Evaluation of Watershed Models for Simulation of Salt Mass Balance of Seasonally Managed Wetlands in the San Joaquin River Basin

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ABSTRACT

Increased demand for and over-allocation of fresh water resources in the San Joaquin River Basin (SJRB) has necessitated the creation of real-time water quality management (RTWQM) strategies to ensure that downstream water quality objectives are met. The Grasslands Water District (GWD), 47,795 acres of natural and artificial seasonal wetlands, has been identified as an area of priority for real-time salinity management. Salinity in the GWD is of special concern as wetland drainage release periods correspond to periods of low assimilative capacity in the SJRB and the irrigation season of salt-sensitive crops. In this study, two proposed RTWQM models, Watershed Analysis Risk Management Framework (WARMF) and WetManSim, were evaluated using the concept of mass balance in order to validate their hydrological assumptions. Major mass imbalances were found in the WARMF model resulting in an average change in catchment storage capacity of ±2.02 feet per water year. This imbalance is most likely due to the lack of integration of irrigation demand calculations and artificial wetland flooding schedules. WetManSim was found to be in mass balance however the model is limited to average monthly as opposed to daily analysis. WARMF shows promise as a powerful water-quality management tool. Integration of an irrigation demand calculator could help more accurately represent inflows to land catchments. As WARMF and other RTWQM models advance it is important that users understand the assumptions behind each model and critically evaluate results before using them for environmental decision-making.

INTRODUCTION

As the demand for water for human consumption, recreation, wildlife and agriculture grows it is becoming increasingly difficult to meet water quality objectives in arid river basins such as the San Joaquin River Basin (SJRB) of California (see figure 1). Total Maximum Daily Loads (TMDLs) are used as a way of quantifying the maximum concentration of a particular constituent that can be safely assimilated into a water body on an average day. Meeting downstream TMDL objectives requires a complex understanding of contaminant loads and the basin's ability to safely assimilate these loads. Real-time water quality management (RTWQM) is an approach currently being developed in order to predict assimilative loads of a water body and facilitate the release of contaminants in a manner that will not violate downstream objectives. Systech's Watershed Analysis Risk Management Framework (WARMF) model is currently being

used in the SJRB. Real-time water quality models will allow watershed managers to coordinate contaminant releases from both point and non-point sources in a manner that ensures that the basin's safe assimilative capacity is neither exceeded nor significantly underutilized.

Increasing salinity is an important issue now being faced in many arid river basins including the SJRB. Excess salt loads can degrade the habitability of fresh water environments but more importantly degrade irrigation water used for valuable salt-sensitive crops. Salt is cycled through water basins via cropland irrigation, natural seepage, managed wetlands and other human uses [1]. Increased water demand removes freshwater from a body of water and returns saltier water exacerbating the salinity issue. The SJR is especially sensitive to salinity driven water quality deterioration due to over-allocation of water resources and lack of coordination between users [2].

The Grasslands Water District (GWD) of the SJRB has been identified as an area of priority for salinity control. The GWD is the largest contiguous wetland in California comprised of natural and seasonal wetlands that provide habitat for migratory waterfowl and other shorebirds [1]. Modification of the natural hydrology of the San Joaquin River has necessitated artificial seasonal flooding of the wetlands with water from the Sacramento-San Joaquin Delta (SJD) that tends to be higher in salt content. Between March and April, the wetlands are drawn-down in order to mimic the natural seasonal dry period essential for grass seeding. This drainage releases significant salt loads, as salts from supply water are concentrated via evapotranspiration. This is a major issue because drawdown schedules correspond with periods of low assimilative capacity in the SJRB as well as correspond with the beginning of the irrigation season of salt-sensitive crops [3].

Current RTWQM models such as WARMF make numerous simplifying assumptions that limit the model's ability to develop accurate water and salt balances. One possible causes of inaccuracy is the simulation of artificial seasonal wetland hydrology using a slow moving stream analog. It is unclear if simplifications of drawdown hydrology have significant effects on salt balances and assimilative load predictions. To assess the significance of wetland drawdown hydrology on RTWQM models manual water mass balances were conducted using input data from WARMF to compare the balances to those produced by the model. Comparison of mass balances will give insight into the validity of assumptions the WARMF model makes as well as perhaps explain certain discrepancies in salt mass balances output from the WARMF simulation. If large discrepancies between the models are found, this comparison will help guide future changes in the WARMF model code

MODEL THEORY

WARMF

Watershed Analysis Risk Management Framework (WARMF) is a software tool created by Systech Water Resources Inc. in order to assist stakeholders in water quality management using a local watershed approach [4]. Based around individual river basins, WARMF is a dynamic model that performs physical process calculations to determine water quality under a variety of user-specified scenarios [5]. WARMF uses historical and forecasted meteorological data to simulate daily hydrology and water quality including runoff, non-point source loading from land, electrical conductivity, pH and temperature. Calculations are integrated into a single Geographic Information System (GIS) graphical user interface (GUI) that allows users to trace loading to individual locations and land

uses (see figure 2). Results of the model are available for easy interpretation through two decision support system (DSS) modules that help provide road-maps for setting TMDLs for a series of control points throughout the water basin.

WARMF models a river basin as a set of three types of linked elements, land catchments, river segments and reservoir layers. The WARMF domain ends at shallow groundwater, modeling reactions in the top four layers of soil. Each element is modeled as a continuously stirred tank reactor (CSTR), meaning within a given soil or reservoir layer or river segment, water and nutrients are assumed to be homogenously mixed [6]. Within each element hydrologic and land use characteristics are defined. A single catchment can have multiple defined land uses that require specific irrigation and nutrient application parameters, however certain parameters such as meteorology, water flow, biogeochemical reaction rates and soil characterization are averaged over the entire catchment area. WARMF utilizes four main types of data- air quality, managed flow, point source, and meteorological. Managed flow data includes flows from diversions, deep groundwater recharge and scheduled reservoir releases. These data are not generally available in real-time, instead WARMF uses a daily average of historical data, or in the case of groundwater recharge- data from other models such as WetManSim (see below) [5]. Meteorological data are the most important driving variables for the WARMF hydrology model therefore real-time data are used.

Land area is idealized as a series of compartments including canopy, snow pack, surface layer, and soil layers. Using provided meteorological data, WARMF calculates soil infiltration, ground water exfiltration, surface runoff and non-point source loading from mixing and reactions using catchment-specific and basin-wide coefficients. This

flow is then rerouted from the surface and soil layers to connected river segments and reservoirs. While naturally runoff may enter multiple streams, the hydrology is simplified to have flow connected to only major outlets. Evapotranspiration (ET) is calculated using the Hargreaves potential evapotranspiration equation which is a function of latitude and daily temperature [4]. This provides the maximum ET that can occur on a given day. If this amount of water is not available in the canopy, surface waters or soil, only the available amount is transpired. WARMF does not calculate crop irrigation demand. Instead, users specify the percentage of flow from any linked diversion, managed flow or point source files to apply specific land uses within the catchment. Determining these percentages requires external analysis and is strongly dependent upon data available and complexity of the system [5]. The resulting quantities of water applied to each land use in theory should reflect the actual daily amount of water added to the catchment. Wetlands are also flooded using irrigation water under the land use of "marsh."

WETMANSIM

WetManSim is a water mass-balance DSS model developed by Nigel Quinn. The model was created in order to predict the effects of salt loads from drawdown of seasonal and permanent wetlands- specifically in the GWD. Based around an easily accessible MS Excel platform, the model incorporates estimates of the weekly water demand for the wetlands as well as adjacent areas with flow, evapotranspiration and recharge in order to create mass balance around individual wetland areas (see figure 3). WetManSim is an annual steady-state model representing average conditions collected for the water district. Existing monthly model inputs and model parameters can be substituted into the model to represent more realistic dry and wet water year conditions. Estimates of flooded surface

area each month are obtained from wetland managers throughout the district. Recharge and seepage loss is calculated using the fillable vadose zone soil porosity characteristics of individual wetlands. Fillable vadose zone calculations also allow calculation of surface water depth. Average monthly pond depth in seasonal wetlands will rise during flood up after all pore space is filled. Pond depth is generally raised to "shooting depth" or approximately 1 ft., in order to attract bottom-feeding waterfowl and birds. WetManSim assumes that once flood-up is completed, shooting depth is maintained as the average pond depth. WetManSim does not specifically model evapotranspiration due to lack of data for model-calibration however ET is estimated daily using standard annually constant crop-coefficients.

WetManSim divides inflow water for multiple uses according to season and pond depth. From August through October, all applied water is assumed to go towards wetland flood-up. From November through February water inflow is used for pond depth maintenance. Between March and July, applied water is used solely for crop irrigation as the wetlands are drawn-down. The model also calculates end of month storage which is the water depth equivalent to the remaining depth of water after accounting for inflows and outflows to the wetland management area according to:

$$Storage = flood\ up + mean\ precipitation - ET - Seepage - \Delta\ Pond\ Depth$$

In order to assure mass balance, WetManSim defines wetland release as the end of month change in storage minus the desired pond depth. Unlike WARMF, which records quantities of water as flow, WetManSim operates in units of depth of water applied/ released.

METHODS

A water mass balance was created for the Grasslands Water District (WARMF Catchments 830 (North) and 793(South)) using a simulation file from October 1, 2000 to September 30, 2005. This time period was selected in order to be able to compare to the WetManSim model. As suggested by Katie van Werkhoven (Systech Water Resources Inc.), the water mass balance was performed on two separate units- the GWD catchment (northern and southern units of GWD) and the canal network delivering and draining water from each catchment.

RESULTS/ DISCUSSION

Mass Balances around River Segments

For the water mass-balance around the North GWD river system, inputs were defined as the flow from Santa Fe Canal as well as return flow (to Mud Slough and the SJR) from the North GWD. The flow in Mud Slough was the only defined output (see figure 4).

$$Water\ Mass\ Balance = Flow\ Santa\ Fe\ Canal + Flow\ off\ catchment\ 830 - Flow\ Mud\ Slough$$

Daily water flows in and out of the river segment were approximately in balance. Annual water mass flow was close to balanced (see table 1). One would expect imbalances to correspond with the water year type, with negative mass accumulation in dry years where very little runoff is expected and positive mass accumulation in wet years. This is not consistently the case with the WARMF outputs over the selected time period. The small differences in mass balances based around river segments could be explained by a variety of factors including stream leakage and interaction with other catchments.

Mass Balances around Catchments

Inputs were defined as precipitation rate (cfs) and irrigation rate (cfs), while outputs were defined as rate of evapotranspiration (cfs), flow off the catchment (cfs) and groundwater recharge rate (cfs) (see figure 5). All data except recharge rate come from the WARMF simulation. WARMF only models the top 4 soil layers, therefore groundwater recharge is mass lost to the model. Recharge is not directly calculated by WARMF but instead is obtained from Reclamations' WestSim groundwater-surface water simulation model and imported as an input into the WARMF model. Alternatively, recharge could be found by performing a mass balance on available watershed (catchment) hydrologic data. A catchment is an assumed control volume, therefore any long-term difference between total influx and total out flux can be assumed to be due to ground water recharge and water detention due to changes in soil storage capacity.

The combined output (from surface and four soil layers) time series for precipitation, irrigation, ET, and flow were downloaded from the main WARMF Output file. The prescribed recharge .FLO time series for the catchment was directly imported into MS Excel. The water mass balance was performed according to:

$$(Precipitation + Irrigation + Managed\ Inflows) - (Catchment\ Flow + ET + Prescribed\ Recharge)$$

Any imbalance was originally assumed to be due to changes in soil storage capacity, however given the large resulting mass flow imbalances - this is clearly not possible (see table 2). In order to compare this imbalance to the WetManSim model output the flow balance was converted to feet according to:

$$Water\ Depth\ (ft) = \sum_{October\ 1}^{September\ 30} \frac{Flow\ imbalance\ \left(\frac{ft^3}{sec}\right) * \frac{86{,}400\ sec}{day}}{Area\ GWD\ (ft^2)}$$

Some of this unaccounted for water is visible as changes in depth of water across the catchment. The combined depth (ft) output series was imported into MS Excel. Changes in depth from day to day were calculated and summed to find the overall change in depth in feet for a water year. This amount of water was converted from units of depth into units of flow according to:

$$Flow\left(\frac{ft^3}{sec}\right) = \Delta Depth\ (ft) * Area\ GWD\ (ft^2) * \frac{day}{86{,}400\ sec}$$

The flows associated with depth change found in table 3 account for nearly all imbalances in catchment 830, however only account for some of the flow imbalance in catchment 793.

Further, surface depth data appears to not accurately describe a managed wetland. Wetlands are flooded up in late summer/early fall (usually starting September 1) to about one foot and this water level is maintained throughout the winter. In early spring the wetlands are completely drawn down to allow germination of moist soil crops. Water level should therefore appear to follow a square wave function with a rapid build up of water level in each wetland impoundment during the fall, a leveling off during the winter as ponds are maintained at "shooting depth", a rapid lowering during spring drawdown, and a small peak in mid summer due to irrigation as opposed to the saw-tooth output obtained from WARMF output (see figure 6).

It seems as though calculation of irrigation is a major issue in the model. Water years with the largest amount of applied irrigation also show the greatest mass imbalances. Due to the WARMF model's estimation of irrigation as a percentage of diversion flows, the largest rate of irrigation actually occurs during an above average

water year. At the same time under this assumption the pattern of irrigation corresponds to the square wave analog with little to no irrigation in the summer, a flooding period in late summer and scant "irrigation" during the winter and spring to maintain wetland water levels. A comparison of the irrigation recharge quantities predicted by WARMF and WetManSim can be found in figure 7 where the depth output from WetManSim was converted into a daily average flow.

In order to determine if WARMF's irrigation estimations play a large role in the model's mass imbalance, irrigation was removed as an input from the WARMF model of catchment 830. The amount of water applied monthly for irrigation and wetland flooding was taken from WetManSim data for the 2002-3003 water year as these values are in mass balance and also assumed to be fairly accurate. Applied water is provided in WetManSim in units of acre-feet. Applied water values were converted to cubic feet then divided by the number of seconds in each month to obtain a flow rate in cubic feet per second. In the WARMF model these data were imported as a point source file (.PTS). This point source was connected to catchment 830 through the "point source" input tab. Irrigation flows were set to zero for all land uses in the input menu. A simulation was then run from October 1, 2000 to September 30, 2005. A water mass balance was conducted using the outputs of this simulation in the same manner as previously.

A water mass balance analysis revealed that WARMF's irrigation estimates have a significant impact on catchment mass balance. The mass imbalance for the 2002-2003 water year was reduced by 75% (see table 4). The WetManSim approximate 2003-2003 flows also significantly reduced water mass imbalances when applied to other years. Mass imbalances also appeared to be more correlated with water year type. Under the

new model assumptions, there was negative mass accumulation in dry years when there very little runoff and there was positive mass accumulation in wet years. Unlike the original WARMF model imbalances, mass imbalances could no longer be seen as changes in water depth. This is a possible indication that other hydrological assumptions elsewhere in the WARMF domain impact the mass balance.

CONCLUSIONS

Major water mass imbalances occur within the WARMF model for the GWD- the reason for these imbalances has not been fully determined. It is clear however, that there is very little understanding of how seemingly minor changes in input assumptions affect the outputs of the WARMF model. Unlike simpler mass-balance models such as WetManSim, WARMF is able to simulate more complex hydrologic systems into one platform so that the affects of decisions in individual water districts can be seen across the entire watershed. WARMF catchments are distributed not lumped (like WetManSim), which allows the model to recognize differences in hydrology within the watershed (i.e. agricultural lands vs. wetlands). This complexity gives WARMF the potential to be an extremely powerful tool in watershed management and bottom up- TMDL management. At the same time, like users of other models, WARMF users must exercise caution in output interpretation. Verifications of individual features of the model similar to those presented in this paper should be run. Many models, like WARMF, were originally developed for a different purpose other than the one for which they are currently being used. Understanding how the model was originally designed reveals assumptions that may no longer be valid for current uses. WARMF was originally developed on a platform (ILWAS) that was an acid rain model and therefore never needed to simulate

groundwater or irrigated agriculture and managed wetlands. Hence the model as currently used in the SJRB has been "tricked" into making simulations that are not intuitive to WARMF. It is of utmost importance that model users understand how a complex model such as WARMF operates and realize that state-of-the-art models do not necessarily mimic conditions in nature

ACKNOWLEDGMENTS

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[4] C.W. Chen, J. Herr and L.H.Z. Weintraub. "Watershed Analysis Risk Management Framework: Update One: A Decision Support System for Watershed Analysis and Total Maximum Daily Load Calculation, Allocation and Implementation," EPRI. Palo Alto, CA, 2001.

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[6] C.W. Chen, J. Herr and L.H.Z. Weintraub, "User's Guide to WARMF: Documentation of Graphical User Interface," EPRI. Palo Alto, CA, 2001.

TABLES & FIGURES

Water Year	Water Year Type	Annual River Balance (cfs)
Oct. 1, 2000- Sep. 30, 2001	Above Normal	59
Oct. 1, 2001- Sep. 30, 2002	Dry	-45
Oct. 1, 2002- Sep. 30, 2003	Dry	50
Oct. 1, 2003- Sep. 30, 2004	Below Normal	-37
Oct. 1, 2004- Sep. 30, 2005	Dry	2

Table 1: Water Mass Balance Around River Segments Using WARMF Output Data

Water Year	Water Year Type	Annual Catchment 830 Flow Balance (cfs)	Catchment 830 Imbalance (ft)	Annual Catchment 793 Flow Balance (cfs)	Catchment 793 Imbalance (ft)
Oct. 1, 2000- Sep. 30, 2001	Above Normal	20,654	1.54	-5,205	-1.23
Oct. 1, 2001- Sep. 30, 2002	Dry	-18,810	-1.37	-19,461	-4.61
Oct. 1, 2002- Sep. 30, 2003	Dry	11,592	0.88	5,511	1.31
Oct. 1, 2003- Sep. 30, 2004	Below Normal	-18,915	-1.37	-17,579	-4.17
Oct. 1, 2004- Sep. 30, 2005	Dry	-6,080	-0.39	-14,170	-3.36

Table 2: Water Mass Balance Around Catchments 830 & 793 Using WARMF Output Data

Water Year	Depth Change Output Catchment 830 (ft)	Flow with Depth Change (cfs)	Depth Change Output Catchment 793 (ft)	Flow with Depth Change (cfs)
Oct. 1, 2000- Sep. 30, 2001	1.55	21,132	-0.19	-822
Oct. 1, 2001- Sep. 30, 2002	-1.39	-18,976	-2.64	-11,136
Oct. 1, 2002- Sep. 30, 2003	1.11	15,153	2.87	12,095
Oct. 1, 2003- Sep. 30, 2004	-1.38	-18,878	-2.13	-8,986
Oct. 1, 2004- Sep. 30, 2005	-0.23	-3,119	-0.22	-918

Table 3: Flow Associated with Depth Change in Catchments 830 & 793

Water Year	Water Year Type	Catchment 830 Flow Balance with Point Source (cfs)	Catchment 830 Imbalance with Point Source (ft)	Depth Change Output with Point Source Catchment 830 (ft)	Flow with Depth Change (cfs)
Oct. 1, 2000- Sep. 30, 2001	Above Normal	21,554	1.58	1.66	22,605
Oct. 1, 2001- Sep. 30, 2002	Dry	-771	-0.06	0.05	673
Oct. 1, 2002- Sep. 30, 2003	Dry	-2,903	-0.21	-0.07	-999
Oct. 1, 2003- Sep. 30, 2004	Below Normal	-2,089	-0.15	0.01	103
Oct. 1, 2004- Sep. 30, 2005	Dry	-2,418	-0.18	-0.01	-85

Table 4: Water Mass Balance Around Catchment 830 After WetManSim Point Source Added

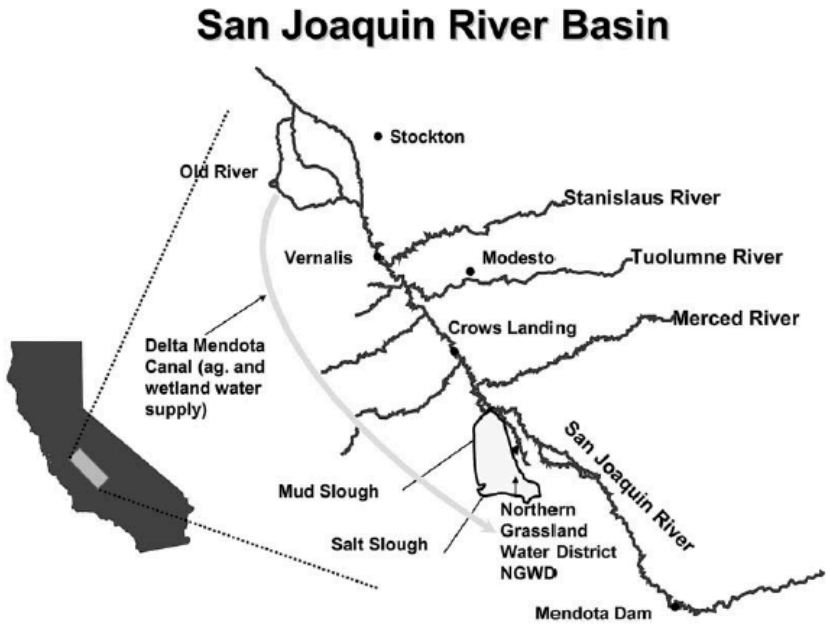


Figure 1: Map of San Joaquin River Basin [1]

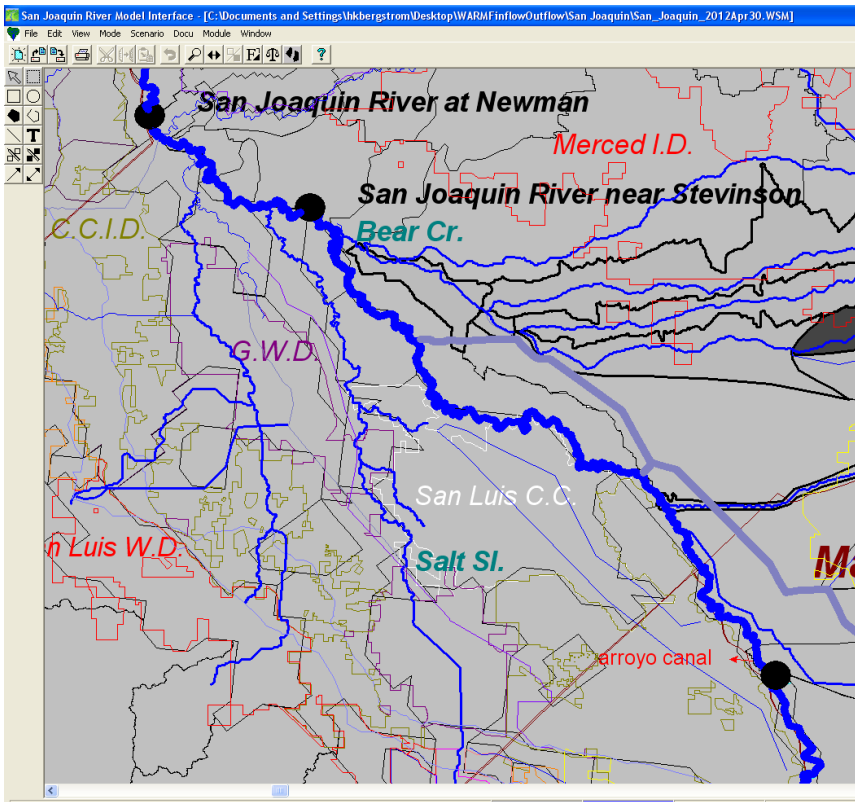


Figure 2: WARMF GIS-Integrated Graphical User Interface Engineering Module Used for SJRB GWD Simulations

	A	B	C	D	E	F	G	I	J	K	L	N	O	P	Q	R
48																
49	GRASSLAND WD - FLOODED SURFACE AREA (Seasonal Marsh)					Basin Flooding				Maintenance				Irrigation/Drawdown		
50	LEVEL-2 + LEVEL-4															
51		units	Aug-Mar	Annual	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
52	Flooded Surface Area	acres	42500		8,708	22,292	22,292	42500	42500	42500	42500	20000	3000	29000	13000	8000
53	ETO loss inches per month	inches			4.0	2.1	1.2	1.2	2.2	3.7	5.7	7.4	8.1	8.7	7.8	5.7
54	mean rainfall	inches	8.9	9.5	0.5	1.5	1.5	1.6	1.6	1.4	0.8	0.3	0.0	0.0	0.0	0.3
55																
56	porosity	percent	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
57	pond depth	inches	9.6	6.5	2.0	7.0	12.0	12.0	12.0	12.0	10.0	8.0	2.0	0.5	0.0	0.0
58	fillable vadose zone porosity	inches	6.9	8.6	13.0	10.0	5.0	5.0	5.0	5.0	5.0	8.0	10.0	10.0	12.0	15.0
59	potential seepage loss	inches	9.6	20.6	2.6	2.0	1.0	1.0	1.0	1.0	1.0	1.6	2.0	2.0	2.4	3.0
60																
61	Applied Water LEVEL 2 + LEVEL-4	acre-feet	139000	180000	16000	55000	29500	21000	8000	5000	4500	500	2500	22000	10000	6000
62	Non-district inflow	acre-feet	27100	52100	2800	7200	1600	1800	6600	4400	2700	2100	2400	8400	7600	4500
63	flood wetlands	inches	71.4	71.4	25.9	29.6	15.9									
64	make-up water	inches	10.9	10.9				5.9	2.3	1.4	1.3					
65	applied irrigation	inches	0.0	3.1								0.0	0.8	0.8	0.8	0.8
66	end of month storage	inches			20.8	24.0	17.2	17.3	12.7	10.1	9.4	3.3	-2.3			
67	wetland release	inches	44.5	47.8	18.8	17.0	5.2	5.3	0.7	-1.9	-0.6	2.3	1.0	0.0	0.0	0.0
68	runoff/ag spill & drainage	inches														
69	released/applied	percent			73%	57%	33%	90%	29%	-134%						
70																
71	EC of supply water	uS/cm			1,200	800	800	900	900	1,000	1,000	1,100	1,200	1,000	1,000	1,200
72	TDS supply water	(mg/L)	603	645	768	512	512	576	576	640	640	704	768	640	640	768
73	TDS wetland discharge	(mg/l)	889	7,142	807	603	576	617	722	985	1,915	24,537	33,515			
74	TDS ag runoff	(mg/l)														
75	total wetland discharge	acre-feet	67,159	71,246	13,648	31,595	9,624	18,875	2,333	-6,688	-2,229	3,879	208	0	0	0
76	wetland discharge salt load	(tons)	81,222	692,015	14,971	25,906	7,538	15,845	2,292	-8,961	-5,805	129,450	9,472	0	0	0
77																
78	combined discharge to SJR	acre-feet	91,459	120,546	13,648	38,795	11,224	20,675	8,933	-2,288	471	5,979	2,608	8,400	7,600	4,500
79	combined discharge TDS	(mg/l)	-81	2,109	800	586	567	614	614	1,650	-5,395	16,166	3,378			
80					total af	af/ac										
81				10% LOSS	90450	2.1										
82					53,292											
83																

Figure 3: WetManSim Mass Balance Model Platform in MS Excel for the GWD

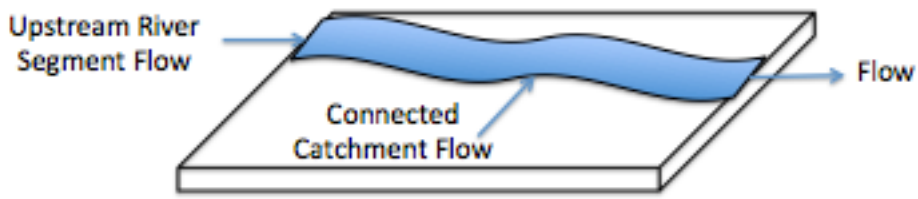


Figure 4: River Segment as Modeled by WARMF Used for Mass Balance

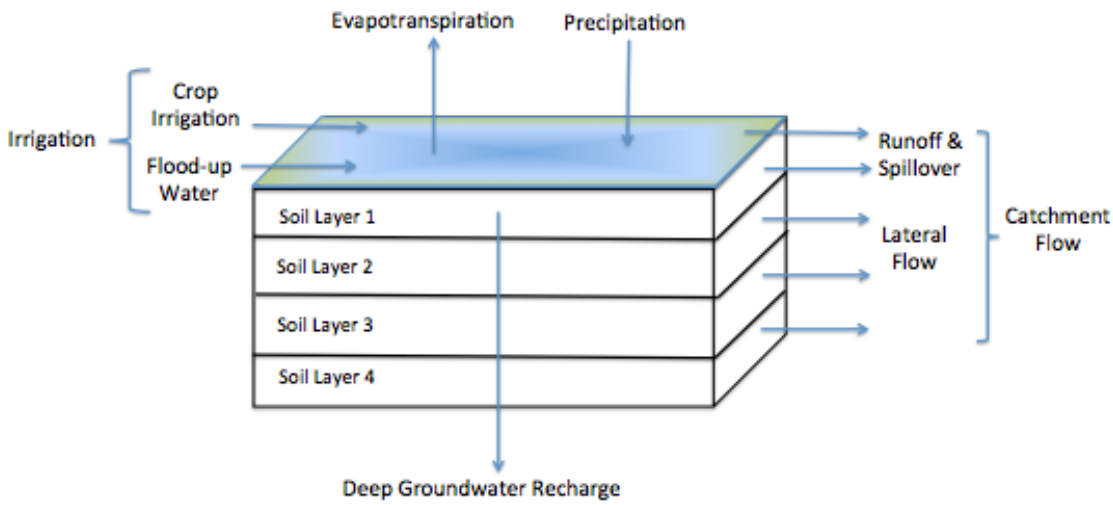


Figure 5: Land Catchment as Modeled by WARMF Used for Mass Balance

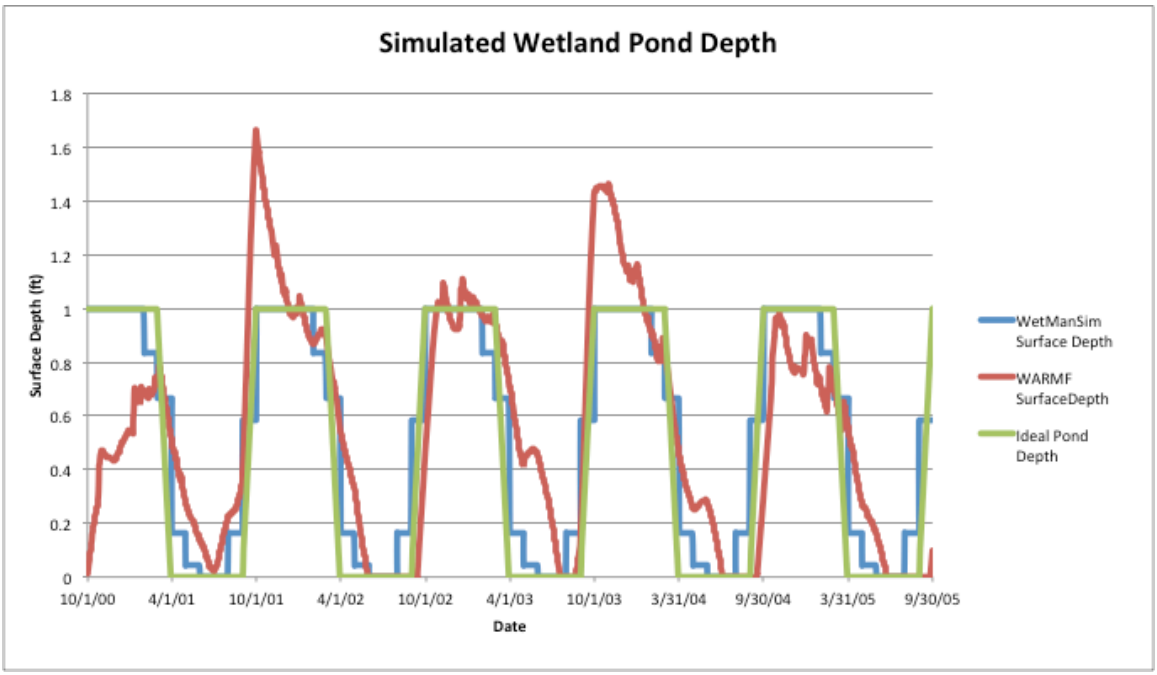


Figure 6: Catchment 830 Surface Water Depth from WetManSim & WARMF Used to Verify WARMF Irrigation Assumptions

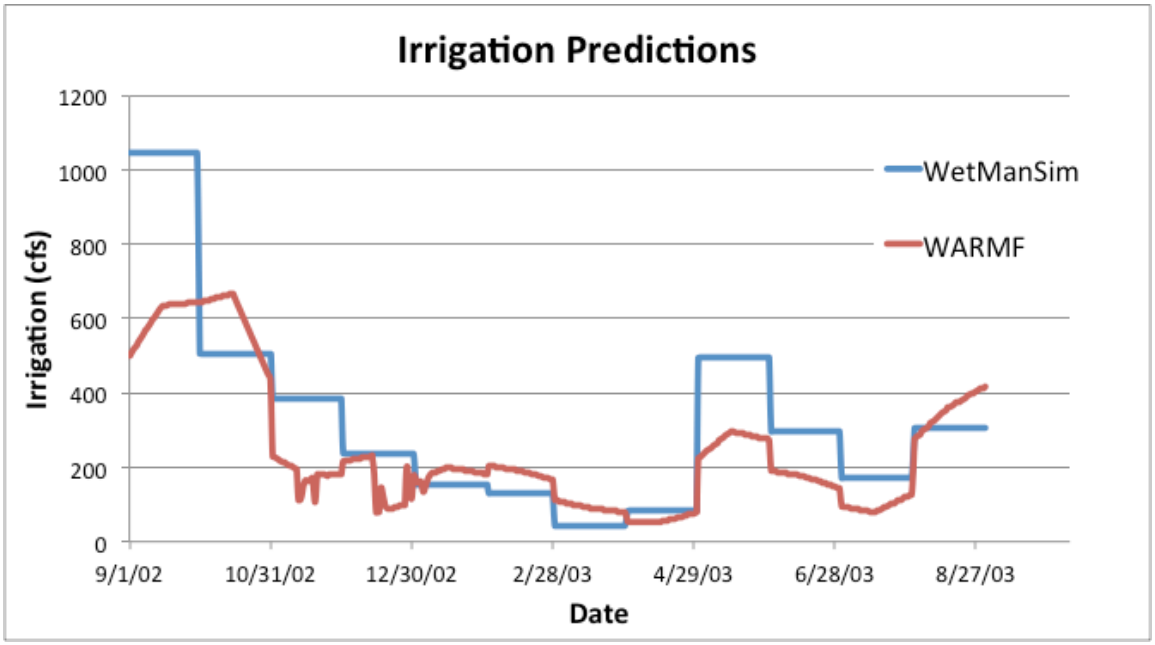


Figure 7: Irrigation Predictions from WetManSim & WARMF

APPENDIX

A. Conversations with Katie van Werkhoven

WARMF is a dynamic model that performs physical process calculations. WARMF is not a mass balance model- rather mass balances are performed for quality assurance.

Terminology:

Catchment Flow: Total outflow from the catchment (from surface plus all soil layers)

Constituents (from "Flux Output menu): concentration of parameter in the total flow. Precipitation and evapotranspiration are constant values applied to the whole catchment (which in this case is also a water district) and converted to volumetric flow rates for output.

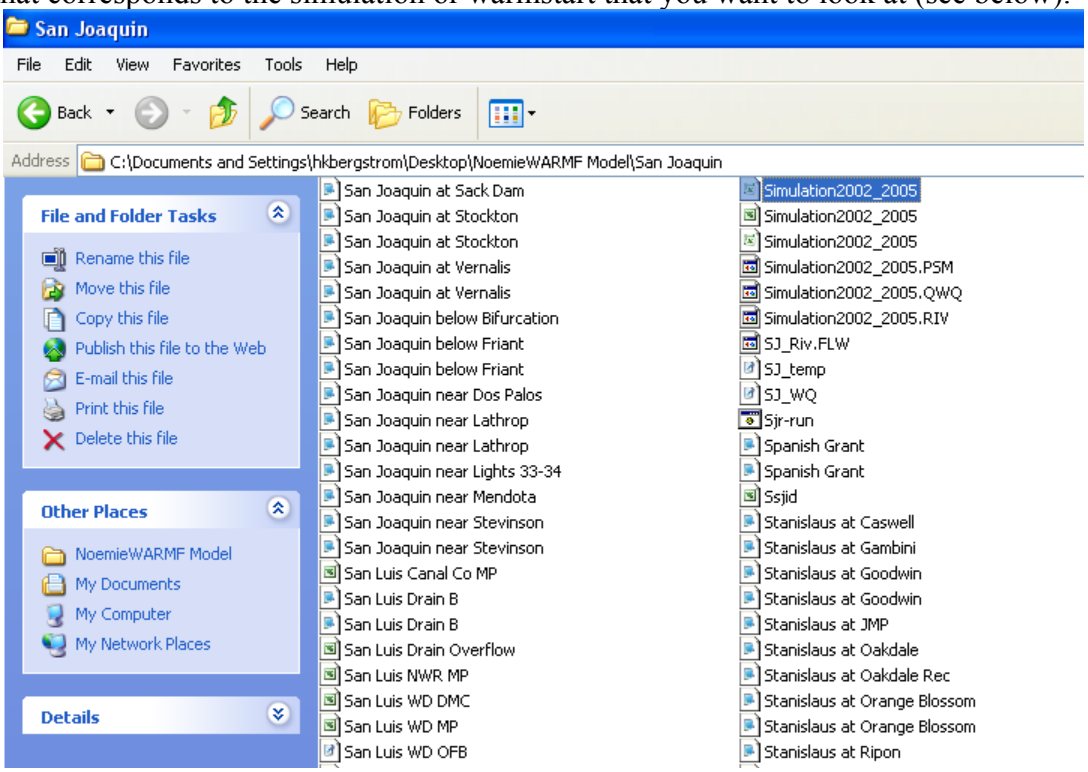
Ground Water Pumping: GW pumping specifies the amount of water pumped from deep groundwater to the catchment as irrigation. Under the "input → irrigation" menu the amount of irrigation from groundwater pumping can be specified. Since the WARMF model domain ends at shallow groundwater, the groundwater irrigation is an external input and is not actually pumped from the soil within WARMF simulations. It should therefore be treated like any other external input such as precipitation.

Percolation: water that infiltrates from the surface into upper soil layers. Percolation is an intermediate process in WARMF and therefore not written to an output file. You can see the daily flux of constituent loads via percolation in "Flux Output" menu under the "Percolation" tab.

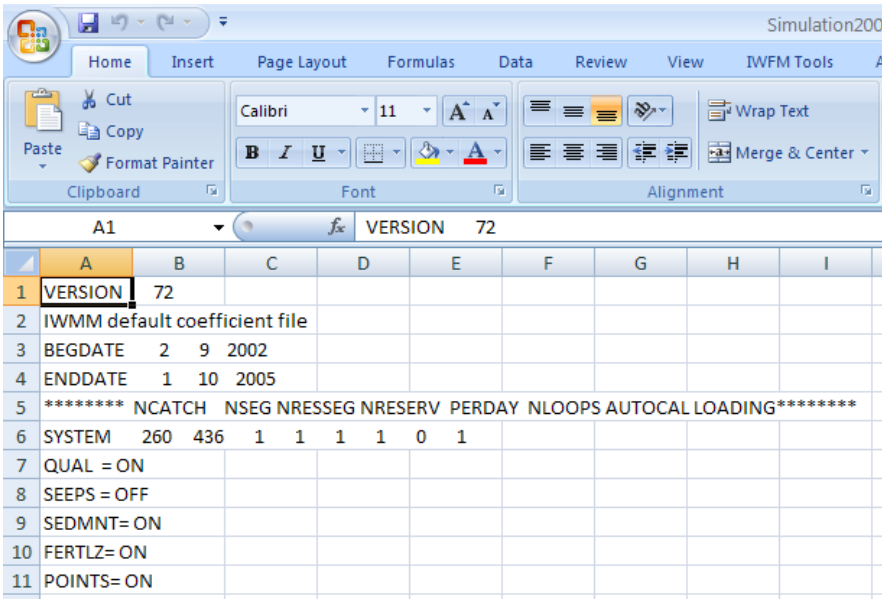
Recharge: deep percolation; the water that is removed from the lowest soil layer and does not enter the connecting stream. It is the volume of water completely lost from the model domain. There is no separate output for recharge. This amount of water is prescribed in input files from WestSim since the WARMF model domain ends (vertically downward) at the lowest soil layer that interacts with the connecting stream (i.e., it only includes near-surface groundwater). The input files with the prescribed deep percolation have the names "Recharge XXX.FLO" where XXX is the catchment ID number. During simulations of the lowest soil layer, this amount of water is 'requested' for removal. If the amount requested on a given day is available, that amount is removed. However is can be (and usually is) less than prescribed since often not enough water is available, so less is removed. You can estimate the actual (as opposed to prescribed) recharge on a long term by process of elimination in a water balance, i.e., total influx (precipitation + irrigation) = total outflux (outflow + ET + recharge).

WARMF Coefficient File:

To open the coefficient file open your WARMF- San Joaquin Folder. Inside find the file that corresponds to the simulation or warmstart that you want to look at (see below).



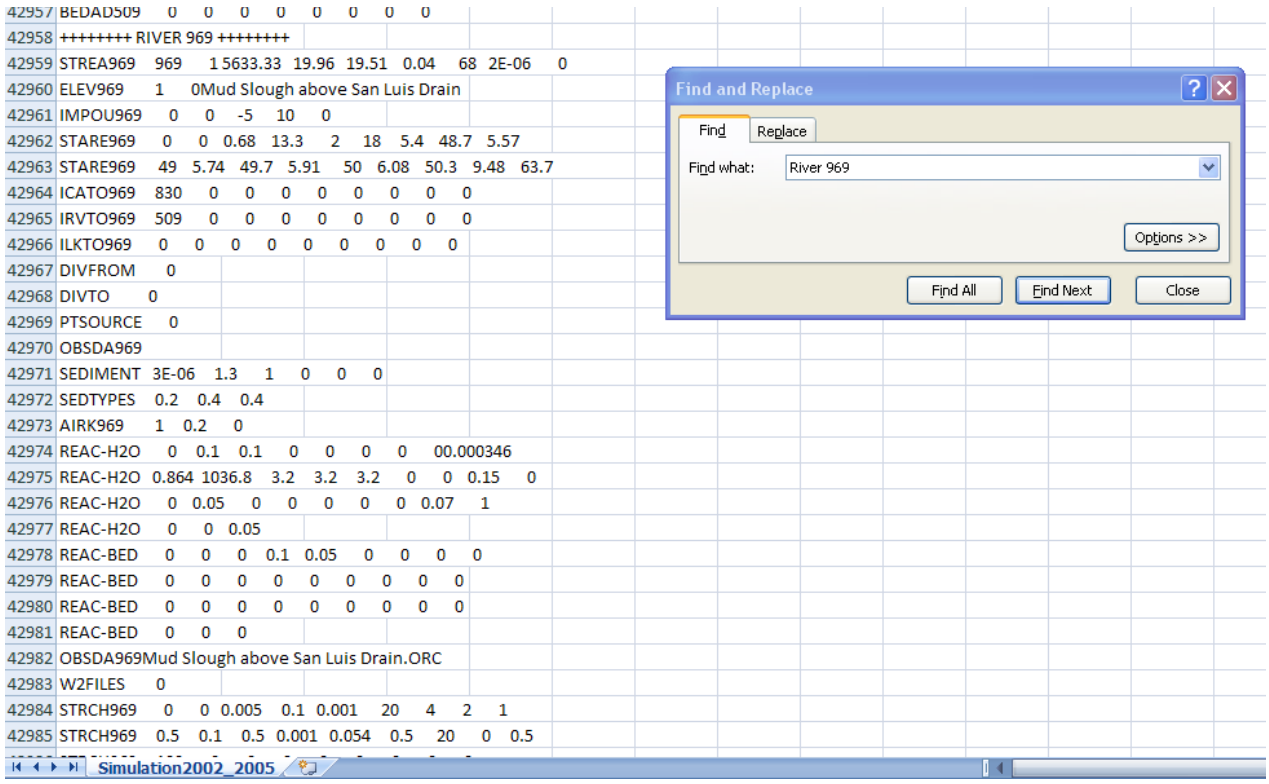
Open this file (in MS Excel if it is not already the default)



Do a search for the catchment, or river that you would like to look at.

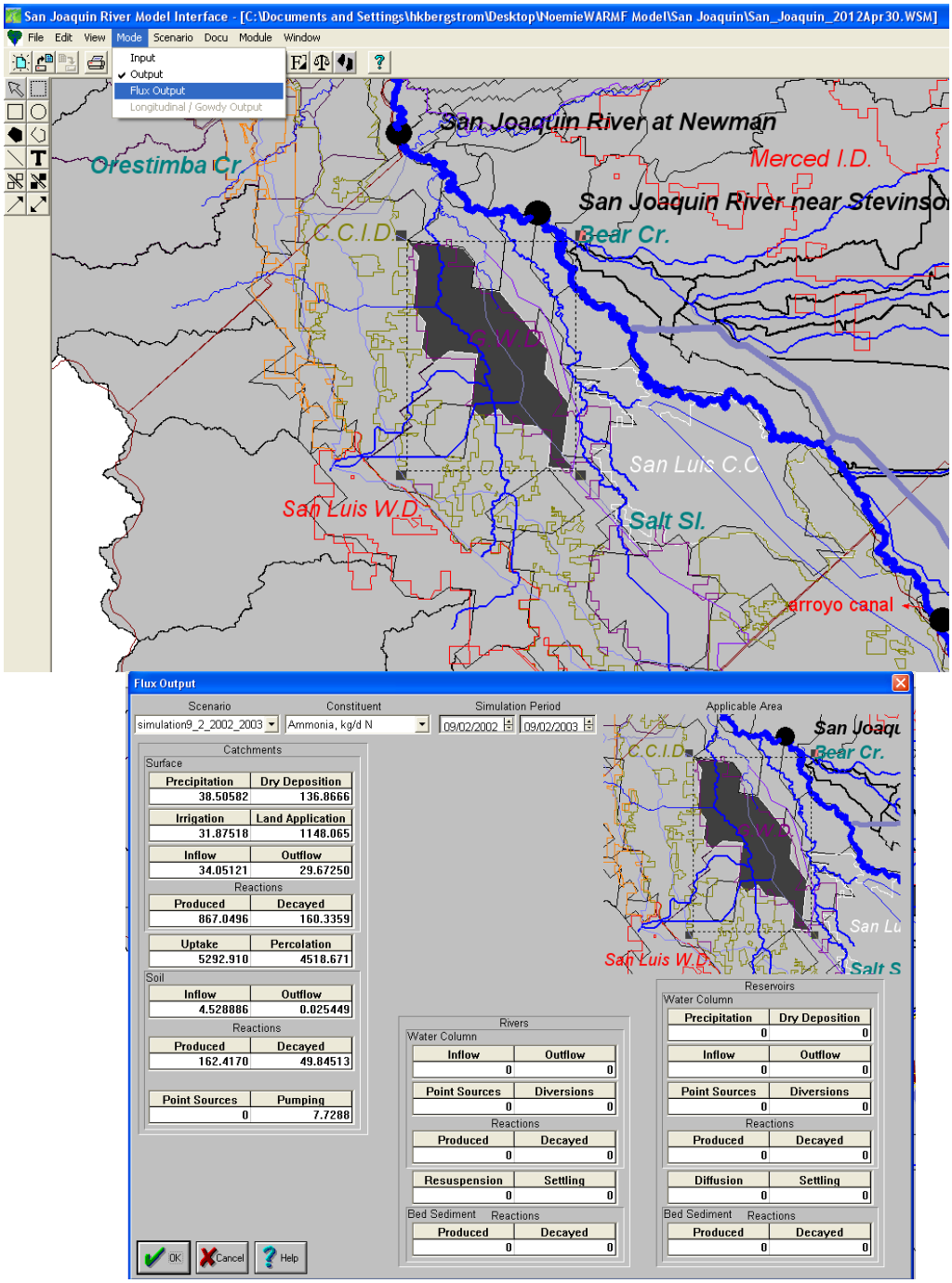
The numbers following ICATOx is the ID for catchment that your river is associated with (i.e. this river receives the flow drainage from that catchment). In this case ICATO969 is followed by 830 (catchment 830: the North GWD) meaning that the flow from catchment 830 drains directly into river 969.

IRVTOx indicates the ID of rivers upstream of the river segment selected. In this case IRVTO969 is followed by 509 (river 509: the Santa Fe Canal). The "Coefficient File Key" PDF provides more details for coefficient file interpretation.



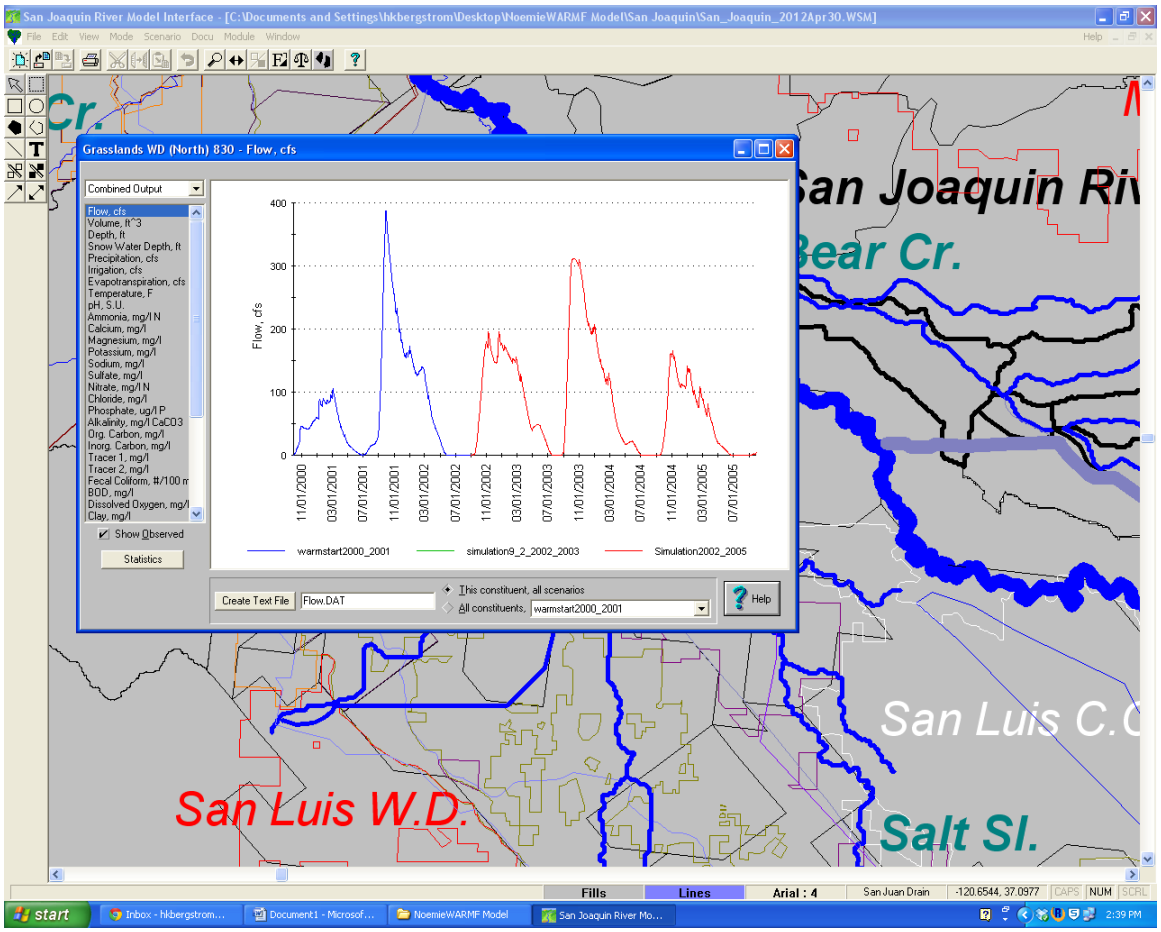
Downloading Output Files for Individual Catchments or Rivers:

Flux Output (single averaged number) of Individual Constituents:
Open the WARMF San Joaquin file. Click on the catchment or river segment you would like data for. From the Mode menu, select Flux Output. Select the scenario, constituent, and dates for which you want the average value.



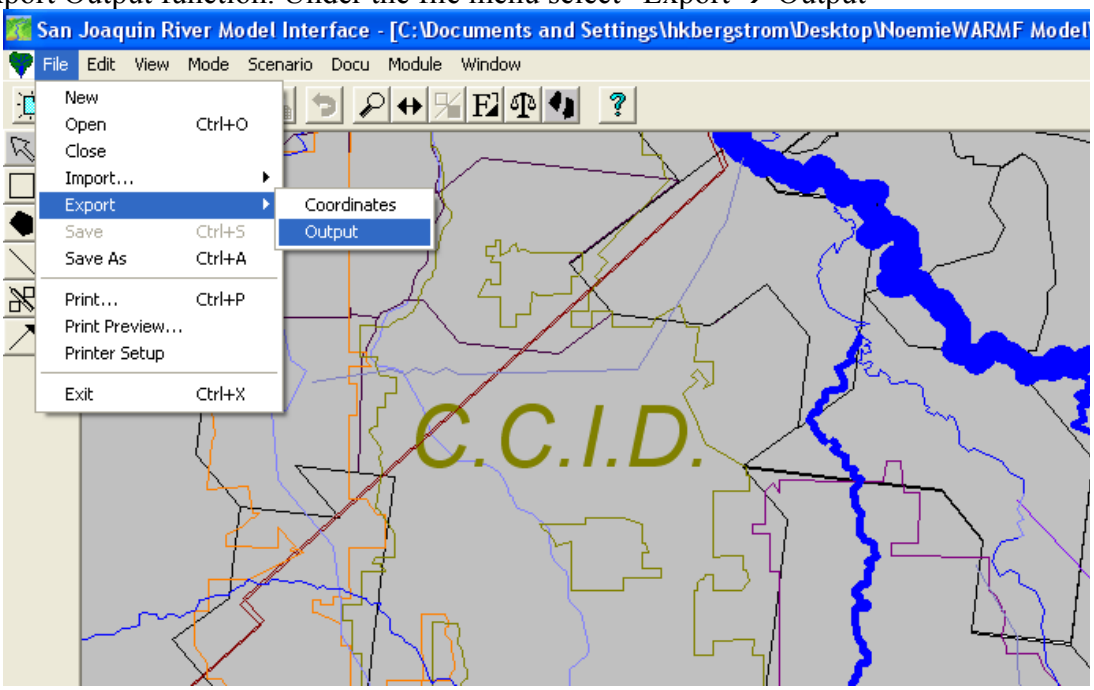
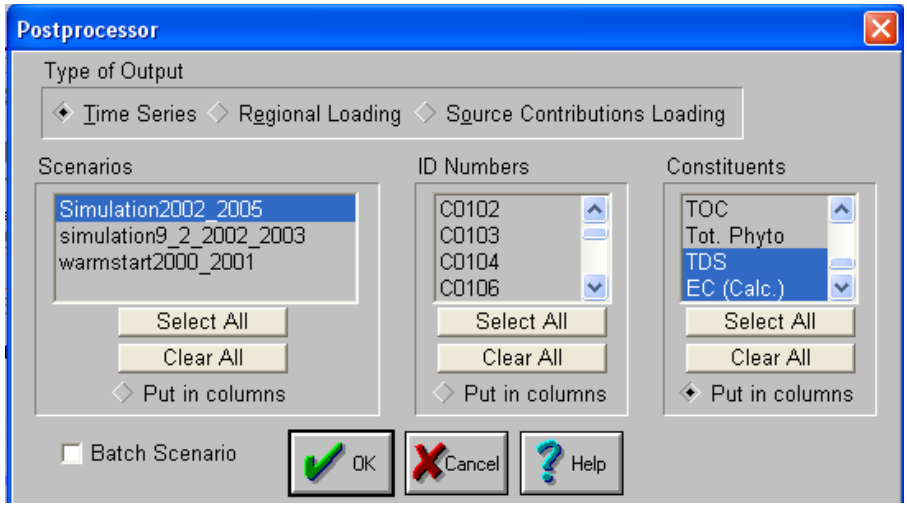
Individual Output

Under the Mode menu, select Output. Click on the catchment or river segment for which you want data. From the drop down menu in the left top corner, you can select the soil layer you want to look at or choose combined output for the whole catchment. On the bottom of the window you can click to create a text file for this data. This file will be saved into your model folder. If you do not rename the .DAT file from its default before creating the text file, you must delete the old file in your program folder.



Multiple Outputs

To download multiple outputs for one catchment or even for multiple catchments, use the Export Output function. Under the file menu select "Export → Output"



Under this menu you can choose the simulation (or simulations), the catchment or river segments, and the constituents for which you want data. Under constituents select "put in columns." If you would like all your scenarios in one file select "batch scenario." When you are done click OK and your files will be created.