

Final Report

**HYDROLOGIC MONITORING AND MODELING
OF NAPA RIVER TRIBUTARIES AND STEWARDSHIP SUPPORT SERVICES,
2004-05**

Prepared for the
City of Napa

by

Bob Zlomke, Paul Blank, Michael Champion and Jenny McIlvaine
Napa County Resource Conservation District

with

J. Carter Borden, DHI Inc.

Napa County Resource Conservation District
Contract #8608

June 2005

Final Report

HYDROLOGIC MONITORING AND MODELING OF NAPA RIVER TRIBUTARIES AND STEWARDSHIP SUPPORT SERVICES, 2004-05

I. Introduction

Since 1999, the Napa County Resource Conservation District (RCD) has contracted with the City of Napa to do hydrologic modeling and monitoring of local creeks. The initial contract was for monitoring and modeling of Napa Creek, and in subsequent years monitoring of flows on Milliken and Salvador Creeks was added. In 2001, the RCD took on the task of developing a hydrologic model of Salvador Creek, while at the same time reconvening the Salvador Creek Stewardship, with a view toward using the model to study issues of interest to the Stewardship group.

This report covers RCD activities between July 2004 and June 2005 under contract #8608. They include a range of monitoring activities, including data maintenance; maintaining and improving discharge rating curves for the three creeks named; measuring suspended sediment concentrations in the three creeks; maintaining and applying MIKE 11 models of the Salvador and Napa Creek drainages; and providing stewardship support services to the Salvador Creek Stewardship Group. The report covers these topics in the order named, with references to the contract scope of work in parentheses.

The work described was done by the following RCD employees: Hydrologist Paul Blank, Education Coordinator Michael Champion, Field Technician Chad Edwards, Stewardship Educator Jenny McIlvaine, and Senior Hydrologist Bob Zlomke. J. Carter Borden of DHI, Inc. provided invaluable support with the MIKE 11 modeling. We are grateful to the City of Napa and the Napa County Flood Control and Water Conservation District for their support.

II. Data Maintenance (Task A)

The RCD finalized the Salvador Creek water level (h) record collected at the Big Ranch Road gage, and generated records of flow depth (d) and stream flow (Q) for the 2003-2004 water year. The data file includes the 15-minute data record since startup of the station on November 7, 2003, through the end of the water year on September 30, 2004, with two large gaps: May 11, 2004 through June 25, 2004, and August 21, 2004 through September 28, 2004. The finalizing process entailed:

- Filling the gaps in the date and time record;
- Adjusting an offset resulting from reprogramming on November 19, 2004;

- Reviewing the data to locate anomalous data points, and correct those points by replacing the water level value with the average of the adjacent values (25 such points were found, and seem to be an effect of using an ultrasonic sensor for water level measurement);
- Generating the d record by subtracting 0.25 feet from the corresponding h value;
- Generating the Q record using the rating equation (d-Q relationship) developed for the site for the 2003-04 water year; and,
- Preparing a read me file describing the station location, data collection methods, and data processing.

This process established: 1) a procedure for finalizing stream stage and flow data; and 2) templates for data processing spreadsheets, final .csv files, and read me files. The data are available from Paul at the RCD office.

Figures 1 and 2 show Salvador Creek stage and flow, respectively, versus time, for the period of November 7, 2003, through April 28, 2004. There were no significant hydrologic events during the remainder of the water year. The figures show that the largest event took place on February 25, 2004, during which stage reached a maximum of 7.28 feet, at a maximum flow of 750 ft³/s.

The RCD has collected a complete 15-minute record of water level for Salvador Creek for the 2004-05 water year, through June 14, 2005, from the Big Ranch Road gage. The dataset will be finalized in the manner described above after the completion of the water year on September 30, 2005.

III. Rating Napa Creek (Task B)

The RCD made two visits to the Coffield Avenue gage site on Napa Creek to measure stream discharge during the 2004-05 streamgaging season. The first was made on January 7, 2005, and was performed using suspension equipment. The average water level was 3.62 feet and the discharge was computed to be 315 ft³/s. The second visit was on March 22, 2005, and was also made using suspension equipment. The average water level was 3.60 feet and the discharge was computed to be 280 ft³/s. These measurements were used to update the rating curve for the gage site. Figure 3 depicts the rating curve with this year's values shown in red. The rating equation can be used to convert the water level record collected at the Coffield Avenue gage to a record of streamflow.

On March 16, 2005, the RCD surveyed a cross-section of Napa Creek at the Coffield Avenue gage site. Figure 4 depicts the survey results. This cross-section can be compared to previously-collected and future annual cross-sections to evaluate geomorphic changes at the gage site.

In addition to updating the stage-discharge rating for Napa Creek with the current years measurements, the RCD finalized rating curves for the 1999-00, 2000-01, 2001-02, 2002-03, and 2003-04 water years, and prepared a read me file describing the finalization

process and recommending a specific rating equation for use in generating flow records. These data are available from Paul at the RCD office.

IV. Rating Milliken Creek (Task C)

The RCD made two visits to the Atlas Peak Road gage site on Milliken Creek to measure stream discharge during the 2004-05 streamgaging season. The first was made on December 27, 2004, and was performed using suspension equipment. The average water level was 3.38 feet, and the discharge was computed to be 179 ft³/s. The second visit was made on March 22, 2005, and was also made using suspension equipment. The average water level was 3.17 feet, and the discharge was computed to be 153 ft³/s. These measurements were used to update the rating curve for the gage site. Figure 5 depicts the rating curve with this year’s measurements shown in red. The rating equation can be used to convert the water level record collected at the Atlas Peak gage to a record of streamflow. Rather than relating discharge to stage, as was done for Napa Creek, the RCD chose to relate discharge to flow depth (d) for Milliken Creek because there is a pool at the gage location. Flow depth is computed by subtracting 0.7 from each measurement of stage.

On March 15, 2005, the RCD surveyed a cross-section of Milliken Creek at the Atlas Peak Road gage site. Figure 6 depicts the survey results. This cross-section can be compared to future annual cross-sections to evaluate geomorphic changes at the gage site.

V. Rating Salvador Creek (Task D)

The RCD made four visits to the Big Ranch Road gage site on Salvador Creek to measure stream discharge during the 2004-05 streamgaging season. The details of streamgaging are listed in the following table.

Date	Equipment	Average Water Level (ft)	Discharge (ft ³ /s)
December 27, 2004	Suspension	3.86	345
December 30, 2004	Wading	1.11	55.8
January 7, 2005	Suspension	1.99	161
March 22, 2005	Wading	1.22	55.4

These measurements were used to update the rating curve for the gage site. Figure 7 depicts the rating curve with this year’s measurements shown in red. The RCD will use the rating equation to convert the 15-minute water level record collected at the Big Ranch Road gage site for the 2004-05 water year to a record of streamflow. As with Milliken Creek, the RCD selected to relate discharge with flow depth for Salvador Creek. Flow depth is computed by subtracting 0.25 from each measurement of stage.

On March 15, 2005, the RCD surveyed a cross-section of Salvador Creek at the Big Ranch Road gage site. Figure 8 depicts the survey results. This cross-section can be compared to future annual cross-sections to evaluate geomorphic changes at the gage site.

VI. Sediment Measurements (Task E)

During the reporting period, the RCD collected two stormwater samples from Napa Creek, two samples from Milliken Creek, and four samples from Salvador Creek, during the streamgaging visits described above. The samples were collected using USGS-type suspended sediment concentration (SSC) samplers and the equal transit rate (ETR) sampling method. The samples were transported to the EPA Laboratory in Richmond, California, for analysis of SSC using the appropriate EPA Methods.

The results of laboratory analyses are presented in the following table.

Site	Creek	Date	Q (ft ³ /s)	SSC (mg/L)
323	Napa	01/07/05	315	440
323	Napa	03/22/05	280	680
302	Milliken	12/27/04	179	17
302	Milliken	03/22/05	153	8
SAL	Salvador	12/27/04	345	220
SAL	Salvador	12/30/05	55.8	28
SAL	Salvador	01/07/05	161	92
SAL	Salvador	03/22/05	55.4	55

Figure 9 shows all SSC data collected from Napa, Milliken, and Salvador Creeks, with this year's data shown in black, versus stream discharge. This figure indicates that, for a given discharge, Milliken Creek has a lower SSC concentration than Napa or Salvador Creeks, likely due to the dam and reservoir on Milliken Creek located upstream of the gage site.

VII. Modeling Napa and Salvador Creeks (Tasks F, I, K)

RCD updated our MIKE 11 model with the 2004 version and loaded it onto an RCD computer. The new model initially ran very slowly, and it turned out there was a problem related to running the model off the network server, rather than off a local disk. The problem was solved by running the model off the local disk (and saving daily to the server, which is backed up nightly). This procedure will be adhered to in the future.

The hydrologic models of Napa Creek and Salvador Creek were maintained and improved during this contract; the specific modeling activities carried out are described below with respect to contract tasks I and K.

A. Modeling Salvador scenarios (Task I)

The Salvador Creek Watershed has hosted considerable construction and development in recent years. Building new homes and constructing new roads can lead to an increased flooding hazard by replacing permeable surfaces with impervious surfaces and by

obstructing natural floodplains. The need for restoration on Salvador Creek has been recognized, but more pressing is the need for both a flood conveyance study and an organized Stewardship group of concerned citizens to focus and guide the restoration process. Under a previous contract with the City of Napa, RCD began working with the nascent Salvador Creek Stewardship Group, and we also began to build an unsteady-flow hydraulic model of the creek on the basis of the MIKE 11 software developed by DHI Water & Environment. That work continued under the present contract.

The RCD completed development of the model and used it to study scenarios identified by the Stewardship Group. We focused on three scenarios identified in discussions with the group. These were, in order of importance, (1) removal of the Garfield Park bridge, (2) finding floodwater storage around the Garfield Park area, and (3) expanding cross-sections in the area of Summerbrook Circle. Work on these scenarios was completed in early fall and presented to the stewardship group on October 20, 2004. Follow-up activities of the group are described under section VIII below.

In response to further interest from the group, the RCD carried out rough modeling of two additional scenarios, flood terraces above Jefferson and detention in Alston Park, which were presented to the group on February 23, 2005. The present report explains in more detail what was done to investigate all these scenarios and offers recommendations to the City for the future.

model setup

The MIKE 11 model is an implicit finite difference model capable of modeling a network of one-dimensional channels, both for hydrodynamics and for a variety of water quality parameters. The Danish Hydraulic Institute developed the model, which is based on the St. Venant equations for one-dimensional unsteady flow. As an unsteady flow model, it is able to track the progress of floods, tidal events, and the interactions between the two, within the constraints of a network of one-dimensional channels. These capabilities permit the study of a large variety of scenarios in which time plays a role. In 2000, the MIKE 11 model was approved by FEMA for use in mapping floodplains within the National Flood Insurance Program.

The model setup used this year was based on the initial model of Salvador Creek described in *Hydrologic Modeling and Stewardship of the Salvador Creek Watershed* (Napa County RCD, 2003). The model was developed with two branches, Salvador Creek from Highway 29 to the river and the Napa River from Oak Knoll Avenue to the 3rd Street Bridge. For the river, we used the cross sections in the RCD model database, which consist of cross sections developed by the Corps of Engineers for the Napa flood project with the addition of further cross sections measured by RCD staff and volunteers in 1995 between Trancas and Oak Knoll. For Salvador Creek, RCD staff carried out field surveys of channel cross sections using a Total Station surveying instrument. The initial RCD survey included 32 cross sections between Highway 29 and the river; a total of 26 cross sections on the North and South branches of the creek west of Highway 29 were also surveyed, although these cross sections have not been used in the model to date.

After June 2003, the RCD added 17 new field-measured cross sections to cover the reach from Garfield Park to the river. By this point our interest had been directed to the possibility of flood storage in the area of Garfield Park, so we also extended the cross sections in the park area (chainage 1776 – 1970) laterally to include substantial areas of the floodplain. Elsewhere, RCD-surveyed cross sections do not generally include the floodplain.

Two MIKE 11 modules were used in this project, the rainfall/runoff module and the hydrodynamic module. The rainfall/runoff and hydrodynamic modules were coupled and run together, with the rainfall/runoff results used as input to the hydrodynamic module. For the rainfall/runoff module, the Salvador watershed was divided into two different sub-basins, an upstream (US) catchment including the area upstream of the highway, and a downstream (DS) catchment including the remainder of the Salvador Creek drainage area down to the river. The MIKE-11 rainfall/runoff module (or “NAM” model) is a lumped continuous model. It is a continuous model in that it offers a series of calibration parameters describing the entire hydrologic response of a specific catchment throughout the modeled period, which typically spans a number of months or years; and it is a lumped model in that these parameters represent average values for an entire catchment.

The results from the rainfall/runoff module were applied as inflows to the hydrodynamic module: the runoff from the US catchment was applied as a point inflow at the beginning of Salvador Lower branch, the “Solano Y,” while that from the DS catchment was distributed linearly along the channel, from chainage 0 to chainage 3834. “Chainage” is defined in the model as the longitudinal location along the line of flow, in meters, beginning at the upstream end of a branch. For Salvador Creek, the upstream end is defined as chainage 0 and the mouth at the river as chainage 3834. Figure 10 shows the hydrodynamic model domain of Salvador Lower branch, with key chainage points.

hydrologic data

The model was developed and calibrated using rain and discharge data for the 2003-04 rainy season. The rainfall data used to drive the model was derived from two City ALERT system gages, no. 2271 (City Corporation Yard) and no. 2253 (Redwood Road at Mt. Veeder Road). The DS catchment gets 100% of its rain from 2271; the US catchment gets most of its water from 2271, with a smaller amount from 2253. The rainfall data for these two gages were adjusted to make up for periods of missing data, by including interpolated and adjusted data from the CIMIS station in Oakville (CIMIS 77), using a multiplier to decrease the amount of rainfall for the Redwood and City records in proportion to the proportional difference in mean annual rainfall. None of these rain gages is in the Salvador Creek watershed. CIMIS 77 was also the source of data on evaporation, another data type required by the rainfall/runoff module.

The discharge data used for calibration of the model are derived from a streamflow record at Big Ranch Road (chainage 2943), which the RCD established before the 2003-04 water year. The discharge record is derived from a 15-minute time series of water

level by the application of a rating curve based on approximately 6 discharge measurements made during water years 03-04 and 04-05. See the discussion under Section V above.

During April and May 2005, the RCD installed two recording rain gages and two crest-stage gages in the Salvador Creek watershed to improve our field instrumentation. The crest gages were installed within the channel of Salvador Creek, to measure future storm peaks near the Jefferson Street bridge and at Garfield Park. These gages provide an accurate high-water mark which can be noted after each major storm. The recording rain gages were installed at two widely dispersed locations within the watershed, one at Alston Park and one at Vintage High School, to provide a more representative rainfall record for future modeling purposes. In addition, a private citizen who operates a recording rain gage at his home near Big Ranch Road has agreed to provide his rainfall data to the RCD.

calibration results

Since the discharge calibration point at Big Ranch Road was well down in the watershed, it was necessary to run both the rainfall/runoff and hydrodynamic modules to obtain a modeled flow record for comparison with the measured record. This was conveniently done by coupling the two modules and running them together.

The resulting modeled discharge record at Big Ranch Road was calibrated to agree closely with total measured volume, by varying the parameters in the rainfall/runoff module. Our success at modeling the peaks and timing of individual storms varied; for some storms the peak discharge was overpredicted, and for others it was underpredicted. This variability is most likely attributable to the spatial variation of rainfall, which is poorly represented by the available rainfall records.

Separate calibration of the hydrodynamic module was carried out by varying Manning's n . The model generally underpredicts water levels at Big Ranch Road, even after calibration. The most likely explanation is uncertainty in the stage-discharge rating curve. It needs more points, particularly at high flow. Although we got a good range of data points for the curve last year, one of the 2 high-flow points suffers from uncertainty about level (since the stream was receding quickly during the measurement), and it is important to buttress the curve with more points next year.

The calibrated results at the discharge gage point, Big Ranch Road, are illustrated in Figure 11, which shows a period including two major storms. Since we had only one season's data, no separate validation of the calibrated model was carried out. It is important to revisit the subject of model calibration as more data becomes available in future years.

The calibrated model includes the Garfield Lane bridge and detailed floodplain cross sections in the park area upstream of the bridge (chainage 1776 – 1970). Elsewhere on Salvador Creek, model cross sections are limited to the channel and the immediate top-

of-bank area. Other bridges are not included in the calibrated model, although they were surveyed, because they are too far from the areas of restoration interest identified by the stewardship group to play a role there.

initial scenarios: Garfield Park area

As was mentioned above, the initial scenarios examined with the model involved flood improvements in the Garfield Park area. Twenty-four hour design storms were developed, using SCS storm type IA, for the following recurrence intervals: 2 years, 10 years, 25 years, 50 years, and 100 years. The 100-year storm shows Salvador Creek up around the top of bank at a number of locations between Highway 29 and the Napa River, especially in the area immediately downstream of Garfield Lane Bridge. All design flows except the 2-year flood rise above the top of the Garfield Lane bridge opening.

The RCD hydrologist determined that widening cross sections in the area of Summerbrook Circle would likely not have noticeable effects on conveyance, since those cross sections were comparable to nearby downstream cross sections in capacity. Modeling efforts were therefore concentrated on the first two issues, which were examined separately and together: removal of the Garfield Lane Bridge and recreation of floodplain storage in Garfield Park.

The design storms were rerun with the Garfield Lane Bridge removed. Since City design standards reference the 100-year flood level, the 100-year design storm was scrutinized most closely. Even at lesser flows, the Garfield Lane Bridge itself seems to act as a definite flow restriction; if the bridge is removed, the peak level immediately upstream of it is reduced by 0.28 m in the simulation from January 1, 2004. For all of the design storms, there is a reduction in peak water level immediately upstream of the bridge, as one would expect, and a much smaller rise in peak level immediately downstream of the bridge: only 3 cm for the 100-year storm.

To examine the effects of increasing floodplain storage in the area of Garfield Park, available space in the park was modeled as a large lowered floodplain, or *flood terrace*, at the level of the 2-year storm, which would allow excess creek water to leave the main channel and flow at reduced depth and velocity for the length of the new flood terrace. The flood terrace is shown in Figures 12 and 13. As Figure 12 shows, the new flood terrace as modeled takes up most of the room in the park. The change in cross section is shown in Figure 13. It is important to remember that the change in topography would be consistent with a variety of park uses; the new flood terrace would receive creek flow only about once every two years, on average, and then not for more than a few hours. At other times, the area would retain elements of its park character. The new flood terrace was modeled as being separated from the main channel by a low weir, which would control flow into the flood terrace at the upstream end (at approximately chainage 1776) and back to the channel at the downstream end (at approximately chainage 1970). The design storms were rerun with the addition of this new flood terrace, both with and without the removal of the bridge.

The results of rerunning the 100-year storm for the two scenarios, separately and together, are shown in Figure 14. There are three plots, each of which compares the existing condition with the three new possibilities (scenario 1 alone, scenario 2 alone, and both scenarios together) at a key location on the creek. The three locations are shown on Figure 12.

Figure 14a shows the effects of the modeled scenarios at the nearest cross section upstream of the park. In that figure, both scenarios show a noticeable reduction in the peak water level, and the two together provide the most benefit; even then, however, the improvement is less than 15 cm (0.5 ft). In the park, as one might expect, the reduction in peak water level is much greater (Figure 14b). The flood terrace has more benefit than the bridge removal, and together they reduce the peak by over 50 cm. At the next cross section downstream of the park, finally (Figure 14c), the effect is more complex: removal of the bridge by itself has the effect of raising the peak slightly, while the flood terrace reduces the peak by about 10 cm.

These results at specific points on the creek are generalized in Figure 15. This figure shows reductions in 100-year peaks that are quite striking throughout the park (chainage 1750 – 2000), but the effect is soon reduced as one moves away from the park in the upstream direction. By chainage 1600, the effect is slight, and by chainage 1500 it is not measurable. In the downstream direction, the effect is more persistent; improvements on the order of 10 cm can be seen 1000 m downstream.

In summary, the results show that

- (1) removal of the bridge gives mixed results, with benefits in the park but higher peaks downstream, where the benefits would probably be most useful;
- (2) the addition of the flood terrace in the park offers general reductions in flood peaks, and over a greater distance, but they are still mostly in the park; and
- (3) carrying out both scenarios would be an attractive course, but most of the benefit is still in the park.

further scenarios: flood terraces above Jefferson, Alston Park detention

The initial scenarios just described demonstrated the potential value of flood terraces on Salvador Creek. A number of residents asked whether such flood terraces might be considered elsewhere on the creek, particularly upstream of Jefferson Street. Accordingly, hypothetical flood terraces above Jefferson were modeled in order to get a rough idea of the possible reduction in flood levels that would result from the creation of overflow flood terraces along the creek there. In order to make the best use of remaining contract resources, this modeling exercise was carried out using a simplified method in MIKE 11, as described below.

Using aerial photographs, we identified two reaches between Jefferson and the highway that had open land on the left bank. The first reach began at chainage 318, 318 m downstream of the highway, and extended for 271 m, and the second began at chainage 701 and extended to Jefferson (chainage 1090), for a distance of 389 m; the total length

of the two reaches was 660 m (2165 ft). Over the lengths of these two reaches, the creation of floodplain terraces was simulated by adding storage in the cross section editor. This method allowed a rough estimation of the effect of such floodplain terraces, but it did not model the hydraulics of flow onto and along the floodplains. The terraces thus modeled were taken to be 75 m (246 ft) wide and to extend completely along the reaches in question (for a total of 660 m). The Garfield Park modeling work done earlier had the same average width over a total length of about 200 m (656 ft), by comparison.

The results of this rough modeling exercise are illustrated in Figure 16. The figure shows the peak 100-year water level along the creek with and without the modeled flood terraces, with the base flow level shown for comparison. There is a reduction of approximately 15 cm (0.5 ft) throughout the reaches altered, and this benefit extends downstream for a considerable distance. In the upstream direction, the benefit does not extend as far as the highway. The reduction is greater than that obtained from a similar rough model of the Garfield Park area, and – perhaps more importantly – it occurs over a much longer stretch of creek, including potentially a number of areas that may lie within the 100-year floodplain. The 100-year floodplain has, however, not yet been delineated. The idea of flood terraces above Jefferson should be studied more thoroughly next year, when we hope to have an improved model showing the areas at risk of flooding during the 100-year flood.

To create a rough model of detention storage at Alston Park, we used a technique designed to “box in” the hypothetical detention and therefore its effects, by making assumptions that exceeded any possible actual detention and observing their effect on peak flows. Specifically, we assumed that the entire park was dedicated to creating as much flood detention storage as possible, and that when we modeled the 100-year rainstorm the entire runoff upstream of the park was completely captured. In effect, this amounted to reducing the effective drainage area of the creek upstream of the highway by 5.6%.

The rainfall/runoff module showed a reduction in peak 100-year discharge for the area upstream of the highway by about 6%, from 51.7 m³/s to 48.8 m³/s. However, when the complete result hydrograph was used as input for the hydraulic module, there was no discernible change in peak level or discharge. It is possible that there is a slight change in the area of highway 29, which is obscured by the computational “noise” present at the model boundary there; however, there is certainly no detectable effect away from the immediate boundary. Given that extreme assumptions were made about the extent of detention storage at Alston Park, the model results suggest strongly that detention at Alston Park would have no measurable effects downstream of the highway.

It is possible, of course, that detention at Alston Park would have a measurable effect on flooding at places closer to the park. If, as some residents have suggested, the culvert under highway 29 is an obstruction at high flow, then any improvements in detention upstream of there could possibly reduce the problem.

B. Napa Creek FCP Model (Task K)

Napa Creek is an important tributary to the Napa River which flows through the City of Napa and is known to flood periodically. Improvements to the creek are planned as part of the Napa River/Napa Creek Flood Reduction Project, which is currently under construction by the Corps of Engineers. Under previous contracts, the RCD established a discharge gage site on Napa Creek at Coffield Avenue, where the City had already installed stage measurement equipment as part of the ALERT system, and developed a MIKE 11 model of the Napa Creek watershed. Gage rating and model development up to the period of the current contract is described in *Hydrologic Monitoring and Modeling of Napa River Tributaries* (Napa County RCD, 2003). For the current work, we were asked to make use of the Napa Creek MIKE 11 model to study two issues: the appropriateness of the 100-year peak discharge of 4400 ft³/s being used in the Napa River/Napa Creek Flood Control Project, and the effectiveness of the Flood Control Project design under various scenarios of interest, such as the 100-yr flood and the flood of December 2002. For both issues, the initial task is to update the MIKE 11 rainfall/runoff module developed under an earlier contract, using all available data.

model setup

As in previous years, the MIKE 11 model used for Napa Creek consisted of two modules, a rainfall/runoff module developed for the Napa Creek watershed and a hydrodynamic module set up to include Napa Creek and the Napa River. The rainfall/runoff module included two subwatersheds. The first, entitled *headwaters*, includes the entire watershed upstream of Coffield Avenue, an area of 41.24 km². The second, entitled *city*, includes the remainder of the Napa Creek watershed, an area of 5.39 km² entirely within the Napa City limits. The hydrodynamic module setup includes two branches, Napa Creek from the gage site at Coffield Avenue to the Napa River and the Napa River from Oak Knoll Avenue down to the Brazos Bridge. Figure 17 shows both modeled domains.

hydrologic data

The Napa Creek MIKE 11 model was run for the entire period of October 2001 through February 2004.

The four ALERT rainfall stations which were used in our earlier work (sites 2251, 2253, 2271, and 2281) were used again. However, since the records are incomplete and the MIKE 11 rainfall/runoff module is designed for continuous modeling over extended periods, it was necessary to fill in the gaps. The Oakville CIMIS station was used for this purpose, with the values scaled down in proportion to mean annual rainfall. During the heavy storm period from December through February of each winter, the ALERT data were generally complete and had realistic totals, so that the CIMIS data were important primarily to model the gradual replenishment of watershed storage in the fall.

It should be noted that two of the four ALERT gages used, Mt. Veeder and Redwood Road at Mt. Veeder Road, are within the Headwaters subwatershed, while the other two

gages are outside the Napa Creek watershed entirely. The weighting of the ALERT rain gages used is shown in the following table:

Sub-watershed (area)	Redwood Rd. (2253)	Mt. Veeder (2251)	City Corp. Yard (2271)	Dry Creek Fire (2281)
Headwaters (41.24 km ²)	0%	90%	0%	10%
City (5.39 km ²)	15%	5%	80%	0%

In addition to these rainfall data, we made use of CIMIS evaporation data and of flow records for Napa Creek at Coffield Avenue (ALERT site no. 2323) and the Napa River at Oak Knoll (USGS site no. 11458000). The Coffield Avenue record was produced by the RCD on the basis of an updated rating curve prepared this year. Finally, a predicted tidal record was used at the Napa River downstream boundary at the Brazos Bridge.

calibration results

Since our gage site is at the upstream end of the domain of our hydrodynamic module and lies at the outlet of the major subwatershed defined in the rainfall/runoff module, it was possible to calibrate the rainfall/runoff module without running the hydrodynamic module.

To re-calibrate the model of June 2003, the rainfall/runoff module was run again using rainfall and evaporation data for the entire period from October 2001 through February 2004, and the result hydrograph for the headwaters subwatershed was compared with the flow record for Coffield Avenue (site 2323) during the same period. This procedure permitted a considerably more challenging calibration of the rainfall/runoff module, since most of three water years, including both wet and dry seasons and a variety of different storms, were included in the period modeled.

Unfortunately, the calibration flow record excludes periods of low flow, because the ALERT level sensor is installed too high on the creekbank to measure them. As of the most recent re-installation of the sensor, no flows can be measured below 182 ft³/s (5.15 m³/s). If we exclude the periods when the level in the creek was below the sensor, however, it is possible to compare volumes of runoff, timing and peaks, all of which can be adjusted by varying model parameters.

Because the model included both wet and dry seasons, it was possible to adjust model parameters to make sure that early-season storms were captured by the model. Once this was accomplished, the remaining task was to match overall volume and the timing and magnitude of peaks. Since flooding is the principal concern of the City, we reasoned that it was more important to capture flood peaks than to get the volume right; accordingly, the volume calibration was used only as a general guide, our main intent being to match the peaks as well as possible. This was accomplished by first adjusting the parameters to get the volume and timing close and then moving to a procedure which minimized the differences between modeled and measured peak magnitudes. To do this, we calculated the root mean square deviation of the modeled peak magnitudes from the measured peak

magnitudes, for the 11 largest storms of the modeled period. The final calibration process was essentially to minimize this quantity.

The results of this process are illustrated in Figure 18, which shows a 4-day period in December 2002, including the very large peak of December 16. As it happens, the two largest storms in the period shown are underpredicted by the model; in particular, the model dramatically underpredicts the peak of December 16. The two smaller peaks are overpredicted, and throughout the three-year simulation a number of peaks are either over- or underpredicted.

The earlier rainfall/runoff modeling work reported in June 2003 used only a brief period in December 2002, and it was possible to achieve a better fit between measured and modeled flow. The present work, by testing the model over a multi-year period with a variety of storms, is a much more realistic test of the model. It would, of course, be possible to tweak the multi-year model to match the peak of December 16, but this would produce a very large volume error in the overall simulation and it would overpredict other peaks by large margins.

Because the model so severely underpredicted the major flood peak of December 16, 2002, we looked at the rainfall input to the model for the period preceding several large storms, including that of December 16, and we found the modeled peaks consistent with the rainfall inputs. There was also no indication that any of the gages were out of order during this storm. The rainfall is simply not there to predict the peak of December 16. The problem evidently is that our rainfall records are not representative of what actually fell during the different storms. The December 16 storm is a particularly striking example of a storm in which a large amount of rainfall fell somewhere in the watershed, just not at our gages.

This model calibration provides a dramatic illustration of the spatial variability of rainfall, and it points to the necessity of increasing the network of rain gages.

The use of this model calibration to model the 100-year flow on Napa Creek is described below under the heading *100-year flow*. Because of concerns about this calibration, and in order to try to give the best answer possible to the question of the 100-year flow on Napa Creek, we also used the Corps of Engineers HEC-HMS model to provide another estimate: an HEC-HMS model of Napa Creek was developed using the ungaged-stream methods used for our Tulucay Creek model done earlier this year. This work is described below in the section entitled *HEC-HMS model*.

hydrodynamic module calibration

With the MIKE 11 rainfall/runoff module calibrated, it remains to revisit the calibration of the hydrodynamic module. The hydrodynamic results differed slightly from those described in our work from 2003, for two reasons: (1) the new calibration of the rainfall/runoff module, which provides inflows to the hydrodynamic model from the City

subwatershed, and (2) RCD's recent update of the rating curve for the Coffield Avenue gage site, retroactively, for the modeled period.

We used the Manning's n values of 0.04 for Napa Creek and 0.036 for the Napa River, values which were proposed in our report of June 2003 and which are consistent with previous local modeling work. As in our report of June 2003, the modeled water level at the height of the December 16 storm was compared with the measured levels reported in the *After-incident Action Report: Flood of December 16, 2002* (City of Napa, 2003).

In our report of June 2003, the conversion of measured peak water levels to NGVD 29 was incorrect. The corrected measured water level at Behrens Street is shown in the following table, along with the modeled peak level from the current work. The modeled peak level is 0.13 m (5.1 in.) lower than the measured peak, which is acceptable given the various uncertainties associated with the model. The version of the model used for calibration includes neither floodplains nor bridges; the bridges were left out intentionally, in order to provide the best simulated values to compare with measured data. The lack of floodplains, a necessary feature of the model in its current state of development, tends to increase modeled water surfaces unrealistically, and putting in the bridges, with their constrictive effects, would make the simulated water surface levels even more unrealistic.

Stream	Chainage & Location	Measured peak water level, m	Modeled peak water level, m	Difference, m
Napa Creek	2601 Behrens St	8.00 ¹	7.87	0.13

HEC-HMS model

The RCD performed a runoff analysis of the Napa Creek watershed in Napa County, California, using HEC-HMS, a computer program developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC) for rainfall-runoff modeling projects. The purpose of the analysis was to estimate the 100-year peak flow of Napa Creek at the Coffield Avenue (2323) gage site.

basin model

Using the Napa County geographic information system (GIS), and GeoHMS, a GIS program provided by HEC for use with HMS, the RCD defined the drainage boundary of the Napa Creek watershed starting at 2323. This area was divided, by major tributary, into four subbasins. GeoHMS computed the area, the centroid, and the longest flow path of each subbasin, as listed in the following table.

Subbasin	Area (mi ²)	Centroid Location	Longest Flow Path
----------	-------------------------	-------------------	-------------------

¹ 29.0 ft NAD88 = 26.26 ft NGVD = 8.00 m NGVD

		Latitude	Longitude	(ft)
Redwood	5.874	38.3471	-122.4191	40,359
Pickle Canyon	2.809	38.3603	-122.3896	28,219
Browns Valley	4.155	38.3113	-122.3520	27,653
Napa	2.628	38.3158	-122.3429	32,781

These four subbasins, with six routing reaches and seven junctions, were used to define the basin model. The seven junctions are the outlet (2323 streamgage), the confluence of Redwood and Pickle Canyon Creeks, the confluence of Redwood and Browns Valley Creeks, and breaks in slope used to divide the routing reaches. The six routing reaches connect the seven junctions and define the main stem of Napa Creek.

loss model

The RCD selected use of the Soil Conservation Service (SCS) models provided in HMS. The SCS curve number (CN) method was selected as the loss model (runoff volume model). The sole HMS input parameter for this model is the CN for each subbasin. To compute the CNs, the RCD used the land use and soil type layers in the GIS. Soil types included hydrologic soil groups B, C, and D. Land uses included forest, shrubland, grassland, agriculture, urban, and open water. The area of each soil type within each land use category was computed using the GIS, and the RCD assigned a CN to each area using the SCS reference tables. The weighted CNs calculated for each subbasin are listed in the following table.

Subbasin	Weighted SCS CN
Redwood	70
Pickle Canyon	73
Browns Valley	77
Napa	80

transform model

The RCD selected the SCS unit hydrograph (UH) as the transform model. The sole input parameter for this model is the SCS lag time (t_{lag}), which is calculated as 0.6 times the time of concentration (t_c). The t_c of each subbasin is the sum of the time spent as sheet flow, shallow concentrated flow, and channelized flow, along the longest flow path. Each of these times is estimated using equations provided by the SCS, which compute the times using length, slope, and estimates of hydraulic radius (R) and roughness (n). The RCD used the GIS to generate topographic profiles of the longest flow paths of the subbasins, divided the profiles by slope into sections, and computed t_c and t_{lag} using estimates of R and n . The computed t_c and t_{lag} values are listed in the following table.

Subbasin	t_c (min)	t_{lag} (min)
Redwood	88.85	53.31
Pickle Canyon	106.95	64.17

Browns Valley	88.06	52.84
Napa	83.33	50.00

channel routing model

The RCD selected the Muskingum-Cunge model for channel routing. This model uses the length, slope, bottom width, side slope, and roughness of the reach to compute outflow hydrographs given an inflow hydrograph. The RCD measured the lengths and slopes, and estimated the bottom widths and side slopes, using the GIS, and selected estimates of roughness for each reach.

baseflow

The RCD added a constant baseflow ranging from 5 to 11 cubic feet per second (ft³/s) to each subbasin.

assumptions

This analysis assumes the following:

- The initial loss is equal to 0.2 times the potential maximum retention of the soil.
- The basin lag is equal to 0.6 times the time of concentration.
- The Manning roughness of the tributaries is 0.04
- The Manning roughness of the Napa mainstem is 0.035
- The hydraulic radius of the tributaries ranges from 1 near the top to 3 near the confluence with the mainstem.
- The hydraulic radius of the mainstem is 3.
- Sheet flow occurs in the upper 100 feet of each subbasin before becoming shallow concentrated flow.
- The overland flow roughness coefficient for sheet flow calculations is 0.24 (for dense grass).
- The 2-year 24-hour rainfall for sheet flow calculations was obtained from NOAA Atlas 2 for the centroid of each subbasin (computed along the flow path).
- The reaches of the mainstem have a prism shape (trapezoidal).
- The rainfall at the centroid of the subbasin (computed along the flow path) is representative of rainfall across the subbasin.
- The average of the 100-year rainfall depths for each subbasin is equal to the 100-year rainfall depth for the entire watershed.
- Baseflow is constant.

sensitivity analyses

The RCD performed sensitivity analyses of the model by varying the CNs and the t_{lag} parameters. The results are presented in the following table.

Parameter	Best Estimates	Increase/decrease	Change in Flow at Outlet
CN	70 to 80	+1 / -1	+2.7% / -2.8%
N	0.24	+0.1 / -0.1	-0.7% / +2.1%
n	0.035 to 0.04	+25% / -25%	-3.2% / +4.5%
R	1 to 3 ft	+25% / -25%	+3.5% / -3.4%

100-year flow

The calibrated MIKE 11 module was used to derive an estimate of the 100-year flow on Napa Creek. The module as calibrated above was run using the SCS IA 100-year 24-hour storm, using the 100-year rainfall depth from the NOAA Atlas. This is the same procedure used to arrive at the 100-year flow on Salvador Creek which was described earlier.

The HEC-HMS model described above was used to obtain a second estimate of the 100-year discharge for Napa Creek. As the meteorological model for the analysis, the RCD selected the SCS hypothetical storm, with SCS Type IA rainfall distribution, and obtained 100-year 24-hour rainfall depths for each subbasin from NOAA Atlas 2. The average depth for the entire watershed was calculated to be 9.01 inches; however, for purposes of comparison, a rainfall depth of 8.88 inches, the same value used in the MIKE 11 model, was used. A computation interval of 15 minutes was selected based on the SCS recommendation that the computation interval should be less than or equal to 0.29 times t_{lag} of the smallest subbasin. The RCD ran the model three times to bracket the best estimate result using the highest and lowest reasonable CNs and t_{lag} parameters. The results of the RCD's HEC-HMS watershed runoff analysis of the Napa Creek watershed are presented in the following table.

Location	Peak Flow (ft ³ /s)			Time of Peak (hrs)	Total Volume (ac-ft)
	Low	High	Best Estimate		
Redwood/Pickle Canyon Confluence	3,599	4,929	4,081	9.00	2,527
Redwood/Browns Valley Confluence	5,321	7,052	5,965	9.15	3,901
2323 Streamgauge	6,491	8,395	7,363	9.15	4,821

In the table below, the 100-year peak discharge at Coffield Avenue is compared with values from other recent RCD modeling activities on local creeks.

Creek	Site	Drainage area, mi ² (km ²)	Model	24-hr Storm	100-yr rain, in.	100-yr Q, ft ³ /s (m ³ /s)
Salvador	Big Ranch Rd (SAL)	4.77 (12.35)	MIKE 11	SCS IA	7.50	2825 (80)

Napa	Coffield Ave (323)	15.92 (41.24)	MIKE 11	SCS IA	8.88	5907 (167)
			HEC-HMS	SCS IA	8.88	7363 (209)
Tulucay	Soscol Ave (no gage)	12.28 (31.81)	HEC-HMS	SCS IA	6.80	4875 (138)
				COE balanced storm	6.14 but higher intensity	5825 (165)

evaluation of Flood Project design for Napa Creek

We hoped to use the model to evaluate the flood project design for Napa Creek, but unfortunately delays with other project tasks prevented RCD from fully carrying out this task. We did succeed in running the model with an initial version of two model setups, an *existing conditions* model and a *flood project improvements* model, but we were not able to fine-tune and analyze the results, so no results are offered here. The following is a description of what has been done so far.

The Flood Project Preferred Alternative includes several major flood management features on Napa Creek which are intended to improve flood conveyance. Bridges at Brown Street, Coombs Street and Behrens Street are to be removed, and three structural improvements are planned: a double box culvert from Main to Pearl, adding capacity to the creek; an overbank flood terrace just upstream of the Main-to-Pearl culvert; and an additional double box culvert bypassing the Behrens Street Bridge.

In order to study these improvements, an existing conditions hydrodynamic module was created by putting in the bridges to be removed. For reasons discussed above in the section on hydrodynamic calibration, no bridges were included in the calibrated model, so it was necessary to add them. The initial version of the existing conditions model included two of the bridges in question, the bridges on Behrens Street and Coombs Street. The model was run using both the 2-year and 100-year 24-hour SCS I-A storms.

To model the conveyance improvements, a new network file was created which omitted the bridges but included both double box culverts described above. The flood terrace was not included in the initial model network but will be added later. For the improvement scenario, the model was run again using the 2-year and 100-year storms.

recommendations for further modeling work

Salvador Creek

- (1) further calibrate the model with rain and flow data from 2004-05
- (2) use the county’s new LIDAR dataset to extend model cross sections onto the floodplain throughout the modeled creek, so as to be able to map areas of inundation under the 100-year flood

- (3) update the hydrodynamic model with long cross sections showing the floodplain, to determine where the creek floods, and develop scenarios to reduce flooding
- (4) develop an HEC-HMS model for Salvador Creek, to shed further light on the 100-year flood and to study the effect of actual and potential development on peak discharges

Napa Creek

- (1) install more rain gages in the watershed like those recently installed in the Salvador watershed
- (2) further study 100-yr flow by using the HEC-HMS model for gaged stream
- (3) update model with latest flow and rain data and complete analysis of flood project design for Napa Creek, considering all bridges, all structures, and the 12/16/02 flood as well as the two-year and 100-year design floods

VIII. Salvador Stewardship (Task H)

The Salvador Creek Stewardship Group continues to play a critical role in the process to develop strategies for addressing flooding, erosion, and other concerns in the Salvador Creek Watershed. The entire group met seven times between July 1, 2004 and June 30, 2005. There were also several subcommittee and working group meetings that were not recorded. The meetings of the entire group took place on October 20, 2004; December 8, 2004; January 11, 2005; February 1, 2005; February 23, 2005; March 16, 2005; and June 9, 2005. Five of the meetings were held at Vintage High School, and the others took place at the Napa RCD office and the Napa City library. The announcement, agenda, and sign in sheet for the meeting on June 9, 2005 can be found in **Attachment A**. The minutes of this meeting will be available soon. For a copy contact Michael Champion.

The meetings have served the important function of providing an opportunity for Salvador Creek Watershed residents to engage in an ongoing dialogue with representatives from the City of Napa, the Napa County Flood Control District, the Napa County RCD, and other stakeholders. The meetings have provided a forum for both residents and agency representatives to ask questions, voice concerns, and share ideas. Meeting discussions have led to the identification of priority issues, a list of ideas for possible approaches for addressing those issues (including ideas that have helped direct the RCD's development of the hydrologic model), and suggestions for ways in which the residents and agencies can best work together to resolve the issues.

Perhaps most importantly, the meetings have resulted in an increased understanding both among agency representatives about the concerns of the residents and among the residents about the challenges the agencies face in addressing their concerns. An example of this is the question and answer forum at the January 11 meeting (see minutes in Quarterly report #3, Attachment B). The group organized a panel of agency stakeholders which included a Napa City Councilmember, City Planning Commissioner, a representative from the Napa County Flood Control District, an RCD hydrologist, and a Napa City engineer. The forum allowed the group to ask questions about a variety of concerns on topics such as development, flooding, and creek maintenance. The panelists

helped clarify some of the issues and helped improve the residents' understanding of the agencies' perspectives. The panelists also expressed their commitment to working with the residents to move forward with the development of both short-term and long-term solutions. Another example is the most recent meeting on June 9th. A representative from the Department of Fish and Game was invited to the meeting and residents were given an opportunity to ask him questions and find out how the group can work cooperatively with the agency.

The group also engaged in efforts outside of the regular meetings that have helped improve understanding among stakeholders. Creekside residents who had been regularly attending the meetings were interested in the concerns of their creekside neighbors who had not been attending meetings, so they developed an eleven-question survey that they took door to door (see **Attachment B**). The survey was the foundation for the development and delivery of a presentation to the Napa City Council, the Flood Control District Board, and the Napa City Planning Commission. The content of the presentation went through three drafts and was edited and agreed upon by all the active members of the stewardship group. The presentations helped raise awareness among the agencies and public officials about the concerns and perspectives of property owners that live directly adjacent to Salvador Creek. The presentations were well received and resulted in some favorable press in the Napa Register.

In addition to providing a forum for ongoing dialogue among stakeholders, the group has also played an important role in increasing awareness of Salvador Creek in the larger Salvador Creek Watershed community. On Saturday, May 7 the group held "Watershed Awareness Day at Salvador Creek," a community event that invited local residents to engage in several creek related activities including a creek cleanup, birdwatching, collecting and analyzing benthic macroinvertebrates, and a presentation about Chinook salmon that have been spawning in Salvador Creek. The flyer for this event can be found in **Attachment C**. This event was the result of a grant that was awarded by NOAA through a partnership with Acorn Soupe and the Flood Control District. This grant will use volunteers and students to restore a section of Salvador Creek near Summerbrook Circle by removing non native plants, and replacing them with native riparian plants. This work is scheduled to begin in the summer of 2005. The group also created the "*Living in the Salvador Creek Watershed*" brochure which is being used as an outreach tool for encouraging more involvement with the stewardship group and educating residents about the watershed and about what they can do to help protect the watershed. This flyer can be found in **Attachment D**.

The original goal for the RCD as outlined in the scope of work was to continue to organize the Salvador Creek Stewardship Group in order to focus and guide the restoration process for Salvador Creek. The aim was to facilitate group discussions about channel improvement scenarios that could then be given to the RCD to model. This goal has been achieved. The group has discussed various channel improvement and restoration options that the RCD has been able to model and will continue to model.

What has also come out of the group discussions in the last year is that, in addition to the flooding concerns and the long-term restoration solutions that the hydrologic model is helping to address, there are other more immediate needs and improvements that the group felt needed to be examined: These included:

- 1) improving creek maintenance activities to address particularly some of the more critical stream bank erosion areas along the creek. The Napa County Flood Control District has stepped up efforts to respond to these concerns. With guidance from the group they have been able to identify high priority areas and they are currently working to repair these areas using various vegetation management and bank stabilization techniques.
- 2) investigating the proper functioning of the stormwater detention systems from several of the new developments in the watershed. The City of Napa is currently responding to these concerns by conducting inspections of existing detention systems to ensure they are being maintained properly and reviewing the existing detention standards to see if they need to be modified.
- 3) increasing education among property owners who live in the watershed and along Salvador Creek. The group recognized that there is a serious need for more education, particularly for creekside residents. Creekside residents need to be aware of the activities occurring along the creek and also need to be made aware of how they can assist in the effort. A suggestion was made to develop a creek care guide for property owner's living along or near Salvador Creek. The guide would include recommendations for assisting with creek bank maintenance, as well as other actions that can be taken in and around the home to help improve the health of the creek. The RCD proposes that, in addition to continuing to facilitate the Stewardship Group meetings and develop the hydrologic model, they also take the lead in an expanded education effort that could include the following:
 - Developing and distributing a creek care guide specific for the Salvador Creek watershed, which could also be adapted to use in other urban creek watersheds;
 - Organizing a community volunteer day replanting streambanks along a portion of Salvador Creek;
 - Organizing two creek cleanup events;
 - Creating content for kiosks with information about the Salvador Creek watershed that would be installed along the bike path or elsewhere;
 - Providing quarterly creek updates through the mail to all the residents along Salvador Creek;
 - Engaging students at Vintage High about Salvador Creek through a series of classroom presentations and activities designed to raise awareness and reduce litter and trash;

- Developing educational materials such as “frequently asked questions” handouts and fact sheets on topics such as streambank erosion and stream dynamics.

At this point it seems relevant to review the group’s Mission Statement that was agreed upon on March 10, 2003. It states: **The Mission of the Salvador Creek Stewardship Group is to identify, protect, and enhance the natural resources in the watershed while recognizing the need for flood and property protection and educational and recreational opportunities.** This statement has been referred to often during meetings and is the guiding principle that the group has been working for. Significant and tangible steps have been taken towards identifying problems, protecting property from flooding and erosion, and creating educational opportunities for the community. More work needs to be done, but much has been accomplished.

Figure 1. Stage vs. Time, Salvador Creek at Big Ranch Road, Water Year 2003-04

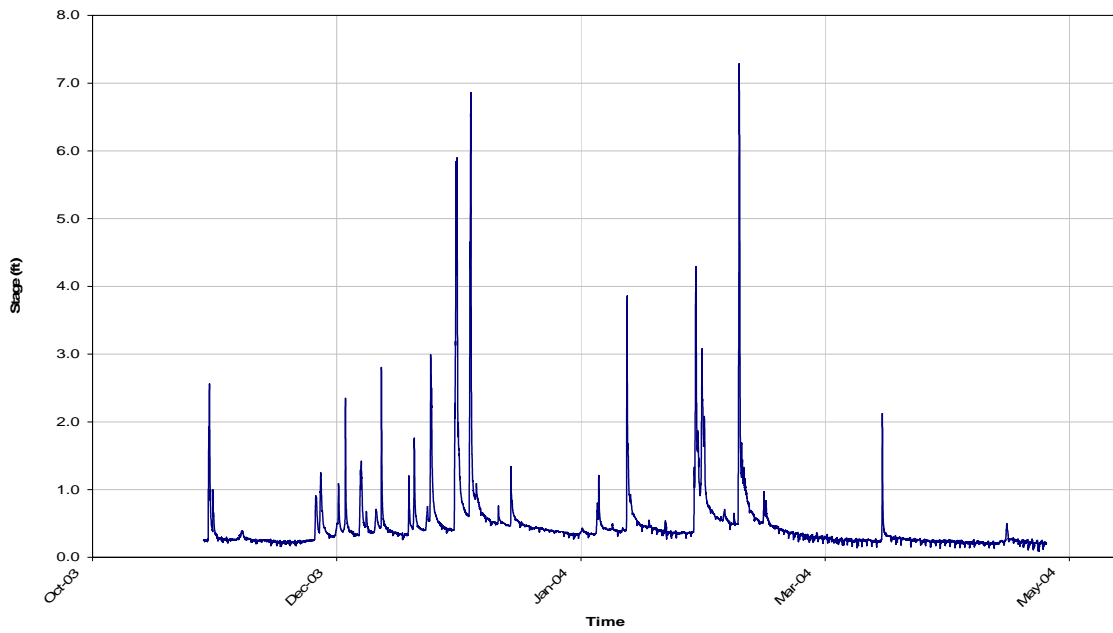


Figure 2. Streamflow vs. Time, Salvador Creek at Big Ranch Road, Water Year 2003-04

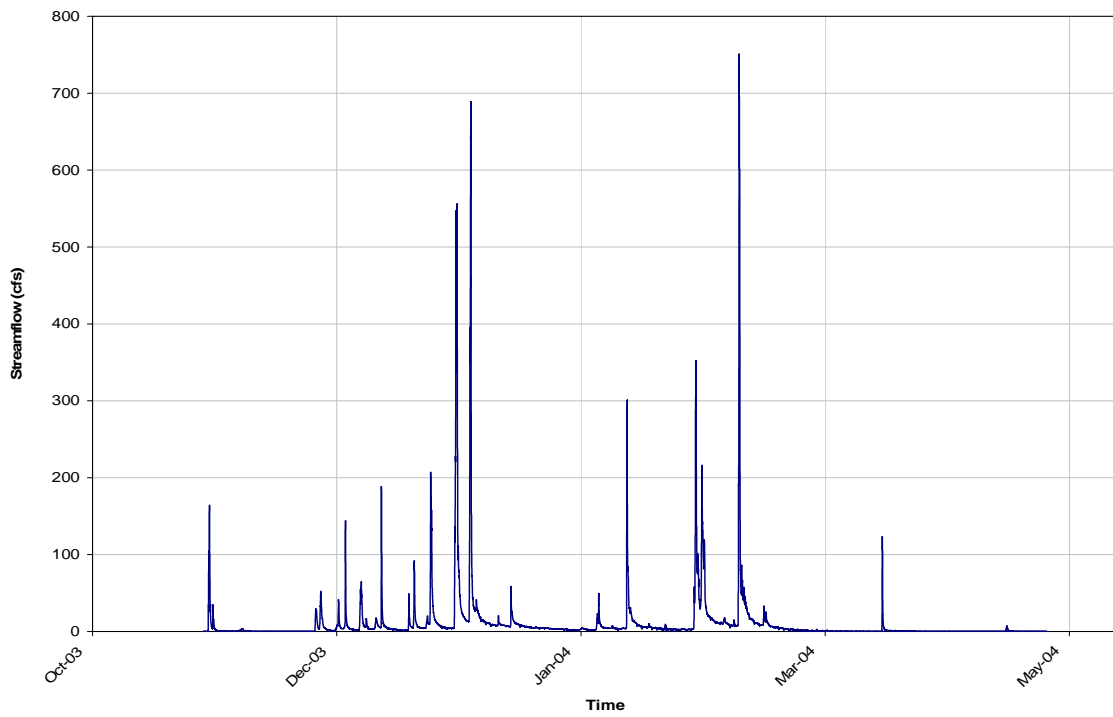


Figure 3. Stage-Discharge (h-Q) Rating, Napa Creek at Coffield Avenue, Water Year 2004-05

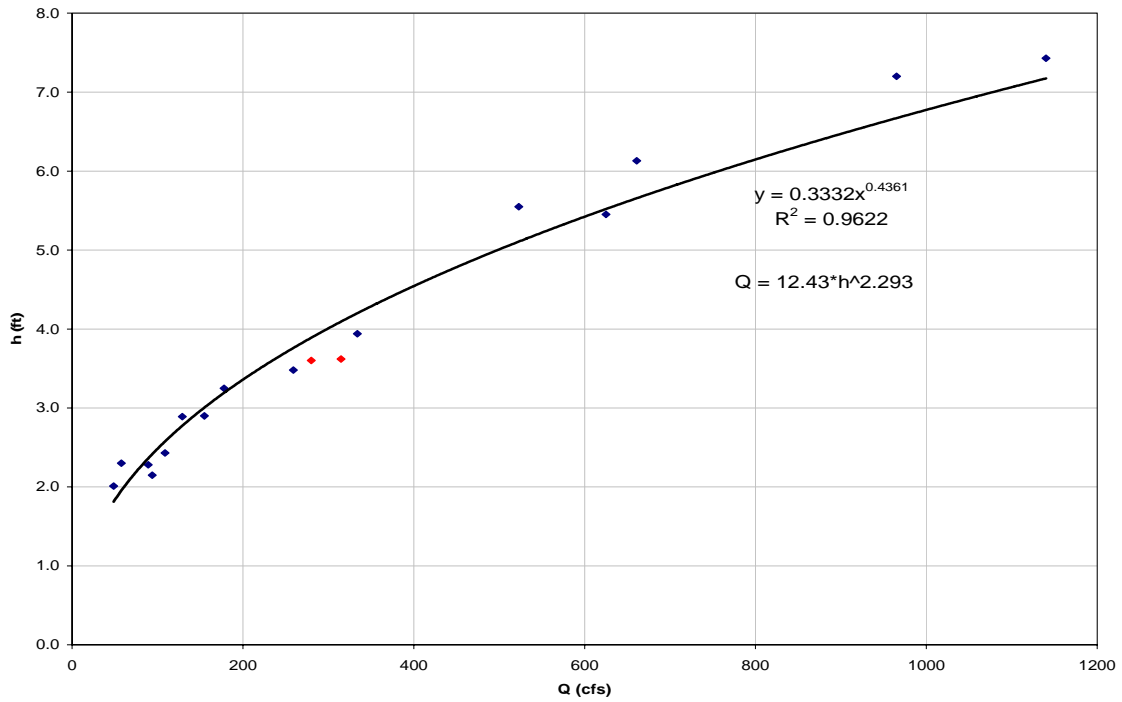


Figure 4. Channel Cross-Section, Napa Creek at Coffield Avenue, Looking Downstream, March 16, 2005

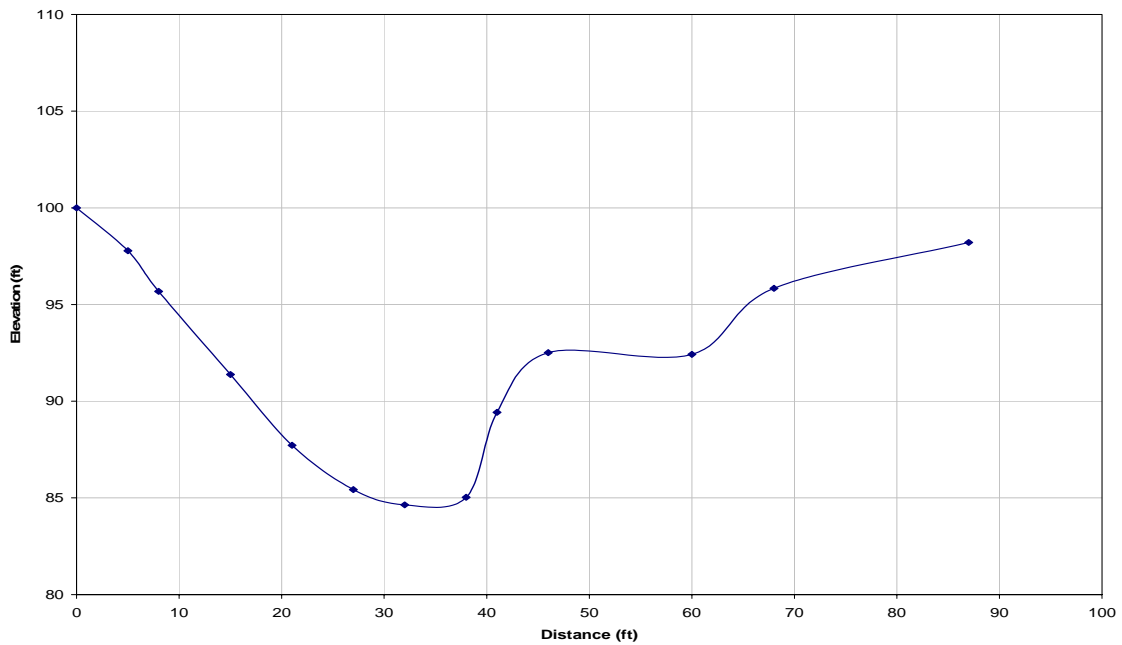


Figure 5. Flow Depth-Discharge (d-Q) Rating, Milliken Creek at Atlas Peak Road, Water Year 2004-05

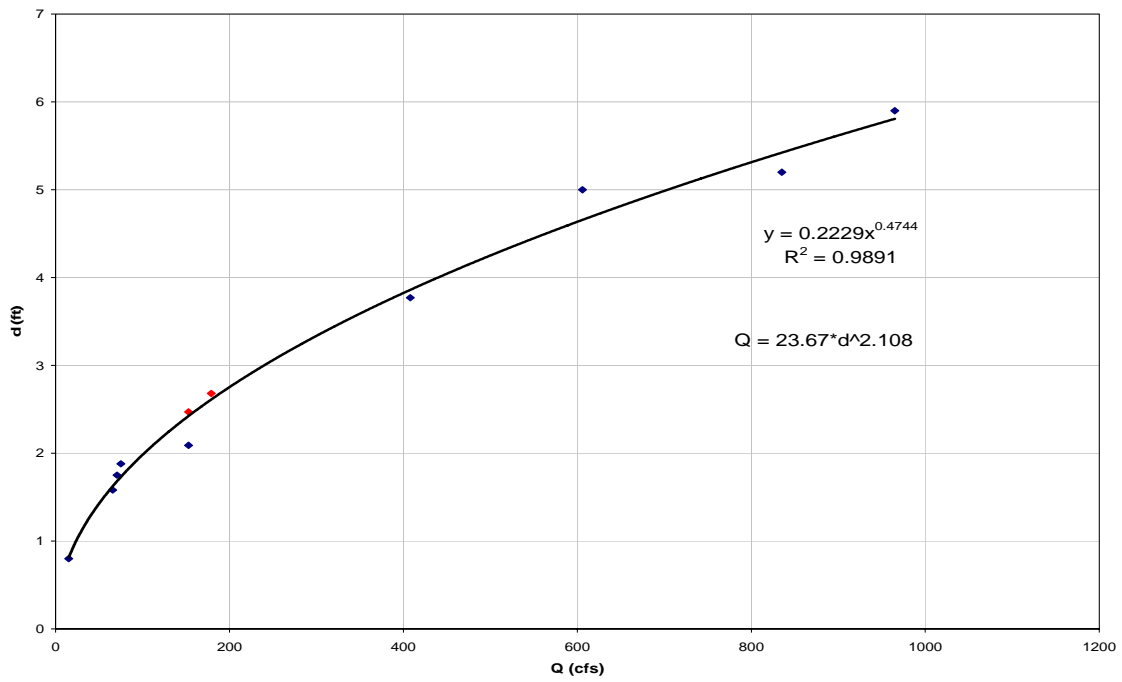


Figure 6. Channel Cross-Section, Milliken Creek at Atlas Peak Road, Looking Downstream, March 15, 2005

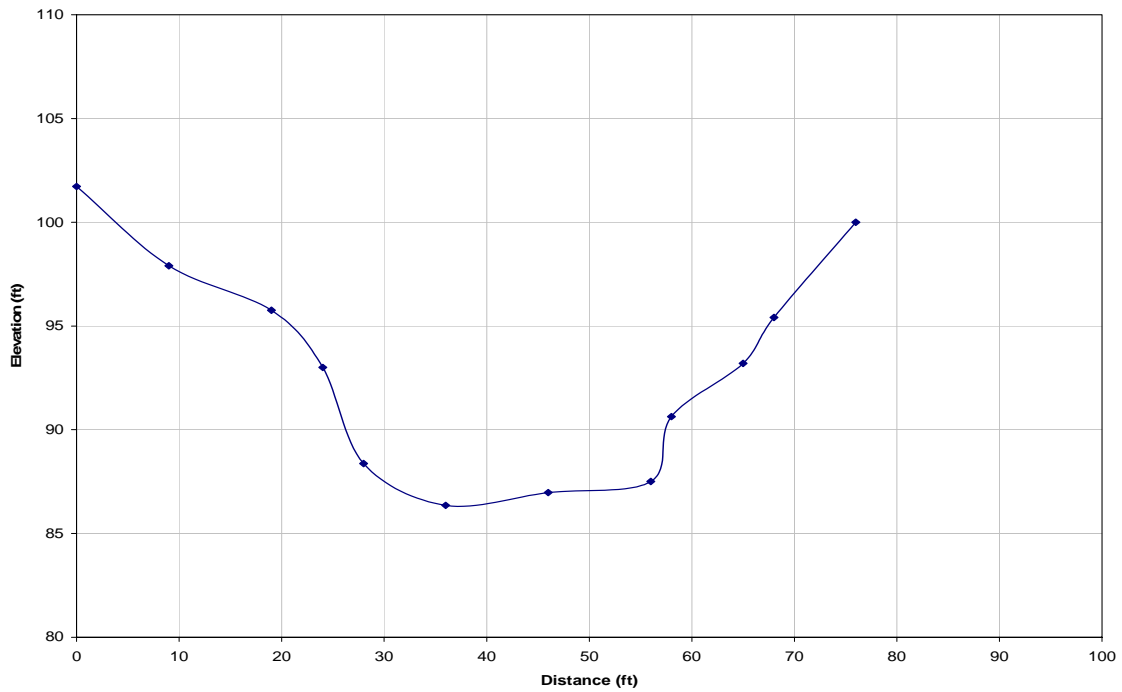


Figure 7. Flow Depth-Discharge (d-Q) Rating, Salvador Creek at Big Ranch Road, Water Year 2004-05

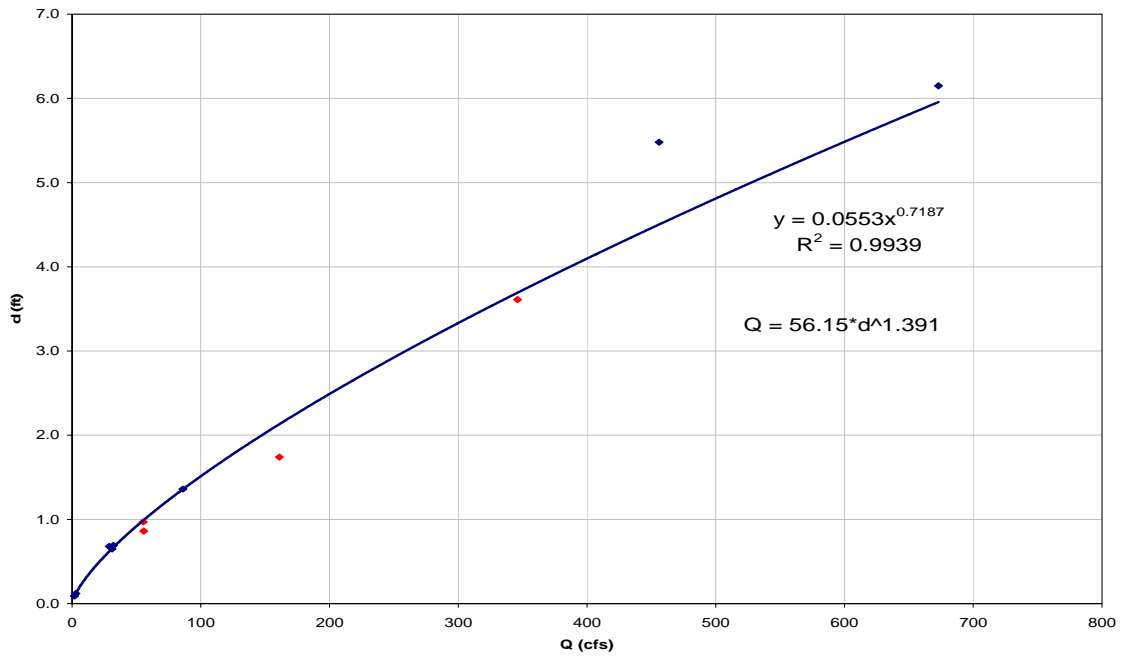


Figure 8. Channel Cross-Section, Salvador Creek at Big Ranch Road, Looking Downstream, March 15, 2005

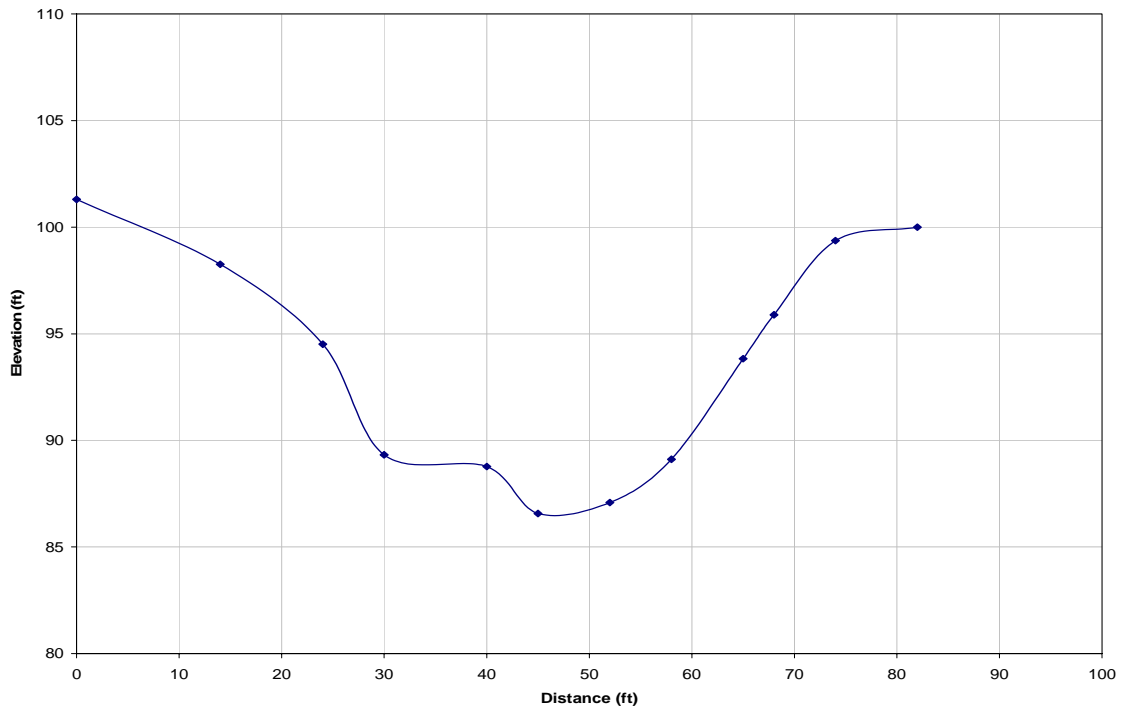


Figure 9. SSC Concentrations vs. Discharge, Sites 302, 323, SAL

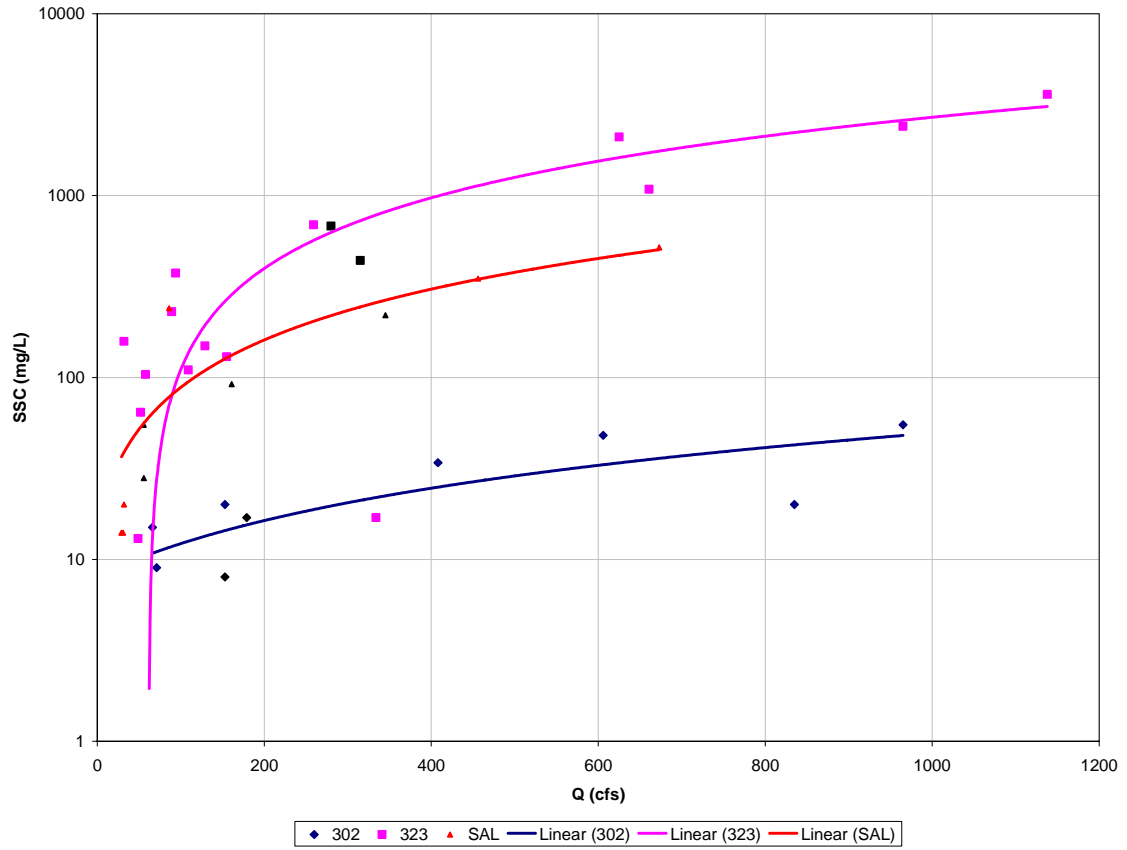


Figure 10. Salvador Creek Model Domain



Figure 11. Storms of 12/29, 1/1 at Big Ranch Rd: Modeled vs. Measured Discharge in ft³/s

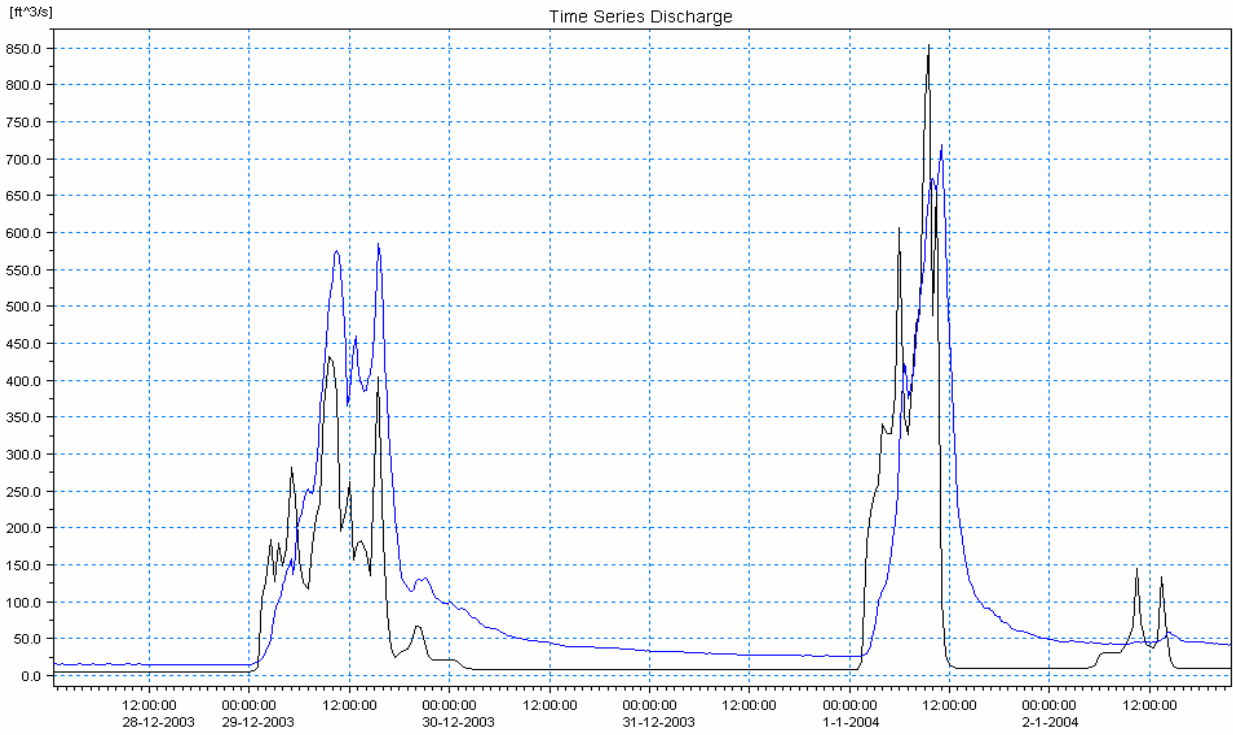


Figure 12. Modeled Floodplain Restoration in Garfield Park: Modeled Area of Alteration, outlined in **Yellow**

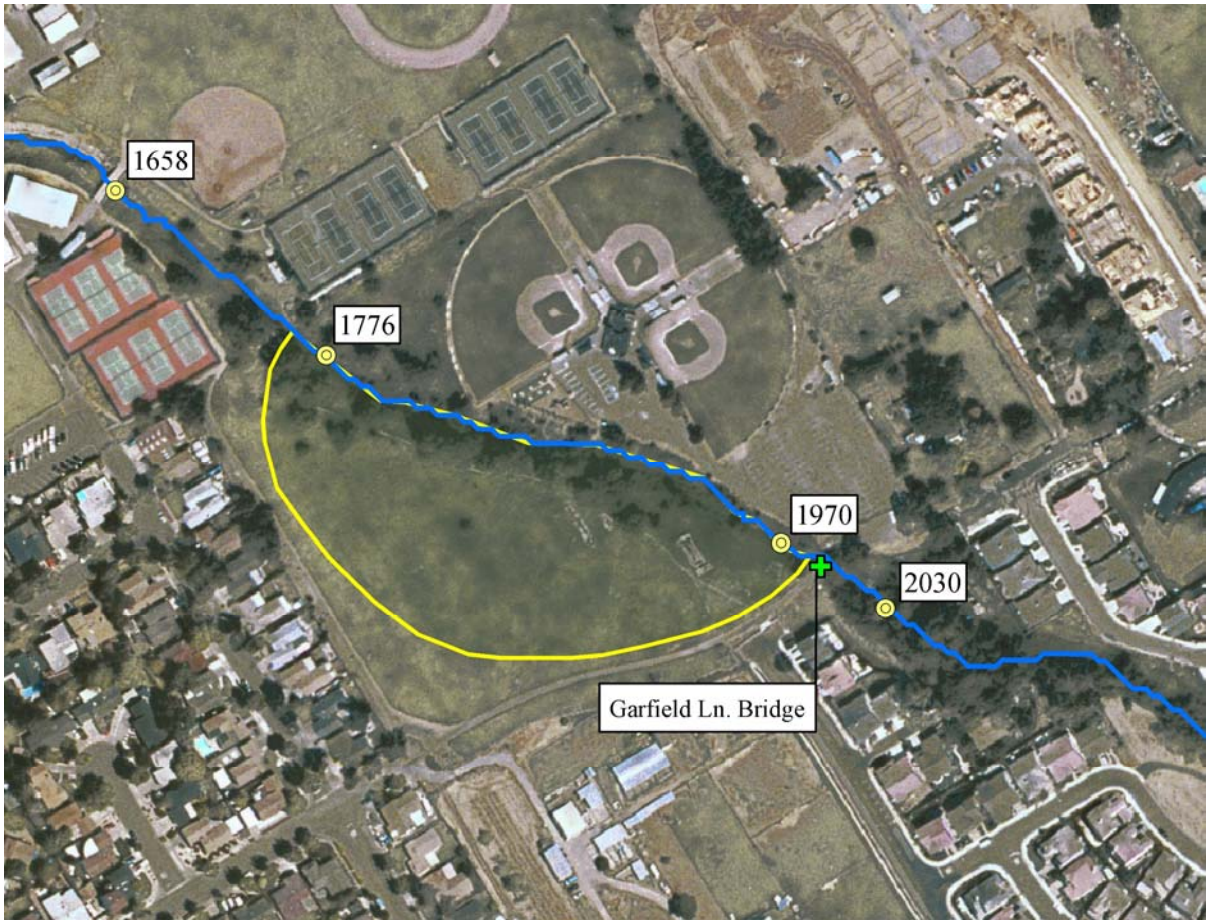


Figure 13. Modeled Floodplain Restoration in Garfield Park: Existing and Altered Cross Sections Compared

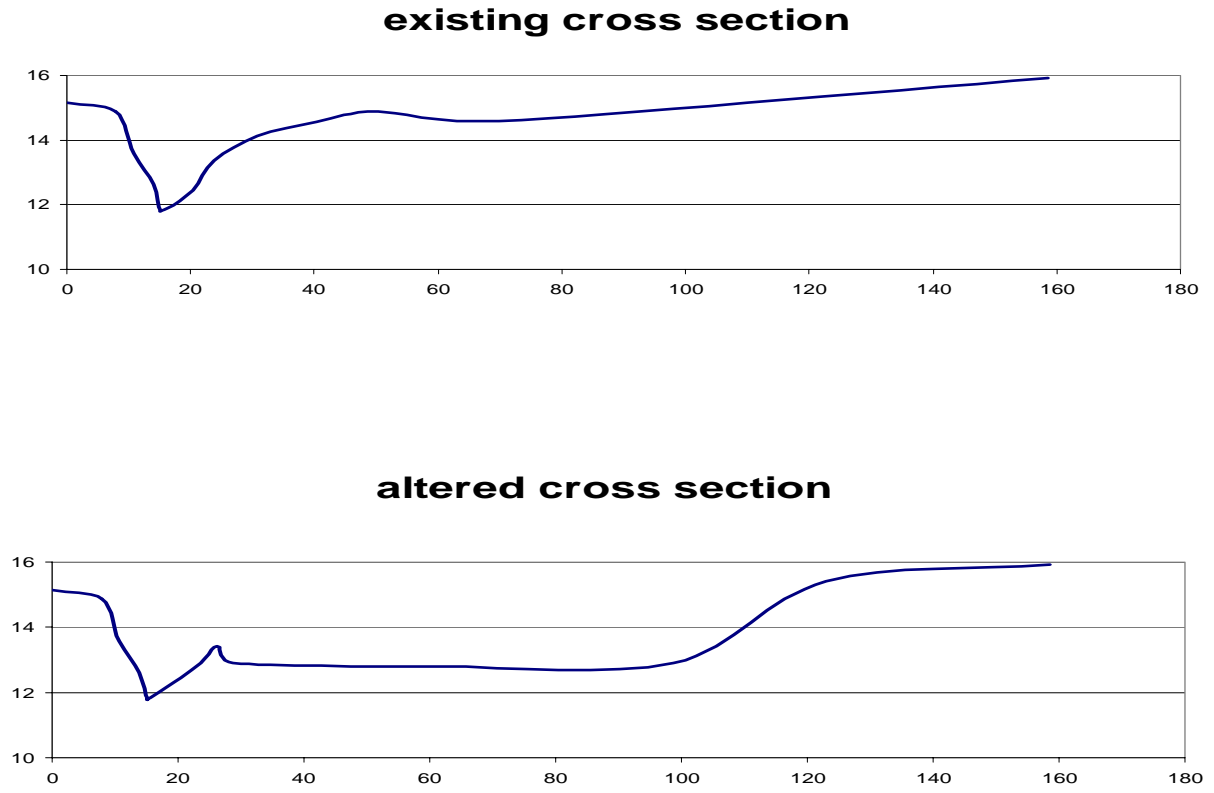
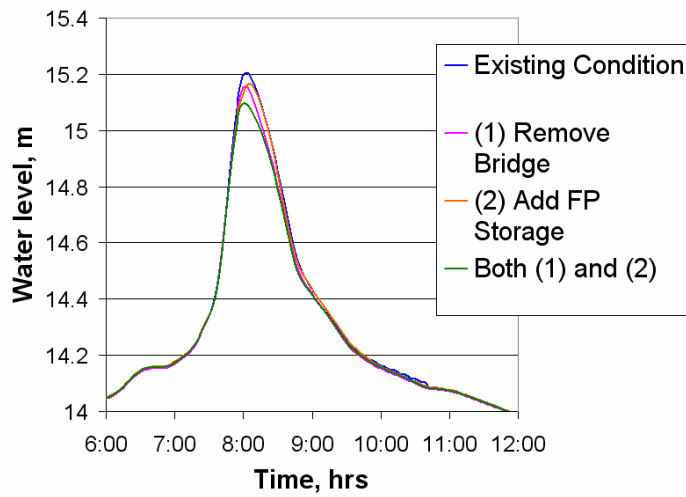
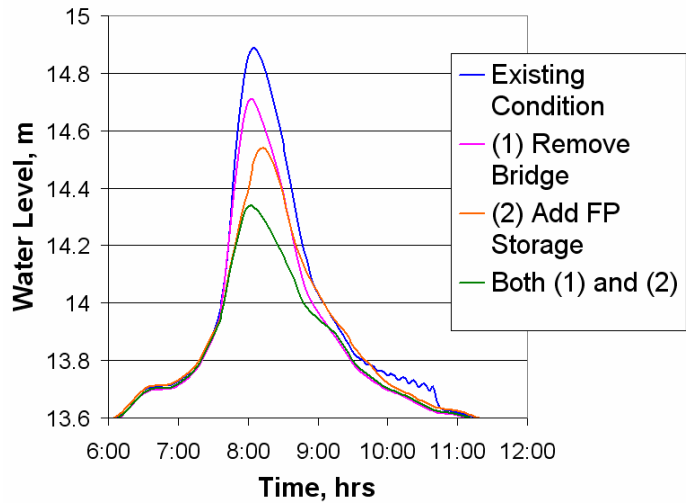


Figure 14. 100-year Storm with Modeled Scenarios, at three Locations

14a. Upstream of Park (chainage 1658)



14b. In Park (chainage 1776)



14c. Downstream of Park (chainage 2030)

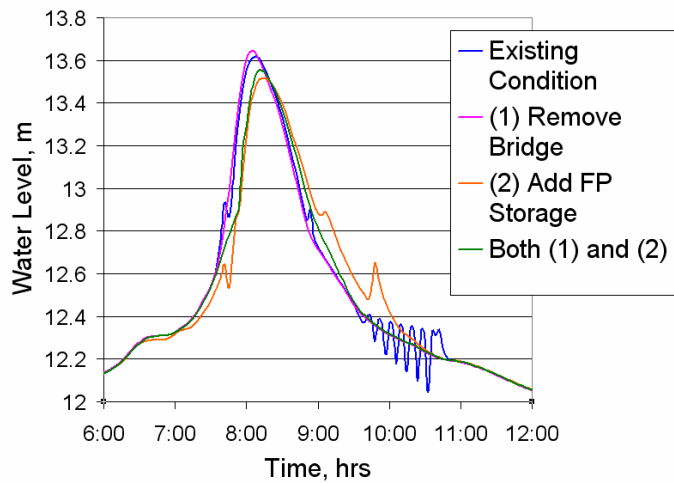


Figure 15. General Reductions in Peak 100-year Levels

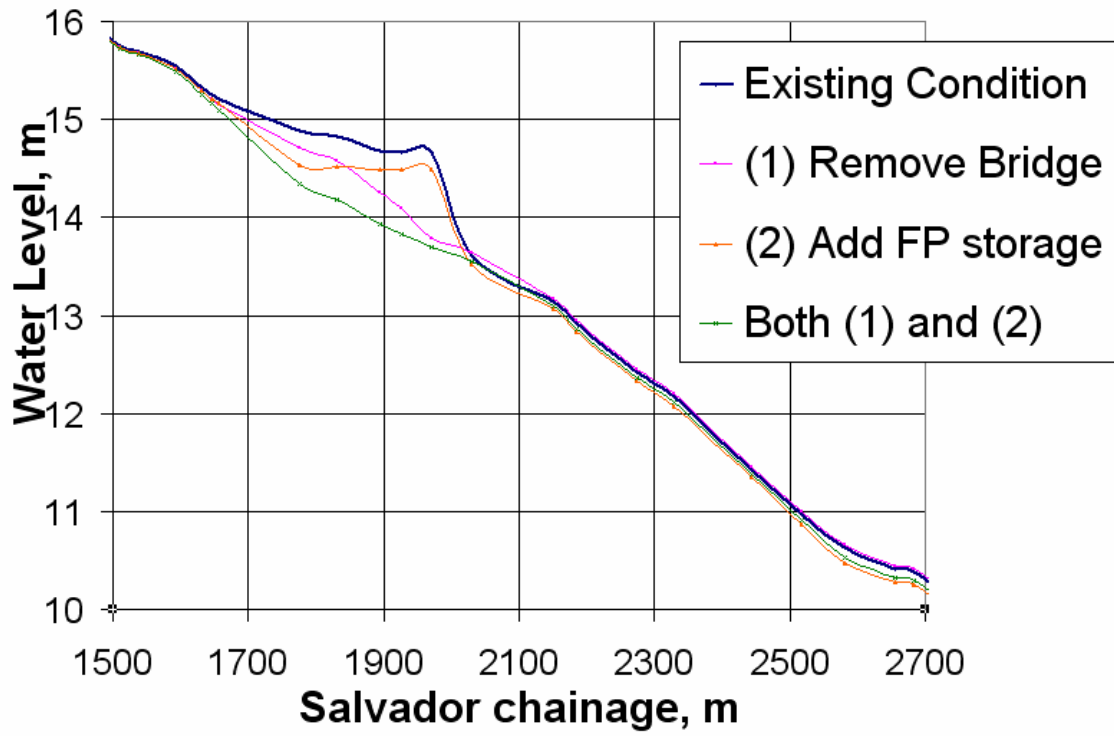


Figure 16. 100-yr Flood Peaks: Effect of Floodplain Storage (Flood Terraces) above Jefferson

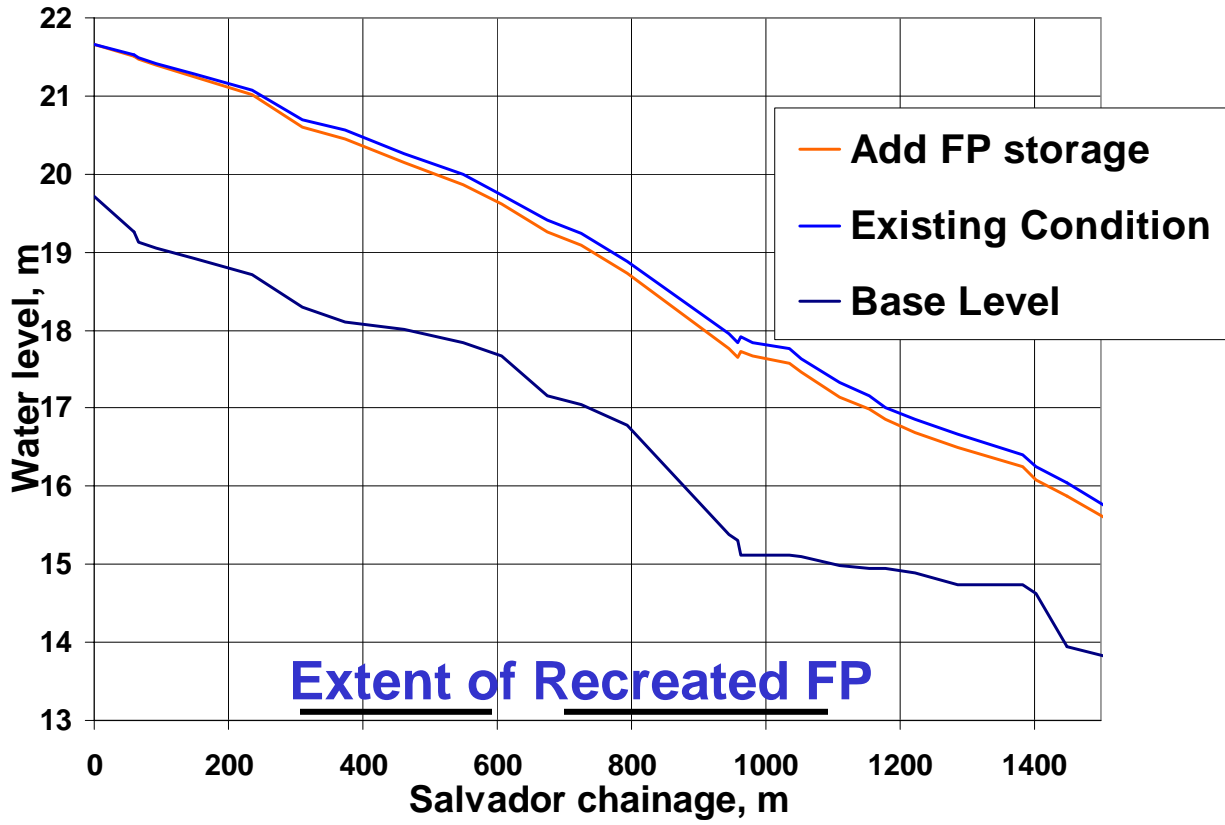


Figure 17. Napa Creek Watershed



Figure 18. Calibration of Napa Creek Rainfall/Runoff Model: Dec . 13-16, 2002

