Computational Assessments of Scenarios of Change in the Delta Ecosystem

CALFED Science Program Project SCI-05-C01-84
Semiannual Project Report
Report No. 5: March 1, 2008 – August 31, 2008

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I. INTRODUCTION AND BUDGET SUMMARY

Funding Source: ***BOR Reimbursible funds through USGS***

Project Location: U.S. Geological Survey, Menlo Park, CA

Brief Description of Project: This project constitutes a model-based approach for developing a long view of the Bay-Delta-River-Watershed system. The long view is developed through simulations with linked models to project changes under a range of plausible scenarios of climate change, Delta configurational changes, and land-use/population change. Elements of the Bay-Delta River-Watershed system addressed by this project are:

① Climate Modeling and Downscaling
② Sacramento-San Joaquin Watershed and San Francisco Bay Modeling
③ Delta Modeling: Hydrodynamics with Temperature and Phytoplankton
④ Sediment, Geomorphology and Tidal-Habitat Modeling
⑤ Fate and Effects of Selenium, Mercury, Silver and Cadmium
⑥ Invasive Species– *Potamocorbula*, *Corbicula*, and *Egeria*
⑦ Native and Alien Fish Population Trends

The cascading effects of changes under these scenarios will be followed as they propagate through these elements, from the climate system to watersheds to river networks to the Delta and San Francisco Bay.

Budget Summary (All tasks should exactly match those identified in the project Scope of Work.)

Task #	% Complete (by dollars)	Amount Invoiced (Current Fiscal Year)	Amount Invoiced to Date (All Years)	Projected Expenditures next 6 months
1	23.54%	55,401.07	60,805.99	30,000.00
2	99.63%	185,416.41	394,350.85	-
3	89.20%	73,195.05	211,510.55	20,000.00
4	97.07%	195,987.46	311,267.27	5,000.00
5	80.06%	25,845.64	63,752.68	10,000.00
6	9.64%	-	7,179.40	20,000.00
7	65.00%	103,563.36	164,588.24	55,000.00
8	30.10%	10,621.76	13,136.89	20,000.00
		650,030.75	1,226,591.87	

II. CURRENT TASK STATUS OVERVIEW

This section presents the status, in brief, of individual tasks. Detailed reports can be found in Section III (page 7).

Task 1

All downscaled gridded data products have been delivered. Development of downscaled point time series data is ongoing.

Task 2

Several refinements to the models and procedures described previously have been implemented to produce more realistic results, and the previous deliverables (monthly flows and stream temperatures) were re-derived. A problem was encountered wherein CALSIM compensates for climate-change-driven changes in reservoir outflows by increasing groundwater pumping to unrealistic levels; efforts are underway to correct this behavior in post-processing. The algorithm for monthly-to-daily disaggregation was refined and will be applied once the groundwater issue is resolved.

Task 3

Phytoplankton: A manuscript describing a mathematical and graphical conceptual model which explains the range of phytoplankton-transport time relationships observed in nature has been submitted for publication to the journal *Limnology and Oceanography*. This manuscript has undergone two rounds of peer-review and is currently in its final round of revision. Lucas has participated in meetings and workshops in support of the Governor’s Blue Ribbon Panel.

Temperature: The emphasis in the past 6 months for us has been on completing our temperature modeling activity in order to provide long-term projections of Delta water temperature. To achieve this, we first focused on the data needs and availability, then developed a statistical model and calibrated it using historical data, then applied the model to downscaled data from climate scenarios.

Hydrodynamics: 1) Simulations of full year base-case scenarios are now operational. Databases of observed data for these scenarios are complete and the verification process has begun. 2) Drogue release studies have begun in order to characterize transport timescales throughout the Delta. 3) Knowles provided output from the watershed model and CALSIM for the four climate scenarios at the Sacramento and San Joaquin boundaries. Monsen evaluated this output to determine how to apply the climate scenarios to the Delta hydrodynamic simulations.

Task 4

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS:
Task 4: The past 6 months included successful calibration and validation of the DELFT3D hydrodynamic and morphodynamic San Francisco Bay model for current conditions. Based on the calibration, a model was

developed that is able to reproduce and hindcast sedimentation patterns during the hydraulic mining from 1856 to 1887.

Additionally, we have completed hindcast modeling of the 1942-1990 period, for Suisun Bay. Ganju combined parts I and II of “Simulation of decadal-timescale estuarine geomorphic change with a tidal-timescale model” and resubmitted it to JGR Earth Surface.

PROBLEMS OR DELAYS ENCOUNTERED:

Neil Ganju moved to the USGS office in Woods Hole but will continue to contribute to the project. The final project simulations will probably be done with the DELFT3D whole Bay model using techniques and boundary conditions developed with our Suisun Bay ROMS simulations.

DELIVERABLES PRODUCED:

- The journal article entitled “Calibration of an estuarine sediment transport model to measured cross-sectional sediment fluxes for robust simulation of geomorphic change”, by Neil K. Ganju and David H. Schoellhamer is in press at Continental Shelf Research.

- A journal article by Ganju, N.K., Schoellhamer, D.H., and Jaffe, B.E., entitled “Simulation of decadal-timescale estuarine bathymetric change with a tidal-timescale model: application to historical change and future scenarios” is in review with the Journal of Geophysical Research-Earth Surface.

- An abstract by Ganju, N.K., Schoellhamer, D.H., van der Wegen, M., and Jaffe, B.E., entitled “CASCaDE hindcast of bathymetric change in Suisun Bay, 1867-1990: model uncertainty and parameter selection” was submitted and accepted by the 2008 CALFED Science Conference.

- Van der Wegen, M., Roelvink, D., and Jaffe, B.E., 2008, Application of a 2D numerical model in the San Francicso Estuary to estimate morphodynamic change from global warming and sea level rise, 2008 Ocean Science Meeting Abstracts, p. 469.

- An abstract by van der Wegen, M., Roelvink, D., Jaffe, B.E., Ganju, N., Schoellhamer, D. entitled "CASCaDE research on hindcasting bathymetric change in San Pablo Bay, 1856-1983: A step towards assessing likely geomorphic change in response to climate change " was submitted and accepted by the 2008 CALFED Science Conference.

Task 5

New experimental data were derived to verify feeding rates in important species in the estuary. Trophic transfer factors for different fish species have been assembled from the experimental and field literature. A large database of particulate/dissolved ratios of Se concentrations from the Bay is assembled and analyzed.

Task 6

Resolution of model parameters are nearing completion with final work on mortality rates for *Corbicula* and growth rates for *Corbula* continuing. Findings from our work in CASCADE are being summarized in CALFED DRERIP conceptual models for *Corbula* and *Corbicula*.

Task 7

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS: We continued to summarize existing information on the environmental tolerances of our fish species of interest. This information will feed directly into the species life cycle models. We analyzed historical flow data from a variety of sources for the major tributary rivers to the San Francisco Estuary using the software package “Indicators of Hydrologic Alteration”. We prepared a draft manuscript based on analyses of flow before and after construction of the major hydrologic infrastructure in the watershed. The manuscript was reviewed by several co-PIs and is being revised in response to comments. We reviewed the initial monthly flow and water temperature outputs from task 2 and identified some potential problems with the CALSIM outputs for the 4 scenarios.

PROBLEMS OR DELAYS ENCOUNTERED: None.

DELIVERABLES PRODUCED:

Larry Brown delivered a presentation at the 2008 Annual Meeting of the California-Nevada Chapter of the American Fisheries Society “Streamflow characteristics of California’s Central Valley Rivers: implications for native and invasive fishes.”

Larry Brown delivered a presentation at the 2008 Meeting of American Fisheries Society, “Streamflow characteristics of California’s Central Valley Rivers: implications for native and invasive fishes.”

Larry Brown, Christa Woodley, and Bill Bennett prepared an abstract for the 2008 CALFED Science Conference, “Increased water temperatures from CASCaDE climate-change scenarios: implications for California fishes.”

Task 8

Two PI meetings were organized, a no-cost extension request was submitted, and a special conference session was planned.

III. CURRENT DETAILED TASK STATUS REPORTS

This section presents detailed accounts of each task's activities during the present reporting period.

Task 1

All downscaled gridded data products have been delivered. Development of downscaled point time series data is ongoing.

Task 2

Narrative/Achievements

The last 6 months were spent refining the methods and results presented in detail in the previous report. First, after fixing some small bugs and correcting some errors in the meteorological input data, the hydrologic model was re-run over the historical period (1950-1999) and for the 21st century under all four climate scenarios.

Second, the approach used to map the resulting simulated flows into CALSIM inputs was thoroughly re-examined and refined. This involved verifying that the constructed analog method used was producing CALSIM inflows that had reasonable annual flow totals and annual flow timing. Different error metrics for the matching procedure were tested and the optimal one chosen. The CALSIM runs for the four climate scenarios were then repeated and the results were checked for reasonableness. Simulating the scenarios in full detail was difficult (but possible) due to the presence of some severe droughts in these scenarios that push the CALSIM model beyond the historical regimes for which it was designed.

The stream temperature model was then rerun using the new CALSIM outputs. Parts of the model had to be re-written to handle the aforementioned extreme droughts in a numerically stable manner.

Finally, the algorithm to disaggregate monthly flows to daily flows was refined and is ready to be applied, pending solution of one problem:

Problems Encountered

A final problem was discovered upon examination of the Delta inflow data. Nancy Monsen had undertaken this work and found that despite significant climate change in the scenarios leading to significant change in both reservoir inflow and outflow, inflows to the Delta were surprisingly unaffected. This spurred me to investigate further, and I realized that CALSIM is compensating for upstream flow changes by simulating increased groundwater pumping as needed. It is in fact a well-known shortcoming of CALSIM that groundwater withdrawals are essentially uncapped, particularly in the Sacramento basin. This is evident in the simulated groundwater storage under the various climate scenarios. In the GFDL-A2 scenario, for example, Sacramento Valley groundwater storage is depleted by a net 50 million acre-feet over 100 years, a highly unrealistic number. I am currently consulting with Randy Hanson of the USGS California groundwater modeling effort to determine more realistic caps on groundwater withdrawal and plan to implement a CALSIM post-processing script that will limit aquifer drawdowns to more realistic levels, and adjust the subsequently applied water, return flows, and downstream channel flows accordingly. Once that is done, more realistic daily flows should follow.

Deliverables and Presentations

Revised monthly flow and stream temperature data

3/11: CALFED “Brownbag” presentation: “Assessing Inundation Vulnerability Due to Projected Sea Level Rise in San Francisco Bay”

4/4: North Bay Watershed Association Conference: “Assessing Inundation Vulnerability Due to Projected Sea Level Rise in San Francisco Bay”

4/15: Participated in DWR Sea Level Rise Research Program Review in Sacramento as technical advisor

4/16: BCDC Bay Area Sea Level Rise Government Forum: “Assessing Inundation Vulnerability Due to Projected Sea Level Rise in San Francisco Bay” (joint presentation with Dan Cayan)

5/12: Pacific Institute Scientific Forum on sea level rise in SF Bay: “New High-Resolution Maps of Areas Vulnerable to Sea Level Rise”

Also in May: Provided 5p brief on Sea Level Rise Impacts in SF Bay to California Resources Agency

6/19: Participated in NOAA Scientific meeting in Menlo Park to present USGS work on sea level rise and climate change impacts in SF Bay.

Task 3

Phytoplankton:

A manuscript describing a mathematical and graphical conceptual model which explains the range of phytoplankton-transport time relationships observed in nature has been submitted for publication to the journal *Limnology and Oceanography*. This manuscript has undergone two rounds of peer-review and is currently in its final round of revision. The concepts in this manuscript are highly relevant to the Delta and to possible future changes to that ecosystem due to climate change or anthropogenic structural manipulations in that the conceptual model presented lays out very simply how phytoplankton biomass should respond to changes in transport time scales (e.g. residence time) given particular estimated growth and loss terms. Also:

- Lucas was invited by the CALFED Science Program to present a seminar and participate in a panel discussion at a workshop on “Linking Physical and Biological Models for Ecosystem Prediction, Planning, and Performance” in support of the Governor’s Delta Vision Blue Ribbon Task Force, May 20, 2008
- Lucas was invited by Prof. Bill Fleenor (UC Davis) and Mr. Chris Enright (CA Dept. of Water Resources) to participate in a meeting to discuss ecologically relevant physical parameters to be derived from hydrodynamic model simulations for exploring large scale water conveyance alternatives for the Sacramento-San Joaquin Delta, June 12, 2008
- Lucas met with colleague Dr. Anke Mueller-Solger (DWR, IEP) to discuss model-field collaborations, possible approaches to validating the numerical phytoplankton model, and variability in zooplankton grazing in the Delta, June 27, 2008
- Lucas agreed to serve as “Community Mentor for Postdoctoral Researcher Cecile Mioni (University of California, Santa Cruz), for a CALFED post-doctoral fellowship proposal (May 2008)
- Lucas has submitted an invited chapter for a textbook on estuarine hydrodynamics and transport entitled “Contemporary Issues in Estuarine Physics” to be published by Cambridge University Press and edited by

Prof. Arnoldo Valle-Levinson. Her chapter is entitled “Implications of Estuarine Transport for Water Quality” and highlights several examples of CALFED funded research in the Delta.

- Lucas was interviewed for a piece on the CASCaDE project in the San Francisco Estuary Project’s *Estuary* Newsletter (February 2008)

Temperature:

Forcing and Calibration Data

Water temperatures were downloaded from IEP (data sources DWR, USGS) for locations throughout the Delta (Figure 1). The length of the records at the varied between stations; those that are circled in figure 1 (see attached PowerPoint file) had significantly more than 1 year of data, while those with dashed circles at approximately 1 year of data. This data was post-processed to remove obvious outliers, then a 4-sigma filter was applied to remove remaining outliers. Gaps in the records were filled when possible using linear interpolation, but interpolation was not used across any seasonal variations.

For the 100-year projections, only daily averaged quantities (or daily extremes) was available to force the statistical projections. Starting from CIMIS meteorlogical data, we found that in the data of interest for these projections, the variation across the Delta was quite small. As such, we spatially-averaged the data over the CIMIS stations adjacent to the Delta to provide representative values of air temperature (max and min), wind and insolation.

Development and Calibration of Statistical Temperature Model

Using the historical water temperature data, which for many stations started in the mid-1980s and extended to the current time, we initially pursued a mechanistic approach to projecting water temperatures. We quickly found, however, that a simpler, statistical approach provided equivalent, if not superior, predictive capability. The statistical approach that we pursued was to use:

$$T_w(n) = \sum_{i=0}^{N} a_i\, T_a(n-i) + b\,T_w(n-1) + c\,R + d$$

where n is the day on which the temperature is being calculated, T_w is the water temperature being calculated, T_a is the air temperature (from CIMIS data), and R is the insolation (from CIMIS data). This general equation allows us to include additional memory in the model by including air temperature from more than 1 day, but we found that the model performance was not significantly improved when more than the current day air temperature was included. Therefore, with $N = 0$, we have a statistical projection for water temperature that has 4 tunable coefficients: a is the coefficient on the current day’s air temperature; b is the coefficient on the previous days water temperature; c is the coefficient on insolation, and d is a constant offset that would allow for a long-term trend (but is generally zero for the records we are focusing on).

To calibrate and verify our statistical model, we split each data set in half, and used the first half to calibrate the four coefficients, and the second half to verify the statistical models predictive skill. As an example of the calibration and verification process, Figure 2 (see attached PowerPoint file) presents time series of the calibration and verification periods from a long-term record at the Stockton Ship Channel. The annual cycle is clearly well-predicted, as is shorter timescale variations, particularly weekly to monthly fluctuations. A more difficult test is shown in Figure 3, where temperature data was only collected during the spring seasons at Prisoner’s Point, but the projection was still able to capture the annual cycle sampled at the end of the verification period. This is most likely due to the fact that the data, while only covering a portion of the year, still sampled most of the annual range in temperature.

The overall success of this approach is summarized in Table 1, where R^2 values are summarized for all stations for maximum, minimum and mean daily temperatures. Those where more than 2 years of data were available (those stations circled in Figure 1) are all of very high R^2 (~0.95).

Projections of Water Temperatures for Climate Scenarios

Our most recent activity has been focused on driving our statistical model with the downscaled conditions from climate scenarios. The data from Mike Dettinger was subsampled for the Delta region, then averaged to produce an equivalent forcing timeseries to those used during the Calibration stage. The data from the scenarios included maximum and miminum daily temperatures, daily averaged wind, etc. Additional forcing was applied from the annual cycle of insolation (assumed unchanged over the 100 year time horizon).

Figure 4 shows one example of these projections, where the historical data has been overlaid for the first 7 years (note that these will not match perfectly due to different realizations of the climate between the "projection" and the historical record). In this particular case, the trend in water temperature over the 100 year time horizon leads to an increase in both the high and low temperatures (shown is daily mean temperature) of several degrees. Graphical summaries of these projections have now been distributed to the CASCaDE team.

<u>Hydrodynamics:</u>

Base Case Scenarios

Simulations of full year base-case scenarios are now operational. Databases of observed data for these scenarios are complete and the verification process has begun. Data that drives the model boundaries and all observation data are now in two formats. The first format allows that to be quickly viewed in the Gr program (developed John Donavon/ USGS Sacramento). This format allows model data to be easily transferred between PIs on the project. The data was also put in a matlab database for comparison with model output. Simulation output will be verified this Fall.

Drogue Releases

Water transport time scales characterize the physical processes that can govern ecological function in some regions of the Delta. For example, in positive growth conditions (rate of loss due to grazing is slower than the growth rate), longer transport time means more algal biomass. Because of the complex nature of the Delta's interlaced channels and flooded islands, standard methods for calculating "residence time" do not necessarily apply or accurately represent this system. We need methods to characterize transport timescales for both flooded islands and complex channel junctions in the Delta. In addition, we need to parameterize how flows altered by climate change will transform the Delta ecosystem. To develop the method to do these transport timescale calculations, the model was run for the dry scenario (1992), using January flow conditions, and releasing 4800 drogues in the Big Break/Lower San Joaquin region. This simulation alone produced 6,000,000 lines of output that was converted into a matlab database for further analysis. The results of this simulation and other simulations scheduled to be completed this Fall will be the topic of a CALFED Science Conference talk in the CASCaDE session.

Climate scenarios based watershed model output

Knowles provided watershed/CALSIM output of monthly-averaged flow at the Sacramento and San Joaquin boundaries for 100 years for all four climate scenarios. We plotted the data both by month and by season to look at general trends. One key finding was that CALSIM draws water from groundwater when it cannot meet demand in the Delta. Therefore, the flows into the Delta do not change as dramatically as was expected. We are currently investigating where the groundwater drawdown is realistic.

Task 4

During the past 6 months a successful calibration and validation was completed of a DELFT3D hydrodynamic and morphodynamic San Francisco Bay model that covers the complete Bay area from the Delta towards Point Reyes. The calibration focused on 2004 measured water levels and sediment transport. The model was used to predict water level and discharge boundary conditions for a 150 years hindcast model. The hindcast model is smaller than the Bay model and aims at hindcasting morphodynamic development of San Pablo Bay and Suisun Bay. Preliminary results of the hindcast model show good agreement with measured bathymetric development in San Pablo Bay and Suisun bay. The sediments delivered during river floods settle in the bays and periods of low river discharge redistribute the sediments over the bays. The hindcast model is a 3D model and includes density currents due to salt and fresh water interaction, graded sediment transport and bed composition, and waves. These processes appeared essential for an adequate hindcast in San Pablo Bay.

Additionally, we have completed hindcast modeling of the 1942-1990 period, for Suisun Bay. We have found that model parameters (such as Delta configuration and sediment characteristics), vary with time. While agreement with net erosion measurements is relatively easy to modulate (by adjusting sediment parameters), spatial agreement is variable. Maximum spatial agreement was achieved during the 1942-1990 period, while minimum spatial agreement was achieved for the 1922-1942 period. Ganju combined parts I and II of “Simulation of decadal-timescale estuarine geomorphic change with a tidal-timescale model” and resubmitted it to JGR Earth Surface.

Task 5

An important characteristic of the Bay-Delta is that the two river systems contain extremely different concentrations of selenium (Se). Thus changes in discharge in either river and changes in the way they mix could have great implications for Se exposures of native upper trophic level species. The biological coefficients necessary to model Se exposures of invertebrates under different climate regimes include assimilation efficiencies from different food types, ingestion rates for different species, and rate constants of loss. New experimental data were derived to verify feeding rates in important species in the estuary. All necessary data are therefore available for modeling expected changes in Se concentrations in invertebrates, as proportional changes in river flows occur. Key species will be bivalves, amphipods, copepods and mysids; representing benthic and pelagic food webs. Trophic transfer factors for different fish species have been assembled from the experimental and field literature. Sufficient data are available to model bioaccumulation in key species from the Bay and Delta. Particulate/dissolved ratios of Se concentrations (Kd's) are another key ingredient in developing the model. A large database from the Bay is assembled and analyzed, including models that estimate changes in these concentrations if San Joaquin River inputs to the Bay increase, allowing determination of concentrations under different potential scenarios for the fate of Se in the system. Thus the ingredients are assembled for a thorough assessment of how Se bioaccumulation in the benthic and pelagic food webs of the Bay and the Delta could respond to changes in river inputs of Se. Because tissue concentrations of Se have been linked to toxicity and reproductive failure, it is possible to deduce risks to reproduction of at least some fish based upon this modeling.

Task 6

Model parameters are nearing completion and have been presented at local forums (IEP Estuarine Ecology Team) and have been in included in two conceptual models (DRERIP) for CALFED. The Corbula model is in review and the Corbicula model will go into review in early September. Samples from the oldest available DWR sampling (1975- through today) have been analyzed and that data is being incorporated into our model parameters that will now include conditions not seen in the last 20+ years in the estuary. Much of the southern Delta experienced much larger freshwater fluctuations that are consistent with our scenario climate projections. We will use these data to verify our model projections.

Publication: Paper in final journal revision incorporates our understanding of bivalve grazing and physical parameters in freshwater systems. The relationships developed in this review paper will be useful in our interpretation of Corbicula's influence on phytoplankton in the delta.
Lucas, L.V., J.K., Thompson, and L.R. Brown. Why do we observe different relationships between phytoplankton biomass and transport time? Limnology and Oceanography.

Talk: IEP Estuarine Ecology Team Meeting – presentation on Corbula's grazing effect on the low salinity zone and how that might influence the Delta Smelt population. Thompson. August 26.

Task 7

We continued to summarize existing information on the environmental tolerances of our fish species of interest. This information will feed directly into the species life cycle models. Literature review of fish-climate change literature is continuous. We decided not to move forward with a review article but the review will provide a basis for future reports and articles. We analyzed historical flow data from a variety of sources for the major tributary rivers to the San Francisco Estuary using the software package "Indicators of Hydrologic Alteration". We prepared a draft manuscript based on analyses of flow before and after construction of the major hydrologic infrastructure in the watershed. The manuscript was reviewed by several co-PIs and is being revised in response to comments. We intend to move forward with publication of this manuscript. We contacted several interested fisheries researchers with various agencies to keep them informed of CASCADE progress. Now that more data analysis will be occurring, we will be using this group as collaborators and to keep various agencies informed of potentially important results. We reviewed the initial monthly flow and water temperature outputs from task 2 and identified some potential problems with the CALSIM outputs for the 4 scenarios. We proceeded with some preliminary analyses of these data to explore methods of data organization and analysis in preparation for the revised data. Initial analysis of the new data sets will be the basis of the presentation at the upcoming CALFED Science Conference.

PROBLEMS OR DELAYS ENCOUNTERED: None.

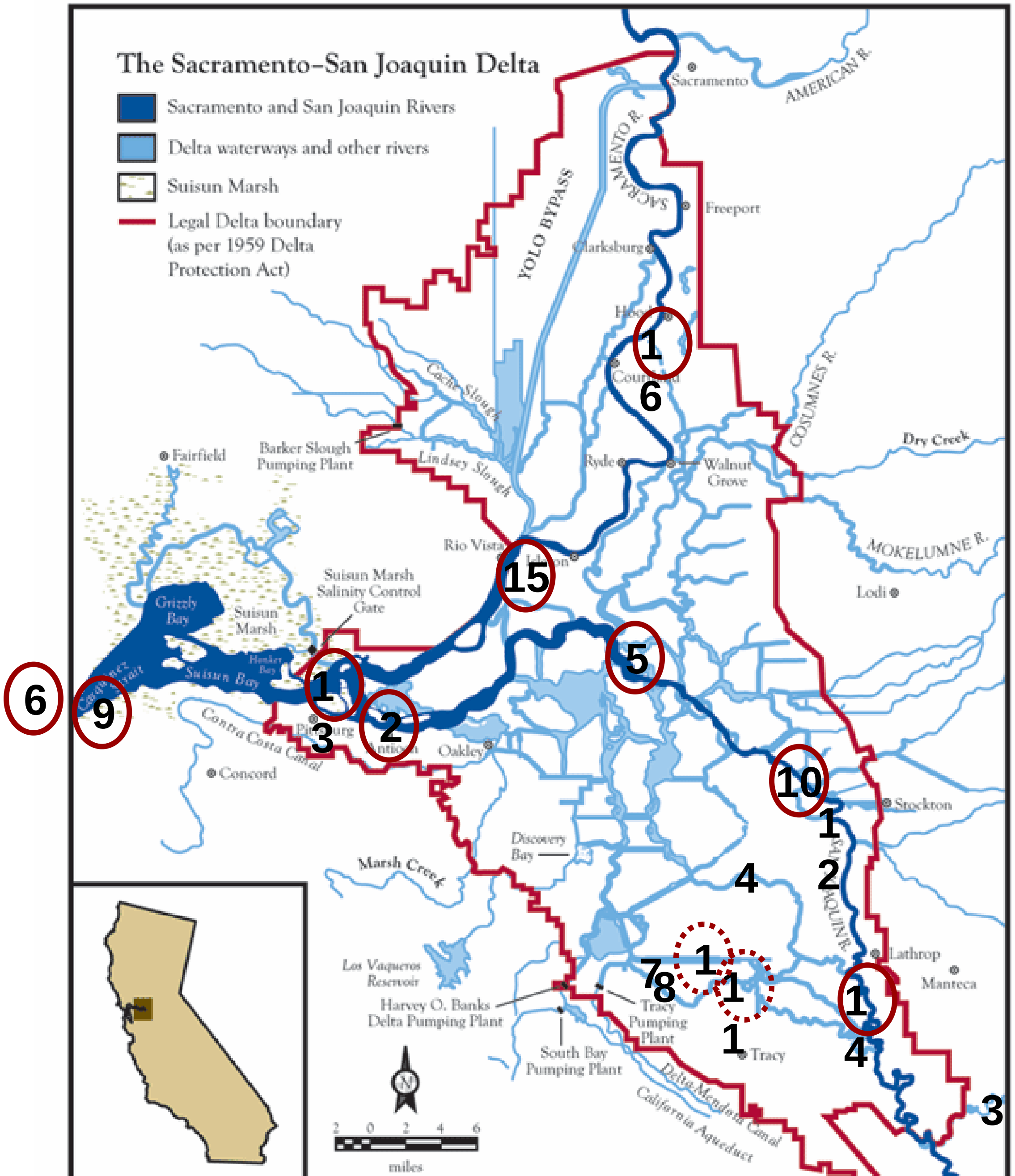
DELIVERABLES PRODUCED:
Larry Brown delivered a presentation at the 2008 Annual Meeting of the California-Nevada Chapter of the American Fisheries Society "Streamflow characteristics of California's Central Valley Rivers: implications for native and invasive fishes."

Larry Brown delivered a presentation at the 2008 Meeting of American Fisheries Society, “Streamflow characteristics of California’s Central Valley Rivers: implications for native and invasive fishes.”

Larry Brown, Christa Woodley, and Bill Bennett prepared an abstract for the 2008 CALFED Science Conference, “Increased water temperatures from CASCaDE climate-change scenarios: implications for California fishes.”

Task 8

- J. Cloern organized and led meetings of project PI’s on 26 March 2008 and 4 June 2008 (agendas and meeting notes are available on the public website).
- M. Dettinger organized a Cascade session for the 2008 CALFED Science Conference.
- J. Cloern submitted a request to the Calfed Science Program for a 6-month no-cost extension of CALFED Project SCI-05-G01-84, CASCaDE: Computational Assessments of Scenarios of Change for the Delta Ecosystem. The original end date is 29 Feb 2009 and we requested a revised grant expiration date of 31 Aug 2009.
- J. Cloern, L. Lucas and J. Thompson presentations: “CALFED Science Program Workshop: A Two-Part Discussion on Conveyance Modeling in support of the Delta Vision Blue Ribbon Task Force Workshop 2: Linking Physical and Biological Models for Ecosystem Prediction, Planning, and Performance”, 20 May 2008 (http://www.science.calwater.ca.gov/pdf/workshops/workshop_dcm2_public_notice_052008.pdf)



Sensor Locations

1 Grantline Canal at Tracy Blvd Bridge
2 San Joaquin River at Antioch between lights 7 & 8
3 Stanislaus River at Ripon
4 Middle River at Tracy Blvd
5 San Joaquin River before Prisoners' Point
6 Selby (Wickland Oil Pier)
7 Old River near Delta Mendota Canal (NW of barrier)
8 Old River near Delta Mendota Canal (SE of barrier)
9 Sacramento River at Martinez
10 Stockton Ship Channel at Burns Cutoff
11 Old River at Tracy Blvd
12 San Joaquin River at the Channel Point Navy Bridge
13 Sacramento River near Mallard island
14 San Joaquin River at Mossdale
15 Sacramento River at Rio Vista Bridge
16 Sacramento River at Hood

Figure 1: Data Locations

Station 10: Stockton Ship Channel

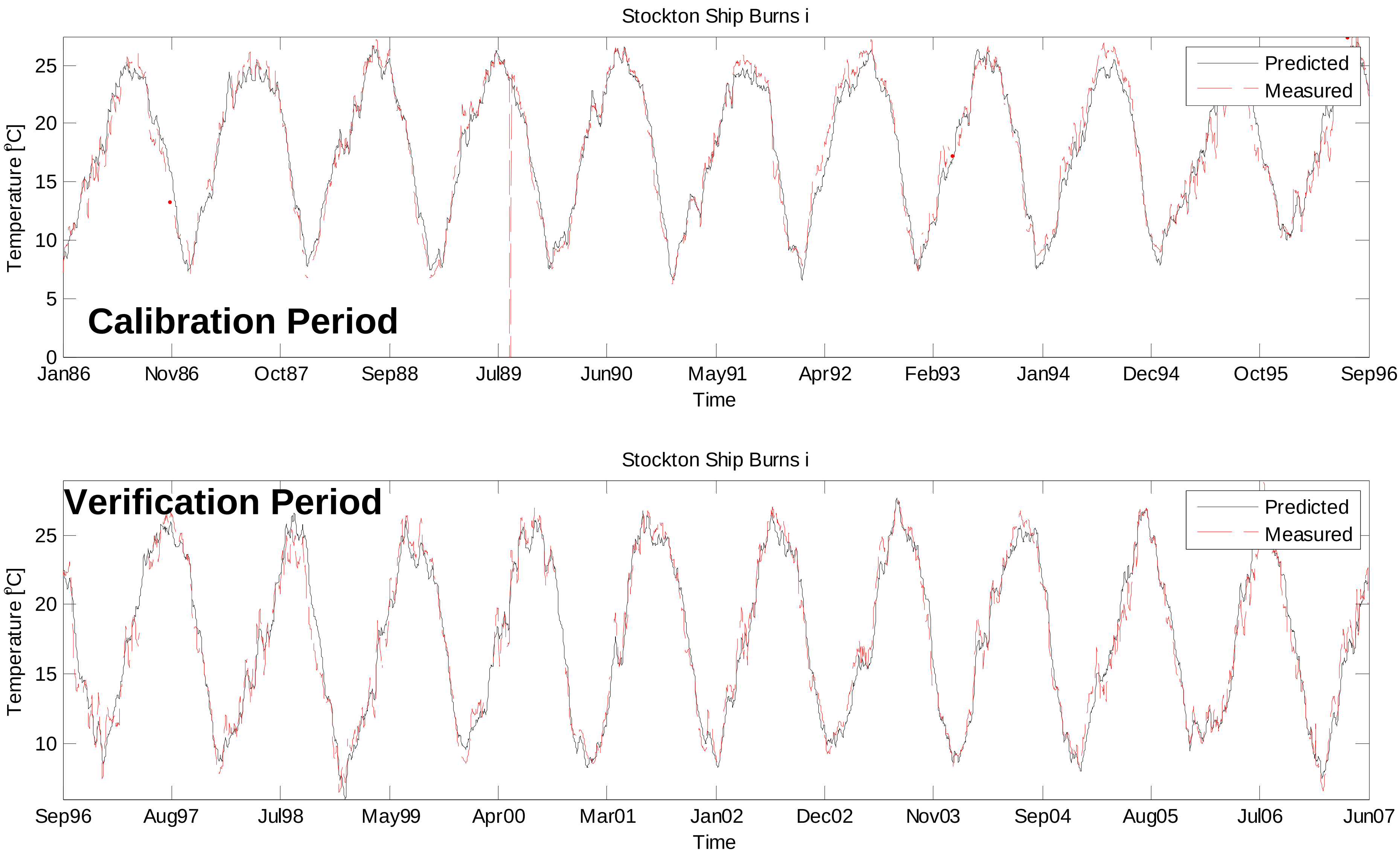
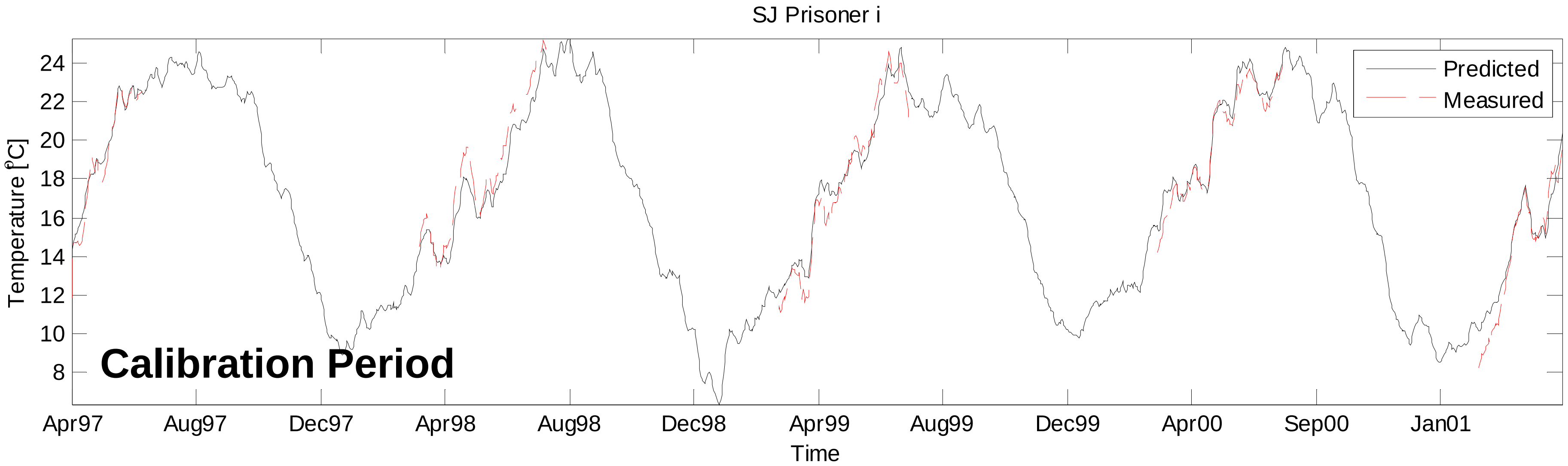


Figure 2: Calibration and Verification at Stockton Ship Channel Station

Station 5: SJR at Prisoner's Point



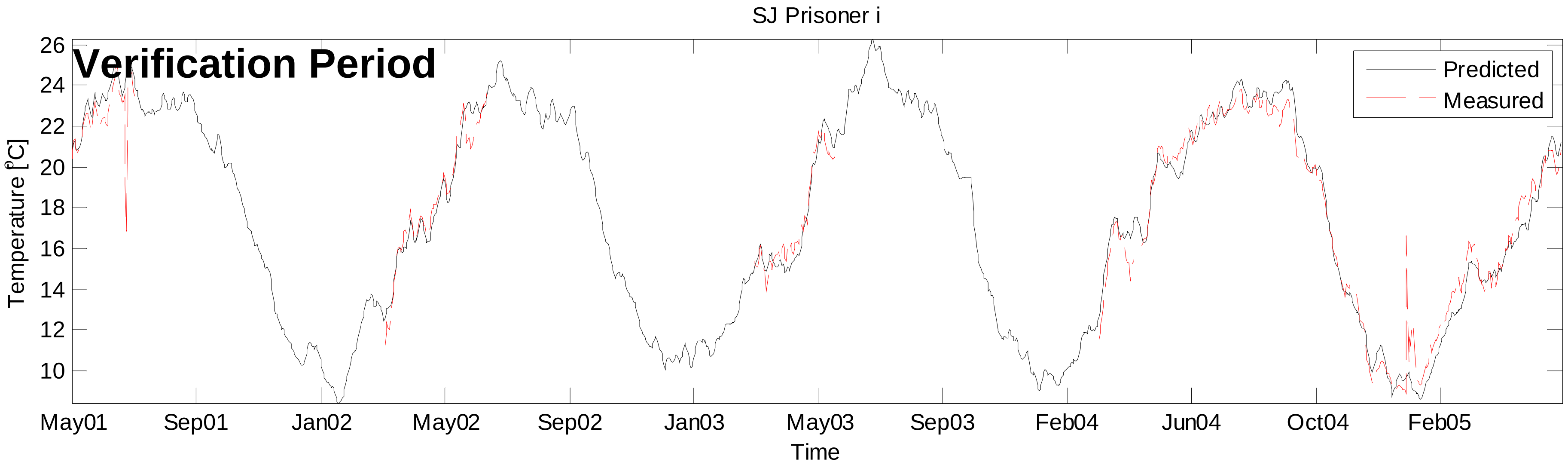


Figure 3: Calibration and Verification at Prisoner's Point

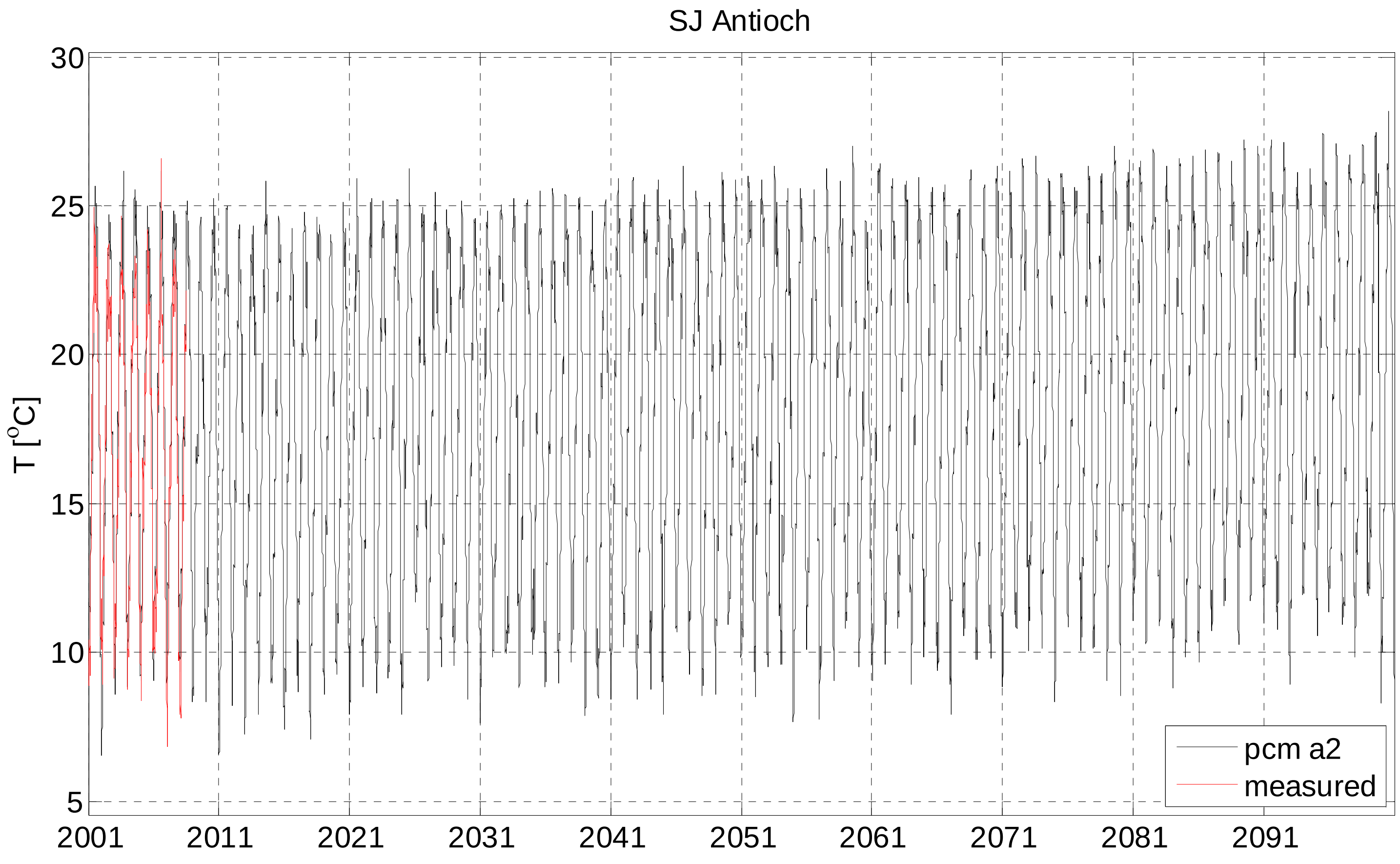


Figure 4: 100 year projection for daily mean temperature at Antioch

		Tmax		Tmin		T	
Stn.	Stn.Name	Calibration	Verification	Calibration	Verification	Calibration	Verification
1	Grantline Tracy	0.69	0.75	0.75	0.78	0.75	0.82
2	SJ Antioch	0.97	0.97	0.98	0.98	0.98	0.98
3	Stanislaus Ripon	0.79	0.89	0.78	0.92	0.79	0.89
4	Middle Tracy	0.91	0.57	0.94	0.44	0.96	0.63
5	SJ Prisoner	0.97	0.93	0.97	0.96	0.97	0.97
6	Wickland Pier	0.97	0.97	0.97	0.97	0.98	0.97
7	Old (NW barrier)	0.57	0.82	0.48	0.73	0.69	0.85
8	Old (SE barrier)	0.76	0.54	0.77	0.52	0.78	0.46
9	Sac Martinez	0.96	0.96	0.96	0.96	0.96	0.97
10	Stockton Burns	0.96	0.97	0.95	0.97	0.96	0.97
11	Old Tracy	0.94	0.80	0.93	0.84	0.94	0.83
12	SJ Navy Bridge	0.91	0.97	0.86	0.97	0.87	0.97
13	Sac Mallard	0.93	0.96	0.93	0.96	0.94	0.97
14	SJ Mossdale	0.96	0.95	0.96	0.95	0.96	0.95
15	Sac Rio Vista	0.97	0.94	0.97	0.93	0.97	0.94
16	Sac Hood	0.97	0.97	0.97	0.97	0.97	0.97

Table 1: Calibration and Verification R^2 for daily maximum, minimum and mean temperature.