The California Central Valley Groundwater-Surface Water Simulation Model

C2VSim Overview

CWEMF C2VSim Workshop

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Outline

Background and Development History

C2VSim Framework

Coarse-Grid and Fine-Grid Versions

Future Directions
California’s Central Valley

- 20,000 sq. mi. (55,000 sq. km.)
- 30 MAF/yr Surface Water Inflow
- Agricultural Production
  - 6.8 million acres (27,500 sq. km)
  - <1% of US farm land
  - 10% of US crops value in 2002
- Population Growth
  - 1970: 2.9 million
  - 2005: 6.4 million
- Groundwater Pumping
  - ~9 MAF in 2002
  - 10-18% if US pumping
  - Not measured or regulated
C2VSim Development

Derived from the CVGSM model
- WY 1981-1998 CH2M Hill for CVPIA PEIS

Steady modification
- DWR IWFM/C2VSim development began in 2000
- IWFM process and solver improvements
- C2VSim data sets reviewed and refined
- C2VSim input data extended through WY 2009

Calibration
- PEST parameter estimation program
- Three phases: Regional, Local, Nodal

Release
- C2VSim 3.02-CG released December 2012, updated June 2013
- C2VSim 3.02-FG expected in 2014
C2VSim Applications

- CalSim 3 groundwater component
- Integrated Regional Water Management Plans
- Stream-groundwater flows
- Climate change assessments
- Groundwater storage investigations
- Planning studies
- Ecosystem enhancement scenarios
- Infrastructure improvements
- Impacts of operations on Delta flows
C2VSim Versions

**C2VSim CG 3.02 (R374): Release Version**
- Current version, released June 2013
- Water Years 1922-2009, monthly time step
- IWFM version 3.02

**C2VSim FG 3.02 (R374): Draft Version**
- Based on C2VSim 3.02 CG
- Refine rivers, inflows, land use
- Upgrade to match CG version before release
- Expected release in 2014

**Planned Improvements**
- C2VSim 3.02 CG/FG: Extend to WY 2011 or 2012
- C2VSim 4 FG: Element-level land use, crop and diversion data
Steady Improvement of C2VSim

R375: September 2013
- Make the supply adjustment flags easier to use

R376: November 2013
- Modify irrigation schedules in subregions 15-17
- Modify curve numbers in small watersheds 103-114
- Add M&I imports from Placer Co Water Agency
- Make irrigation fraction flags easier to use

R377: April 2014
- Remove ASR at end of the Tule & Kaweah Rivers
- Limit ASR on the Kern River Flood Channel to 1,000 cfs

R378: April 2014
- Modify basement altitude between Merced and Los Banos to match base of fresh water
C2VSim Coarse Grid

“C2VSim CG-3.02”

DWR Web Site
- Model files
- Documentation
- C2VSim ArcGIS GUI
- IWFM Application
- IWFM Tools

Support
- Training: IWFM and C2VSim workshops will be offered through CWEMF
- Technical support: Email and telephone

A Google search for “C2VSim” brings up this page
C2VSim Portal

Interactive Web Site
- Tutorial Files
- Project Files
- Collaboration
- Message Board
- User/Password for additional access

Additional Tools tab on C2VSim page
C2VSim Coarse-Grid

“C2VSim CG-3.02”

Finite Element Grid
- 3 Layers or 9 Layers
- 1393 Nodes & 1392 Elements

Surface Water System
- 75 River Reaches, 2 Lakes
- 243 Surface Water Diversions
- 38 Inflows, 11 Bypasses
- 210 Small-Stream Watersheds

Land Use Process
- 21 Subregions (DSAs)
- 4 Land Use Types

Simulation periods
- 10/1921-9/2009 (88 yrs)
- runs in 3-6 min

IWFM version 3.02
C2VSim Framework

- Nodal coordinates
- Nodes form elements
- Vertical aquifer stratigraphy
- Lakes
- River nodes
- River reaches & flow network
- Element properties
- Pumping wells
- Assign elements to subregions
Nodes

X-Y Grid
- UTM 10N
- X = Easting
- Y = Northing

Convert to FT
- FACT = 3.2808
Elements

Finite Element Mesh
- 4 nodes = quadrilateral
- 3 nodes = triangle

1392 elements
Stratigraphy

‘Hangs’ from Ground Surface

-280 ft
-20 ft
60 ft
250 ft
Stratigraphy

At each node:

Land Surface Elevation

For each layer

- Aquiclude thickness
- Aquifer thickness
C2VSim Aquifer Cross Section

Altitude vs. MSL (feet)

Distance from Western boundary (miles)

1. Unconfined
2. Confined w/pumping
3. Confined no pumping

Legend:
- GSE
- B1
- B2
- B3

Coast Range Sediments
Sierran Sediments
Coast Range Basement
Sierran Basement
Connate Water

D-D'
C2VSim Aquifer Thicknesses
Base of Fresh Water

Three dimensional view (looking north) of the base of fresh water surface
River Nodes and Reaches

Listed by Reach
Nodes linked to mesh
River Nodes and Reaches

Rating table for each node at the end of the file

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<th>QRTB</th>
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River Nodes and Reaches

Rating table for each node at the end of the file

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<thead>
<tr>
<th>ID</th>
<th>Stream node number</th>
<th>BOT</th>
<th>Stream bottom elevation relative to a common</th>
<th>HR</th>
<th>Stream depth [L]</th>
<th>HRTB</th>
<th>Stream depth rate</th>
<th>QRTB</th>
<th>Flow rate at stream depth HRTB [L^3/T]</th>
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<td>1000.75</td>
<td>14.4</td>
<td>6000.00</td>
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</table>

The following lists a stream rating table for each of the stream nodes. Note: In order to define a specified stream depth, enter all HRTB values as equal to the specified depth value.
Lakes

Groups of Elements

Outflow = River Node #
Element Characteristics

- Precipitation data column
- River node receiving drainage
- Subregion
- Soil type
  A = 1  B = 2
  C = 3  D = 4
Pumping Wells

X-Y Location
- UTM 10N
- X = Easting
- Y = Northing

Convert to FT
- FACT = 3.2808

Well Properties
- RWELL = 1
- Screen Top
- Screen Bottom
## Calibrated Parameters

<table>
<thead>
<tr>
<th>Aquifer nodes</th>
<th>Soil properties</th>
<th>Small Watersheds</th>
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<tr>
<td>– Conductivity</td>
<td>– Field capacity</td>
<td>– Field capacity</td>
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<tr>
<td>– Storage</td>
<td>– Porosity</td>
<td>– Porosity</td>
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<tr>
<td>– Subsidence</td>
<td>– Recharge factor</td>
<td>– Conductivity</td>
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<td>River nodes</td>
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<td>– Discharge threshold</td>
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<td>– Conductance</td>
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<td>– Recession coefficients</td>
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<tr>
<td>– Porosity</td>
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</tr>
<tr>
<td>– Conductivity</td>
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Calibration with PEST
Calibration with PPEST
C2VSim Calibration

- Calibrate parameter values at each model node and layer

- Using computers at the USDOE National Energy Research Scientific Computing Center (NERSC)
  - Carver
    - IBM iDataPlex
    - 3,200 CPU cores, 34 Tflop/s

- Comparison:

<table>
<thead>
<tr>
<th></th>
<th>PPs</th>
<th>Computer</th>
<th>Run Time</th>
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<td>R300</td>
<td>137</td>
<td>15 PCs</td>
<td>1 week</td>
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<td>R326</td>
<td>394</td>
<td>15 PCs</td>
<td>3 weeks</td>
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<td>R346</td>
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<td>15 PCs</td>
<td>16 weeks</td>
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<tr>
<td>R346</td>
<td>1393</td>
<td>NERSC</td>
<td>2 weeks</td>
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</table>
Calibration Observations

Groundwater Heads
  – 56,947 observations at 1,145 wells

Vertical Head Difference
  – 3,017 observations at 121 well pairs

Surface Water Flow
  – 5,636 observations at 21 locations

Stream-Groundwater Flows
  – Average annual rates on 24 reaches
Parameter Sensitivity

Parameters
- Ungaged Watersheds
- Land Surface
- Streambed
- Unsaturated Zone
- Saturated Zone

Observations
- Groundwater Head
- River Flow
- Groundwater Gradient
- Stream-Groundwater Flow
Parameter Sensitivity

![Parameter Sensitivity Chart](image-url)
Hydraulic Conductivity

Layer 1

Layer 2
Storage Parameters

Layer 1

Layer 2

SY

0.32
0.24
0.16
0.08

Ss₂

6.0e-5
4.0e-5
2.0e-5
1.0e-5
River-Bed Conductance
# Model Performance

<table>
<thead>
<tr>
<th>Observation Type</th>
<th>No. Observation Sites</th>
<th>No. Observations</th>
<th>Range</th>
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<tbody>
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<td>Groundwater heads</td>
<td>1,378</td>
<td>62,981</td>
<td>1,252</td>
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<tr>
<td>Vert. Groundwater Head Difference</td>
<td>163</td>
<td>3,017</td>
<td>698</td>
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<tr>
<td>River Flows</td>
<td>22</td>
<td>5,636</td>
<td>6,561,453</td>
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<tr>
<td>River-Groundwater Flows</td>
<td>33</td>
<td>33</td>
<td>38,117</td>
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<td>Subsidence</td>
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<td>3,700</td>
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<td><strong>TOTAL</strong></td>
<td><strong>1,620</strong></td>
<td><strong>75,367</strong></td>
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</table>

<table>
<thead>
<tr>
<th>Observation Type</th>
<th>Root Mean Squared Error</th>
<th>Residual</th>
<th>RMSE Range</th>
<th>Residual Range</th>
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<td>River-Groundwater Flows</td>
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<td>-11.5</td>
<td>2.81</td>
<td>-1.86</td>
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</tbody>
</table>

Units: Heads and subsidence in feet, flows in acre-feet
Head and flow observations from October 1975 to September 2003, Subsidence observations from September 1957 to May 2004
Groundwater Heads

62,981 observations at 1,378 wells

RMSE/Range = 0.052 Ft

Residual/Range = 0.002 Ft
Surface Water Flows

- 5,636 observations at 22 gages
- RMSE/Range = 0.022 Ac-Ft/mo
- Residual/Range = -0.002 Ac-Ft/mo

![Graph showing simulated versus observed flows with a scatter plot and a line of best fit.](image)
Simulated Annual Water Budget

Average Flows for water years 2000-2009
[Million Acre-Feet/Year]
River-Groundwater Flows
Sacramento River reach near Chico

Greater than zero means a net flow from Groundwater to the River
Less than zero means a net flow from the River to Groundwater

Groundwater Pumping

Urban Water Supply

Change in Groundwater Storage
Process-level output tables have a complete water balance, and can be used to produce budget figures.

Groundwater budgets can also be produced for ‘zones’ of one to many elements.
Water Table Altitude
Produced from IWFM’s TecPlot® output files
IWFM
C2VSim Model

- **Land Surface Processes**
  - Land and Water Use Budget
  - Root Zone Budget

- **Groundwater Process**
  - Groundwater Budget
  - Z-Budget Budget

- **Surface Water Processes**
  - Stream Reach Budget
  - Lake Budget

- **Small-Streams Watershed Process**
  - Small Watershed Budget