AGENDA

Seminar / Discussion of
Sacramento -San Joaquin Delta Watershed Models for Water Supply / Water Quality
Sponsored by the Central Valley Drinking Water Policy Workgroup

Date: Tuesday April 16, 2013, 1:30 – 3:30pm

Location: 10060 Goethe Road, Sacramento CA (Sacramento Area Sewer District Building)

1. Introductions and Description of Workgroup Efforts (10 minutes) Sue McConnell, Central Valley Water Board
2. Development and Capabilities of WARMF Model (30 minutes) Joel Herr, Systech Water Resources, Inc.
3. Development and Capabilities of DSM2 Model (30 minutes) Marianne Guerin, Resources Management Associates
4. Implications for Agriculture and Irrigated Lands Stakeholders (15 minutes) John Dickey, PlanTierra LLC
5. Modeling Needs and Opportunities for Partnering(15 minutes) Tom Grovhoug, Larry Walker Associates
6. Questions / Answers / General Discussion (remaining time) All

If you have questions regarding this event, please contact Lysa Voight at VoightL@sacsewer.com or 916-876-6038.

WARMF Modeling of the Central Valley

Joel Herr
Systech Water Resources

Sacramento-San Joaquin Delta Watershed Models for Water Supply / Water Quality

April 16, 2013

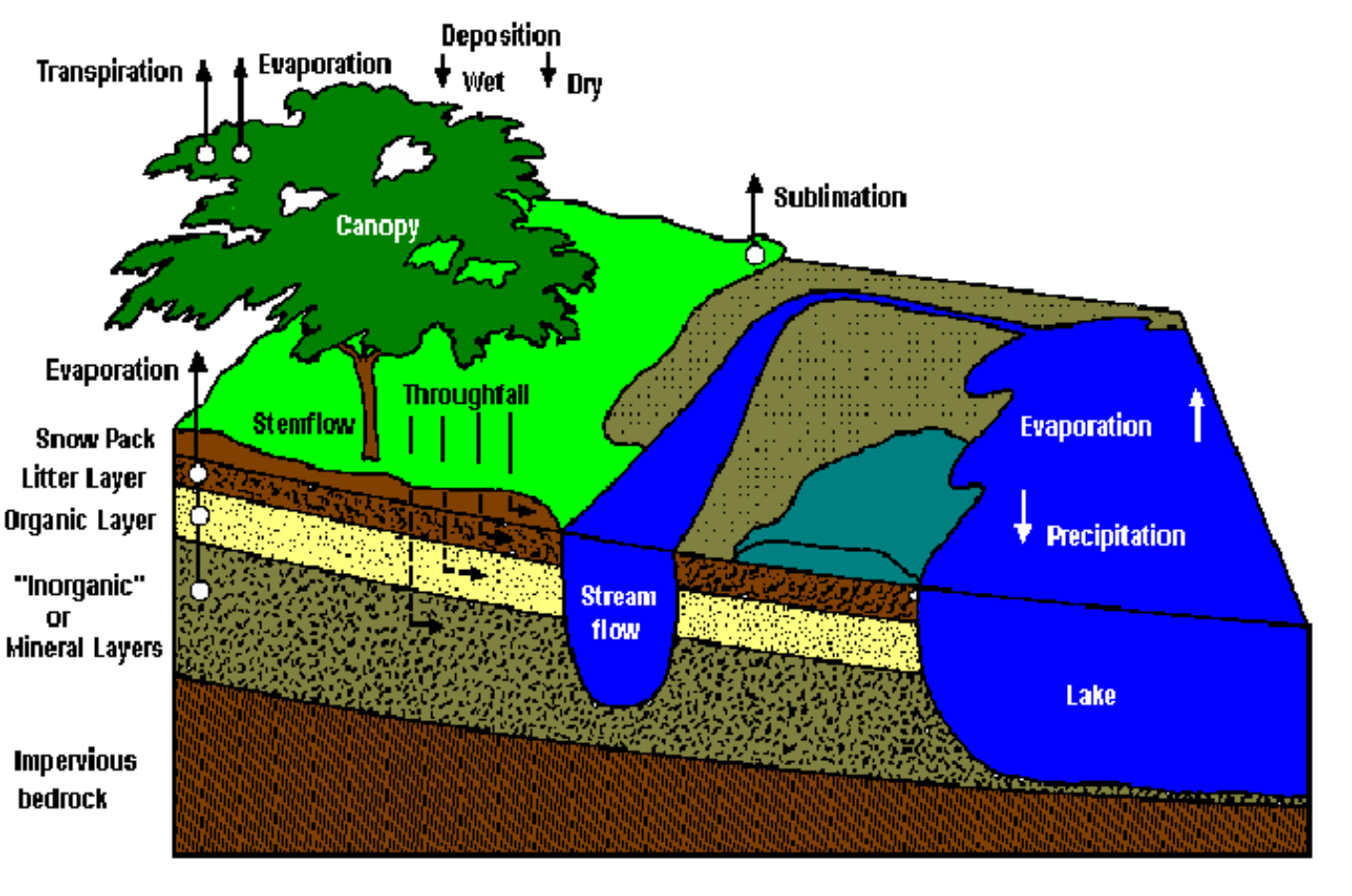
What is WARMF?

- “Watershed Analysis Risk Management Framework”
- Watershed modeling software which can be applied anywhere
- Applied to Sacramento, Delta eastside, San Joaquin, Tule River watersheds
- Used by multiple agencies

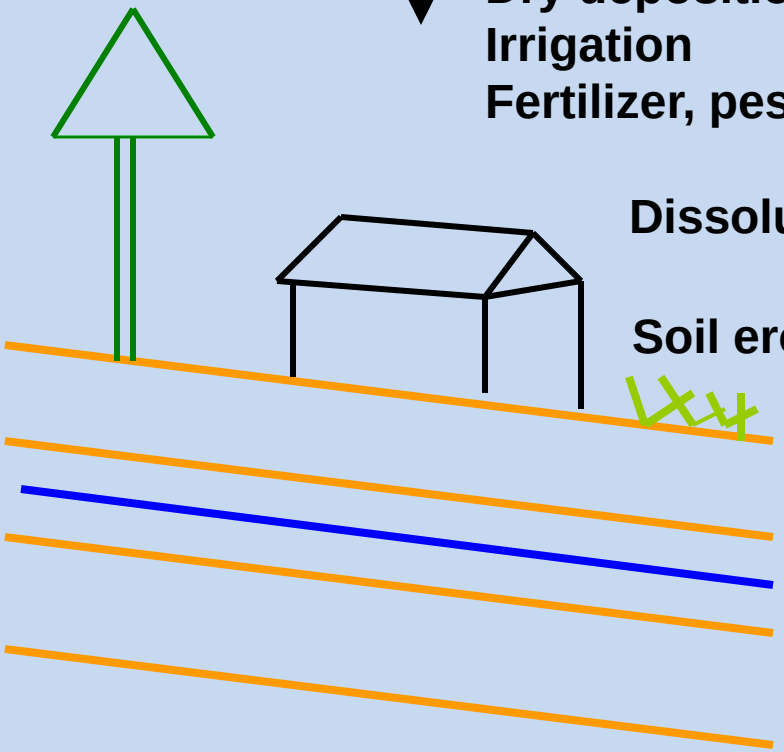
Principles of WARMF

- Watershed divided into land catchments, river segments, reservoir layers
- Catchments divided into land uses on surface, multiple soil layers
- Water volume balance, mass balance, chemical / physical processes and transport
- Used for surface water, root zone / shallow groundwater simulation

Watershed Processes in WARMF



Nonpoint Source Simulation



Wet deposition
Dry deposition
Irrigation
Fertilizer, pesticide, dairy waste

Dissolution, advection, decay

Soil erosion & wash off

Mineral weathering
Septic systems
Organic matter decay
Nitrification/Denitrification
Cation exchange
Plant uptake/nutrient cycling

Theory of WARMF

- CSTR = canopy, land surface, soil layers, stream segments, and lake layers
- Hydrologic network = 1,000's of interconnected CSTR
- Mass-heat balance equation for each CSTR = Advection + Diffusion + Sink + Source
- Sink & Source = kinetic expressions of processes
- Solve mass-heat balance equations for each CSTR with hourly or daily time step
- Inputs change: meteorology, atmospheric deposition, point sources, reservoir releases, diversions

Dynamic Mass & Heat Balance

- Dynamic mass balance equation
  $V\,[dC/dt] + C\,[dV/dt] = \text{inflow } (Q_{in}C_{in}) - \text{outflow } (Q_{out}C) + \text{sinks \& sources}$
- Dynamic heat budget equation
  $V\,[dT/dt] + T\,[dV/dt] = \text{inflow } (Q_{in}T_{in}) - \text{outflow } (Q_{out}T) + \text{sinks \& sources}$

Simulated Constituents

- Hydrology: flow, precipitation, irrigation, ET, snow water depth, reservoir surface elevation
- Conventional water quality
  - Temperature
  - Suspended sediment / turbidity
  - Major ions (Ca, Mg, K, Na, SO_4, Cl, inorganic carbon, TDS/EC)
  - Nutrients (NH_4, NO_3, TKN, TN, PO_4, TP)
  - Organic carbon, phytoplankton, BOD, DO
- Trace metals (optional)
  - Hg, Se, As, Fe, Zn, Mn, Al, Cu, Cd, Pb etc.

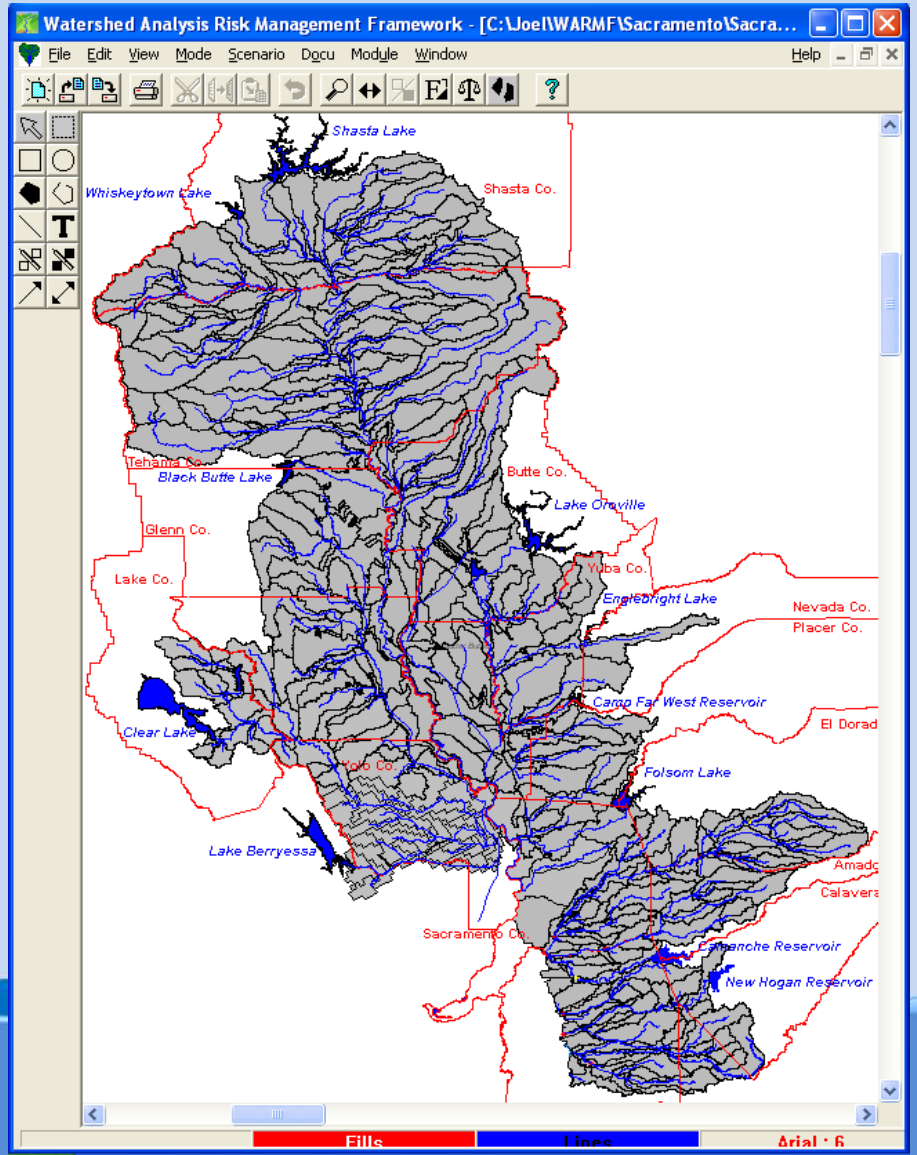
Output Types

- Time series output
  - Values for each model time step compared against measured data
- Loading output
  - Loading from land regions or total attenuated loading in rivers traced back to land use
- Flux output
  - Tracks transport and transformations
- Gowdy output
  - Shows loading sources and sinks for any simulation day and any location

Questions Answered by WARMF

- What is the source of loading observed in the river?
- How much benefit would be achieved with implementation of BMPs?
- What are the mass fluxes between the groundwater and surface water systems?
- What will be the water quality next week?
- What is the impact of climate change on water supply and water quality?

Sacramento River / Delta Eastside Watersheds Model Domain



Systech Water Resources, Inc.

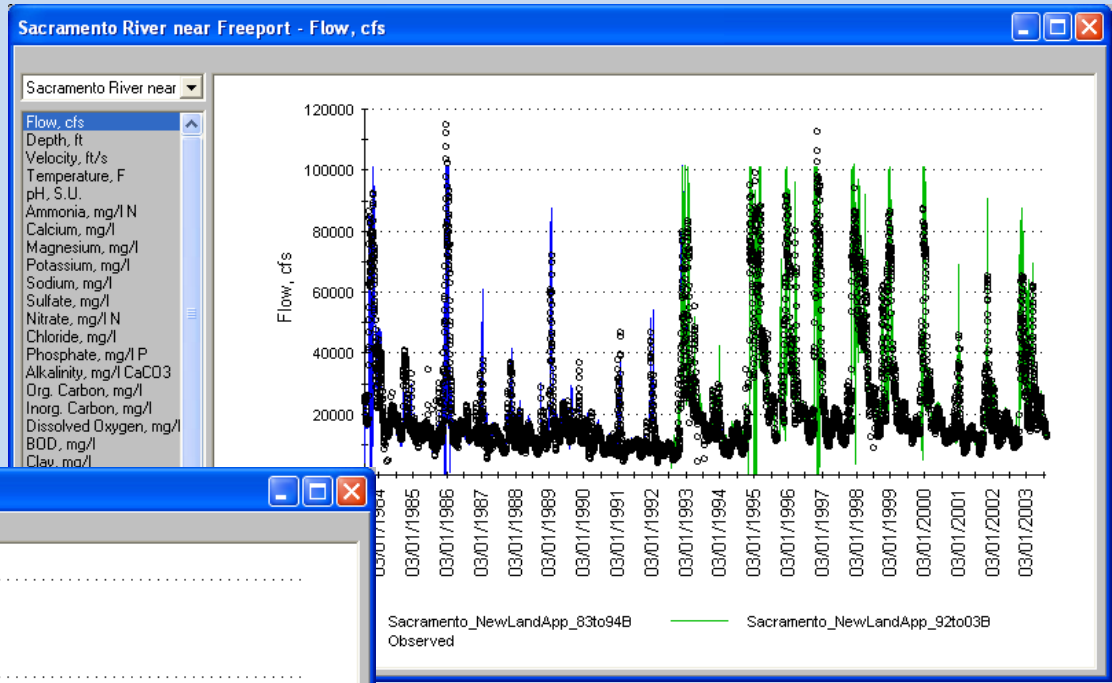
Sacramento River / Delta Eastside Watersheds Model Setup

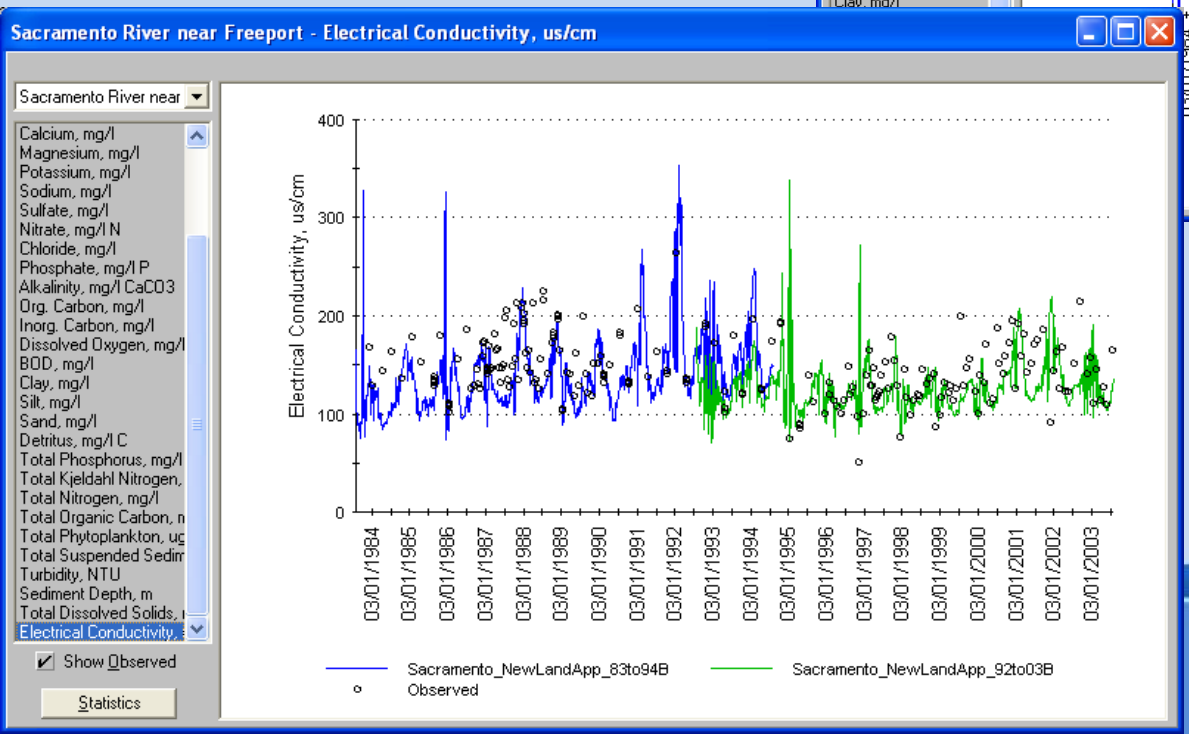
- Use inputs from reservoirs around the valley
- Rivers simulated to Delta tidal boundaries
- Land Use
  - DWR for agricultural areas
  - Enhanced treatment of urban areas
  - NLCD used for natural land cover
- Irrigation
  - Primary source is surface waters

Sacramento / Delta Eastside Watersheds Model Uses

- CUWA / Drinking Water Policy Work Group
  - loading of nutrients, organic carbon to Delta
- Metropolitan Water District
  - Real-time forecasting of flow, turbidity entering the Delta in winter
- CV-SALTS Coalition
  - Analyses of salt, nitrate loading to surface water, groundwater

Example Output: Time Series





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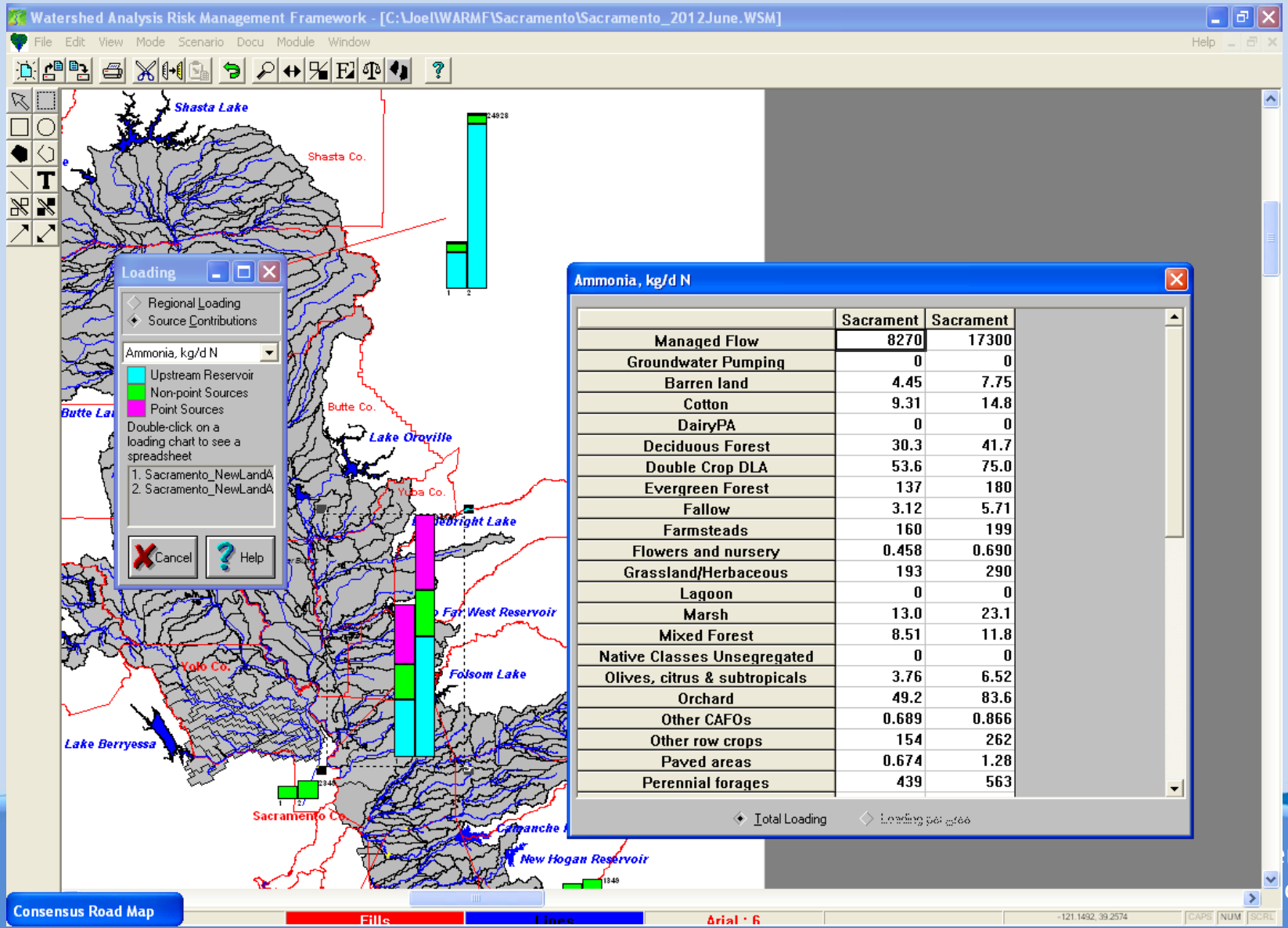
Example Output: Loading

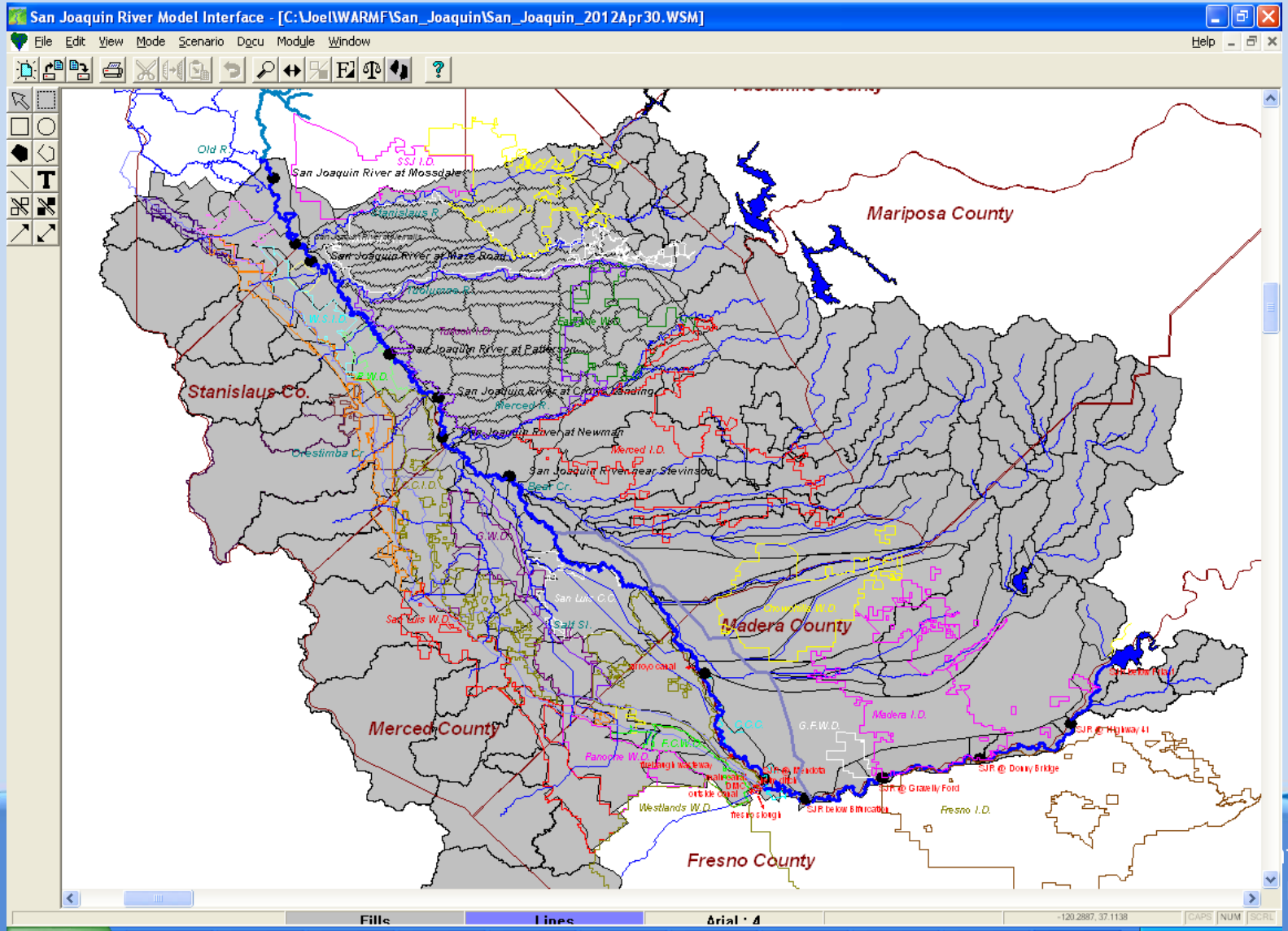


	Sacrament	Sacrament
Managed Flow	8270	17300
Groundwater Pumping	0	0
Barren land	4.45	7.75
Cotton	9.31	14.8
DairyPA	0	0
Deciduous Forest	30.3	41.7
Double Crop DLA	53.6	75.0
Evergreen Forest	137	180
Fallow	3.12	5.71
Farmsteads	160	199
Flowers and nursery	0.458	0.690
Grassland/Herbaceous	193	290
Lagoon	0	0
Marsh	13.0	23.1
Mixed Forest	8.51	11.8
Native Classes Unsegregated	0	0
Olives, citrus & subtropicals	3.76	6.52
Orchard	49.2	83.6
Other CAFOs	0.689	0.866
Other row crops	154	262
Paved areas	0.674	1.28
Perennial forages	439	563

Sacramento / Delta Eastside Watersheds: Potential Upgrades

- Adjustment of applied water rates
  - Rates currently too low in central watershed
  - Loading from agricultural areas underestimated
- Mercury simulation
  - WARMF includes peer-reviewed mercury processes and bioaccumulation, not currently used in California

San Joaquin River Watershed Model Domain



San Joaquin River Watershed Model Setup

- Uses flow, loading inputs from Friant Dam, east side tributaries, Delta-Mendota Canal
- Catchment boundaries aligned with irrigation district boundaries
- Land use
  - DWR, NLCD for general coverage
  - Advanced treatment of urban areas, dairies

San Joaquin River Watershed Model Uses

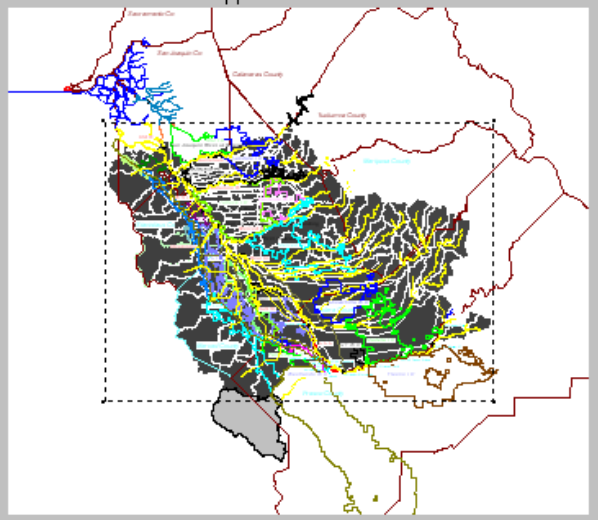
- CUWA / Drinking Water Policy Work Group
- Metropolitan Water District
- CV-SALTS Coalition
- Bureau of Reclamation
  - Tracking of salt, nitrate loading
  - Tracking contribution from Delta-Mendota Canal
- California Department of Fish & Game
  - Simulation of organic loading entering Delta
  - Focused study of agricultural loading

Example Output: Flux Output

Flux Output

Scenario: SJR_NewLandApp_95_03I | Constituent: Nitrate, kg/d N | Simulation Period: 10/01/1995 – 09/30/2003

Applicable Area



Catchments

Surface

Precipitation	Dry Deposition
2100.700	2711.670

Irrigation	Land Application
23489.53	22041.99

Inflow	Outflow
92.03942	2483.185

Reactions

Produced	Decayed
6551.159	45222.36

Uptake	Percolation
45222.36	52484.02

Soil

Inflow	Outflow
18.84952	2488.636

Reactions

Produced	Decayed
6431.214	12232.91

Point Sources	Pumping
1851.656	1521.014

Rivers

Water Column

Inflow	Outflow
486820.3	483095.7

Point Sources	Diversions
42110.29	45743.46

Reactions

Produced	Decayed
1068.626	1163.390

Resuspension	Settling
0.157181	0.204075

Bed Sediment Reactions

Produced	Decayed
0	0.003624

Reservoirs

Water Column

Precipitation	Dry Deposition
1.236795	0.52271

Inflow	Outflow
93.62903	62.95517

Point Sources	Diversions
0	0

Reactions

Produced	Decayed
10.97892	45.09936

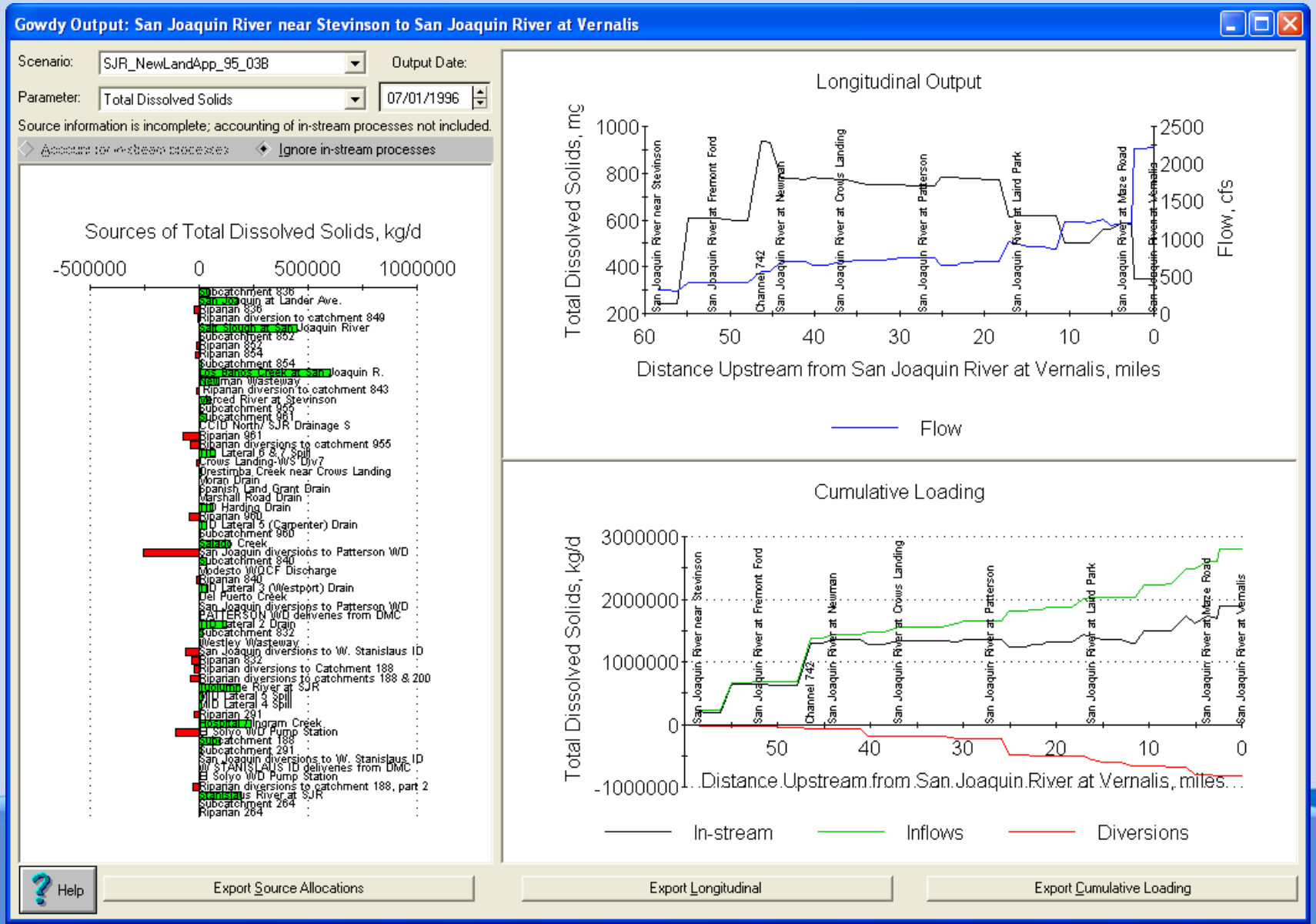
Diffusion	Settling
-0.024041	0

Bed Sediment Reactions

Produced	Decayed
0	0.002249

OK | Cancel | Help

Example Output: Gowdy Output



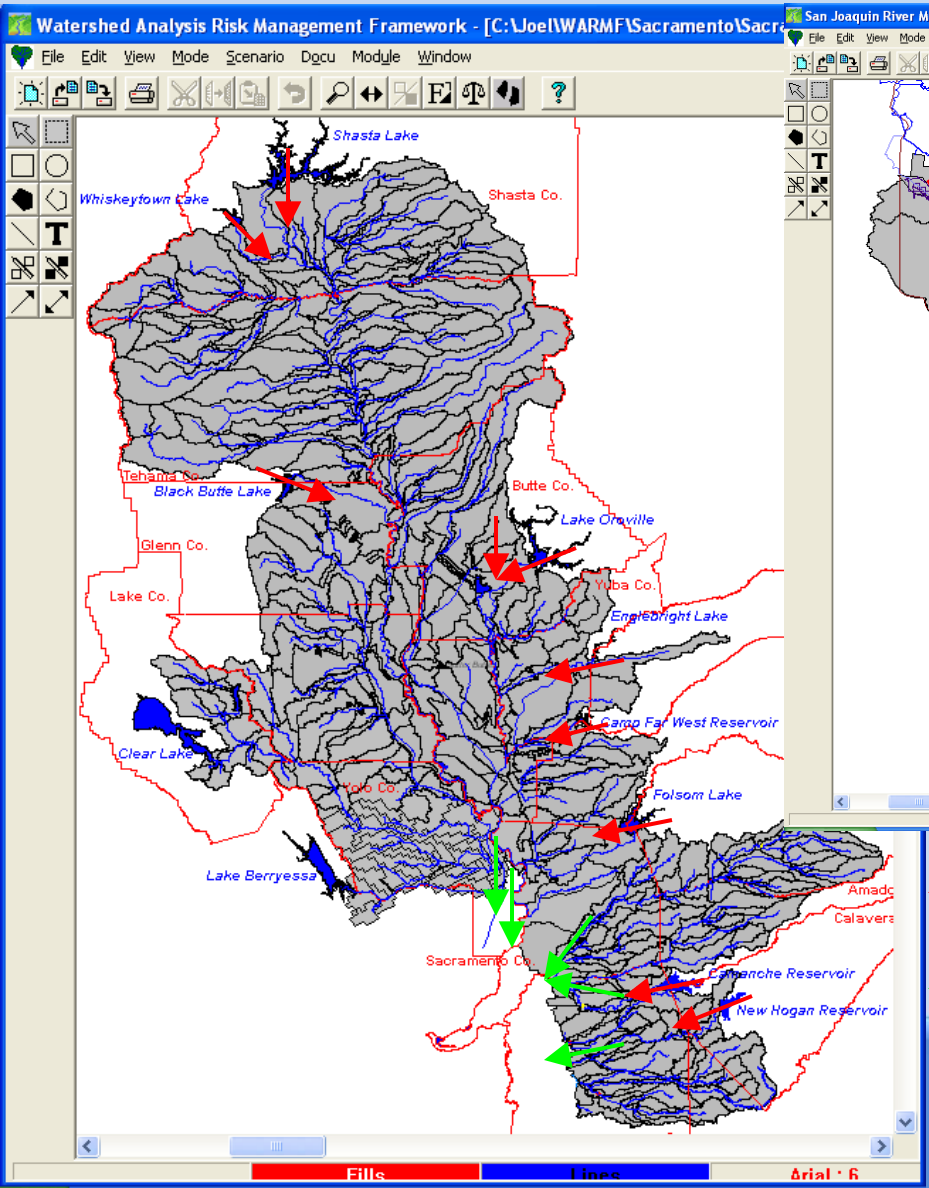
San Joaquin River Watershed Potential Model Upgrades

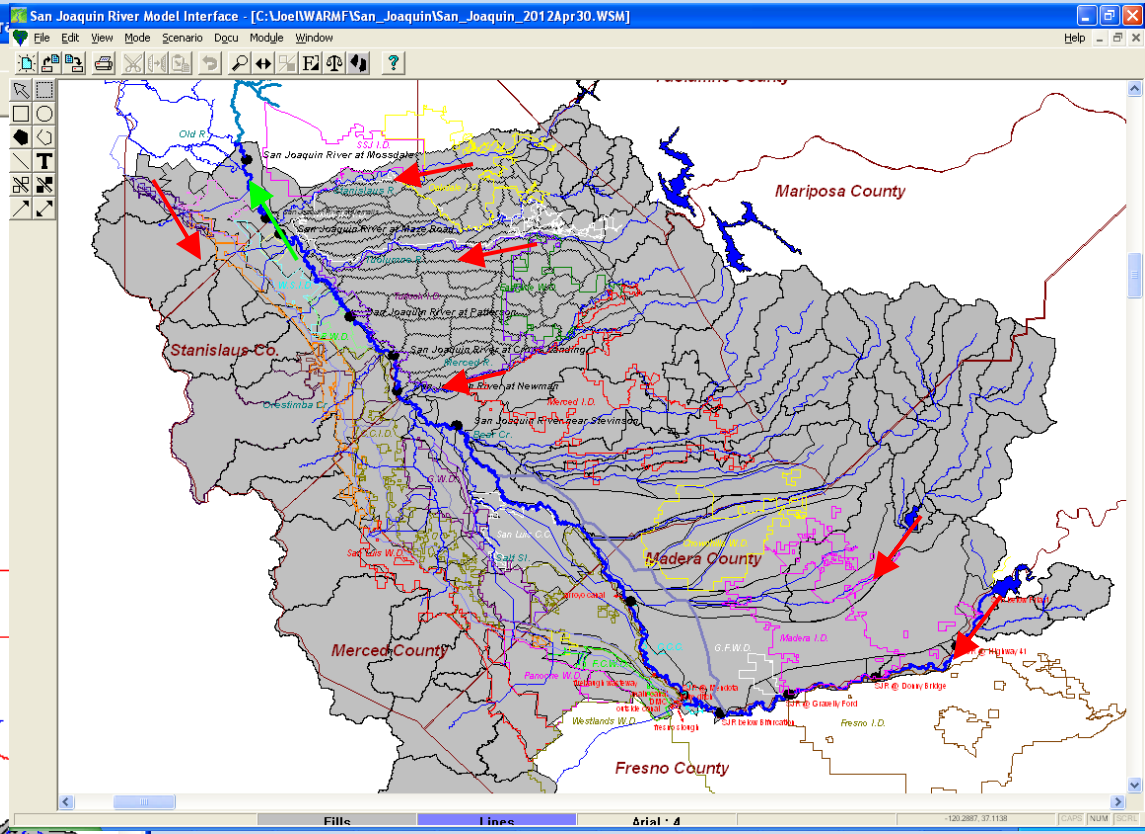
- Real-time water quality forecasting
- Completion of dry reach watersheds
  - Currently set up for winter conditions only
  - Upgrade would improve groundwater loading analysis
  - Could be used for river restoration studies

Model Linkages

- CALSIM with WARMF
  - CALSIM output replaces historical WARMF input
  - Reservoir releases, major diversions
- WARMF with groundwater models
  - Groundwater models provide irrigation amount, recharge
  - WARMF calculates mass loading to groundwater
- WARMF with Delta / DSM2 models
  - WARMF provides flow, water quality at tidal boundaries

Model Linkages





Boundary Inflows from CALSIM (diversions not shown)

WARMF Output to Delta Model

Systech Water Resources, Inc.

Questions?

DSM2: Capabilities for Delta Water Quality Modeling

Marianne Guerin
Resource Management Associates

RMA

4/17/2013

Overview

- DSM2
  - HYDRO, QUAL and PTM
  - Calibration - Data needs, nutrient model examples
- Drinking Water Policy Project
  - Historical Model *vs.* Planning Studies
  - Example model output
- Related applications, projects

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DSM2 – Delta Simulation Model

- Suite of 1-dimensional flow and transport models
  - Developed, calibrated and maintained at DWR's Delta Modeling Section
- HYDRO – hydrodynamics
- QUAL - water quality
  - Conservative transport
  - Non-conservative transport
- PTM – particle tracking model

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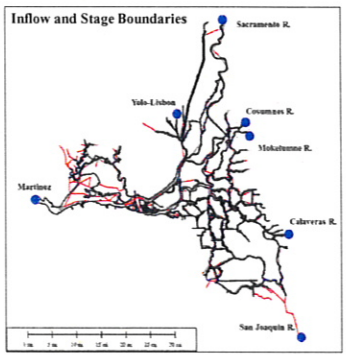

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DSM2-QUAL Capabilities

- Conservative transport
  - Salinity as EC (electrical conductivity)
  - DOC (dissolved organic carbon)
- Non-conservative transport
  - Nutrients and water temperature – UCD PhD thesis
    - ammonia, nitrate, nitrite, dissolved oxygen, CBOD, organic-N, organic-P, orthophosphate, algae, water temperature, EC
  - Water temperature
  - Single arbitrary constituent (*e.g.*, turbidity)

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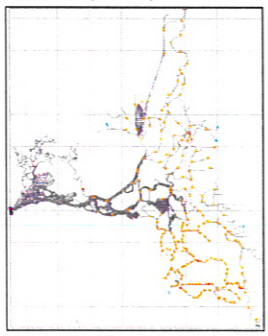
Delta Island Consumptive Use (DICU) Model

Accounts for monthly water balance on Delta islands
- 142 subareas
- 20 crop types –values for Critical and Non-Critical water years

Flows:
Seepage Flow
Diversion Flow
Drain Flow (+ water quality)

Water Quality: for each Constituent

NOTE – this is not the DSM2 grid.



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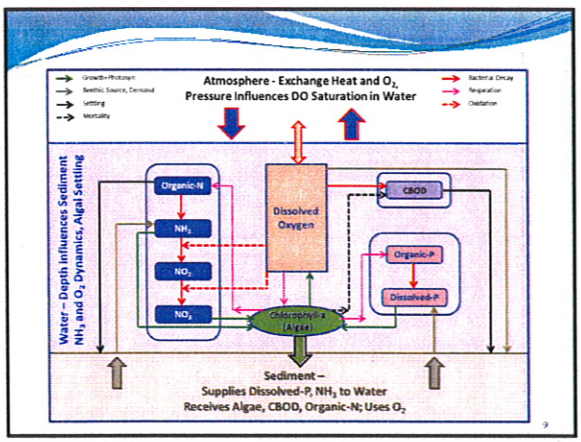
Data Needs and Model Calibration

HYDRO

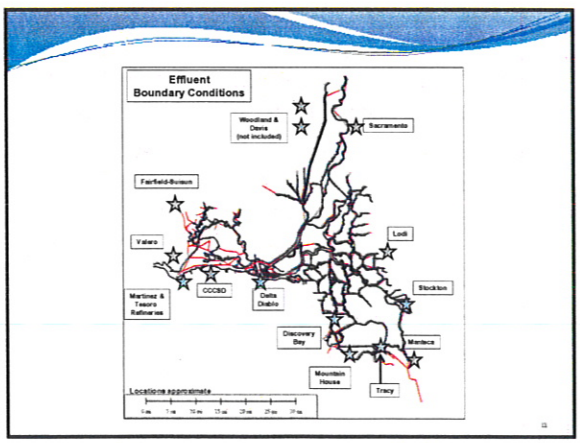
- Boundary Condition Data Needs –
  - Inflow, exports, stage at Martinez, timing of gate and barrier operations
  - DICU flows
- Calibration –
  - Well-documented online*
  - Calibration/validation data
    - 15-min, hourly, daily data publically available (Water Data Library, USGS, CDEC)
    - Some areas have better data coverage

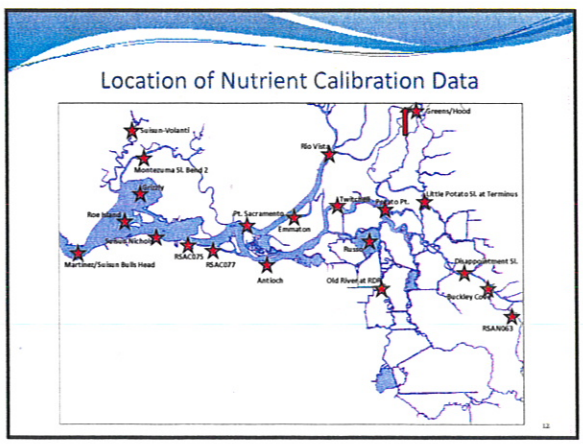
* http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2.cfm

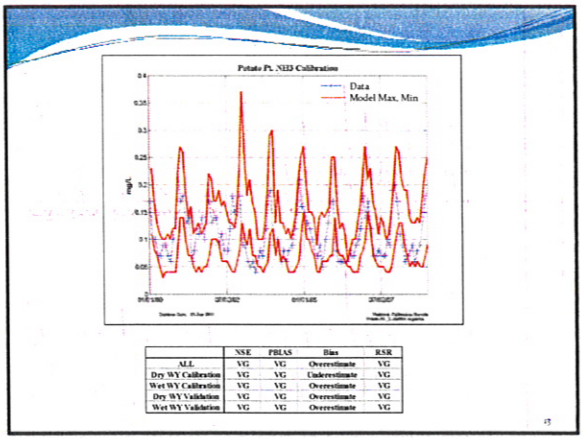


QUAL – BC and Calibration Data

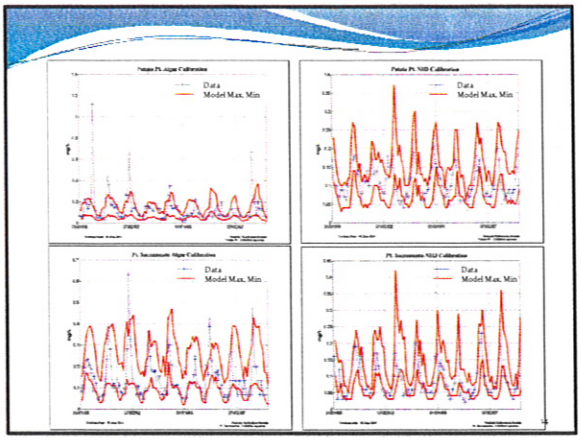
- Salinity:
  - Data availability very good; See calibration link on HYDRO slide
- Nutrients and water temperature:
  - Data availability for water temperature good
  - Data availability for nutrient model – mixed, mostly grab samples, monthly
  - WARMF - model output can be used as DSM2 upstream input
- Calibration of QUAL nutrient model in Delta by RMA:
  - Effluent sources included
  - Initial calibration: Covered 1990 – 2008 (DSM2 version 6)
  - Subsequent calibrations: Covered 2000 - 2008 (DSM2 version 8)

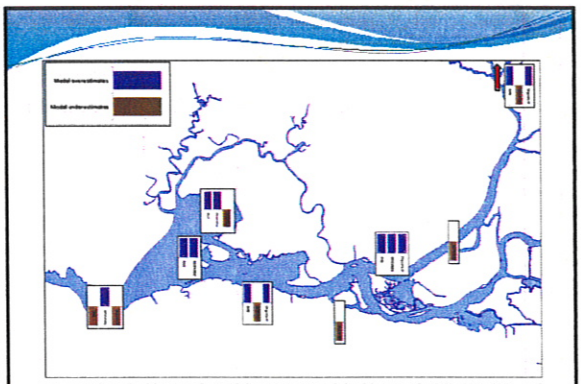






	NSE	PBIAS	Bias	RSR
ALL	VG	VG	Overestimate	VG
Dry WY Calibration	VG	VG	Underestimate	VG
Wet WY Calibration	VG	VG	Overestimate	VG
Dry WY Validation	VG	VG	Overestimate	VG
Wet WY Validation	VG	VG	Overestimate	VG





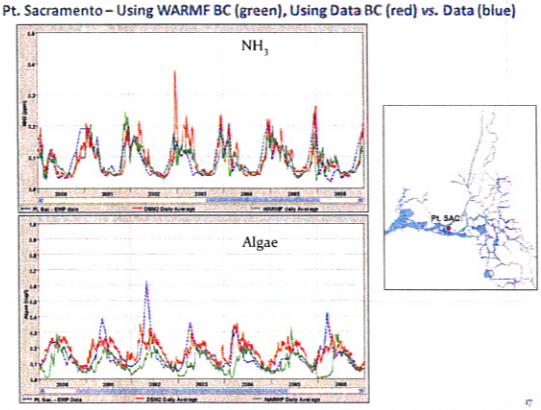
Categorical residual bias analysis of the nutrient model calibration for NH_3, NO_2+NO_3, and Organic-N. The arrow indicates Hood results.

Historical model BC – SJR BC example Data *vs.* WARMF

Most BC data is Monthly, WARMF can be Monthly or Daily

- QUAL SJR variables
  - Chl-a data (Algae)
  - DO data
  - NH_3 data
  - NO_3 data
  - PO_4 data
  - CBOD = constant
  - Water temp data
  - NO_2 = constant
  - Organic_N data
  - Organic_P = constant
- WARMF output
  - Chl-a
  - DO
  - NH_3
  - NO_3
  - PO_4
  - BOD
  - Water temp
- *Calculated for DSM2*
  - $NO_2 = 0.01 * NO_3$
  - *Organic_N* = DOC**0.123*
  - *Organic_P* = Chl-a**0.0004*

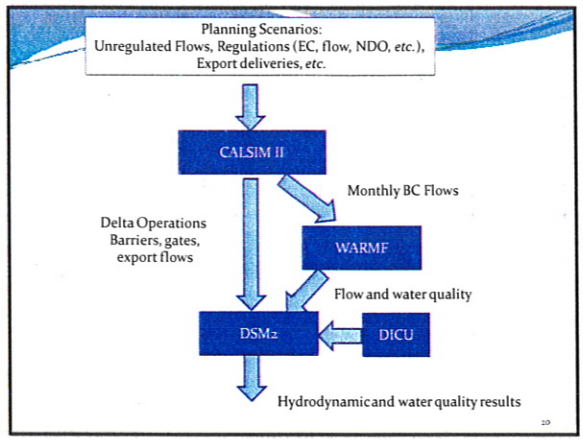
Pt. Sacramento – Using WARMF BC (green), Using Data BC (red) *vs.* Data (blue)



CVDWP Project: DSM2 Planning Scenarios

DSM2- Historical *vs.* Planning

- Historical model:
  - Simulations use actual historical data and conditions
  - Boundary conditions: flows, stage, water quality, consumptive use (DICU)
  - Model calibrated to historical data, reproduces historical conditions
  - Used for forecasting
- Planning Model:
  - Uses synthetic/proposed conditions in hypothetical scenarios
  - Scenarios cannot be calibrated or verified
  - Model boundary conditions supplied by external models – *e.g.*, CALSIM II, WARMF, DICU
  - Results typically analyzed comparatively - *i.e.*, analyze differences between scenarios, not results in an 'absolute' sense



CVDWP Scenario Development:

- Scenarios:
  - Current Condition ~ Base Case
  - Future: Planned, Plausible, Outer Bound
- Basic Assumptions:
  - DSM2 flow, EC, DOC and nutrient models are calibrated
- Boundary conditions:
  - Effluent BC: supplied to DSM2 for 4 scenarios
  - CalSim II monthly flow boundary conditions (BC) used in HYDRO
  - WARMF water quality output used for upstream boundary conditions
  - DICU (flow and water quality) same for all models

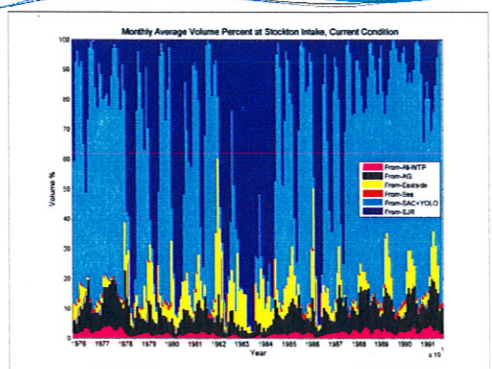
Example – Effluent BC developed by experts

Effluent Source	Current Condition NO3-N	Future Planned NO3-N	Future Plausible NO3-N	Future Outer Bound NO3-N
Stockton, City of	0.78	0.8	0.3	0.1
Sacramento Regional County Sanitation District	23.0	0.5	0.3	0.1
Contra Costa Central Sanitary District	20.0	20.0	0.3	0.1
Delta Diablo	30.0	32.0	0.3	0.1
Discovery Bay, Town of	0.50	0.5	0.3	0.1
Fairfield-Suisun	0.50	0.5	0.3	0.1
Lodi, City of	0.50	0.5	0.3	0.1
Manteca, City of	0.25	0.3	0.3	0.1
Mountain House Community Services District	0.50	0.5	0.3	0.1
Tracy, City of	0.50	0.5	0.3	0.1
Rio Vista, average conc mixture	13.8	9.6	0.3	0.1

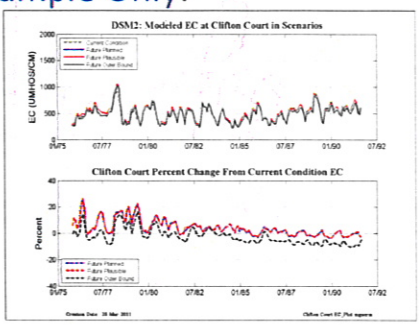
Effluent Source	Current Condition NO3-N	Future Planned NO3-N	Future Plausible NO3-N	Future Outer Bound NO3-N
Stockton, City of	18.0	19.0	1.5	1.5
Sacramento Regional County Sanitation District	0.2	7.3	1.5	1.5
Contra Costa Central Sanitary District	1.1	1.1	1.5	1.5
Delta Diablo	3.0	3.2	1.6	1.6
Discovery Bay, Town of	15.0	15.0	1.5	1.5
Fairfield-Suisun	15.0	16.0	1.6	1.6
Lodi, City of	6.4	6.7	1.5	1.5
Manteca, City of	8.5	8.9	1.6	1.6
Mountain House Community Services District	7.0	2.5	1.5	1.5
Tracy, City of	7.0	2.5	1.5	1.5
Rio Vista, average conc mixture	2.7	2.7	1.5	0.8

QUAL Output Variables

- DOC, EC
- Volumetric percentages
  - Bromide load – calculated from EC and Volumetric using P. Hutton linear relationship
- Nutrients
- Scenario comparisons:
  - Plots comparing 4 scenarios at specified locations
  - Percent Difference from Current Condition - plots and tables
    - At export locations
    - Could be anywhere in DSM2 domain



Example Only:



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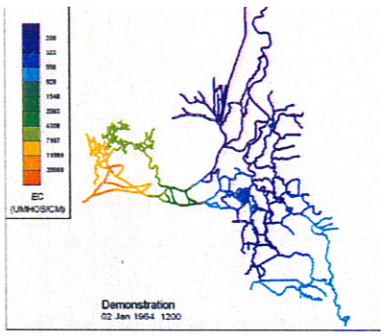

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Related Applications and Projects

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DSM2 Historical Turbidity

- Metropolitan Water District funded project
  - RMA calibrated DSM2-QUAL turbidity model
    - Approximates turbidity "transport" in Delta
    - Used only in winter high flow "first flush" periods
  - Real-time and forecasting models (DWR Operations group utilizes)
  - 2010 -2012 Historical models run with turbidity data BC
  - Historical 1975 – 2011 with WARMF turbidity BC and/or suspended sediment data

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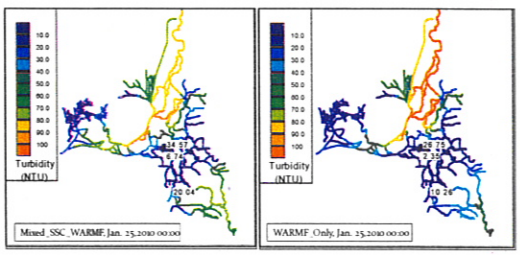
Comparison of Results With Different BC



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DSM2 Nutrient Model Projects

- IEP funding
  - Carol Kendall – USGS scientist
    - In conjunction with isotope data interpretation
    - Supplying flow and stage output at data acquisition locations
    - Nutrient 'travel time' estimates
  - SFEI and USGS - David Senn, Carol and others...
    - Nutrient model recalibration
    - Long-term interpretation of nutrient sources, sinks and transformations
      - Seasonal trends, nutrient loads
      - Relationships with flow conditions
      - Identify data gaps

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Thank-you!

Implications for Agriculture and Irrigated Lands Stakeholders

John Dickey

April 16, 2013

Sacramento -San Joaquin Delta Watershed Models for Water Supply / Water Quality -- Seminar

California Rice

PLANTIERRA

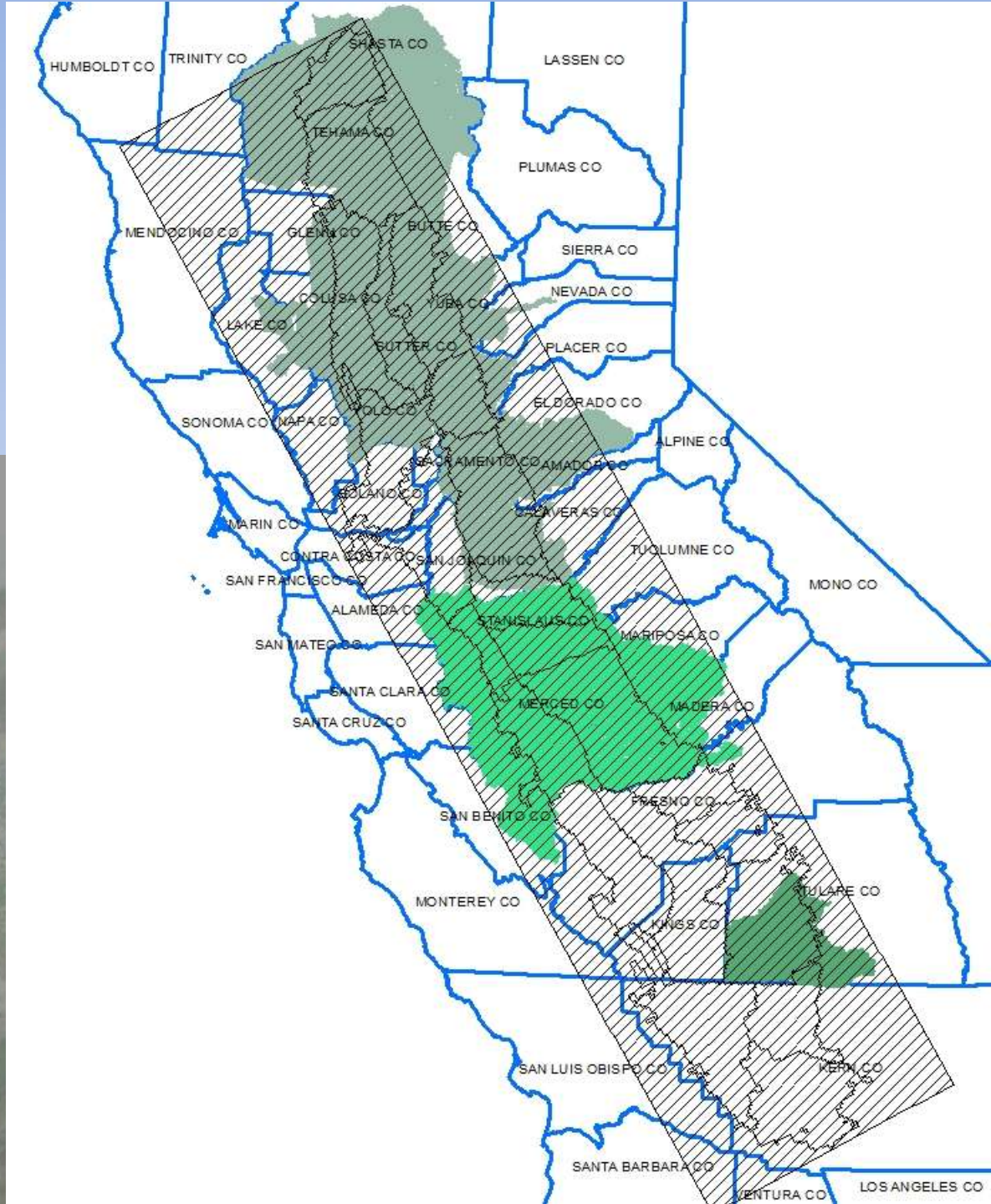
Quantifying Influence (impacts and value added)

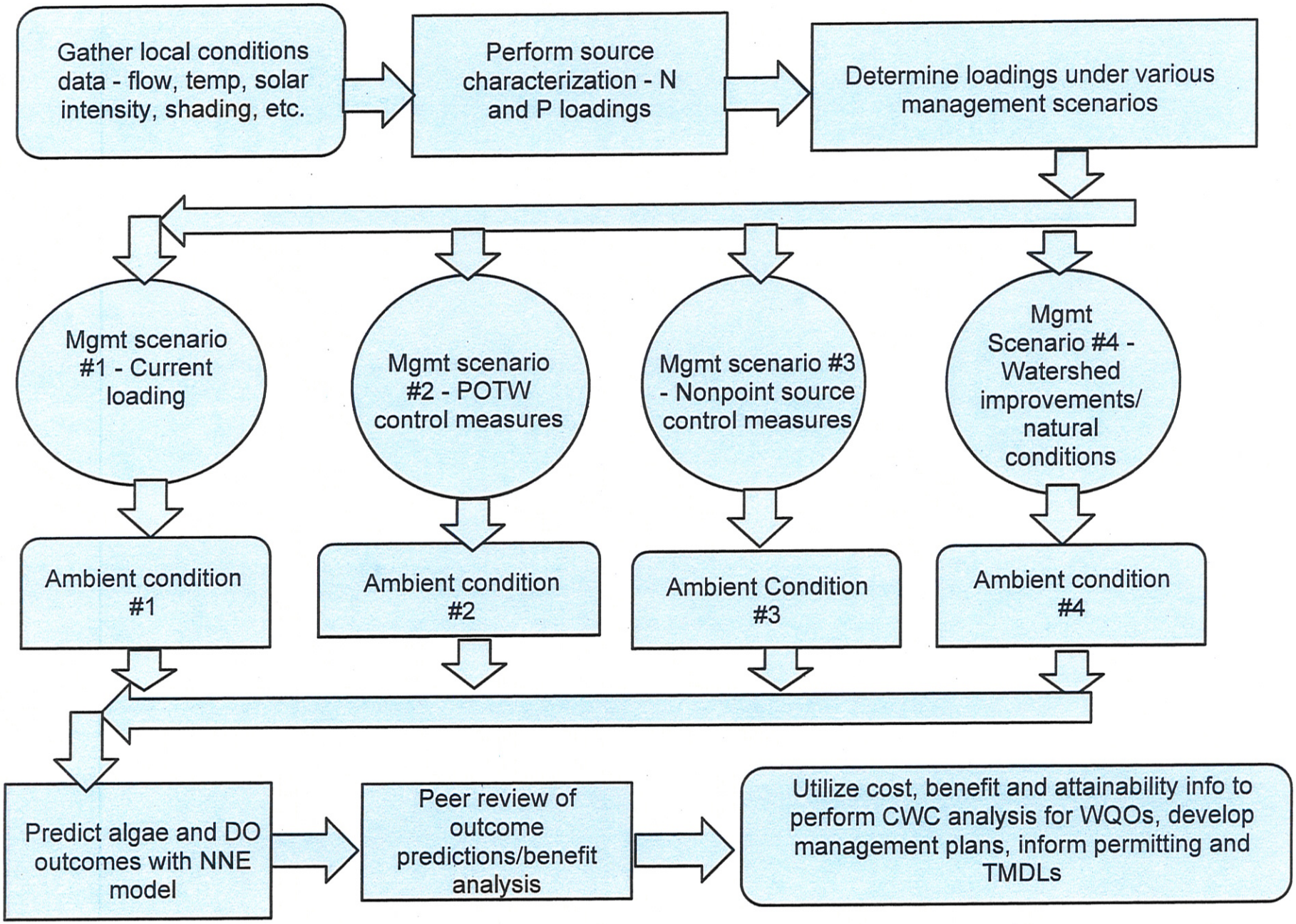
- How does a discharge concentration relate to impacts elsewhere in the watershed?
  - What is the seasonal influence of dilution? Of other discharges?
    - In-stream flow and water quality
    - At drinking water intakes
    - On groundwater recharge volume & quality
  - What is the influence and value of a management approach:
    - Of current management practices
    - Of hypothetical future practices and facilities
- What are the likely alternatives to knowing?
  - Guilty until proven innocent (every source becomes significant), + the tributary rule → more stringent constraints and more costly solutions

Irrigated Lands Coalitions & General Permit

- Dairy
- East Side SJV
- West Side
- South SJV
- Delta
- Sac Valley
- Rice Commission
- Westlands
- Goose Lake

CV-SALTS Analysis Area




Gather local conditions data - flow, temp, solar intensity, shading, etc.
Perform source characterization - N and P loadings
Determine loadings under various management scenarios
Mgmt scenario #1 - Current loading
Mgmt scenario #2 - POTW control measures
Mgmt scenario #3 - Nonpoint source control measures
Mgmt Scenario #4 - Watershed improvements/ natural conditions
Ambient condition #1
Ambient condition #2
Ambient Condition #3
Ambient condition #4
Predict algae and DO outcomes with NNE model
Peer review of outcome predictions/benefit analysis
Utilize cost, benefit and attainability info to perform CWC analysis for WQOs, develop management plans, inform permitting and TMDLs