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Modeling Temperature and Flow Dynamics Middle Fork American River Hydroelectric Project

Leon Basdekas
Mike Deas
Ert Sogutlugil
Nimal Jayasundara
Watercourse Engineering, Inc
424 2nd Street, Suite B
Davis, CA 95616

Principal Project Tasks

- System Definition and Conceptualization
- Model Implementation/Construction
  - Reservoirs
  - Rivers
- Model Calibration
  - Reservoirs
  - Rivers
- Other Tasks (field visits, model review/refinement, project management, etc.)

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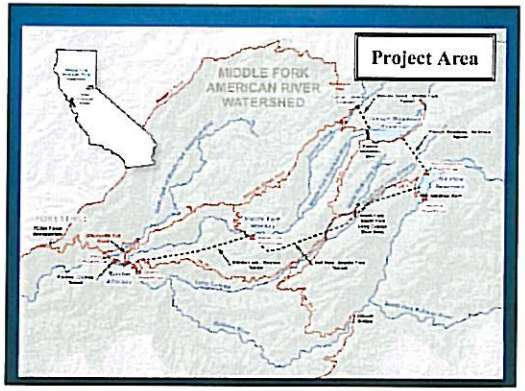
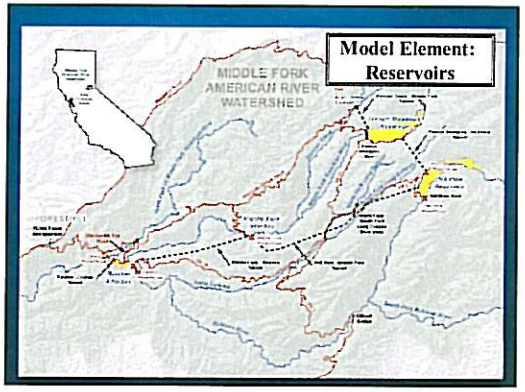
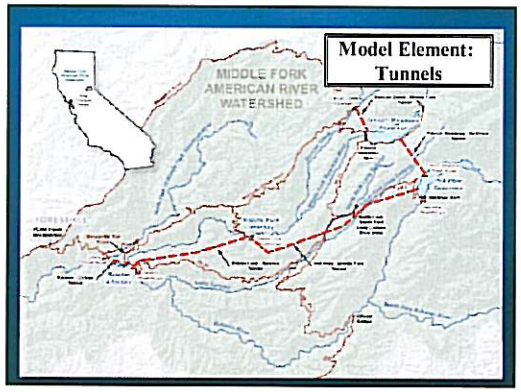
System Definition and Conceptualization

- Define Reservoir Reaches
- Identify Tunnel System Elements
- Define River Reaches and Principal Tributaries
- Status: 90 percent

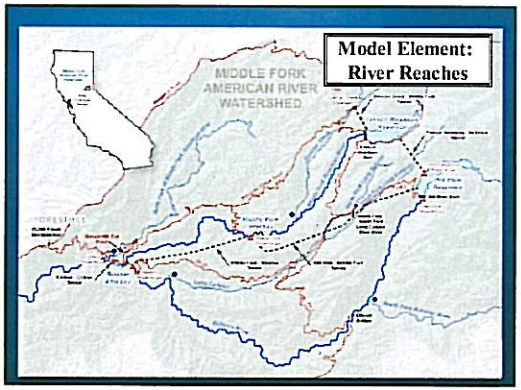


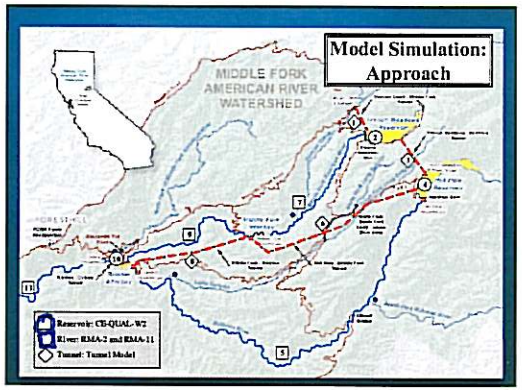


LARGE RES + RALSTON



CONDUCTION MODEL FOR TUNNELS





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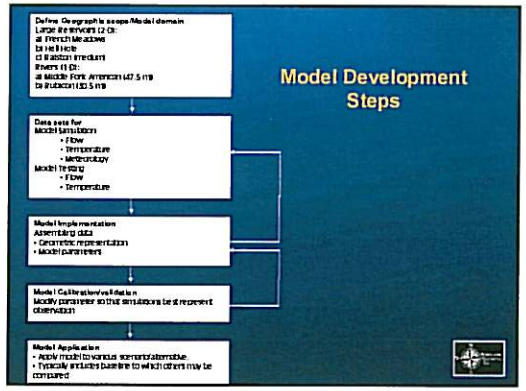


Model Implementation: Status

- Data Acquisition and Review
- Reservoir Implementation
- Tunnel Model Development
- River Model Implementation (current task)

Data Acquisition and Review

- Reservoir
  - Geometry: complete
  - Flow: in progress (data need – peaking)
  - Water Temperature: complete (tributary temperature gap analysis)
- River
  - Geometry: complete
  - Flow: in progress (data need – peaking, tributaries)
  - Water Temperature: in progress (data need - 2007 data from PCWA)
- Tunnel
  - Geometry: complete
  - Flow: in progress
  - Water Temperature: in progress (data need – 2008 data)
- Global
  - Meteorological Data: complete (gap analysis, spatial range)

Spatial Meteorological Representation

Purpose

Represent meteorological variability spatially throughout project area, specifically reaches below French Meadows and Hell Hole reservoirs

Data Availability

- Full Meteorological Stations
- Partial Meteorological Stations

Spatial Meteorological Representation

Approach

Identify parameters that illustrate systematic spatial variability

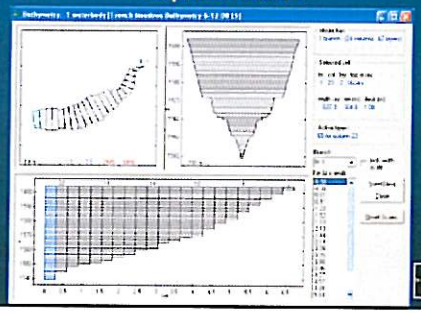
1. **Solar Radiation (SR):** lacks sensitivity
2. **Wind Speed (WS) and Wind Direction (WD):** highly dependent on local conditions
3. **Dew Point Temperature (DP) & Wet Bulb Temperature (WB):** can be estimated with Relative Humidity and Ta. Dependent on local conditions. Relative Humidity is dependent on vapor pressure, local conditions.
4. **Atmospheric Pressure (Patm):** insensitive, absent from data sets
5. **Air Temperature (Ta):** most reliable data type to analyze different met stations data (i.e., data follow theoretical lapse rate conditions)

*Spatial assignment of meteorological conditions along river reaches in progress

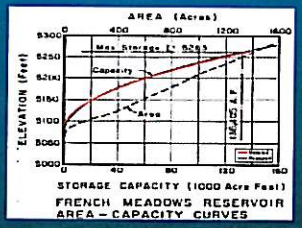
Reservoir Model Implementation

- French Meadows (complete)
- Hell Hole (complete)
- Ralston (largely complete)
  - Implementation – Ralston refinement near dam, test
  - Peaking flow test

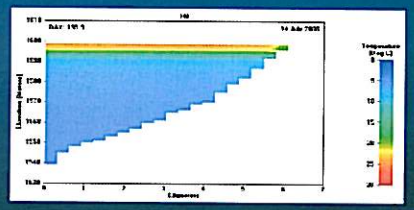
French Meadows CE-QUAL-W2 Representation



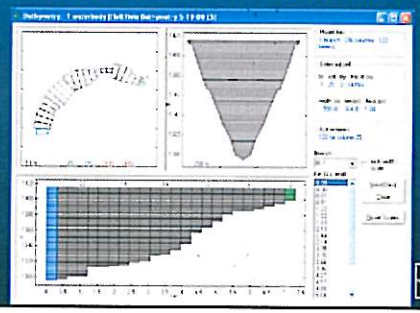
French Meadows Storage-Volume Curve



Test implementation of French Meadows Reservoir



Hell Hole CE-QUAL-W2 Representation



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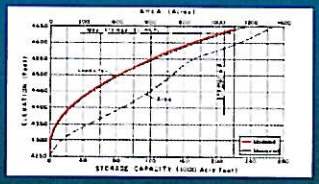
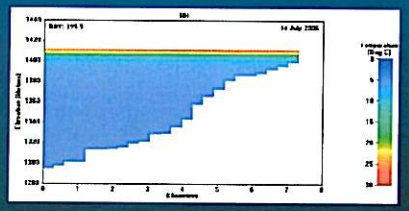
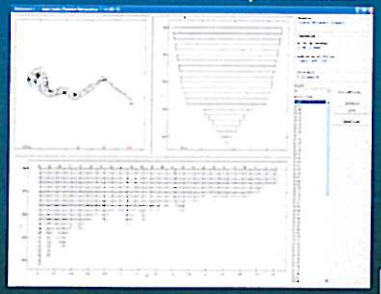


Test Implementation of Hell Hole Reservoir



Ralston CE-QUAL-W2 Representation



Tunnel Model

- Conduction-based heat transfer model
  - Function of entry temperature, tunnel geometry, flow rate, matrix temperature, and physical properties of water
  - Algorithm is embedded in a spreadsheet that be used to pre- and post-process data sharing among model elements
- Test field data to be collected summer 2008

Tunnel Heat Conduction

$$T_w^{n+1} = e^{-\frac{4h\Delta t}{\rho C_p D}}(T_w^n - T_s^n) + T_s^n$$

$$h = \frac{0.023k}{R}\mathrm{Re}^{0.8}\,\mathrm{Pr}^{0.4}$$

Where,

Δt = time step (s)

T_s = Undisturbed temperature (°C)

D = Diameter (m)

C_p = Specific heat of water (J kg^{-1} °C^{-1})

ρ = density of water (kg m^{-3})

h = Heat exchange coefficient (W m^{-2} °C^{-1})

T_w^n = time temperature profile along the tunnel with time

Where,

k = thermal conductivity of water (W m^{-1} °C^{-1})

R = hydraulic radius (m)

Re = Reynolds number

Pr = Prandtl number

Future Work

- Model Implementation/Construction
  - Rivers
    - Geometry - Alignments and elevations complete. Awaiting updated cross-section data
- Model Calibration
  - Reservoirs
  - Rivers