulation model of the west-side of the San Joaquin Valley covering the entire federal service area. The model is unique in its resolution at the water district level, the attention devoted to developing accurate land-use data and the graphical user interface and data management system that support the current model. WESTSIM was one of the first applications using the Integrated Water Flow Model (IWFM), developed within DWR, and simulates phenomena such as surface water reuse and seasonal wetland hydrology that have hitherto been ignored by regional groundwater models of the area. The model uses the same aquifer discretization as the USGS Regional Groundwater Model (Belitz et. al.,1990), the same model alignment and texture based aquifer hydraulic properties to allow comparisons to be made with the older model. The model also contains robust land and water use input data for the entire area for the model's calibration period, 1970-2000. Current applications of the model include: integrated groundwater/surface water modeling, conjunctive use analysis, water district budgets for water conservation planning, impacts of land retirement on selenium affected lands, and assessing the potential impacts of regional aquifer subsidence. Significant findings to date include evidence that the crop coefficient-based ET estimates, commonly used in groundwater simulation models of the Basin, seem to over-predict evaporation losses by as much as 20%.

WESTSIM model development was facilitated through the application of a unique groundwater data management tool, named SHEDTOOL. SHEDTOOL was developed by MWH Americas Inc. under contract with the US Army Corp of Engineers and sponsorship from DWR. SHEDTOOL recognizes that groundwater management depends on data accessibility and data sharing between models and analytical tools. SHEDTOOL is a single, stand-alone application that allows entry, storage, retrieval, and presentation of groundwater and surface water data, recognizing that groundwater data are generated in many forms, stored in various formats, and maintained by numerous private, local, state, and federal agencies.

[1]*Berkeley National Laboratory, Berkeley, CA*
[2]*MWH Americas, Inc. Sacramento, CA*

HydroGeoSphere Application in Multi-Scale Hydrological/Ecological Processes in San Joaquin River Basin

Jeff Randall[1], Mary Kang[1], Don DeMarco[1] and George Matanga[2]

Optimal management of water resources at a basin scale requires consideration of comprehensive restoration and long-term protection of complex subsurface and surface-based ecosystems. The surface-based ecosystems are closely interconnected and include aquatic habitats (stream channels, wetlands, vernal pools, lakes, periodic floods and other surface-water bodies); riparian zones; lowlands (valley floor); and uplands (mountains). From a hydrological perspective, the surface-based ecosystems are known to closely interact with the subsurface ecosystem. In this work, the surface-based ecosystems are treated as two-dimensional systems, while the subsurface ecosystem is handled as a three-dimensional system. The two- and three-dimensional systems can be integrated into a single system by using geospatial technologies. The riparian zones are generally small in area in comparison to the landscapes of lowlands and uplands.

Therefore, in order to accurately evaluate the hydrological and ecological processes at a basin scale, in terms of process simulation, it may be necessary to apply a small scale (refined model grid) for the stream channels and riparian zones and a large scale (coarse model grid) for the lowlands and uplands. Therefore, appropriate numerical models for hydrological/ecological analyses require the capability to account for multi-scales in management of water resources and ecosystems in a basin. Geospatial technologies such as geographic information systems (GIS) can easily support both large and small scale data integration within the model. Success of predictive and conjunctive analyses of hydrological and ecological processes in integrated subsurface and surface (or surface-based ecosystem) regimes depend on availability of robust numerical models, with capability to account for hydrological and ecological processes within and at the interfaces of the subsurface and surface water regimes and interconnected ecosystems.

A sub-gridding scheme has been incorporated into HydroGeoSphere to facilitate grid-refinement over a surface or volume of an element and is being tested in a model of the San Joaquin River basin currently under development. This model accounts for variably-saturated subsurface flow, precipitation, irrigation, river inflows, subsurface extractions, evapotranspiration, surface water, surface-subsurface water interactions, and exchange flux at the surface/subsurface interface. The subsurface system includes discrete layers representing surficial sediments, unconsolidated overburden I, Corcoran clay (where present), and unconsolidated overburden II.

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HGS-CalSim: A Tool to Conjunctively and Dynamically Simulate Hydraulic Processes and Multi-reservoir Systems for Evaluation of Climate Change Impacts

Mary Kang[1] and Varut Guvanasen[2]

Computer models are frequently used to guide decisions pertaining to the operation, planning and management of the State Water Project (SWP) and the federal Central Valley Project (CVP) water storage and conveyance systems. CalSim, developed by California Department of Water Resources and the U.S. Bureau of Reclamation (BOR), is the standard reservoir-river basin simulation model for studies relating to the SWP/CVP system. HydroGeoSphere (HGS), developed by the BOR, University of Waterloo, Laval University, and HydroGeoLogic, is a distributed-parameter, fully-integrated surface-subsurface numerical model that accounts for three-dimensional variably-saturated subsurface flow and two-dimensional overland/stream flow. HGS is well suited for physically-based predictions of the impacts of climatic change with regard to surface-subsurface temperature, hydrology and water quality, and has been successfully applied at regional scales to the Central Valley.

To benefit from functionalities of both HGS and CalSim, a dynamic linkage between HGS and CalSim is being developed to facilitate conjunctive simulation of hydrologic processes and multi-reservoir systems without oversimplified representation of key physical processes. The linked HGS-CalSim model provides a comprehensive tool for evaluating the impact of climate change on California's water resources in addition to analyzing water supply, water quality and ecosystem health issues in an integrated and optimal manner. Potential applications include major river restoration, ecosystem-health and water resource management, climate change studies, and CALFED Bay-Delta Programs.

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San Joaquin County DYNFLOW Model

Brian J. Heywood[1] and Brandon Nakagawa[2]

An integrated groundwater/surface water flow model for San Joaquin County (SJC) has been applied to numerous studies and plans to aid in water resources planning in the region. The SJC model utilizes the fully 3-D finite element DYNFLOW simulation code. This model is capable of simulating groundwater/surface water interaction, groundwater pumping, and complex land use-based (i.e. agricultural) water demands.

San Joaquin County is currently home to approximately 650,000 people and sustains a $1.75 billion agricultural economy. The population is expected to increase to over 1.17 million by 2030. Water demand countywide is approximately 1,600,000 acre-feet per year, 60 percent of which is supplied by ground water. The California Department of Water Resources (DWR) has declared the Eastern San Joaquin Ground water Basin "critically overdrafted," indicating that the current rate of ground water pumping exceeds the rate of recharge and is not sustainable.

The SJC DYNFLOW model was used during the development of the San Joaquin County Water Management Plan (WMP) in 2001 by simulating alternative water management scenarios. These alternatives attempt to improve the “overdraft” condition in the basin by increasing recharge to the basin either through direct or in-lieu processes. Changes in groundwater levels and saline water migration simulated by the model were used to assess the alternatives. The acknowledgment that multi-party discussions were necessary to work on groundwater system issues, the Northeastern San Joaquin County Groundwater Banking Authority (GBA) was organized in 2001 and provided a consensus-based forum to local, State, and federal water interests to work cooperatively to study, investigate, plan, and develop locally supported ground water banking and conjunctive use programs.

In addition to use in support of the WMP, the SJC DYNFLOW model was used in 2005 to support the Environmental Impact Report (EIR) for the City of Stockton Delta Water Supply Project (DWSP). The SJC DYNFLOW model was most recently used in 2007 for the preparation of the Eastern San Joaquin Integrated Regional Water Management Plan (IRWMP). Simulations of alterative water management scenario, including a no-action alternative, were simulated and presented in the IRWMP. Again, changes in groundwater conditions was a major metric used to evaluate each alternative against target groundwater levels within the Basin Operations Criteria Framework. The model is currently being used to support the EIR for the County’s Integrated Conjunctive Use (ICU) Program as evaluated in the IRWMP and also explore the potential for an Inter-Regional Conjunctive Use Project with the Mokelumne River Forum, a stakeholder group comprised of water management agencies in the Mokelumne River Watershed.

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City Wide Groundwater Modeling for Remediation and Management – City of Lodi

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As part of simulating the hydrogeologic regime underlying the City of Lodi (City), Treadwell & Rollo, Inc. (T&R) and the City developed a flexible, multipurpose, three-dimensional groundwater flow and contaminant transport model that is currently being applied to integrate the following groundwater remediation and management tasks: 1) demonstrate and support groundwater containment and compliance proposals to the RWQCB in accordance with California legislation AB303, SB1938, and AB3030; 2) evaluating remedial alternatives for the source areas, the Central Plume, and other chlorinated solvent plumes in the context of nearby City supply wells; 3) developing a City-wide groundwater monitoring program to effectively establish the behavior of the contaminant plumes; and, 4) evaluating modifications in the management of the City's groundwater supply system including new well design, wellhead protection, groundwater recharge basins, water recycling, aquifer storage and recovery, potential overdraft, and system optimization. The *Groundwater Modeling System™ (GMS)*, a fully integrated pre- and post-processing modeling platform, was utilized for constructing the numerical groundwater model. The United States Geological Survey (USGS) Modular Three-Dimensional Finite Difference Groundwater Flow Model, *MODFLOW2000*, the particle tracking algorithm *MODPATH*, and the contaminant transport module *MT3DMS* were used for simulating groundwater flow and evaluating the effectiveness of the conceptual remedial alternatives. The model domain encompassed the Mokelumne River and existing City water supply wells, and extended southward to the East Stockton well field. The vertical extent of the model domain was simulated by eight layers to provide additional resolution to the movement of groundwater and contaminants in the vertical direction. Data from a regional flow model, previous site investigations, and local and state agencies (such as DWR) were used to develop a conceptual site model and the model domain boundary conditions, and provide the hydrogeologic and contaminant transport parameters for the numerical model. Groundwater extraction within the model domain was simulated for 27 City supply wells and 700 irrigation and domestic wells that surround the City. In the future, the numerical model and other mathematical tools will be applied to evaluate groundwater sensitivity and vulnerability.

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Impact of climate change on crop water requirements, groundwater and soil salinity in the San Joaquin Valley, CA

Jan W. Hopmans[1], Edwin P. Maurer[2] and Gerrit Schoups[3]

Recent analyses of climate change over California have provided projections of the range of warming and other changes that the region may face by the end of the 21st century. The projected reduction in surface water availability and potentially increased water requirements is expected to cause California's farmers to respond by supplementing available irrigation waters by increasing groundwater pumping. However, increased pumping will increase energy costs, and diminishing quality of groundwater applied as irrigation water will generally increase soil salinity. Our study applies a recently developed hydrosalinity model to project the impact of climate change on groundwater resources, crop water requirements, and soil salinity for a representative 1,400 km2 agricultural area in the San Joaquin Valley. The model couples projections of climate change through the 21st century with the MODHMS subsurface hydrology model, to evaluate the impact of climate change on irrigation water availability, crop water requirement and soil salinity. We contrast the variability in impacts due to different greenhouse gas emissions scenarios and different changes in availability of surface water deliveries on the impacts on both groundwater quantity and quality, and assess the sustainability of irrigated agriculture in this
region under the different scenarios.

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Sustainable root zone salinity in the context of shallow perched water table, and attenuation: Land retirement demonstration project in the west San Joaquin Valley

Purnendu Singh[1] and Wes Wallender[2]

In the San Joaquin Valley of California, intensive irrigation in conjunction with a shallow underlying layer of heavy clay, and absence of a drainage system caused the root zone to become highly saline and a shallow water table to rise. Land retirement, which is proposed as one of the management tool to address the problem, would remove from production those farmlands contributing the poorest quality subsurface drain water. Based on numerical models results, it was expected that with land retirement of substantial irrigated lands with poor drainage characteristics, beneath which lies shallow groundwater with high salt load, the shallow water table beneath those lands should drop. On the other hand, a potential negative side of the land retirement option is that in certain enabling evapotranspiration, soil and water table conditions, water will be drawn upwards and evaporated, leaving a deposit of salts on the surface and in the root zone. The deposits of salt on the surface may then be wind blown to adjacent areas creating a potential environmental hazard.

Using field results from the Land Retirement Demonstration Project at the Tranquillity site located in western Fresno County by U.S. Department of the Interior, principles of mass balance in a control volume, the HYDRUS-1D Software Package for simulating one-dimensional movement of water, heat, and multiple solutes in variably-saturated media, and PEST, a model-independent parameter optimizer, we have investigated the processes of soil water and salinity movement in root zone, the deep vadose zone and the groundwater. The simulation period covered was 5 years and we used measured perched water table depth and changes in the average root zone soil salinity as given by electrical conductivity measurements to optimize soil water retention properties, solute transport parameters and downward flux values at three locations of the Tranquillity site. The calibrated model is used to calculate the daily as well as the cumulative water and salt flux in the root zone for a sustainable water table elevation and root zone salinity. A new paradigm using a “bottom up” approach to site selection for land retirement as well as management of retired land has been developed. With this “bottom up approach”, we show that it is feasible to select a sustainable land use regimen for the retired lands.

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Applications of the Sacramento County Integrated Groundwater and Surface water Model (SacIGSM)

Jim Blanke[1], Jon Traum[1] and Ali Taghavi[1]

The Sacramento County Integrated Groundwater and Surface water Model (SacIGSM) was developed in the early 1990s and has widely been used over the past 15 years by the local and state agencies. The model has been maintained by various agencies responsible for the water resources planning and management in the Sacramento county area, and is a living model of the regional water resources conditions in the basin. The broad acceptance of the model across the community as the best available regional model for the area has allowed for the utilization of the model in numerous projects across the county. Refinements and updates are made to the model to meet the needs of each project, improving the model for future work. Projects include the Water Forum agreement, American River Basin Cooperative Agencies studies, Zone 40 Water Supply Master Plan, assessment of impacts from development projects, assessment of project impacts to private wells, environmental impact studies, and river restoration projects. The model has been used by government, non-profits, and private parties and underwent a major refinement in 2007. This presentation will briefly discuss the model features, and will mostly focus on the myriad of applications that the model has been used for.

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Butte Basin IWFM Model

Brian J. Heywood[1], Karilyn J. Heisen[1] and Kristen E. Hard[2]

The Butte County Department of Water and Resource Conservation's mission is "to manage and conserve water and other resources for the citizens of Butte County." To assist with this goal, Butte County developed a fully functional integrated groundwater/surface water model using California Department of Water Resources' (DWR) Integrated Water Flow Model (IWFM). This model is capable of assessing flow directions, water levels, and hydraulic gradients in the portions of the Butte Basin which includes portions of Butte, Colusa, Glenn, Sutter, Tehama, and Yuba Counties. This model represented a significant update of an earlier model that used the USGS's FEMFLOW3D code.

The geologic layering included in the model was updated to be consistent with the latest interpretation available from DWR's Northern District. The updated geologic interpretation included nine separate units including the Tuscan and Tehama formations. Updated land and water use information from DWR was also incorporated into the model.

As is common in areas utilizing groundwater for agricultural irrigation, information quantifying groundwater pumping was scarce. Therefore, the Butte County model was built to utilize IWFM's irrigation supply requirement calculation capabilities. Based on the specified land use acreage and crop evapotranspiration patterns, IWFM calculated the amount of water required for irrigation. Any irrigation demand that is not met by applied surface water or natural precipitation is assumed to be satisfied by groundwater pumping.

The calibration simulation period covers water years 1971 through 1999. Historical groundwater level and stream flow measurements were used to calibrate the model. A "base case" simulation was developed using the calibrated model. Groundwater levels from the base case and potential water management scenarios are compared to assess impacts to the groundwater aquifer. To date, a single water management scenario has been simulated. This scenario involved quantifying the maximum drawdown and recovery rates due to potential cutbacks in California State Water Project surface water deliveries. In the water management scenario, the cutbacks in surface water deliveries were assumed to result in both land fallowing and increased groundwater pumping. In regions with cutbacks in surface water deliveries, the groundwater table dropped an average of 4 and 7 feet following the cutback. Maximum drawdown of the groundwater table was from 11 to 15 feet. After one year, the average recovery in the impacted region was approximately 50%. Seventy percent of recovery was achieved at around two years after maximum drawdown. Groundwater levels had recovered to approximately 95% of the pre-cutback values after six years.

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SACFEM: A Land Use Based Transient Finite-Element Groundwater Flow Model of the Sacramento Valley

Peter Lawson[1]

A finite-element groundwater flow model of the Sacramento Valley has been developed, linking a relatively high resolution groundwater flow model (89,000 surface nodes, 7 layers) with an external surface water budgeting tool to provide transient surface water budget terms. Monthly estimates of the deep percolation of applied water and precipitation were computed according to current land use, crop type, location, and water year type. Agricultural pumping quantities were computed as the difference between applied water demand and available surface water for irrigation. The linked models can be used to compute well field scale impacts on groundwater levels and surface water flows due to groundwater substitution and conjunctive water management type projects.

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Application of MODFLOW's Farm Process to California's Central Valley

Claudia C. Faunt[1], Randall T. Hanson[1], Wolfgang Schmid[2] and Kenneth Belitz[1]

Historically, California's Central Valley has been one of the most productive agricultural regions in the world. The Central Valley also is rapidly becoming an important area for California's expanding urban population. During 1980–2007, the population nearly doubled in the Central Valley, increasing the competition for water. Because of the importance of ground water in the Central Valley, the U.S. Geological Survey (USGS) Ground-Water Resources Program is evaluating ground-water conditions in the valley on the basis of historical and anticipated water use. This study updates the USGS Central Valley Regional Aquifer System and Analysis (CV-RASA) model that was originally? calibrated to observed conditions for the period 1961-77. The model developed for this study utilizes MODFLOW-2000, and was calibrated to observed conditions for the period 1961-2003. Key updates include characterization of the aquifer system using a detailed textural analysis of more than 8,500 drillers' logs; use of the MODFLOW subsidence package (SUB) to simulate aquifer-system compaction; and, most importantly, use of the newly developed MODFLOW Farm Process (FMP) for simulating irrigation and other landscape processes.

The FMP provides coupled simulation of the ground-water and surface-water components of the hydrologic cycle for irrigated and non-irrigated areas. A dynamic allocation of ground-water recharge and ground-water pumping is simulated on the basis of residual crop-water demand after surface-water deliveries and root uptake from shallow ground water. The FMP links with the Streamflow Routing Package (SFR1) to facilitate the simulated conveyance of surface-water deliveries. Ground-water pumpage through both single-aquifer and multi-node wells, irrigation return flow, and variable irrigation efficiencies also are simulated by the FMP.

The simulated deliveries and ground-water pumpage in the updated model reflect climatic differences, differences among defined water-balance regions, and changes in the water-delivery system, during the 1961–2003 simulation period. The model is designed to accept forecasts from Global Climate Models (GCMs) to simulate the potential effects on surface-water delivery, ground-water pumpage, and ground-water storage in response to climate change. The model provides a detailed transient analysis of changes in ground-water availability in relation to climatic variability, urbanization, and changes in irrigated agriculture.

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Integrated Hydrologic Models in the Central Valley, CA

Ali Taghavi[1]

The Central Valley of California is home for variety of land use and water use challenges, including environmental and biological issues. Water resources professionals and hydrologists have numerous types of tools and technologies available to them to quantify the scale and magnitude of issues, define problems, evaluate a host of solution options, prioritize the solutions, and support the decision makers and stakeholders in making appropriate technical and policy decisions for better management of the water resources in the Valley. Several integrated hydrologic models have been in the core of technical analysis and decision making process for their respective coverage area and beyond. This presentation introduces methodology, geographic coverage, major features, and types of past and potential applications for a number of integrated hydrologic models throughout the Central Valley. In addition, potential applications to local and regional projects, along with major issues that water resource professionals are facing in modeling the surface water and groundwater conditions in the Central Valley will be discussed.

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Simulating the historical evolution of the Central Valley hydrologic flow system with the California Central Valley Groundwater-Surface Water Model

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The California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM) is an integrated hydrologic model developed using the Integrated Water Flow Model (IWFM) program. C2VSIM simulates land-surface, groundwater and surface-water flow in the alluvial portion of California's Central Valley, an area of approximately 20,000 mi^2, with a monthly time step from October 1921 through September 2003. The Central Valley's hydrologic system experienced significant changes during this period as a result of steady agricultural expansion, extensive groundwater pumping, the development of surface water storage and conveyance systems, and recent urban expansion. Simulating the aquifer system over this period provides an understanding of historical water budget components, especially rates and distribution of groundwater pumping, and serves as a useful planning tool to assess the impacts of regional water management programs such as conjunctive use of groundwater and surface water, changes in surface water inflows to the valley, or significant changes in land use.

IWFM incorporates a three-dimensional finite element groundwater flow process dynamically coupled with one-dimensional land surface, river, lake and unsaturated zone processes and a simplified land-surface process to simulate surface and subsurface flows from ungaged small-stream watersheds adjacent to the model boundary. In the C2VSIM model, the groundwater flow system is represented with three layers of 1392 elements, the surface-water network is simulated using 449 river nodes representing 75 river reaches, with a single outflow point at the Carquinez Straits, and the small-stream watershed process calculates surface and subsurface flows from 210 ungaged watersheds. Monthly input data include the elemental distribution of agricultural crops, urban area and native vegetation, precipitation, and evapotranspiration; boundary surface-water inflow at 40 gaged river locations; and 107 surface-water diversions from 97 diversion locations. The IWFM land-surface process partitions precipitation to infiltration and runoff, calculates aggregate water demands, routes runoff to rivers and deep percolation to the unsaturated zone, allocates available surface water to meet agricultural and urban demands, and calculates the amount of groundwater pumping required to meet the remaining demands (especially useful in California where groundwater pumping is not recorded), and the IWFM surface water process routes river flows and calculates stream-groundwater interactions.

Simulation results provide insight into the evolution of the groundwater flow system over time. Estimated groundwater extraction increased from approximately 6 million acre-feet (MAF) per year in the 1920's to a maximum of 16 MAF/yr in 1977, and more recently declined to an average of 9 MAF/yr between 1994 and 2003. Simulated groundwater discharges to rivers dropped from 2.9 MAF/yr in the 1920's to 1.2 MAF/yr between 1994 and 2003 as groundwater extraction altered groundwater flow patterns. Simulated evapotranspiration increased from 17 MAF/yr in the 1920's to 28 MAF/yr between 1994 and 2003 as agricultural and urban expansion supplanted native vegetation. The calibrated model is being used in several on-going studies and as the groundwater component of the CALSIM-III surface-water allocation model.

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Drought scenario analysis of the California Central Valley surface-groundwater-conveyance system

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An initial quantification of the impacts of long-term droughts - *an analogue for climate change related snowpack reduction* – has been performed to illustrate the potential for subsurface storage to limit the adverse impacts of drought and snowpack reduction on water supply in the California Central Valley. This includes how groundwater pumping compensates for reductions in surface inflow, the extent in which the water table is reduced, and how, when, and if this system recovers or reaches a new equilibrium. This study also includes estimates of the impacts of changes in groundwater levels and surface supplies on crop acreage and crop water demands. In this study, analysis of California Central Valley impacts of sustained droughts are based on a series of specified reductions in net surface flows corresponding to historical 30% (below average), 50% (dry), and 70% (critically dry) effective reduction, for periods ranging from 10 to 60 years, and applied to the CDWR's California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM). This simplified methodology represents a means to evaluate the impacts of reductions in net surface flow from reservoirs and Central Valley precipitation.

The model is being modified for this analysis and includes crop response functions to evaluate changes in crop acreage occurring during a prolonged drought. The impact of crop changes on groundwater levels is indicated by comparing groundwater levels at the end of the drought scenarios estimated with C2VSIM with and without crop response functions. Preliminary C2VSIM simulations without crop response functions assuming 1973-2003 demand, land use, and population levels indicate that the Central Valley groundwater decreases 36% for the severe drought scenario and fall 10% for the light drought scenario diversions fall 10%.

The impacts of the droughts are modeled separately for four different regions in the Central Valley, including the Sacramento Basin, Eastside, the San Joaquin Basin, and the Tulare Basin. Initial results show that on a regional per acre basis drought scenario impacts are concentrated in the San Joaquin and Tulare Basins. In the severe 60-year drought scenario the Tulare and San Joaquin Basins experience a 0.41 ft and 0.42 ft per year decline in surface deliveries, compared to the base period. In the moderate 30-year and light 60-year drought scenarios, deliveries to the San Joaquin decline about 0.20 ft and 0.13 ft per year from base year levels. Deliveries to the Tulare basin decline 0.36 ft and 0.14 ft per year respectively, during the moderate and light drought scenarios. The Sacramento Basin and Eastside regions experience comparatively small changes in surface diversions during droughts. Sacramento Basin diversions decline 0.22 ft per year in the severe drought, but only change by a slight amount (0.04 to 0.07 ft) for the other two drought scenarios. Eastside diversions are virtually the same during all drought scenarios. The Central Valley groundwater levels decline 0.55 ha-m/ha and 1.16 ha-m/ha), respectively, during the light and severe drought scenarios, with substantial variation shown by region. Groundwater levels at the end of the severe drought drop 15 ft and levels at the end of the moderate drought fall 13 ft.

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