Merced Integrated Regional Water Management Implementation Grant Proposal

Appendix 7-1

Feasibility Study and Addendum 1, Black Rascal Creek Flood Control

FEASIBILITY STUDY

BLACK RASCAL CREEK FLOOD CONTROL PROJECT

JUNE 2008

ADDENDUM 1

FEBRUARY 2009

Prepared by:

URS

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URS

February 27, 2009

Alfred L. Alvarez, R.C.E.
Department of Public Works
County of Merced
345 W. 7th Street
Merced, CA 95340-6041

Re: Addendum 1 to Final Report
Feasibility Study
Black Rascal Creek Flood Control Project
URS Project No. 18715153 and 18715212

Dear Mr. Alvarez:

Enclosed are six (6) copies of Addendum 1 and our June 2008 Final Report. Also enclosed are six (6) compact disks containing the PDF file of the entire document including Addendum 1 and the Final Report. The addendum incorporates and addresses the comments of the County and other members of the Streams Group on previously submitted drafts.

This completes our scope of services under Amendment No. 1 to amended Project Supplement No. 11 - Contract No. 2004001. We appreciate the opportunity to be of service to the County of Merced and the Streams Group on this important project. Please feel free to contact us if there are questions or if further information would be useful.

Sincerely,

URS Corporation

Ralph T. Boyajian, PE, GE
Vice President / Branch Manager

Enclosure: Report and Addendum 2 (six copies)
Compact Disk (six copies)

C: Phillip Mineart, PE (w/Encl)
Thomas MacDonald, PE (w/Encl)

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URS

Via Email (AAlvarez@co.merced.ca.us) & Federal Express

June 26, 2008

Alfred L. Alvarez, R.C.E.
Department of Public Works
County of Merced
345 W. 7th Street
Merced, CA 95340-6041

Re: Final Report
Feasibility Study
Black Rascal Creek Flood Control Project
URS Project No. 18715153

Dear Mr. Alvarez:

Enclosed are six (6) copies of our Final Report. Also enclosed is one (1) compact disk containing the PDF file of the entire document, which I previously transmitted to you by email. The report incorporates and addresses the comments of the County and Merced Irrigation District staff, as discussed at our meeting on May 27, 2008.

This completes our scope of services under Project Supplement No. 11 to Contract No. 2004001. We appreciate the opportunity to be of service to the County of Merced on this important project. Please feel free to contact us if there are questions or if further information would be useful.

Sincerely,

URS Corporation

Ralph T. Boyajian, PE, GE
Vice President / Sr. Branch Manager

Enclosure: Report (six copies)
Compact Disk (one)

C: Phillip Mineart, PE (w/Encl)
Thomas MacDonald, PE (w/Encl)

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Feasibility Study
Black Rascal Creek Flood Control Project
Final Report
June 26, 2008

Disclaimer

This Feasibility Study for the Black Rascal Creek Flood Control Project was completed for the County of Merced in a manner consistent with the level of care and skill ordinarily exercised by professional engineers, geologists, and environmental scientists in the geographic area of the site. URS provides no other warranties, either expressed or implied, concerning the contents of this report, which was prepared under the technical direction of the undersigned.

URS CORPORATION
Phillip Mineart, P.E.
Senior Hydrologist

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Senior Consultant

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Acronyms

Cfs	cubic feet per second
CN	curve number
DEM	digital elevation model
DSOD	California Division of Safety of Dams
HEC-HMS	Hydrologic Engineering Center's Hydrologic Modeling System
MID	Merced Irrigation District
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

1.1 BACKGROUND

Black Rascal Creek is tributary to Bear Creek at two locations. The reach of Black Rascal Creek above Yosemite Avenue is diverted directly to Bear Creek through the Black Rascal Creek Overflow at Yosemite Avenue (herein called the diversion). The reach of Black Rascal Creek downstream of the diversion flows into Bear Creek south of Highway 99. Black Rascal Creek, Bear Creek, The City of Merced, and watershed sub-areas tributary to the Black Rascal Creek diversion are shown on Figure 1-1.

Flooding along Bear Creek in the City of Merced and along Black Rascal Creek near the diversion has occurred on a number of occasions during recent years. The City and County of Merced anticipate additional housing and other development near the University of California Merced campus and in areas west of the Fairfield Canal that were inundated by Black Rascal Creek flood flows in April 2006. The U.S. Army Corps of Engineers (USACE) has investigated construction of a dam on Black Rascal Creek upstream of Le Grand Canal siphon to control flooding. However, environmental impacts and other issues associated with a large dam and reservoir on the creek have prevented the project from moving forward.

Based on initial review of existing data, Merced County (County) believes that reducing flood flows in Black Rascal Creek at the Yosemite Avenue diversion to less than about 3,000 cubic feet per second (cfs) by use of detention basins will substantially reduce, if not eliminate, some of the flooding in the City of Merced (Merced County, pers. comm., 2007). In addition, Merced Irrigation District (MID) operates Lake Yosemite as a flood control facility when it is not being used for an irrigation system regulating reservoir. MID wants to know if flows in Black Rascal Creek at the diversion can be reduced by alternative operating scenarios and/or infrastructure improvements for the lake and district canals and if these improvements are needed in conjunction with other flood control facilities, such as detention basins.

Merced County retained URS Corporation to investigate the feasibility of alternative flood control improvements, including alternative operation procedures and infrastructure improvements to the Lake Yosemite facilities, to reduce flows at the Black Rascal Creek diversion. The County did not specify a level of flood control that the alternative projects should provide. However, the County did request that the level of flood control that may be provided be identified.

1.2 PURPOSE

The purpose of this feasibility study is to identify and evaluate the effectiveness of alternative detention basin flood control projects that will reduce flood flows in Black Rascal Creek at the diversion. Alternative operation of Lake Yosemite and infrastructure improvements to the lake and irrigation canals were also evaluated.

1.3 SCOPE

The following tasks are included in the scope of work for this project:

1. Collect available data needed to develop a hydrologic model that can be used to evaluate potential sites for detention facilities.

2. Develop a hydrologic model of the study area using USACE's HEC-HMS computer model.
3. Calibrate the hydrologic model using measured precipitation and runoff data from historic large storm events.
4. Calculate runoff hydrographs at pre-selected locations along Black Rascal Creek for various storm events.
5. Identify and evaluate alternative flood control detention basins for effectiveness, cost, and environmental impacts.
6. Evaluate alternative operation of Lake Yosemite and possible infrastructure improvements to the lake to improve flood control.
7. Meet with County representatives to select specific alternative projects that would be evaluated in more detail.
8. Develop concept-level designs and layouts for alternative projects that include detention basins and possible operation and infrastructure improvements to Lake Yosemite.
9. Evaluate the refined alternative projects based on feasibility, constructability, effectiveness, costs, environmental considerations, and other factors identified as important during the studies.
10. Prepare draft and final study reports that document the data, analyses, and alternatives investigated for flood control projects.

2.1 DESCRIPTION OF MODEL

Hydrologic modeling of the Black Rascal Creek watershed above the diversion was performed using the USACE Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) Version 3.1.0 (HEC 2006.) Inputs into the HEC-HMS model include the following information:

- Watershed characteristics and sub-area average runoff parameters
- Precipitation data
- Channel routing parameters
- Reservoir storage and outlet data

HEC-HMS uses the precipitation data to compute runoff hydrographs from sub-areas in the study area for selected storm events. These hydrographs are then routed downstream to estimate flow rates at select locations.

The data used in these studies are described in the following paragraphs.

2.2 WATERSHED DATA

The watershed contributing to the Black Rascal Creek diversion was divided into the sub-areas shown in Figure 1-1 and Table 2-1 and include areas upstream from the diversion point to Bear Creek, areas east of Lake Yosemite that drain to the Le Grand Canal and Fairfield Canal, and areas west of Lake Yosemite (e.g., Fahren's and Parkinson Creeks) that drain to the Main Canal and Lake Yosemite. Table 2-1 lists the areas of each of the sub-areas included in the model. Parkinson and Fahren's Creeks do not drain directly to Black Rascal Creek but drain to Lake Yosemite. They are included in the model so that these flows are accounted for in the outflows from Lake Yosemite.

The Natural Resource Conservation Service (NRCS, formerly the Soil Conservation Service) curve number method was used to calculate runoff hydrographs from sub-areas in the study area. These hydrographs were routed and combined with hydrographs from downstream sub-areas to evaluate the potential effectiveness of alternative detention basins that should be considered within the study area.

The NRCS curve number method calculates runoff based on a curve number, which is estimated from soil type and land cover. A curve number is analogous to a runoff coefficient but varies from zero to 100. A low number indicates low runoff potential and a high number indicates a large runoff potential. NRCS has published tables for selecting a curve number based on land cover and condition and soil hydrologic group (A, B, C, or D), where soil group A has high permeability and soil group D has low permeability. The method is empirical and is primarily based on undeveloped watersheds. The existing Black Rascal Creek watershed is undeveloped and no major development is planned within the watershed in the foreseeable future. The land cover in the study area was determined from aerial photographs and a site visit in February 2007.

The NRCS Soil Survey for Merced Area California (NRCS 1991) was used to determine the soil hydrologic group for each sub-area. Soils in the Black Rascal Creek watershed are in the Redding-Pentz-Peters soil classification. These soils are generally gravely alluvium, some of which are underlain by claypan or hardpan. The survey also shows that the dominant soils in this

area include Redding gravelly loam and Corning gravelly loam with some Pentz gravelly loam in the upper watersheds. These soil types vary in permeability but the Redding and Corning soils are underlain by hardpan and/or claypan so they have limited ability to drain after large amounts of rainfall. For this analysis, it was assumed that the presence of a hardpan or claypan would reduce the permeability within the watershed, and hydrologic soil types C or D were assumed.

The Black Rascal Creek watershed and surrounding areas are primarily covered with sparse grasses and very few trees or shrubs grow in this area. As such, the Herbaceous cover type from the TR55 Manual (Soil Conservation Service 1986) was selected for use in these studies, which consists of a mixture of grass, weeds, and low-growing brush, with brush the minor element. Curve number data from the TR55 Manual are presented in Table 2-2. Because the vegetative ground cover is scarce, a poor hydrologic condition was selected for the Black Rascal Creek watershed, resulting in a recommended Curve Number (CN) between 87 and 93.

The HEC-HMS model calculates runoff hydrographs from sub-areas using the unit hydrograph methodology. The parameter needed as input into HEC-HMS to calculate the unit hydrograph is the sub-area lag time. Lag time is defined as the time difference between the occurrence of the center of mass of excess rainfall and the peak of the unit hydrograph. Estimates of basin lag times were calculated using Equation 2-1, which was developed by the USBR (1987).

$$t_p = 24 \cdot K_n \left(\frac{L \cdot L_c}{\sqrt{S}} \right)^{0.38} \qquad \text{Eq. 2-1}$$

In Equation 2-1, t_p = basin lag-time (hours), K_n = basin roughness, L = length of the longest flow path (miles), L_c = length to centroid along longest flow path (miles), and S = basin slope (feet/mile). Calibration studies discussed in Section 3 indicate a basin roughness (K_n) value of 0.09 in Equation 2-1 gives the best match of the time difference between measured peak precipitation and measured peak runoff. A basin roughness coefficient (K_n) of 0.09 is consistent with estimates based on observations during the field inspection. Runoff from the sub-areas would be via sheet flow and in numerous shallow grass-lined swales. General guidelines published by the U.S. Department of Agricultural in their Agricultural Handbook Number 667 (September 1987) suggests that during the runoff season Black Rascal Creek sub-areas would have a relatively high effective roughness consistent with the calibrated value.

Parameters other than K_n needed in Equation 2-1 to calculate lag-time were estimated using a digital elevation model (DEM) obtained from the United States Geological Survey (USGS). Table 2-1 presents the estimated basin lag times and physical parameters used to calculate lag time for each sub-area.

2.3 PRECIPITATION DATA

For event simulation modeling the HEC-HMS model requires the amount, duration, and temporal distribution of precipitation. Precipitation data are directly input as user-specified hyetographs developed from rain gauge data or developed using guidelines for estimating theoretical storm precipitation. Precipitation is assumed to be uniform over each sub-area.

Four precipitation gauges are available in the project vicinity, one at Lake Yosemite (Le Grand Head), one just south of the Black Rascal Creek diversion (CIMIS #148), one at Merced Airport, and one at Burns Reservoir (BUR). Data from all four gauges were reviewed with emphasis on

the Le Grand Head and CIMIS #148 gauges since they are the closest to the project area. Figure 1-1 shows the locations of the four gauging stations.

Hourly precipitation data for the CIMIS #148 gauge are available for the period October 1998 through July 2007 from the following website address:

http://wwwcimis.water.ca.gov/cimis/welcome.jsp

Hourly precipitation data for the Burns Reservoir gauge (BUR) are available from the Sacramento District of the Army Corps of Engineers, Sacramento District, for the period 1995 through present from the following website address:

http://www.spk-wc.usace.army.mil/plots/plot_menu_ca.html

Hourly precipitation data for the Merced Airport gauge are available for the period from September 1946 to present from the National Weather Service, Station 23257.

Hourly precipitation data for the Lake Yosemite gauge were provided by MID for April 3 through April 6, 2006 storm event.

Figure 2-1 compares the measured rainfall at the CIMIS #148, Le Grand Head, Merced Airport and BUR gauges for the April 2006 storm event. As shown by Figure 2-1, the CIMIS #148 and Le Grand Head gauges are not only closest to the study area but experienced more intense rainfall during the April 2006 storm.

California Department of Water Resources (DWR) provides statistical analyses of precipitation data for many gauges located throughout the state. Included in the analysis are estimates of the volume of rainfall for various frequencies and durations. For the study area, analyses are available for the CIMIS #148 gauge (7 years of data) and Merced Airport (64 years of data). A statistical analysis of only 7 years of precipitation data will not provide meaningful results and, therefore, only the statistical analysis of the Merced Airport gauge data were considered in this study. The data for the Merced Airport gauge was obtained from:

http://www.weather.water.ca.gov/engineering/

The National Weather Service publishes precipitation-frequency-duration estimates for central and northern California in the National Oceanic and Atmospheric Administration (NOAA) Atlas 2 (Miller, Fredrick, and Tracy 1973). The information in NOAA Atlas 2 is based on statistical analyses of a large number of gauges and incorporates the effects of topography.

Table 2-3 and Figure 2-2 present precipitation-duration data for a theoretical 100-year storm event, as determined from the DWR publication and NOAA Atlas 2, and measured precipitation-duration at the CIMIS #148, Le Grand Head Gate, and Merced Airport stations for the April 2006 storm event. The comparisons presented in Table 2-3 and Figure 2-2 indicates that the April 2006 storm was about a 100-year return frequency event.

As shown in Table 2-3 and on Figure 2-2, the maximum 24-hour precipitation amounts for the Merced Airport and BUR gauges during the April 3 through April 6, 2006 storm were 0.86 inches and 0.90 inches, respectively. These precipitation amounts are significantly less than the amounts measured at the CIMIS #148 and Le Grand Head gauges, indicating the April 2006 storm was a relatively small intense storm centered northeast of the City of Merced over the study area.

2.4 FLOW DATA

Flow data in Black Rascal Creek at two locations were provided by MID for the April 2006 storm event. These locations are Black Rascal Creek at the Le Grand Canal crossing and Black Rascal Creek at Yosemite Avenue (i.e., at the diversion). In addition, data were provided for Lake Yosemite, including outflows from the lake at the broad-crested weir on Fairfield Canal (Fairfield BCW). Provisional hourly flow measurements in Black Rascal Creek at the diversion are also available for water years 1995 to present from the USACE website address:

http://www.spk-wc.usace.army.mil/plots/plot_menu_ca.html

Black Rascal Creek flow data and the precipitation data discussed in Section 2.3 were used to calibrate watershed parameters. Figure 2-3 presents the flow measurement data provided by MID and reported by USACE for the April 2006 flood event. As shown in Figure 2-3, the peak flow at the Black Rascal Creek diversion reported on the USACE website is less than half the peak flow provided by MID. The reason for this large discrepancy is not known. Thus, both reported flow measurements were evaluated in the calibration studies discussed in Section 3 of this report.

2.5 CHANNEL ROUTING DATA

Runoff hydrographs from each of the sub-areas shown on Figure 1-1 were routed through the downstream network of channels using USACE's HEC-HMS computer model. A schematic showing sub-areas within the study area and routing reaches used in the HEC-HMS model is presented in Figure 2-4.

HEC-HMS provides several methods for channel routing. For this study, Muskingum-Cunge routing was selected because the parameters could be easily developed from available data. Peak flow rates for large events are generally not sensitive to the routing method.

HEC-HMS input data needed for these routings are the lengths of each routing reach, longitudinal channel slopes, and channel geometry and roughness. The lengths of each channel routing reach were determined by measurements from the USGS Digital Elevation Model (DEM). The average slope of each routing reach was calculated by taking the upstream and downstream elevation difference and dividing by the total reach length. Channel cross sections were estimated from the USGS DEM.

Manning's n for routing reaches were estimated to be 0.08 for the channel reach between the outlet of sub-area BR6 and the Black Rascal Creek diversion at Yosemite Avenue (see Figure 1-1) and 0.06 for other natural channel routing reaches. Manning's n for the canals was assumed to be 0.035. These estimated roughness values are based on the calibration studies discussed in Section 3 and the field inspection. Black Rascal Creek has a cobble bed and is relatively wide with little or no discernable banks. Flows in the creek, even modest to large flows, would be relatively shallow and the cobble bed would provide a significant resistance to the flow. Most of the reach between the outlet of sub-area BR6 and the diversion at Yosemite Avenue is cultivated and flow through this reach during major flooding would be shallow through nearly level fields that would provide a high effective roughness to the flow. Table 2-4 lists the channel routing parameters for each routing reach.

2.6 LAKE YOSEMITE ROUTING DATA

Flows in Le Grand Canal are a combination of outflows from Lake Yosemite and contributions from sub-areas on the north side of the canal between Lake Yosemite and Black Rascal Creek. During flood season, Le Grand Canal is blocked upstream of the Black Rascal Creek crossing and the south bank of the canal is opened such that canal flows are diverted into Black Rascal Creek. During the irrigation season flows in Le Grand Canal continue past Black Rascal Creek to Bear Creek.

To estimate flows out of Lake Yosemite into Le Grand Canal, which will ultimately discharge into Black Rascal Creek during the flood season, it is necessary to route all inflows into Lake Yosemite through the lake. Inflows into the lake are from Fahren's and Parkinson Creeks and direct runoff to the lake. Outflows from Lake Yosemite are to the Fairfield and Le Grand Canals. Thus, these Black Rascal Creek analyses include the Parkinson and Fahren's Creek watersheds north of the Main Canal, the watershed directly tributary to Lake Yosemite, and the Main and Fairfield Canals.

Elevation-storage and elevation-discharge data for Lake Yosemite are needed to route lake inflows through the lake and into Le Grand and Fairfield Canals. These data were provided by MID. Table 2-5 presents elevation-storage and elevation-discharge data for Lake Yosemite.

Calibration studies were made to determine watershed parameters that should be used in the HEC-HMS model to give calculated runoff characteristics that are similar to measured runoff characteristics. Watershed parameters that were considered are hydraulic roughness values of the sub-areas (K_n in Equation 2-1), hydraulic roughness values for the channel routing, and Curve Number (CN) values for rainfall losses.

Historical measurements of stream flow and precipitation are needed for calibration of the HEC-HMS input parameters. Sources of historical precipitation data are discussed in Section 2.3 and historical flow data are discussed in Section 2.4.

Precipitation and stream flow data for the historic storms of January 11-18, 1998 and April 3-6, 2006 were used to calibrate the sub-area hydraulic roughness and channel hydraulic roughness parameters in the HEC-HMS model. The sub-area hydraulic roughness is used to calculate the lag time between rainfall and runoff at the outlet of the sub-areas. The channel hydraulic roughness is used in the model to calculate the time required for a sub-area hydrograph to travel downstream and combine with runoff hydrographs from downstream sub-areas.

Various values of sub-area hydraulic roughness (K_n), ranging from 0.08 to 0.10, were used to calculate lag times for the sub-areas which were input into the HEC-HMS model. Runoff hydrographs for the sub-areas were calculated by the model and compared with measured hydrographs for the January 1998 and April 2006 storms. It was found that a K_n value of 0.09 resulted in the best timing match of calculated and measured peak runoff from the sub-areas. Figure 3-1 compares, for the storm of April 2006, calculated and measured hydrographs of runoff in Black Rascal Creek at the Le Grand Canal crossing using a K_n value of 0.09. As shown by this Figure, the calculated time of peak runoff matches the measured time of peak runoff. As discussed in Section 2, a value of K_n equal to 0.09 is consistent with observed conditions in the study area.

Various values of channel hydraulic roughness (Manning's n) values, ranging from 0.04 to 0.10, were input into the HEC-HMS model to route sub-area runoff hydrographs through the downstream channels. The routed sub-area hydrographs were then combined with hydrographs from downstream sub-areas. The calculated combined hydrographs were then compared with the measured runoff hydrograph at the downstream location. These comparisons were made for measured runoff hydrographs during the storms of January 1998 and April 2006 storms. It was found that a Manning's n value of 0.08 for the channel reach between the outlet of sub-area BR6 and the Black Rascal Creek diversion (see Figure 1-1) and Manning's n values 0.06 for other routing reaches gave the best matches between the calculated combined hydrographs shapes and measured hydrograph shapes. Figures 3-1 and 3-2 compare calculated and measured hydrographs in Black Rascal Creek at the Le Grand Canal Crossing and at the diversion for the storm of April 2006. As shown by this Figure, the calibrated Manning's n values result in calculated hydrograph shapes that nearly match the measured shapes. As discussed in Section 2, the calibrated Manning's n roughness values are consistent with observed conditions of the study area channels.

Significant precipitation and stream flow data are available for the April 2006 event, as well as information on flooding conditions during this event. Thus, the April 2006 storm event was used to calibrate curve number (CN) values to use in the HEC-HMS model and to analyze alternative flood control detention basins. In the HEC-HMS model, the CN parameter determines the volume of rainfall runoff and, to some extent, the peak rate of runoff. Merced County

specifically required that the April 2006 flood event be used as the basis for sizing detention basins for this study.

Figure 2-1 presents observed precipitation during the April 2006 storm event for the four precipitation gauges located near the project site. The peak rainfall generally occurred at the CIMIS #148 gauge about 1 hour before the peak rainfall at the Le Grand Head gauge. Peak and total rainfall amounts at the Burns and Merced gauges were considerably less than either the CIMIS #148 or Le Grand Head gauges. As shown in Table 2-3, the 24-hour-duration maximum rainfall volume of the April 2006 storm was 3.30 inches at the CIMIS #148 gauge and 2.96 inches at Le Grand Head gauge. Comparable rainfall amounts at the Merced Airport and Burns gauges were 0.86 inches and 0.90 inches, respectively. Thus, the Merced Airport and Burns rainfall measurements were not used in the calibration studies.

Time-series measurements of precipitation at the CIMIS #148 and Le Grand Head gauges were input into the HEC-HMS model. The CIMIS #148 gauge data were used for sub-areas BR1, BR6, and BR7 (see Figure 1-1) and the Le Grand Head gauge data were used for all other sub-areas considered in the HEC-HMS model. This aerial distribution of the measured rainfall data was selected based on gauge/sub-area proximity and calibration analyses conducted using only the CIMIS #148 data, only the Le Grand Head data, and the combination of precipitation data described above.

Figure 3-1 compares measured and calculated flows in Black Rascal Creek at the Le Grand Canal crossing. Two calculated estimates of runoff are shown, one using a CN value of 91 in the HEC-HMS model and one using a CN value of 97. The calculated peak flow using a CN value of 91 is only about 4 percent lower than the observed peak flow, well within the measurement and calculation margin of error. A CN value of 91 is consistent with conditions found in the watershed, as discussed in Section 2.2 of this report. However, the runoff volume calculated by the HEC-HMS model is almost 50 percent more than the volume given by the measured runoff values. A review of the precipitation data (see Figure 2-1) shows that the second peak that occurred on the morning of April 4 did not occur at the Burns gauge although it occurred at the CIMIS #148 and Le Grand Head gauges, indicating that the storm had moved, perhaps missing parts of the upper Black Rascal Creek watershed. As shown by Figure 3-1, using a CN value of 97 in the HEC-HMS model over-estimates the peak flow by 30 percent and over estimates the volume of runoff by 77 percent, indicating that CN=97 is too high at this location.

For comparison purposes, two theoretical 100-year storm runoff hydrographs for Black Rascal Creek at the Le Grand Canal crossing are included in Figure 3-1, one hydrograph calculated using precipitation data for the area obtained from the NOAA Atlas 2 publication and the other hydrograph calculated using precipitation data developed by DWR for the Merced Airport gauging station. These two hydrographs were calculated using the HEC-HMS model, calibrated sub-area and channel roughness parameters, and a CN value of 91.

Figure 3-2 compares the measured and calculated flows in Black Rascal Creek at the diversion. Again, two calculated estimates of runoff are shown, one using a CN value of 91 in the HEC-HMS model and one using a CN value of 97. It should be noted that the Soil Conservation Service (1986) recommends a CN value of 98 for parking lots and paved surfaces and does not recommend CN values as high as 97 for conditions found in the study area. Two measured hydrographs are also included on Figure 3-2, one provided by MID and one obtained from the USACE website. The measured hydrographs provided by MID and USACE are both based on

the gauge located at the diversion. The measured data from MID and USACE report the same peak stage during the flood but use different rating curves to arrive at the flow rate. The hydrograph calculated using a CN value of 91 under-predicts the MID peak flow by about 30 percent and the runoff volume by about 50 percent. Using a CN value of 97 in the HEC-HMS model calculates a peak flow that is only 3 percent less than the MID measured peak flow, but still has a runoff volume that is almost 40 percent less than the measured volume.

For comparison purposes, two theoretical 100-year storm runoff hydrographs for Black Rascal Creek at the diversion are included in Figure 3-2, one hydrograph calculated using precipitation data for the area obtained from the NOAA Atlas 2 publication and the other hydrograph calculated using precipitation data developed by DWR for the Merced Airport gauging station. These two hydrographs were calculated using the HEC-HMS model, calibrated sub-area and channel roughness parameters, and a CN value of 91.

Computed stages in Yosemite Lake during the April 2006 flood are compared with measured stages in Figure 3-3. As shown by this Figure, the HEC-HMS model accurately reproduces the measured data.

Runoff coefficients, i.e., the ratio of runoff volume to rainfall volume, were calculated for the April 2006 storm event to help explain the differences between calculated and measured flows. Table 3-1 lists runoff coefficients using data for different combinations of observed precipitation and flow. Runoff coefficients are also provided in Table 3-1 for HEC-HMS calculated results.

Estimated runoff coefficients vary from about 0.5 to 1.8, depending on the precipitation gauge (Le Grand Head or CIMIS #148), contributing area (Black Rascal Creek only or all areas east of Lake Yosemite), and whether measured or HEC-HMS calculated runoff is used in determining the runoff coefficient. A runoff coefficient greater than 1.0 indicates that either the observed runoff has been over-estimated or the observed rainfall under represents the actual rainfall that fell on the watershed.

As shown on Table 3-1 for Black Rascal Creek at the Le Grand Canal crossing, the runoff coefficient varies from 0.50 to 0.61, depending on which precipitation gauge is used. For HEC-HMS calculated results, the runoff coefficient is between 0.74 and 0.89 for a CN value of 91 and 97, respectively.

As shown on Table 3-1 for Black Rascal Creek at the diversion, the runoff coefficient varies from 0.56 to 1.79, depending on which precipitation gauge, flow data, and drainage areas are used. For HEC-HMS calculated results, the runoff coefficients for CN values of 91 and 97 is 0.75 and 0.91, respectively, for the assumed drainage areas and 0.70 and 0.85, respectively, if possible additional drainage areas are included in the calculation.

The following conclusions are based on these comparisons of calculated and measure runoff hydrographs completed for the calibration analyses discussed above.

1. A sub-area roughness coefficient (K_n) of 0.09 for calculation of the sub-area lag times and Manning's n roughness coefficients of 0.06 and 0.08 for channel routing gave a temporal distribution of calculated runoff similar to the measured distribution of runoff.
2. An inconsistency exists between the reported rainfall and runoff values at the Black Rascal Creek diversion provided by MID, which is indicated by the estimated runoff coefficient exceeding 1.0. Given the uncertainty in estimating flows during large storm events, the actual flow is likely less than the reported value of 5,900 cfs.

3. A curve number of 91 matches the observed peak flow at the Le Grand Canal gauging station but is between the MID and USACE estimated peak flow at the Black Rascal Creek diversion station. A curve number of 97 exceeds the observed peak flow at the Le Grand Canal station and approximately equals the MID flow data at the Black Rascal Creek diversion.
4. The predicted runoff coefficient using a CN of 91 varies from about 0.70 to 0.75, and from 0.85 to 0.91 using a CN of 97. A runoff coefficient of 90 percent in an undeveloped watershed is high even for a 100-year precipitation event.
5. Based on the above considerations, a CN of 91 was adopted for evaluation of alternative detention basins and other flood control improvements. Figure 3-4 shows the discharge per square mile (cfs/mi^2) by watershed area for a 100-year event based on the Flood Insurance Study (FIS) for Merced County (FEMA, 2008). The HEC-HMS model using the 100-year NOAA precipitation and the CN of 91 matches the runoff values used in the FIS well. This provides additional support for the choice of using a CN of 91.

During past major storm events flooding has occurred along Black Rascal Creek at and downstream from the diversion at Yosemite Avenue. The purpose of these studies is to evaluate alternative improvements in the study area that would control flooding during modest flood events and reduce flooding during larger events. The following paragraphs discuss design criteria adopted for the analyses, alternative projects that were analyzed and their effectiveness in reducing Black Rascal Creek flows, costs to construct the alternative projects, and issues or potential issues that should be considered in evaluating the alternative projects. Environmental issues associated with the alternative detention basin projects are discussed in Section 5. Section 6 compares the alternative projects.

4.1 CRITERIA FOR FEASIBILITY DESIGN

Based on preliminary results of these studies and discussions with Merced County, it was decided that the design storm to use in these feasibility studies should be equivalent to the April 3-6, 2006 storm event. Flooding occurred along Black Rascal Creek at and downstream from the Yosemite Avenue diversion during the April 2006 event and, therefore, use of an equivalent storm for evaluation of alternative flood control improvements would be meaningful. As shown by Figures 3-1 and 3-2, the April 2006 storm is approximately equivalent to a 100-year return frequency event and, therefore, the 100-year storm event given by the NOAA Atlas 2 publication was adopted as the design storm for these studies. The watershed parameters determined from the calibration analyses (i.e., K_n = 0.09, Manning's n = 0.06 & 0.08, and CN = 91) were used in the analyses.

As previously mentioned, during the winter flood season, Le Grand Canal is blocked just upstream from the Black Rascal Creek crossing and the southern bank of the canal is breached to release canal flows into Black Rascal Creek. During the irrigation season, flows in the canal would bypass Black Rascal Creek and be conveyed to Bear Creek east of the Black Rascal Creek diversion. For a project that requires reduction of Black Rascal Creek flood flows, the winter flood season operation of Le Grand Canal is the more critical operation. Thus, for feasibility design of the alternative projects, it was assumed that flows in Le Grand Canal would discharge into Black Rascal Creek at the crossing.

No design criteria have been specified as to the effectiveness of flood control improvements but Merced County believes that reducing flood flows to less than about 3,000 cfs at the Black Rascal Creek diversion by use of detention basins or possible modification of operating criteria and/or infrastructure improvements to Yosemite Lake and district canals will substantially reduce, if not eliminate, some of the historical flooding in the City of Merced (Merced County, pers. comm., 2007). Merced County has specified that this criterion should be used in these analyses. Thus, flood control improvements were sized to reduce peak flows at the Black Rascal Creek diversion to 3,000 cfs, plus or minus 10 percent (2,700 cfs to 3,300 cfs).

4.2 ALTERNATIVE DETENTION BASIN PROJECTS

Project detention basins would consist of impoundment structures that temporarily store runoff in Black Rascal Creek, or one of its tributaries, and then release the stored water at a controlled rate. Four different basins were included in the analyses and their locations and sizes are shown on Figures 4-1 and 4-2. It was assumed that the two small basins, the one located in the upper Black Rascal Creek sub-area (site A on Figure 4-1) and the one in sub-area BR6 (site B on

Figure 4-1), would be used in combination with a larger downstream basin to potentially reduce environmental impacts. Although the topography is not favorable for a basin located at the Yosemite Avenue diversion, this location may be the most favorable because it would have the least environmental impact on vernal pools in the area (this area is already disturbed by agricultural use).

For purposes of these feasibility analyses, the detention basin structures were assumed to consist of earthen embankments that span the natural channels and adjacent low-lying areas with a concrete outlet and spillway at the approximate location of the natural channel. The locations of the assumed embankments and the general configuration of the assumed outlet works and spillways are shown on Figures 4-2 and 4-3, respectively. Outlets from the basins were assumed to consist of 10-foot by 10-foot box culverts for embankments greater than 13 feet in height and 10-foot by 5-foot box culverts for embankments less than 13 feet in height. The floor of the box culverts is at the natural streambed elevation so that the embankment cannot permanently impound water and will only temporarily impound water during major storm events. The top surface of the box culvert is assumed to act as the emergency spillway. An integer number of box culverts that will limit the peak flow at the diversion to about 3,000 cfs were assumed.

Three alternative detention basin projects were analyzed. For Alternative 1, a single large basin is provided at Site C (see Figure 4-1). For Alternative 2, a combination of three basins are provided, one each at Sites A, B, and C. For Alternative 3, a single large basin is provided at Site D. The project design storm parameters presented in Section 4.1 were input into the HEC-HMS model and a runoff hydrograph at the Black Rascal Creek diversion was calculated assuming no flood control facilities. Stage-storage and stage-discharge data were then input into the HEC-HMS model to simulate detention basins at the potential sites for each of the alternative projects. The model was then operated and the detention basin parameters varied, on a trial and error basis, until the project effectiveness criterion presented in Section 4.1 was met. These analyses resulted in the required detention basin sizes presented in Table 4-1 for each of the alternative projects. As noted in Table 4-1, the outlet for the basin at Site B was sized to limit outflows from sub-area BR6 to a practical minimum, about 100 cfs.

Figure 4-4 presents the discharge hydrographs at the Black Rascal Creek diversion during the design flood for existing conditions (no detention basins) and for each of the three alternative detention basin projects. As shown by Figure 4-4, all of the alternative detention basin projects reduce the peak flow at the diversion to about 3,000 cfs.

The goal of reducing Black Rascal Creek peak flows to about 3,000 cfs by use of the detention basin alternative projects examined in these studies can only be achieved by providing a relatively large detention basin at either Site C or Site D. The Site C and D basins can be made smaller if basins at Site A and/or Site B are also provided. However, all of the detention basins analyzed are larger than the minimum size that would be subject to California Division of Safety of Dams (DSOD) jurisdiction. Smaller-sized basins (non-DSOD jurisdiction) were briefly evaluated and found to be ineffective in reducing flood flows.

Figure 4-5 presents results of routing the April 2006 storm event through the above alternative projects. The results are similar to the 100-year storm event results since the April 2006 event was similar in size to a 100-year storm event.

4.3 ALTERNATIVE YOSEMITE LAKE OPERATION AND CANAL IMPROVEMENTS

Alternative operations of Lake Yosemite, in conjunction with irrigation infrastructure modifications, were also considered in these studies. It was found that the current lake operation significantly attenuates and detains lake outflows into Le Grand Canal, resulting in lower and later peak inflows into Black Rascal Creek during the winter flood operation season of the canal. The delayed lower outflows from the lake do not significantly contribute to peak flows at the Black Rascal Creek diversion.

It was determined that modifications to the Lake Yosemite operation or outlet structure would not provide any significant benefit, at least not under the current flood season operating criteria, and further analysis of this concept was not considered for this report. It is our understanding that the flood season operating criteria is mandated by USACE. If this mandate is waived, all Le Grand Canal flows could be conveyed directly to Bear Creek without passing through the Black Rascal Creek diversion. Waiving of USACE's winter canal operation requirement would result in a reduced flow at the diversion of about 600 cfs, which is the maximum reduction that can be achieved by modifications to the existing lake and canal. Flow reductions that might be possible by changing the physical characteristics of lake and canal facilities would be much less than 600 cfs.

4.4 COST OF ALTERNATIVE DETENTION BASINS

To assist Merced County in evaluation and selection of an interim flood protection project, URS developed concept-level cost estimates to construct each of the alternative detention basin configurations listed in Table 4-1. Actual costs would be determined during final design when requirements imposed by DSOD, environmental requirements, and site-specific conditions are better known. Assumptions used in the cost estimate include:

- The embankment of the dam could be constructed from onsite materials.
- Three feet of material would be excavated for the foundation.
- The general layouts of the impoundment structure, outlet, and spillway are as shown on Figures 4-2 and 4-3.
- The spillway for each detention basin is sized to pass the 100-year flood event with 3 feet of freeboard. However, since all the basins have a hydraulic height greater than 6 feet, DSOD could require more stringent spillway requirements even though the reservoirs are in a relatively undeveloped area. The spillway crest length on the larger basins analyzed in this study (Sites C and D) is about the same length as the spillway at Burns Reservoir which drains a much larger area (74 mi^2). Therefore, although the DSOD requirements will not be known until more detailed designs are developed, the spillway costs included in these studies should provide a reasonable estimate of the final costs.
- For purposes of the feasibility cost estimate it is assumed that the reservoir lands will be purchased in fee. A small cost savings may be realized if flood easements can be obtained.
- Environmental costs are assumed to consist of mitigation for loss of habitat due to the dam footprint and possible damage to vernal pools within the inundation area. Construction of the dam is not assumed to destroy the vernal pool habitat but may change the characteristics of the pools that are inundated. Therefore, a lower cost was assigned to the pool impact.

Construction quantities, project costs, and environmental impacts and their costs are presented in Table 4-2 for the alternative projects. In addition, unit costs used in the estimate as well as assumptions associate with environmental impacts are presented as footnotes on Table 4-2.

4.5 POTENTIAL ISSUES

Issue No. 1: Merced County has indicated that it would be desirable if the detention basins for Black Rascal Creek would be small enough to not be considered a dam and, therefore, would not come under DSOD's jurisdiction. DSOD's definition of a dam is an impoundment structure that is 25 feet or more in height or stores more than 50 acre-feet of water. However, if the structure is less than 6 feet in height DSOD does not consider it a dam regardless of its storage capacity, and if the structure stores less than 15 acre-feet of water DSOD does not consider it a dam regardless of its height.

Detention structures considered for Black Rascal Creek are less than 25 feet in height and designed to permanently store little or no water. However, during flood events more than 50 acre-feet of water would be temporarily stored to effectively control flooding. If this case occurs, it is likely that DSOD would consider the detention basin as being in its jurisdiction. The safety criteria that DSOD would impose on the alternative dams are unknown. However, considering the small dam heights, temporary nature of storage, remoteness of the facility, and degree of downstream hazards, the criteria should not be greater than imposed on Burns Dam. The Burns Dam spillway has a 40 foot crest length (USACE, undated). This is similar in size to the crest length assumed for the basins described in this report.

Issue No. 2: The analyses presented herein are limited to the Black Rascal Creek watershed upstream from the Yosemite Avenue diversion. The analyses do not include flow estimates in Bear Creek or other creeks tributary to the City of Merced. The impacts of one or more detention facilities on areas downstream from the Black Rascal Creek diversion were not investigated as part of these studies.

Issue No. 3: The criterion imposed for these analyses was to reduce peak flows in Black Rascal Creek at the diversion to about 3,000 cfs. This criterion is, URS believes, based on the assumption that the safe capacity of the diversion channel is about 3,000 cfs or greater. To the extent that the capacity of the channel is significantly less than 3,000 cfs (e.g., due to vegetation or sedimentation clogging the channel), the benefits of constructing detention basins described in this report would be reduced.

5.1 ENVIRONMENTAL SETTING

The four detention basin sites considered in this report are located in the upper portions of the Black Rascal Creek watershed, as shown on Figure 1-1. This portion of the watershed receives runoff from an extensive area of incised alluvial terraces. These terraces are widely distributed along the eastern side of the San Joaquin Valley and are characterized by hardpan soils and microtopographic features known as mima mounds and vernal pools.

Typical vegetation types throughout the upper Black Rascal Creek watershed include annual grasslands and vernal pool wetlands. Several irrigation canals traverse the lower portions of the Black Rascal Creek watershed, including Le Grand Canal and Fairfield Canal. These canals contain flowing water during the irrigation season (approximately March through September), and seepage from the canals has created some wetland features that contain water during the summer irrigation season in addition to the winter rainy season.

Sensitive biological resources that exist at the detention basin sites and vicinity include:

- Special-status species
- Wetlands
- Non-wetland aquatic habitats

Several federal- and state-listed species are known to exist in the vicinity of the potential sites. Examples include:

- Vernal pool fairy shrimp (federal threatened)
- Conservancy fairy shrimp (federal endangered)
- Vernal pool tadpole shrimp (federal endangered)
- California tiger salamander (federal threatened)
- Swainson's hawk (California threatened)
- San Joaquin kit fox (federal endangered/California threatened)
- Succulent owl's clover (federal threatened/California endangered)
- Boggs Lake hedge hyssop (California endangered)
- Colusa grass (federal threatened/California endangered)
- San Joaquin Valley Orcutt grass (federal threatened/California endangered)
- Hairy Orcutt grass (federal endangered/California endangered)
- Keck's checkerbloom (federal endangered)
- Greene's tuctoria (federal endangered/California rare)

More than half of these listed species are associated with vernal pool habitats or other seasonal wetlands. Table 5-1 lists these species and additional special-status species that are documented in the vicinity of the detention basin sites. Table 5-1 was compiled based on a review of records

in the California Natural Diversity Data Base (CNDDB 2007) and the U.S. Fish and Wildlife Service online database (USFWS 2007).

5.2 ENVIRONMENTAL CONSIDERATIONS - DETENTION BASIN SITES

The following paragraphs discuss environmental considerations associated with each of the four detention basin sites considered in these studies. In previous studies, URS prepared maps showing locations of vernal pools and various sensitive biological resources within the study area of this report. These maps have been reproduced and are included in Appendix A of this report.

5.2.1 Detention Basin Site A

Detention basin Site A is located approximately 6.2 miles north of the Black Rascal Creek diversion. This location is substantially higher in the watershed than the other sites that are evaluated in this report. This site, like Sites B and C, is located within a high-density vernal pool habitat unit that was mapped in 1997 by Robert Holland for the U.S. Fish and Wildlife Service (USFWS). No occurrences of special-status species are documented within a 0.5-mile radius of this site. However, this site probably has not been previously surveyed because it is outside of the study area for the University of California campus site and the subsequent regional studies that were coordinated by John Vollmar (2002).

The Site A detention basin embankment and inundation area would overlap vernal pool habitat that may be occupied by one or more listed species. A pond that may provide aquatic habitat suitable for breeding tiger salamanders is located approximately 0.6 mile west of this site but the available data do not indicate any aquatic habitat that would remain for at least 12 weeks in the embankment or inundation area at this site. Therefore, tiger salamanders may be present in the uplands during the non-breeding seasons.

5.2.2 Detention Basin Site B

Detention basin Site B is located approximately 2 miles east of the Black Rascal Creek diversion. This location has approximately the same elevation as Site C but the topography of sub-area BR6 places the Site B detention basin embankment and inundation area slightly above the lowest vernal pool terraces that are associated with Site C. Site B, like Sites A and C, is mapped as high-density vernal pool habitat on the 1997 USFWS vernal pool habitat map compiled by Robert Holland.

At least five documented occurrences of special-status species are documented within a 0.5-mile radius of this site (CNDDB 2007). These species include Conservancy fairy shrimp, western spadefoot, Colusa grass, and San Joaquin Valley Orcutt grass. The absence of occurrences at the basin site is probably due to the lack of previous surveys. This site is outside of the study area for the University of California campus site and the subsequent regional studies that are reported by John Vollmar (2002).

A review of recent aerial photographs indicates that the detention basin embankment and inundation areas would overlap vernal pool habitat that may be occupied by one or more listed species. Two vernal playas are located within 0.5 mile of this site that may provide aquatic habitat suitable for breeding tiger salamanders. The available data do not indicate aquatic habitat

that would persist for at least 12 weeks within the footprint of the dam or the inundation area at this site. Therefore, tiger salamanders may be present in the upland and wetland portions of this site during the non-breeding seasons but are not likely to breed at this site.

5.2.3 Detention Basin Site C

Detention basin Site C is located approximately 1.4 miles north of the Black Rascal Creek diversion. This site is on a low terrace within an extensive vernal pool complex. A large number of occurrences of vernal pool fairy shrimp, vernal pool tadpole shrimp, succulent owl's clover, and other special-status species are documented at this site and the immediate vicinity. One of the only sightings of San Joaquin kit fox in eastern Merced County is documented at this site (Vollmar 2002; CNDDB 2007). The detention basin site and other portions of Ichord Ranch were intensively studied for special-status plants, vernal pool invertebrates, small mammals, and San Joaquin kit fox (Vollmar 2002).

The Site C embankment and inundation area would overlap vernal pool habitat that may be occupied by one or more listed and other special-status species. Several ponds and larger seasonal pools that may provide aquatic habitat suitable for breeding tiger salamanders are located within 0.5 mile of this site. Vollmar (2002) did not observe breeding or adult California tiger salamanders within 1 mile of this site but the upland habitat is potentially suitable for this species.

5.2.4 Detention Basin Site D

Detention basin Site D is located at the Black Rascal Creek diversion, approximately 1.4 miles downstream of Site C. The Fairfield Canal is the western boundary of this site and most of the inundation area is currently cultivated. A small part of the inundation area (approximately 40 acres) would overlap a grassland area interspersed with vernal pools and swales adjacent to Black Rascal Creek. The 40 acres of overlap is based on the inundation area shown on Figure 4-2 that is associated with a Curve Number (CN) value of 91. This uncultivated area has known occurrences of vernal pool fairy shrimp, vernal pool tadpole shrimp, and other special-status species. The grassland portion of the detention basin site and other portions of Ichord Ranch were intensively studied for special-status plants, vernal pool invertebrates, small mammals, and San Joaquin kit fox (Vollmar 2002).

The Site D embankment and inundation area may overlap vernal pool habitat that may be occupied by one or more listed and other special-status species. However, the affected area would be smaller than at Site C and the area may be reduced by reconfiguration of the embankment. Several ponds and larger seasonal pools that may provide aquatic habitat suitable for breeding tiger salamanders are located within 0.5 mile of this site. Vollmar (2002) did not observe breeding or adult California tiger salamanders within 1 mile of this site but the upland grassland habitat is potentially suitable for this species.

5.3 DISCUSSION

Construction and operation of a detention basin would result in two types of impacts to sensitive biological resources: direct loss of habitat at the embankment site and any related permanent structures (e.g., access roads or control structures), and indirect degradation of seasonal wetland

habitats due to periodic, seasonal inundation. The proposed structures would cause water to temporarily inundate uplands as well as vernal pools and other seasonal aquatic habitats. The increased depth and duration of inundation caused by the detention dam could displace or adversely affect upland species, such as vernal pool pollinators, that are critical to the persistence of special-status vernal pool plants.

All of the detention basin sites would require the following permits prior to construction:

- U.S. Army Corps of Engineers Section 404 Individual Permit
- U.S. Fish and Wildlife Service Section 7 Biological Opinion
- Regional Water Quality Control Board Water Quality Certification
- California Department of Fish and Game Section 1600 Agreement

These permits would require at least 1 to 2 years to obtain based on current processing times and the amount of existing data that are available or inferred.

The options considered in this report would potentially affect similar biological resources. However, the size and known sensitivity of Site C would probably make it less desirable. Sites A and B would both require longer access routes during construction but the natural topography would require relatively small embankments and inundate small areas and would allow for the reduction in the size of the basin at Site C. Site D has the least environmental impact since the embankment footprint and most of the inundated area is on cultivated land. However, since it is the most downstream detention basin it would have the largest inundated area and could therefore impact some sensitive habitat in the upstream area. The area impacted could likely be reduced through modification of the design, but more detailed topographic data would be needed to determine the amount of the reduction. Possible changes to the conceptual design provided in this study would be to extend the embankment footprint to isolate some sensitive areas and/or use the inundated cultivated area as a borrow pit, if the soils are acceptable, to increase storage in the cultivated area.

The alternative projects listed in Table 4-1 were qualitatively evaluated based on their performance in relation to addressing the following four issues. The relative advantages and disadvantages of the detention basins and combinations of detention basins in addressing these issues are summarized in Table 6-1.

- Potential DSOD Jurisdiction
- Effectiveness in Reducing Black Rascal Creek Flows
- Environmental Acceptability
- Project Costs

Limited measurements of precipitation within and adjacent to the Black Rascal Creek watershed were available and not always consistent with available measurements of runoff. To the extent that precipitation is not uniform over the entire watershed, calculated runoff and detention basin attenuation of runoff will be different from the values calculated and presented herein.

The analyses presented herein are limited to the Black Rascal Creek watershed and its tributaries upstream from the Yosemite Avenue diversion. The analyses do not include flow estimates in Bear Creek or other creeks tributary to the City of Merced.

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Tables

Table 2-1 Sub-area Physical Parameters

Sub-area ID	Sub-area Size (mi^2)	Longest Flowpath (mi)	Centroidal Flowpath (mi)	Basin Slope (ft/mi)	Estimated Basin Roughness	Lag Time Used in Model (hr)
F3	4.51	3.37	0.83	89	0.09	1.37
F2	0.84	0.92	0.22	212	0.09	0.43
F1	9.94	7.53	3.73	64	0.09	3.48
P1	4.78	5.02	2.27	68	0.09	2.45
BR1a	8.75	5.49	2.6	78	0.09	2.57
BR1b	12.26	7.58	4.17	48	0.09	3.85
BR2	0.21	0.96	0.41	36	0.09	0.77
BR3	1.41	2.18	0.77	92	0.09	1.12
BR4	2.52	2.97	1.68	51	0.09	1.88
BR5	0.58	0.88	0.28	57	0.09	0.59
BR6	3.1	2.43	0.77	58	0.09	1.27
BR7a	0.91	1.33	0.57	19	0.09	1.12
BR7b	3.39	2.84	1.14	9	0.09	2.23
Total	53.2					

Table 2-2

Runoff Curve Numbers for Arid and Semiarid Rangelands

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover Type	Hydrologic Condition				
		A	B	C	D
Herbaceous - Mixture of grass, weeds, and low-growing brush, with the bush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen - Mountian brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper - Pinyon, juniper, or both; grass understory	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert Shrub - Major plants include saltbrush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

Poor: <30% ground cover (litter, grass, and brush overstory).

Fair: 30 to 70% ground cover.

Good: > 70% ground cover.

Curve numbers for group A have been developed only for desert shrub.

Table 2-3 Volume of Precipitation for 100-Year Event and for April 2006 Storm Event

Duration		Frequency Curve		April 2006 Event			
Hours	Minutes	DWR Merced (100-Year)	NOAA Atlas #2 (100-Year)	CIMIS #148 Gauge	Le Grand Head Gauge	Merced Airport Gauge	Burns Gauge
0.083	5	0.35	0.23	---	---	---	---
0.25	15	0.54	0.46	---	---	---	---
1	60	0.9	0.8	0.87	0.52	0.39	0.51
2	120	1.19	1.06	1.37	0.76	0.48	0.68
3	180	1.38	1.3	1.75	0.76	0.49	0.75
6	360	1.78	1.88	2.38	1.00	0.54	0.77
12	720	2.31	2.75	2.85	2.56	0.76	0.77
24	1440	2.81	3.5	3.30	2.96	0.86	0.90

Table 2-4 Channel Routing Parameters

Reach[1]	Length (ft)	Slope (ft/ft)	Manning's n	Shape	Width (ft)	Side Slope (xH:1V)
BR1to Yosemite Avenue Diversion	15700	0.0083	0.06	Trapezoid	40	10
BR6 to Yosemite Avenue Diversion	15000	0.002	0.06	Triangle	na	50
Fairfield Canal	27,600	0.002	0.035	Trapezoid	40	1.5
Le Grand Canal	29,500	0.002	0.035	Trapezoid	50	1.5
Main Canal	27,500	0.0004	0.035	Trapezoid	50	1.5

1 See Figures 1-1 and 2-4 for routing reaches.

Table 2-5 Stage-Storage-Discharge, Lake Yosemite

Stage (feet elev.)	Storage (acre-feet)	Net Lake Storage (acre-feet)[1]	Yosmite Lake Outflow (cfs)	Le Grand Canal Inflow (cfs)	Fairfield Canal Inflow (cfs)
237.30	3553	3	0	0	0
237.40	3578	28	0	0	0
237.50	3603	53	0	0	0
238.00	3728	178	0	0	0
238.50	3853	303	0	0	0
239.00	3988	438	0	0	0
239.50	4138	588	0	0	0
240.00	4288	738	0	0	0
240.50	4438	888	1	0	1
241.00	4588	1038	10	0	10
241.50	4738	1188	26	0	26
242.00	4888	1338	46	0	46
242.50	5040	1490	69	0	69
243.00	5202	1652	96	0	96
243.50	5369	1819	125	0	125
244.00	5539	1989	220	0	220
244.50	5709	2159	377	0	377
245.00	5887	2337	501	50.5	450.5
245.50	6086	2536	607	103.5	503.5
246.00	6286	2736	710	155	555
246.50	6486	2936	811	211	600
247.00	6686	3136	913	313	600
247.50	6886	3336	1007	407	600
248.00	7089	3539	1114	514	600

1 Net storage is storage above Elevation 237.3

Table 3-1

Runoff Coefficients for Flows in Black Rascal Creek for April 3-5, 2006 Storm Event

Storm Period	Precipitation Gauge	Precipitation Amount (feet)	Source of Flow Data	Assumed Drainage Area[a] (mi^2)	Possible Additional Drainage Area[b] (mi^2)	Rainfall Volume (acre-feet)	Runoff Volume (acre-feet)	Runoff Coefficient
Runoff in BRC at Bear Creek Diversion (12:00 Apr. 3, 2006 to 15:00, Apr. 5, 2006)	Le Grand Head	0.29	MID	30.93		5,806	10,372	1.79
	Le Grand Head	0.29	USACE	30.93		5,806	4,272	0.74
	Le Grand Head	0.29	MID	30.93	2.2	6,220	10,372	1.67
	Le Grand Head	0.29	USACE	30.93	2.2	6,220	4,272	0.69
	CIMIS #148	0.36	MID	30.93		7,093	10,372	1.46
	CIMIS #148	0.36	USACE	30.93		7,093	4,272	0.6
	CIMIS #148	0.36	MID	30.93	2.2	7,598	10,372	1.37
	CIMIS #148	0.36	USACE	30.93	2.2	7,598	4,272	0.56
Runoff in BRC at at Le Grand Canal (20:00 Apr. 3, 2006 to 23:00, Apr. 5, 2006)	Le Grand Head	0.29	MID	21.01		3,944	2,402	0.61
	CIMIS #148	0.36	MID	21.01		4,818	2,402	0.5
Predicted Runoff in BRC at Bear Creek Diversion (12:00 Apr. 3, 2006 to 15:00, Apr. 5, 2006)	Le Grand Head & CIMIS #148		HEC-HMS Model (CN=91)	30.93		7,093	5,319	0.75
	Le Grand Head & CIMIS #148		HEC-HMS Model (CN=91)	30.93	2.2	7,598	5,319	0.7
	Le Grand Head & CIMIS #148		HEC-HMS Model (CN=97)	30.93		7,093	6,454	0.91
	Le Grand Head & CIMIS #148		HEC-HMS Model (CN=97)	30.93	2.2	7,598	6,454	0.85
Runoff in BRC at at the Le Grand Canal (20:00 Apr. 3, 2006 to 23:00, Apr. 5, 2006)	Le Grand Head & CIMIS #148		HEC-HMS Model (CN=91)	30.93		4,818	3,589	0.74
	Le Grand Head & CIMIS #148		HEC-HMS Model (CN=97)	30.93		4,818	4,311	0.89

[a] Area of 30.93 mi^2 includes subareas BR1, BR10, BR4, and BR6 (see Figure 1-1); area of 21.01 mi^2 includes subarea BR1.

[b] Area of 2.2 mi^2 includes subareas BR2, BR3, and BR5

Table 4-1 Alternative Detention Basin Projects

Project Alternative	Culvert Outlets	Height - culvert floor to spillway crest	Height - culvert floor to embankment crest	Basin storage @ spillway crest, (acre-feet)	Basin storage @ dam crest (acre-feet)
Alternative 1 - A single large detention basin at Site C	4 - 5' x 10' culverts	10 feet	13 feet	764	1039
Alternative 2 - Three detention basins:					
Site A Basin	2 - 5' x 10' culverts *limit outflow to 100 cfs	9 feet	12 feet	167.5	278
Site B Basin		10 feet	13 feet	244.5	418
Site C Basin	6 - 5' x 10' culverts	6.5 feet	9.5 feet	467	720
Alternative 3 - A single large detention basin at Site D	8 - 5' x 10' culverts	9 feet	12 feet	1,230	1,630

Table 4-2: Black Rascal Creek Project Cost Estimate

Project Cost	Alternative 1 Single Basin @ Site C	Alternative 2 Basin @ Site A	Alternative 2 Basin @ Site B	Alternative 2 Basin @ Site C	Alternative 3 Single Basin @ Site D
Embankment Fill:					
Emb. Crest Width, ft. =	15	15	15	15	15
Height to 100-Year Water Surface, ft. =	10	9	10	6.5	9
Freeboard Above 100-Year Water Surface, ft. =	3	3	3	3	3
Emb. Height, ft. =	13	12	13	9.5	12
Upstr. Emb. Slope, H:1V =	2.5	2.5	2.5	2.5	2.5
Dwnstr. Emb. Slope, H:1V =	2.5	2.5	2.5	2.5	2.5
Emb. Length (excl. outlet), ft. =	4,509	408	380	3,135	8,000
Emb. X-Sect. Area, sq.-ft. =	288	248	365	68	540
Emb. Vol. (excl. outlet), CY =	**48,057**	**3,748**	**5,133**	**7,898**	**160,000**
Foundation:					
Foundation Excavation Depth, ft. =	3	3	3	3	3
Emb. Base Width, ft. =	53.8	48.5	58	29.5	75
No. Outlet Culvert Barrels, # =	4	2	1	6	8
Outlet/Spillway Width, ft. =	45	23	12	67	89
Embankment & Outlet Length, ft. =	4,554	431	392	3,202	8,089
Embankment & Outlet Footprint, sq.-ft. =	245,005	20,904	22,736	94,459	606,675
Foundation Vol., CY =	**27,223**	**2,323**	**2,526**	**10,495**	**67,408**
Culvert Concrete:					
Culvert Length, ft. =	15	15	15	15	15
Wall, Roof, Floor Thickness, ft. =	1.0	1.0	1.0	1.0	1.0
Barrel Width, ft. =	10	10	10	10	10
Barrel Height, ft. =	5	5	5	5	5
X-Sect. Concrete, sq.-ft. =	115	61	34	169	223
Culvert Concrete, CY =	**64**	**34**	**19**	**94**	**124**
Spillway Crest Concrete:					
Crest Elevation Above Culvert Floor, ft. =	10	9	10	7	9
Crest Height Avove Culvert Roof, ft. =	4	3	4	1	3
Crest Length, ft. =	43	21	10	65	87
Crest Thickness, ft. =	1.0	1.0	1.0	1.0	1.0
Spillway Crest Concrete, CY =	**2**	**1**	**0**	**2**	**3**
Inlet/Outlet Apron Concrete:					
Width @ Culvert, ft. =	45	23	12	67	89
Width @ Emb. Toe, ft. =	110	83	77	114.5	149
Upstr. & Dwnstr. Apron Length, ft. =	65	60	65	47.5	60
Total Apron Area, sq.-ft. =	5,038	3,180	2,893	4,311	7,140
Apron Thickness, ft. =	0.7	0.7	0.7	0.7	0.7
Apron Concrete, CY =	**124**	**79**	**71**	**106**	**176**
Wingwall Concrete:					
Wall Thickness, ft. =	0.7	0.7	0.7	0.7	0.7
Wall Height at Culvert (one side), ft. =	7.0	6.0	7.0	3.5	6.0
Concrete Above Culverts (two sides), CY =	5	4	5	3	4
Wall Height (@ Apron), ft. =	13	12	13	9.5	12
Wall Base Length (one side/end), ft. =	46	42	46	34	42
Area - 4 walls, sq.-ft. =	1,195	1,018	1,195	638	1,018
Total Wingwall Concrete, CY =	**35**	**30**	**35**	**18**	**30**
Total Concrete, CY =	**225**	**143**	**125**	**221**	**333**
Land Requirements: (Inundated area)					
Undeveloped Land, acres =	95	40	65	86	0
Agricultural Land, acres =	0	0	0	0	70
Orchard Land, acres =	0	0	0	0	70
Unit Costs:					
Embankment Fill, $/CY =	$20	$20	$20	$20	$20
Foundation, $/CY =	$9	$9	$9	$9	$9
Concrete, $/CY =	$600	$600	$600	$600	$600
Undeveloped Land, $/ac =	$3,200	$3,200	$3,200	$3,200	$3,200
Agricultural Land, $/ac =	$3,250	$3,250	$3,250	$3,250	$3,250
Orchard Land, $/ac =	$42,000	$42,000	$42,000	$42,000	$42,000

Table 4-2: Black Rascal Creek Project Cost Estimate

Project Cost	Alternative 1 Single Basin @ Site C	Alternative 2 Basin @ Site A	Alternative 2 Basin @ Site B	Alternative 2 Basin @ Site C	Alternative 3 Single Basin @ Site D
Project Construction Costs:					
Embankment Cost	$961,142	$74,951	$102,658	$157,965	$3,200,000
Foundation Cost	$245,005	$20,904	$22,736	$94,459	$606,675
Concrete Cost	$134,733	$85,663	$75,222	$132,649	$199,796
Total Construction Costs	**$1,340,880**	**$181,517**	**$200,616**	**$385,072**	**$4,006,471**
Contingencies					
Engineering @ 10% =	$134,088	$18,152	$20,062	$38,507	$400,647
Contingencies @ 50% =	$670,440	$90,759	$100,308	$192,536	$2,003,236
Construction Costs with Contingencies	**$2,145,409**	**$290,428**	**$320,986**	**$616,116**	**$6,410,354**
Undeveloped Land Cost	$304,000	$128,000	$208,000	$275,200	$0
Agricultural Land Cost	$0	$0	$0	$0	$227,500
Orchard Land Cost	$0	$0	$0	$0	$2,940,000
Total Land Costs	**$304,000**	**$128,000**	**$208,000**	**$275,200**	**$3,167,500**
Total Construction Cost Including Land =	**$2,449,409**	**$418,428**	**$528,986**	**$891,316**	**$9,577,854**
Environmental Impacts:					
Direct Environmental Impacts, acres =	5.66	0.53	0.55	2.2	13.9
Indirect Environmental Impacts, acres =	95	40	65	86	0
Environmental Impacts Unit Costs					
Wetland/vernal pool density	0.2	0.2	0.2	0.2	0.2
Direct (vernal pools) (3:1 mitigation)					
Preservation of Vernal pools (cost/acre) (2:1)	$65,000	$65,000	$65,000	$65,000	$65,000
Creation of new Vernal Pools (1:1)	$130,000	$130,000	$130,000	$130,000	$130,000
Indirect Environmental Costs (vernal pool habitat)					
Preservation of Vernal pools (cost/acre) (2:1)	$65,000	$65,000	$65,000	$65,000	$65,000
Environmental Review/Permitting (per alternative)	$500,000			$500,000	$500,000
Direct Environmental Impacts for Agricultural Land	$15,000	$15,000	$15,000	$15,000	$15,000
Environmental Costs:					
Direct Environmental Costs =	$294,399	$27,464	$28,676	$112,761	$208,910
Indirect Environmental Costs =	$2,470,000	$1,040,000	$1,690,000	$2,236,000	$0
Total Environmental Costs =	**$3,264,399**	**$1,067,464**	**$1,718,676**	**$2,848,761**	**$708,910**
Total Including Land and Environmental Costs =	**$5,713,808**	**$1,485,891**	**$2,247,662**	**$3,740,077**	**$10,286,764**
				$7,473,630	
Total Costs Without Land Costs =	**$5,409,808**	**$1,357,891**	**$2,039,662**	**$3,464,877**	**$7,119,264**
				$6,862,430	

NOTES:

(1) Area of direct impact is assumed to be equal to foot print of the dam.

(2) Indirect impacts are assumed equal to the inundated area.

(3) Costs of impacts are based on a 3:1 mitigation ratio for direct impacts to wetlands. Wetland density is assumed to be 20 percent of total grasslanc area affected. Mitigation for direct impacts would include 2:1 preservation at $65,000 per impact acre and 1:1 creation at $130,000 per acre of impact. Mitigation for indirect impacts is assumed to be preservation credits at a 2:1 ratio based on a cost of $65,000 per acre of indirect impact. A flat cost of $500,000 is included for each site that would include all environmental review and permitting.

(4) Site D basin is located on land that is currently cultivated with low potential for vernal pool species. Cost estimate is based on a 1:1 mitigation ratic for direct loss of potential foraging habitat for Swainson's hawks and San Joaquin kit fox at $15,000 per acre.

Table 5-1

Special-Status Species Known to Occur in the Study Area Vicinity

Common Name	Scientific Name	Federal Status	State Status	CDFG/CNPS*
Tricolor blackbird	*Agelaius tricolor*			SC
Henderson's bent grass	*Agrostis hendersonii*			3.2
California tiger salamander	*Ambystoma californiense*	Threatened		SC
Burrowing owl	*Athene cunicularia*			SC
Conservancy fairy shrimp	*Branchinecta conservatio*	Endangered		
Vernal pool fairy shrimp	*Branchinecta lynchi*	Threatened		
Midvalley fairy shrimp	*Branchinecta mesovallensis*			No status
Ferruginous hawk	*Buteo regalis*			SC
Swainson's hawk	*Buteo swainsoni*		Threatened	
Hoover's calycadenia	*Calycadenia hooveri*			1B.3
Succulent owl's-clover	*Castilleja campestris* ssp. *succulenta*	Threatened	Endangered	1B.2
Mountain plover	*Charadrius montanus*			SC
Beaked clarkia	*Clarkia rostrata*			1B.3
Merced kangaroo rat	*Dipodomys heermanni dixoni*			No status
Dwarf downingia	*Downingia pusilla*			2.2
Western pond turtle	*Emys (=Clemmys) marmorata*			SC
Spiny-sepaled button-celery	*Eryngium spinosepalum*			1B.2
Western mastiff bat	*Eumops perotis californicus*			SC
Merlin	*Falco columbarius*			SC
Boggs Lake hedge-hyssop	*Gratiola heterosepala*		Endangered	1B.2
Bald eagle	*Haliaeetus leucocephalus*	Threatened	Endangered	
Vernal pool tadpole shrimp	*Lepidurus packardi*	Endangered		
California linderiella	*Linderiella occidentalis*			No status
Molestan blister beetle	*Lytta molesta*			No status
Hardhead	*Mylopharodon conocephalus*			SC
Pincushion navarretia	*Navarretia myersii* ssp. *myersii*			1B.1
Shining navarretia	*Navarretia nigelliformis* ssp. *radians*			1B.2
Colusa grass	*Neostapfia colusana*	Threatened	Endangered	1B.1
San Joaquin Valley orcutt grass	*Orcuttia inaequalis*	Threatened	Endangered	1B.1
Hairy orcutt grass	*Orcuttia pilosa*	Endangered	Endangered	1B.1
San Joaquin pocket mouse	*Perognathus inornatus inornatus*			No status
Merced phacelia	*Phacelia ciliata* var. *opaca*			1B.3
Foothill yellow-legged frog	*Rana boylii*			SC
Sanford's arrowhead	*Sagittaria sanfordii*			1B.2
Keck's checkerbloom	*Sidalcea keckii*	Endangered		1B.1
Western spadefoot	*Spea (=Scaphiopus) hammondii*			SC
Giant garter snake	*Thamnophis gigas*	Threatened	Threatened	
Greene's tuctoria	*Tuctoria greenei*	Endangered	Rare	1B.1
San Joaquin kit fox	*Vulpes macrotis mutica*	Endangered	Threatened	

SC – Species of Special Concern

List 1B – Plant species that are rare, threatened, or endangered in California and elsewhere

List 2 – Plant species that are rare, threatened, or endangered in California but more common elsewhere

List 3 – Plants about which we need more information

CNPS Threat Codes (indicated as a number to the right of the decimal point):

.1 - Seriously endangered in California (over 80 percent of occurrences threatened / high degree and immediacy of threat)

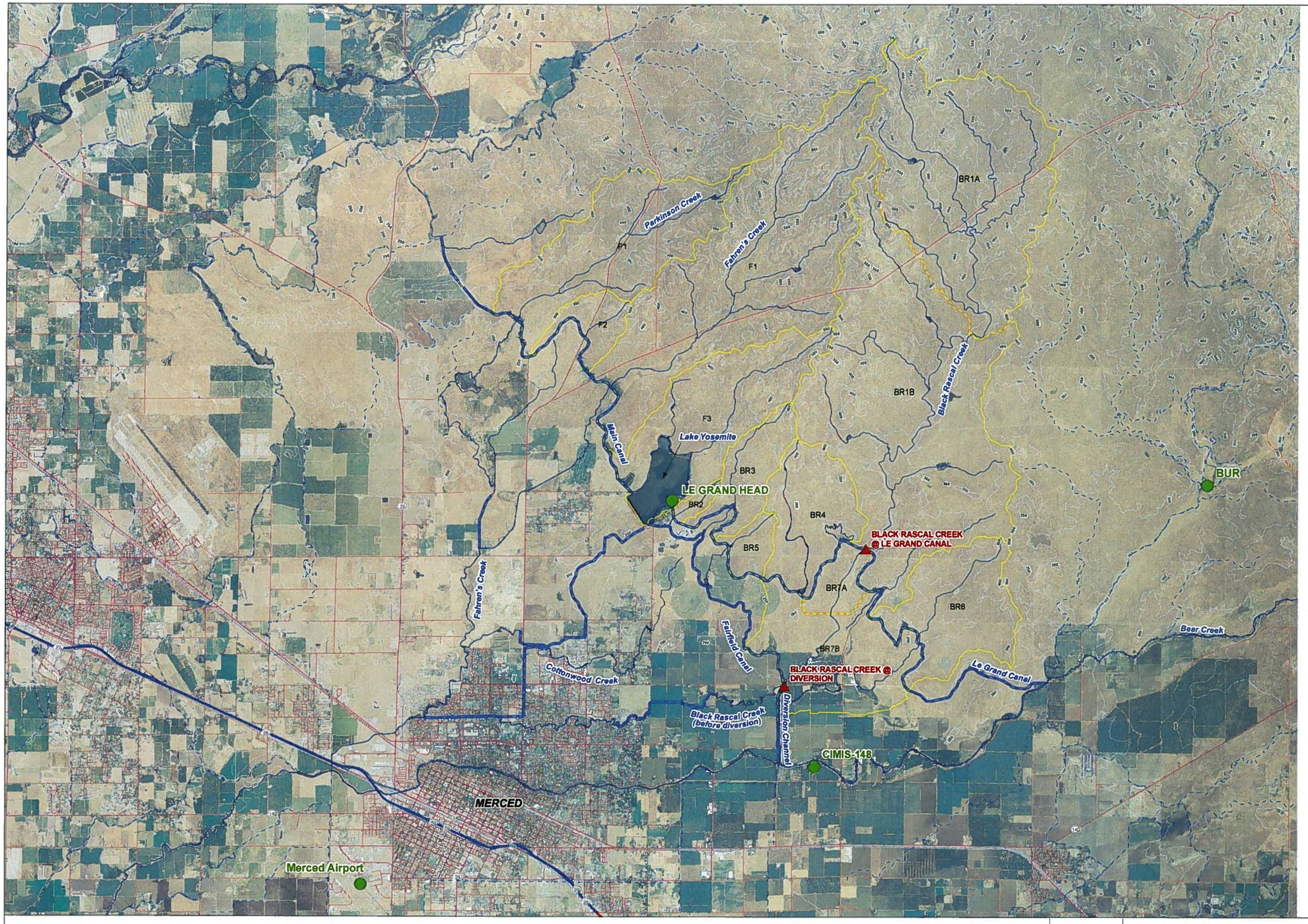
.2 – Fairly endangered in California (20-80 percent occurrences threatened)

.3 – Not very endangered in California (<20 percent of occurrences threatened or no current threats known)

Table 6-1
Comparison of Alternative Projects

Evaluation Criteria	Basin/Project Capabilities	Comments
Potential DSOD Jurisdiction:	All basins, regardless of whether or not they are provided in combination with other basins or as the only basin, will probably be under DSOD jurisdiction.	Based on comparison to Burns Dam, the spillways for the larger basins at Sites C & D may be adequate.
Effectiveness In Reducing BRC Flows:	All Alternatives are equally effective in reducing BRC flows.	
Environmentally Acceptable:		
Site C - Alternatives 1 & 2	Has Known Adverse Environmental Impacts - **Probably Not Permitable**	If Permitted, Environmental Mitigation May Be Very Costly
Site A - Alternative 2	Probably Has Adverse Environmental Impacts But Needs Investigations (not previously studied in detail)- Possibly Permitable	Will Probably Incur Significant Environmental Mitigation Cost. Requires long access road and associtate impacts
Site B - Alternative 2	May have least adverse environmental impacts, needs more investigation (not previously studies in detail) - Probably Permitable	Will Probably Have Some Environmental Mitigation Cost. Requires long access road and associated impacts.
Site D - Alternative 3	May have least environmental impacts - impacts primarily to agricultual land	May be one house relocation - no other known social impacts. Environmental impacts could possibly be reduced further. Detailed topographic data should be collected for final design if this option is selected.
Relative Project Costs:		
Alternative 1 - Site C Only	$5,713,808	Construction Cost = 38%, Land Cost = 5%, Environmental Cost = 57%
Alternative 2 - Sites A, B, & C	$7,473,630	Construction Cost = 17%, Land Cost = 8%, Environmental Cost = 75%
Alternative 3 - Site D Only	$10,286,764	Construction Cost = 62%, Land Cost = 31%, Environmental Cost = 7%

Figures



URS

Black Rascal Creek

Project no. 18715153

Watershed Map and Location of Precipitation Stations

Figure 1-1

URS Corp - Oakland CA - S.Lowrie X:\v_water\Black_Rascal_Creek\Watershed_Map_061908\Figure_1-1_Watershed_Map.mxd - 7/1/2008 @ 11:30:28 AM

FIGURE 2-1: Measured Precipitation near the Black Rascal Creek Watershed for the April 2006 Storm Event

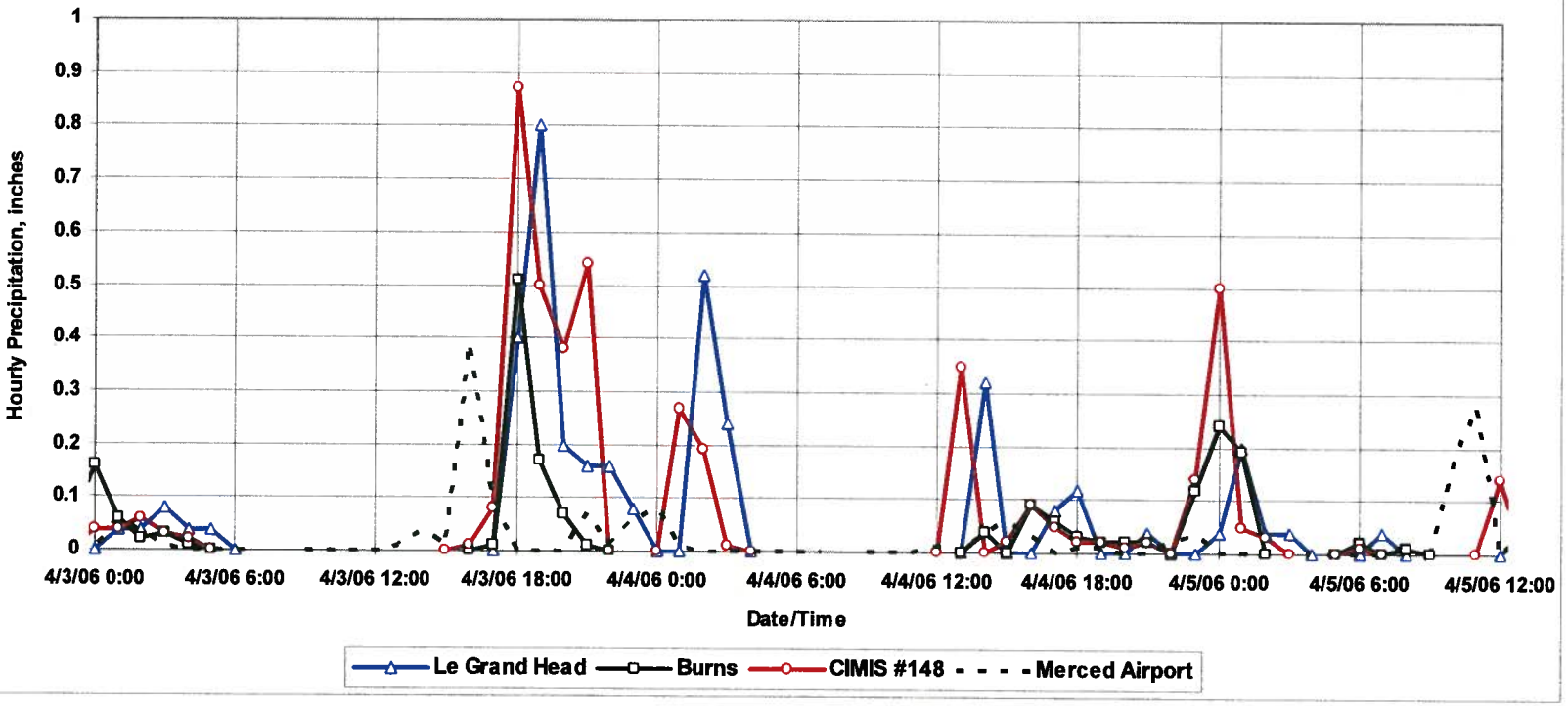


FIGURE 2-2 Comparison between Measured Rainfall Volumes at Selcted Gauges near the Project Site for the April 2006 Storm Event and Estimates of the 100 - Year Rainfall Volume

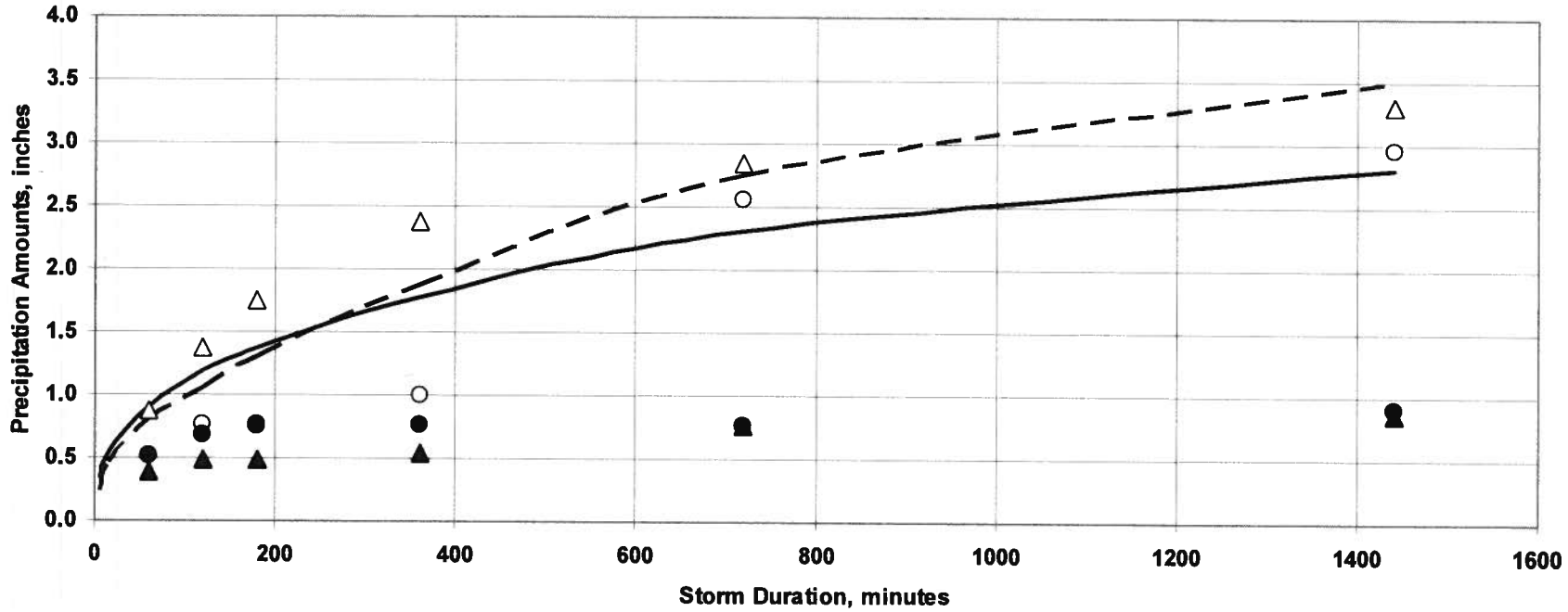


FIGURE 2-3 Measured Flows in Black Rascal Creek (BRC) and the Fairfield Canal for the April 2006 Storm Event

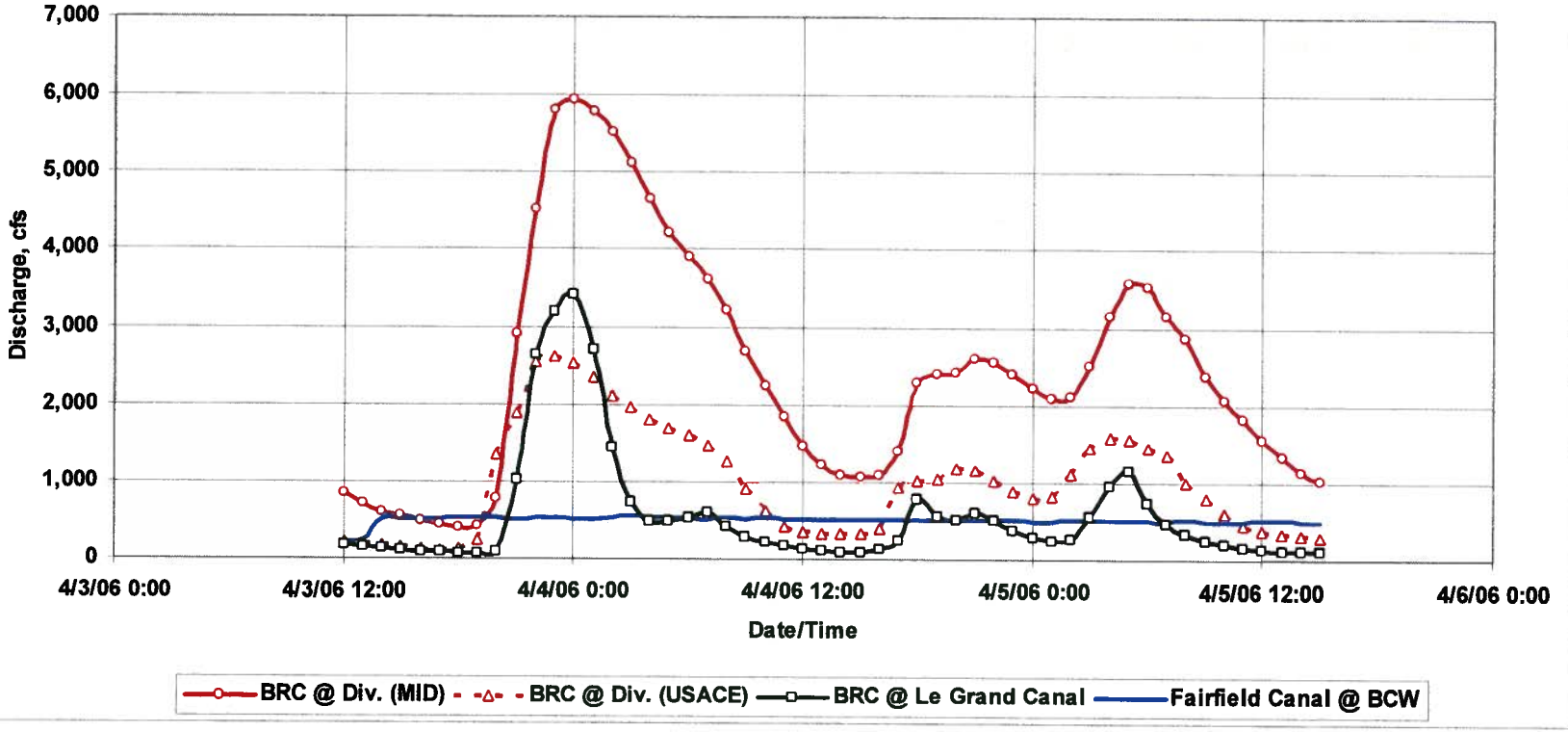


Figure 2-4: Schematic of HEC-HMS Model Used to Simulate Black Rascal Creek Watershed Detention Basins

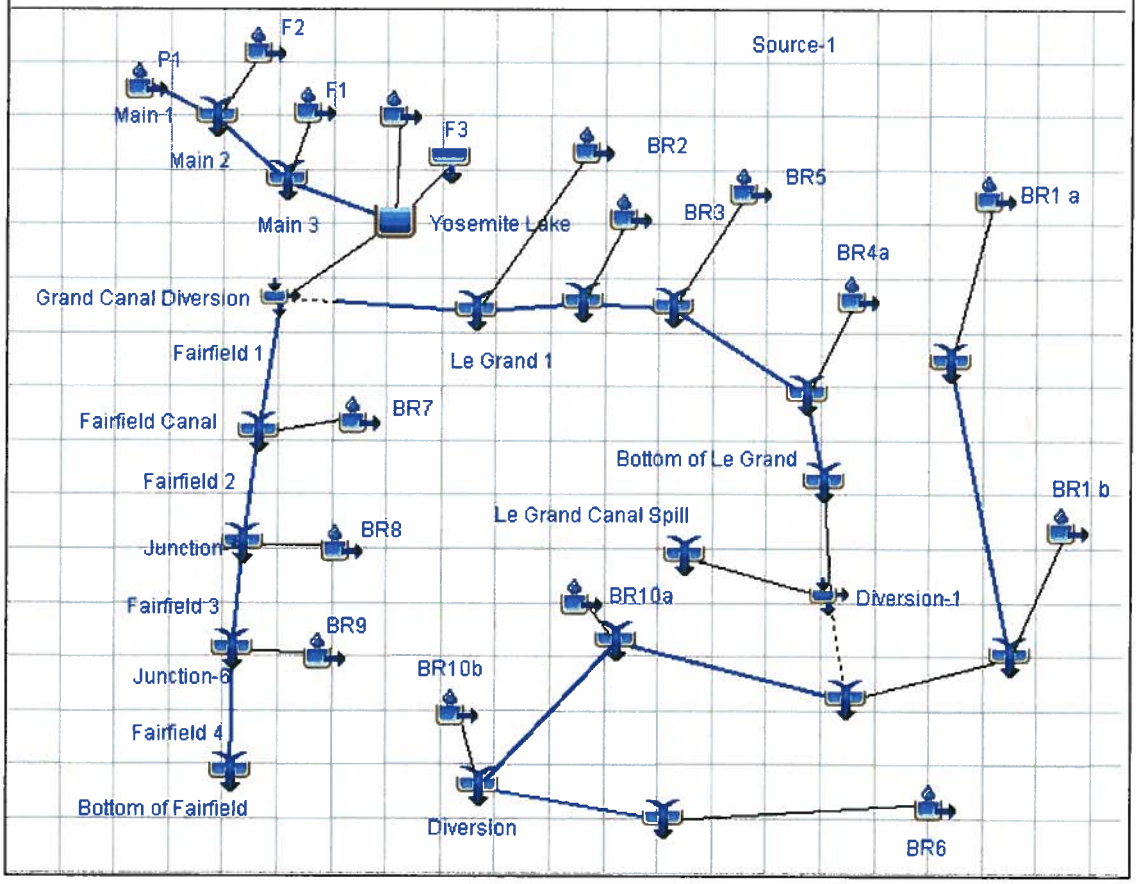


FIGURE 3-1 Comparison between Calculated and Measured Flows in Black Rascal Creek at the Le Grand Canal Crossing for the April 2006 Storm Event

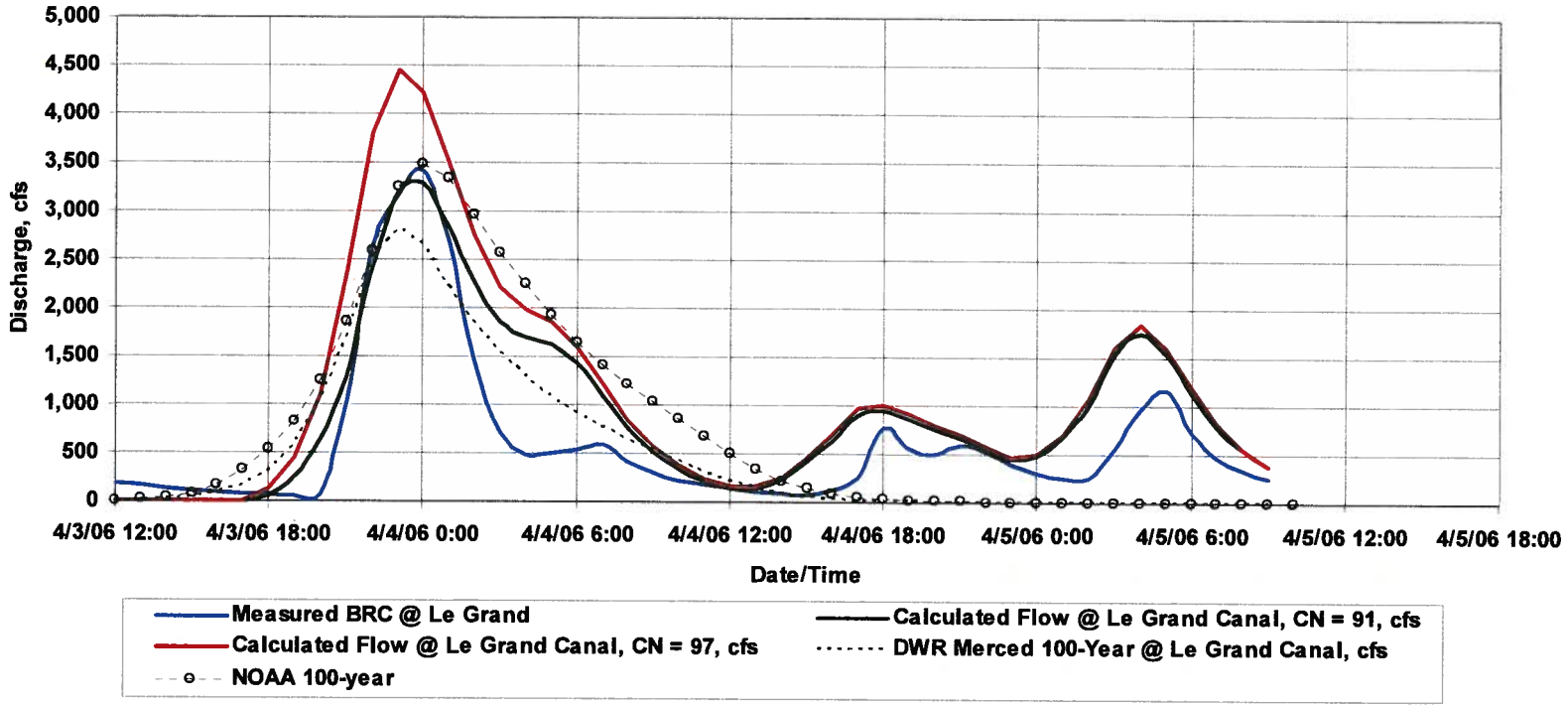


FIGURE 3-2 Comparison between Calculated and Measured Flows in Black Rascal Creek at the Diversion for the April 2006 Storm Event

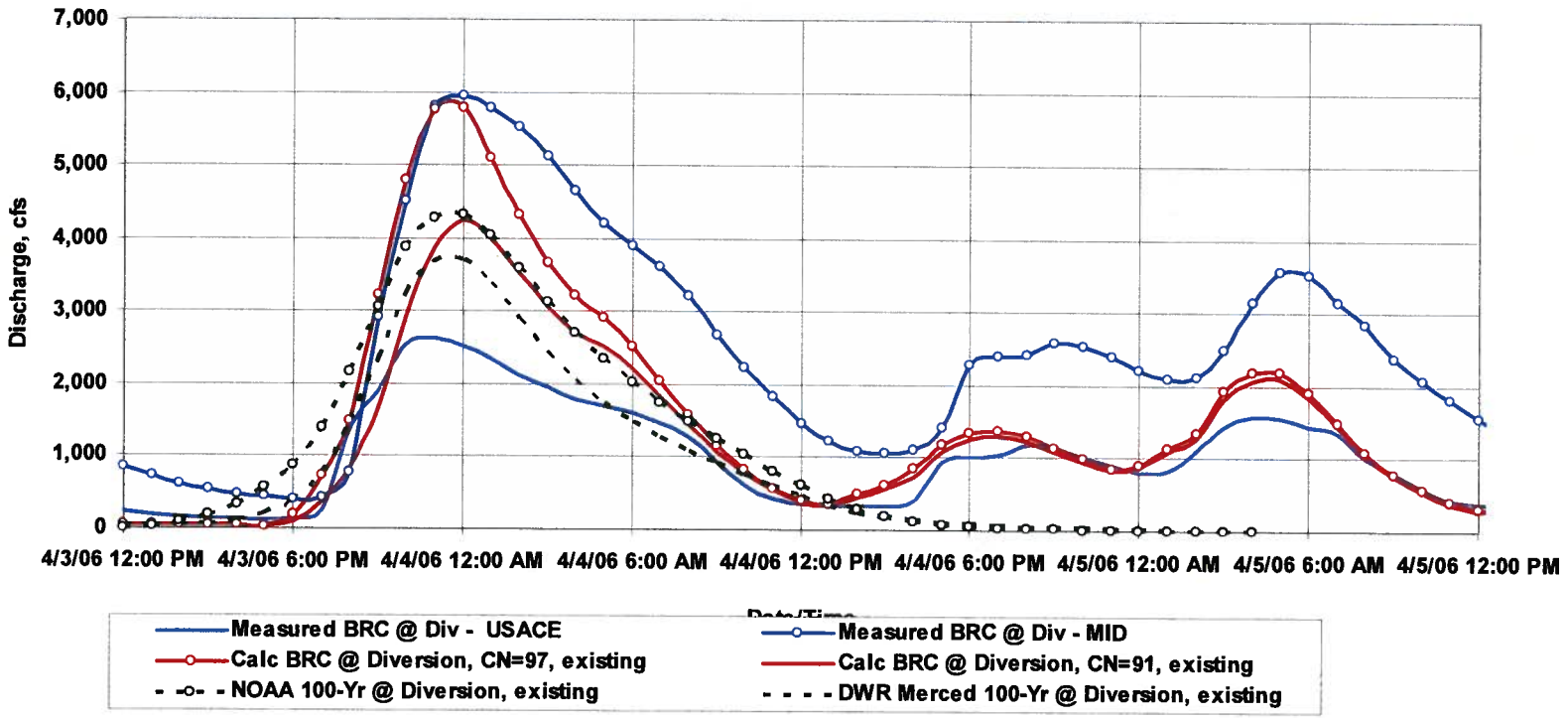


Figure 3-3: Stage in Lake Yosemite During April 2006 Storm Event

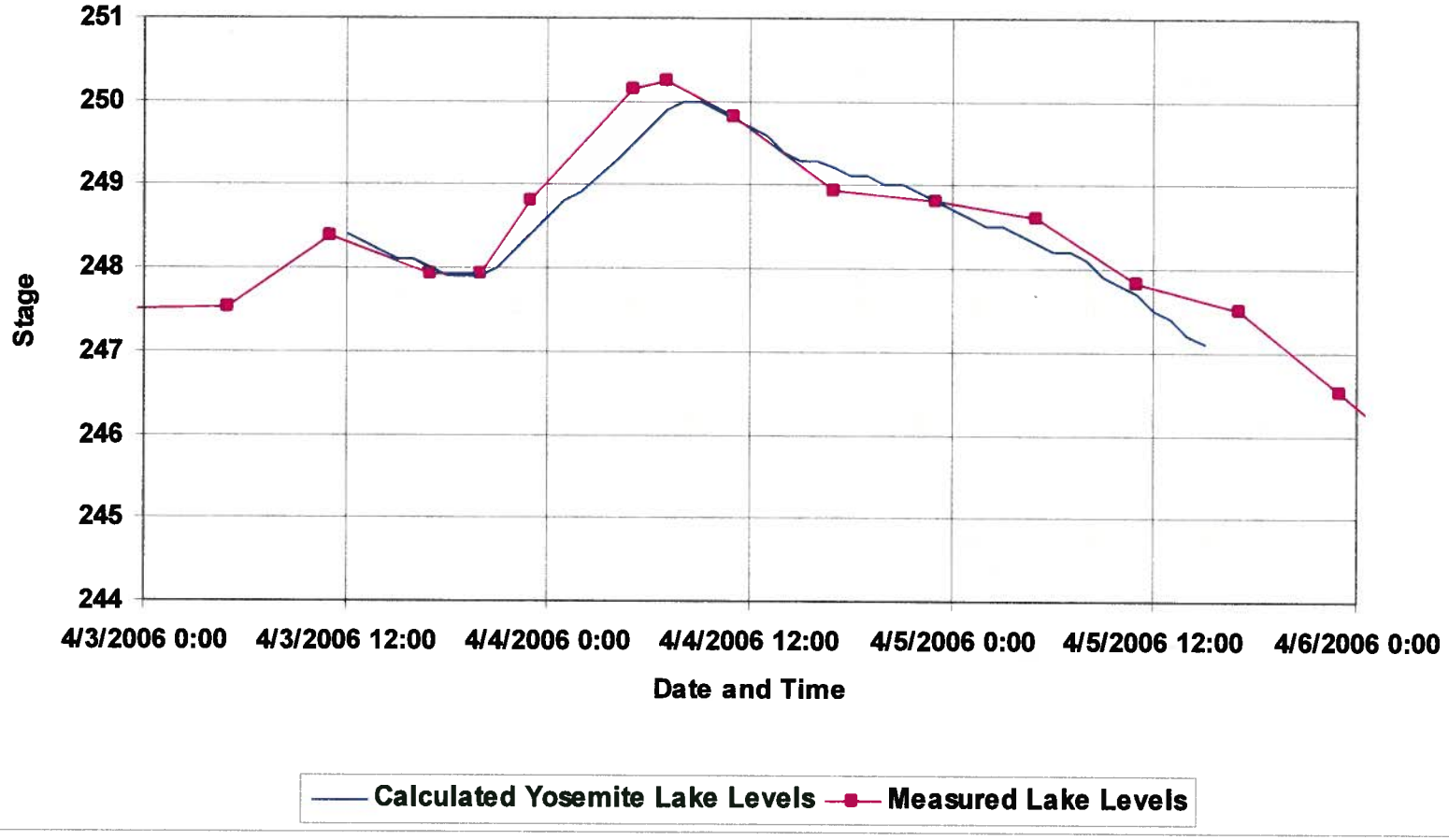
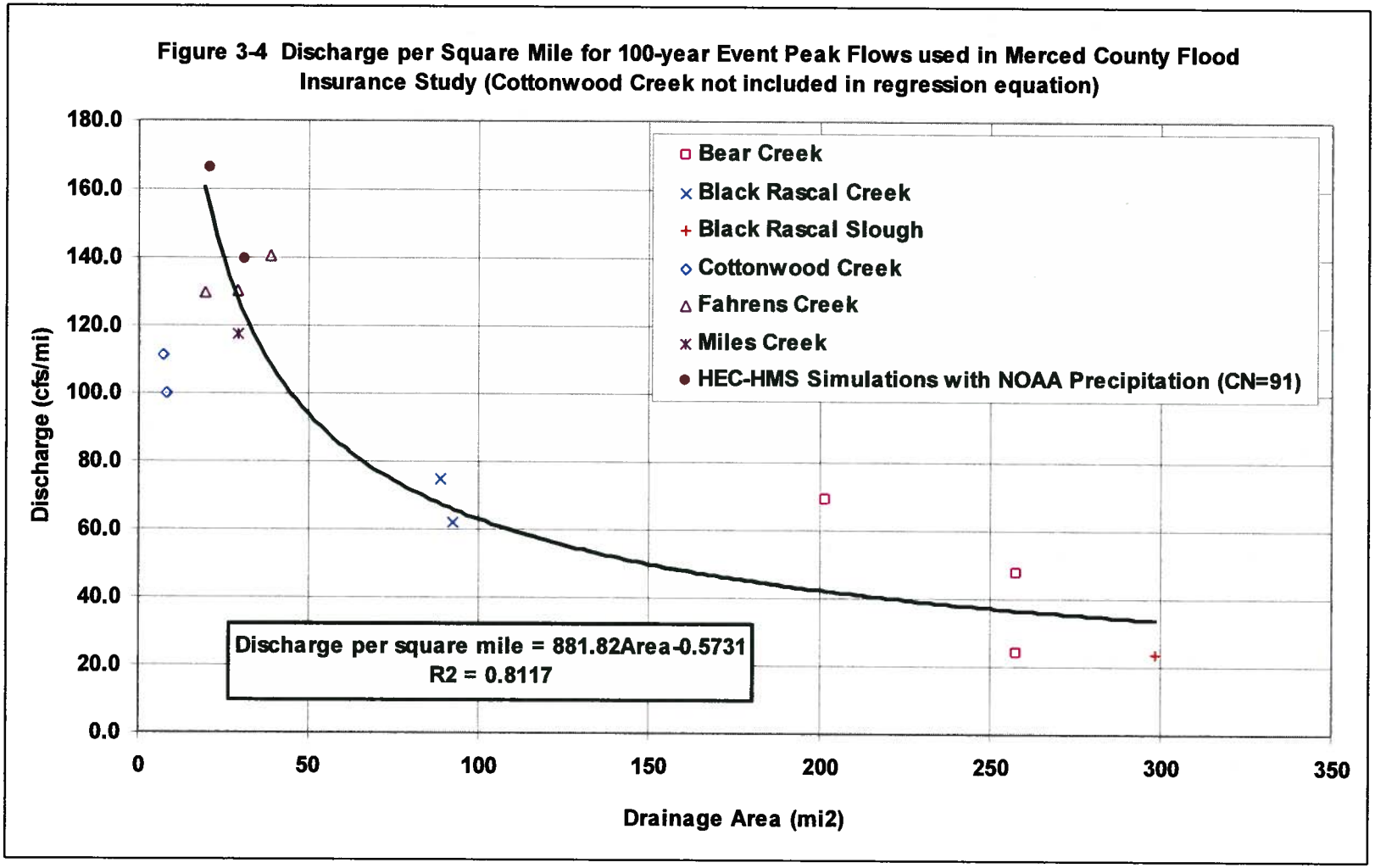
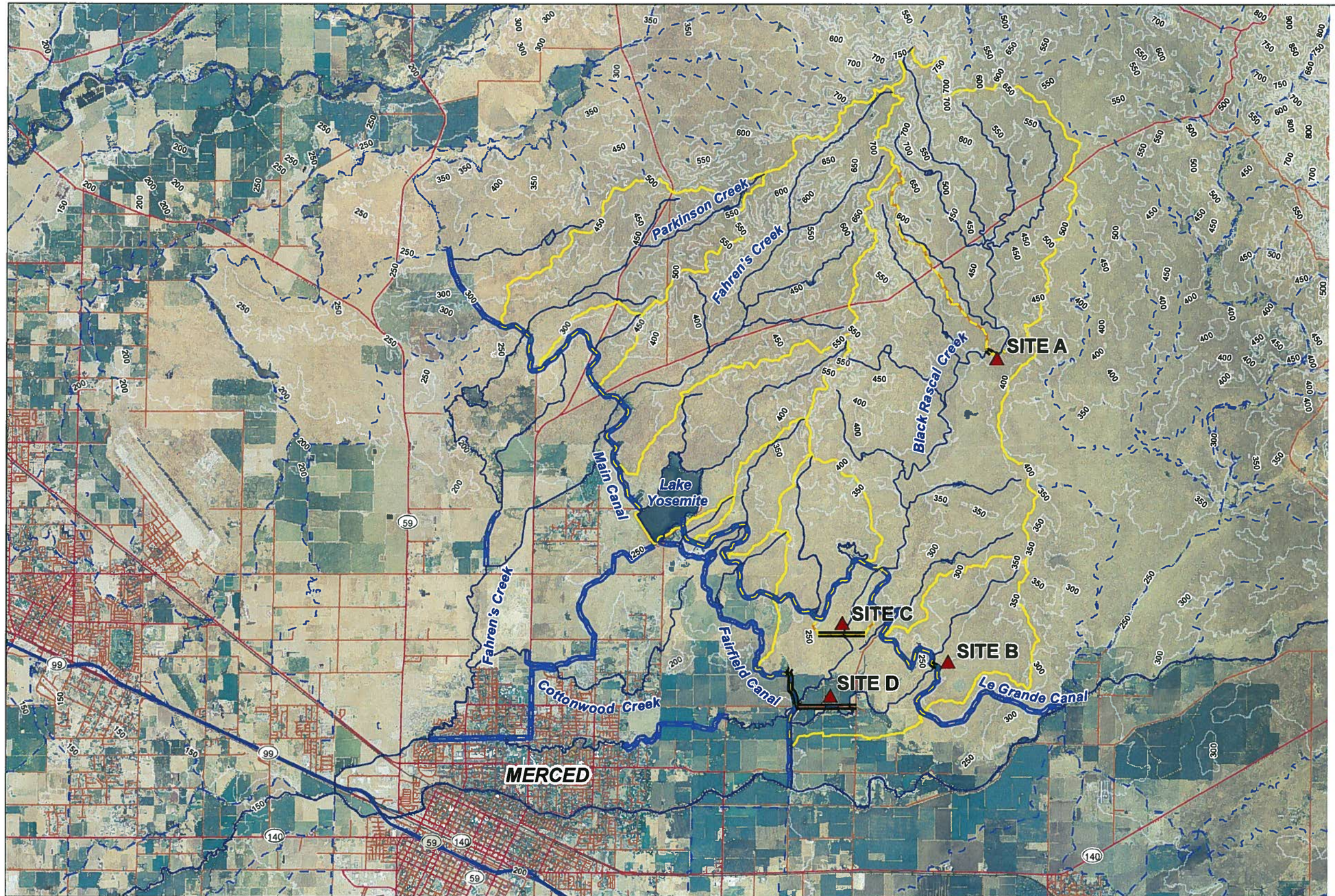


Figure 3-4 Discharge per Square Mile for 100-year Event Peak Flows used in Merced County Flood Insurance Study (Cottonwood Creek not included in regression equation)





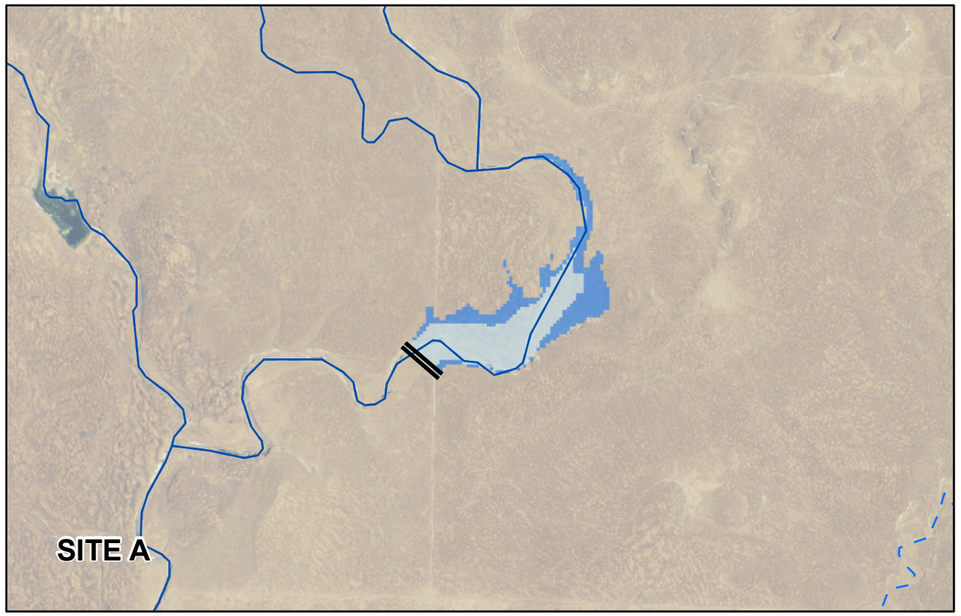
URS

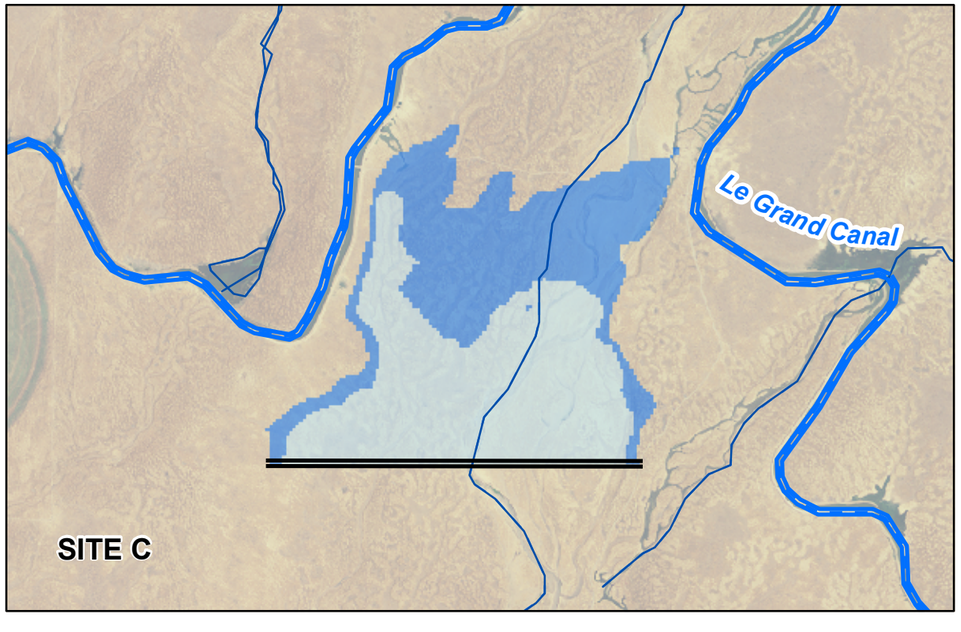
Black Rascal Creek

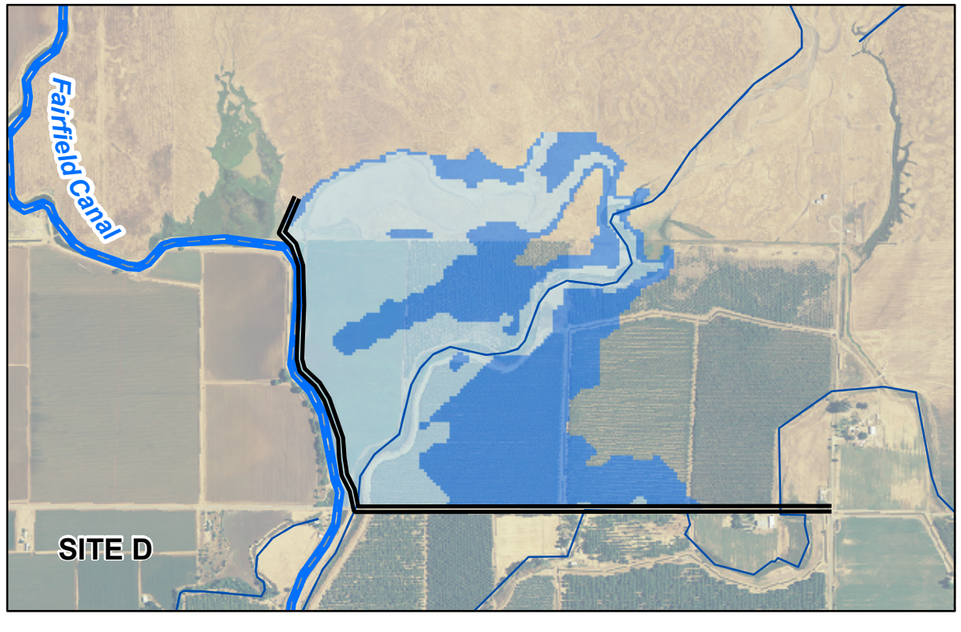
Project no. 18715153

Location of Detention Basins

Figure 4-1







100 - Year Flood Inundation Areas

CN = 91

CN = 97

Detention Basin Embankment

0 500 1000 2000
Feet

0 0.125 0.25 0.5
Miles

N

URS

Black Rascal Creek

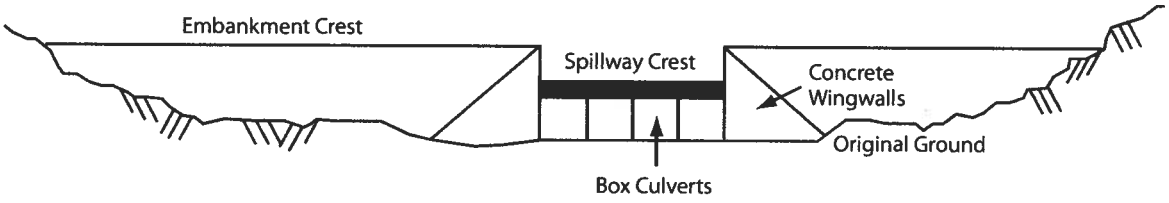
Project no. 18715153

Detail of Detention Basins

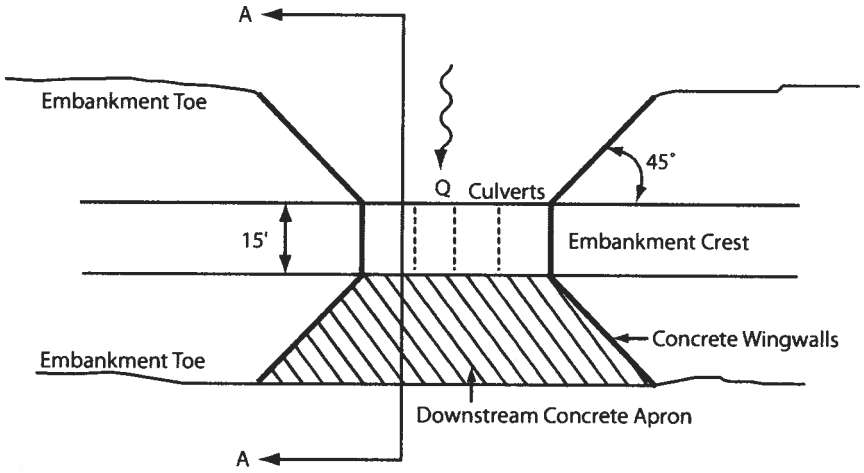
Figure 4-2

URS Corp - Oakland CA - S:\Levine X-fs_water\Black_Rascal_Creek\Watershed_Map_061908\Figure_4-2_Watershed_Map.mxd - 7/11/2008 @ 2:02:41 PM

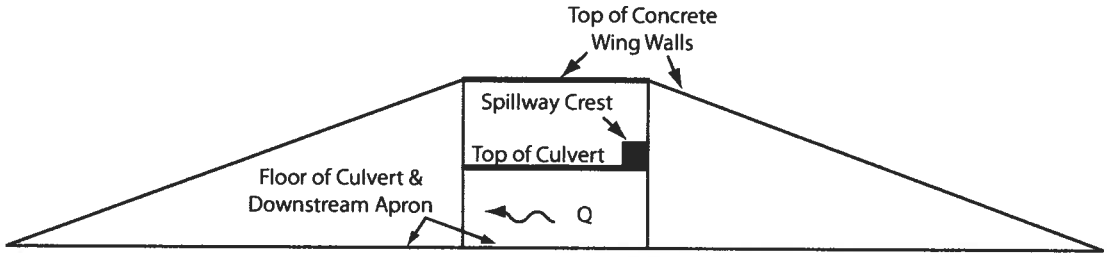
Figure 4-3
Conceptual Design of Detention Basin Dams



Profile—Detention Basin Embankment



Plan View—NTS



Section A-A—NTS

FIGURE 4-4 Discharge Hydrographs for the Three Detention Basin Alternatives Proposed for the Black Rascal Creek Watershed

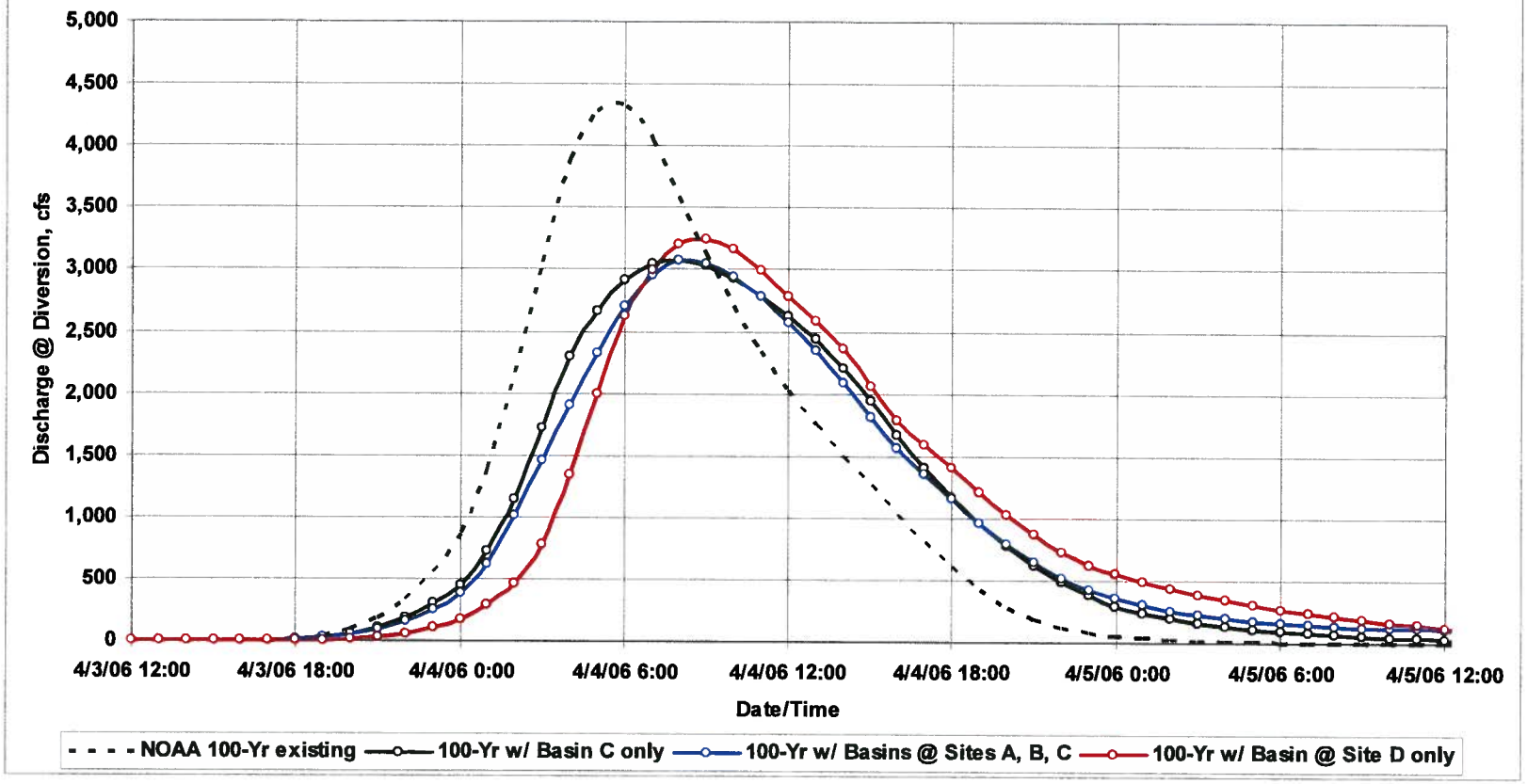
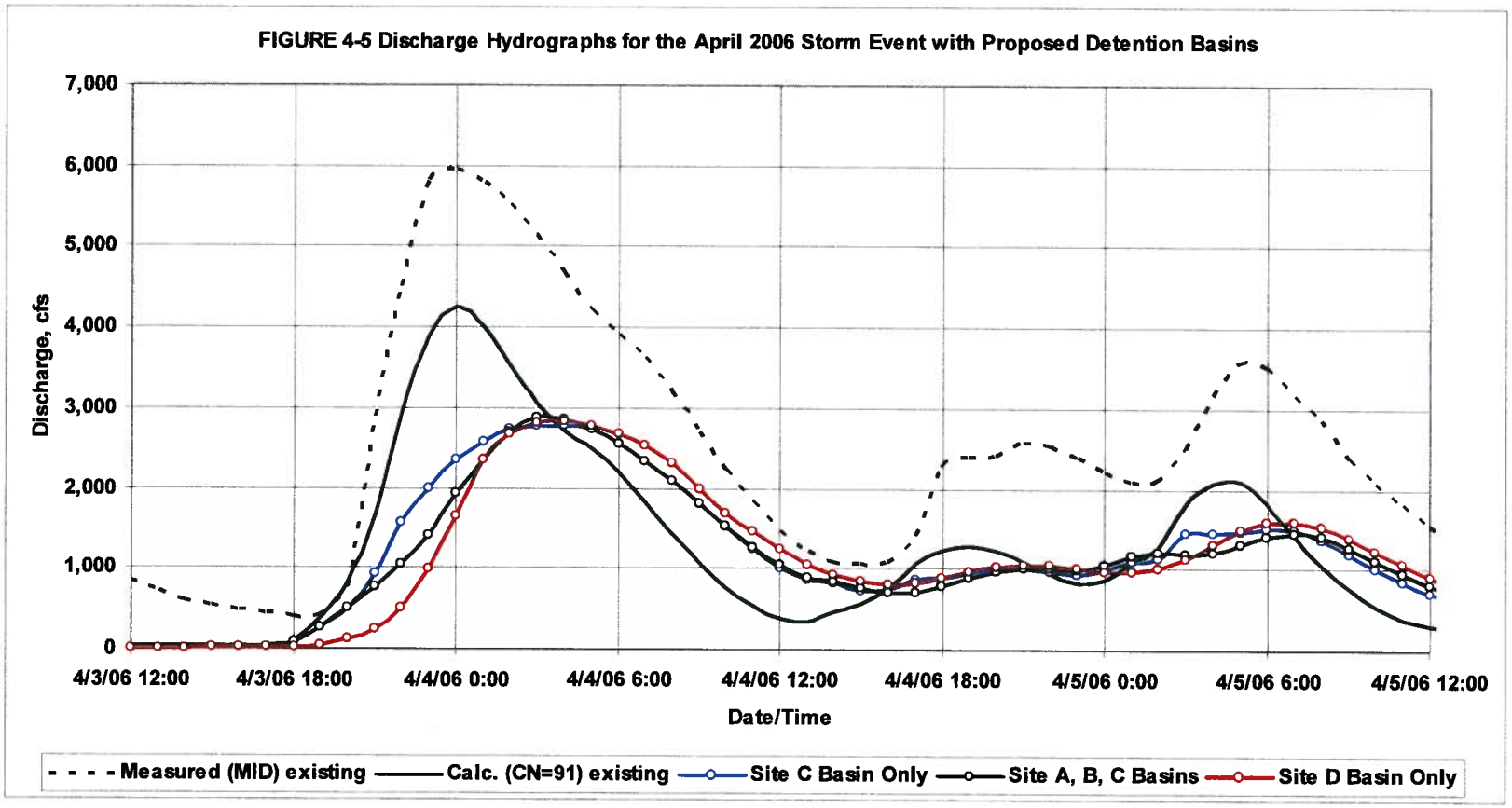


FIGURE 4-5 Discharge Hydrographs for the April 2006 Storm Event with Proposed Detention Basins



Appendix A
Environmental Resources

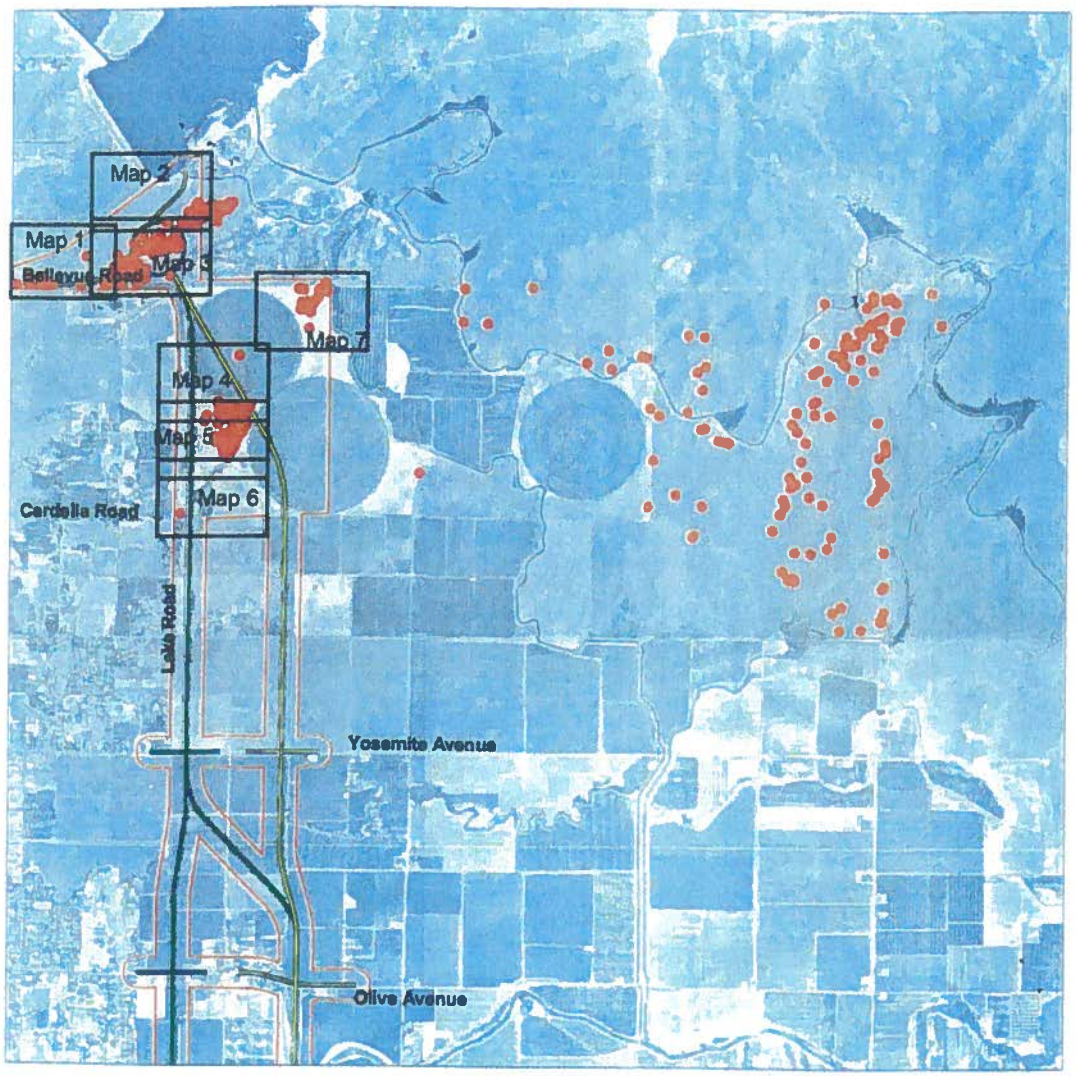


Figure A-1. Occurrences of Vernal Pool Fairy Shrimp in the Project Area

Figure A-2. Occurrences of Midvalley Fairy Shrimp and Vernal Pool Tadpole Shrimp in the Project Area

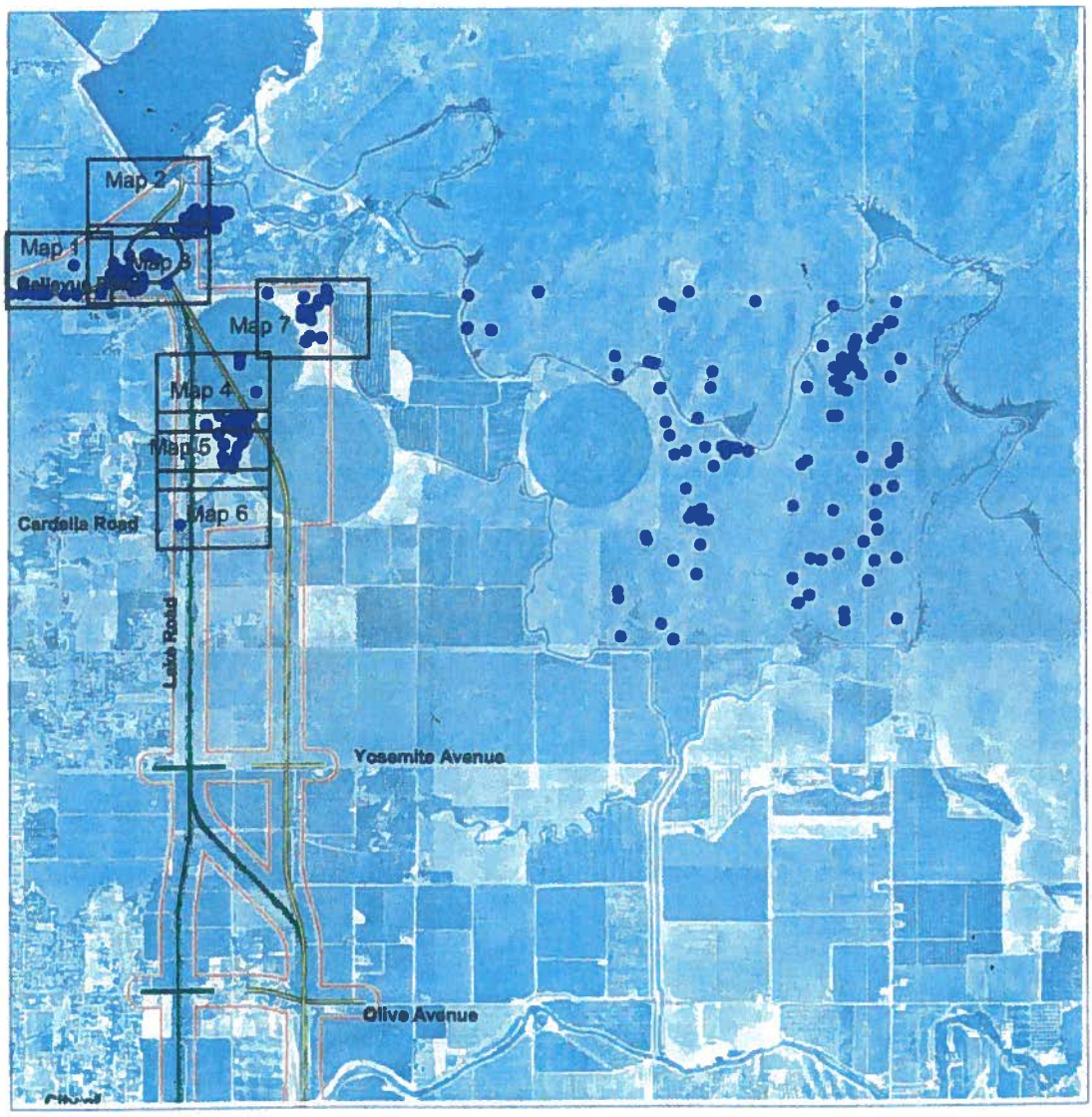


Figure A-3. Occurrences of California Fairy Shrimp

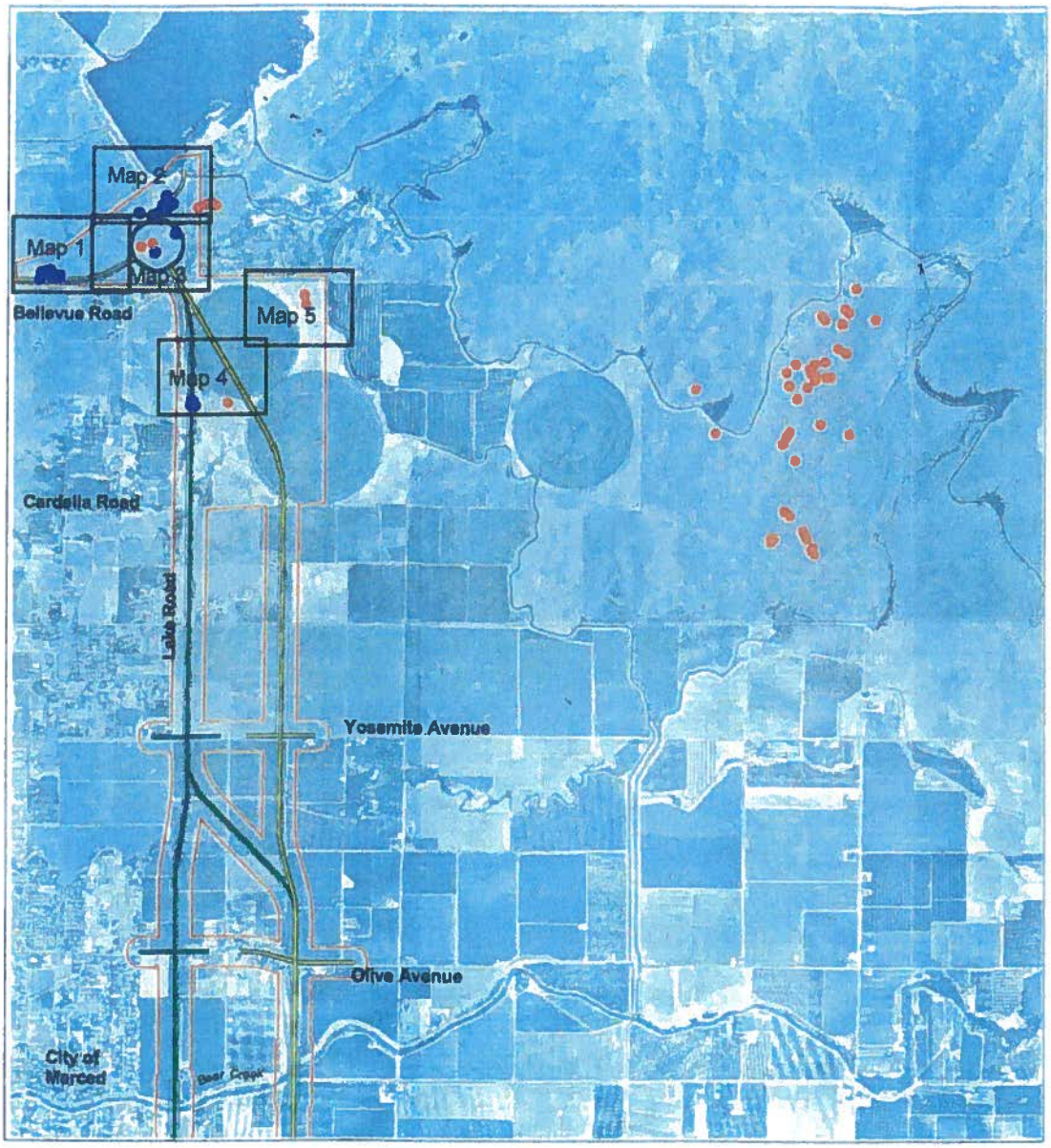


Figure A-4. Occurrences of Special Status Species (Succulent Owl's Clover) in the Project Area

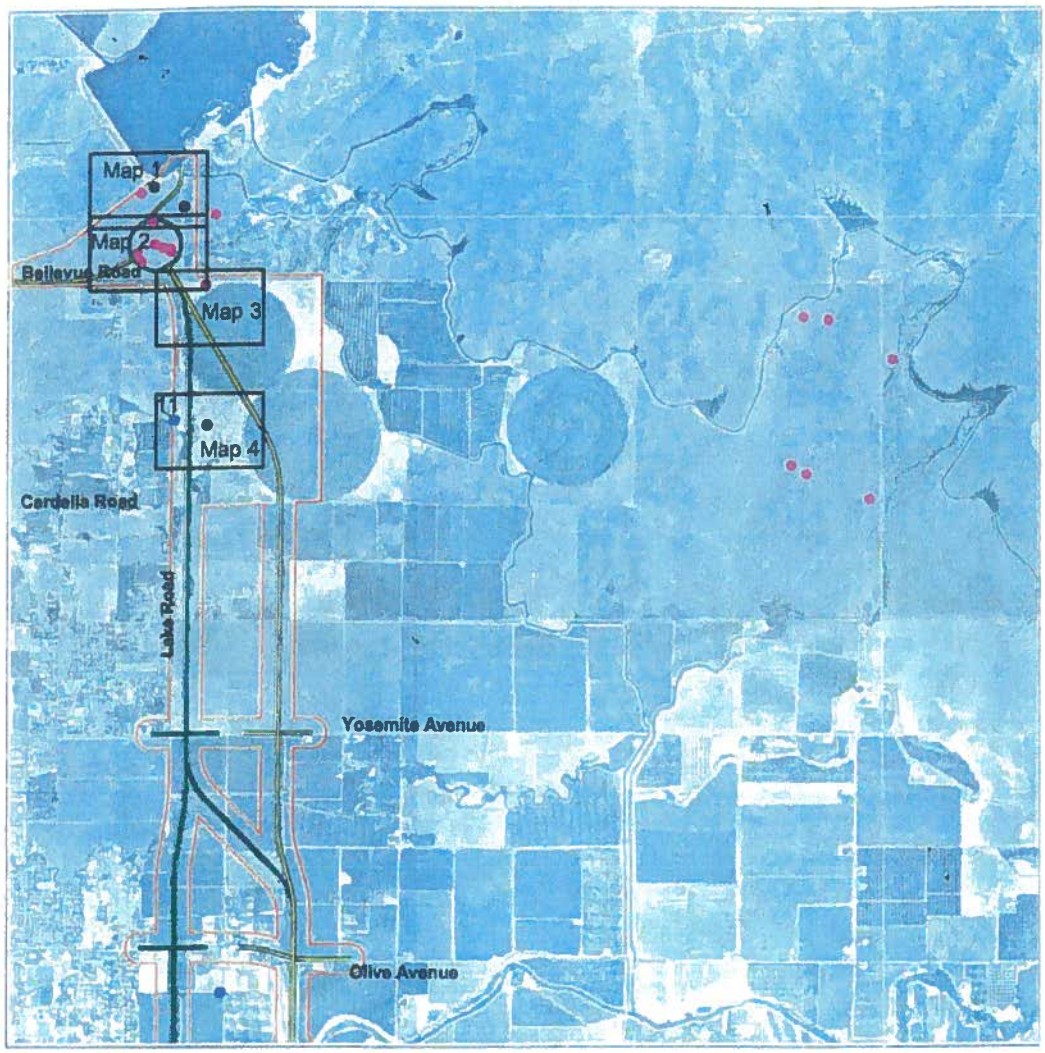


Figure A-5. Occurrences of Burrowing Owl in the Project Study Area

Appendix B
Addendum 1

Feasibility Study

Black Rascal Creek Flood Control Project

Addendum 1 to Final Report

February 27, 2009

Disclaimer

This Addendum 1 to the Final Report of Feasibility Study for the Black Rascal Creek Flood Control Project was completed for the County of Merced in a manner consistent with the level of care and skill ordinarily exercised by professional engineers, geologists, and environmental scientists in the geographic area of the site. URS provides no other warranties, either express or implied, concerning the contents of this report, which was prepared under technical direction of the undersigned.

URS Corporation

Phillip Mineart, PE
Senior Hydrologist

Thomas C. MacDonald, PE
Senior Consultant

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1.0 INTRODUCTION

1.1 Background

In June 2008 URS prepared the report, *Feasibility Study, Black Rascal Creek Flood Control Project.* The report presented three alternative detention basin projects that would reduce the peak 100-year flood discharge at the upstream end of the Black Rascal Creek diversion channel to about 3000 cubic feet per second (cfs).

Since completion of the June 2008 report, the City of Merced, County of Merced and Merced Irrigation District (the Streams Group) have requested that additional studies be completed to determine the approximate facility sizes, costs, and impacts if the three alternative project concepts presented in the June 2008 report are upgraded to reduce the peak 200-year flood discharge at the upstream end of the diversion channel to about 3000 cfs. URS understands that the Streams Group needs protection against a 200-year flood event to obtain funding assistance for a flood control project.

In November 2008, the County of Merced (on behalf of the Streams Group) authorized URS to prepare an addendum to the June 2008 report. This addendum presents the results of additional studies of the three original project alternatives but with increased capacity to protect against a 200-year flood event. In addition, they asked that a variation on one of the original project alternatives that would reduce environmental impacts be added to the studies.

1.2 Purpose

The purpose of this addendum is to increase the scope of URS' June 2008 ("main") report to address flood protection against a 200-year flood event.

1.3 Scope

The three flood control concepts presented in the main report were analyzed to determine approximate facility sizes, costs, and impacts if they are designed to protect against a 200-year flood event. A variation on one of the original project alternatives to reduce environmental impacts was also studied.

This addendum is not a stand-alone document but is intended to be used in conjunction with the main report. Thus, analyses methodologies, data descriptions and sources, numerical model description and calibration, and description of the environmental setting are not included in this addendum but are included in the main report. In addition, the figures and tables presented in this addendum use table and figure numbers that correspond to the table and figure numbers used in the main report, by adding the letter "A" as a prefix. For example, Table A2-3 corresponds to Table 2-3 in the main report but includes the 200-year event data. The exceptions are Figures A-1 and A-2, which are unique to this addendum. This facilitates comparison of the 200-year results presented in the addendum to the 100-year results presented in the main report.

The following specific tasks are included in the scope of work for this addendum:

1. Research NOAA Atlas 2 and Merced Airport precipitation gauges. Determine 24-hour duration, 200-year precipitation by plotting, interpolation, and extrapolation and prepare a new precipitation versus duration table and figure for the 200-year storm event (equivalent to Table 2-3 and Figure 2-2 in the main report).
2. Calculate the temporal distribution of the theoretical 24-hour duration, 200-year
3. Conduct HEC-HMS analyses of detention basin requirements for the 200-year storm event for the three alternative project configurations described on page 4-2 of the main report.
4. Add one new optional alternative that provides a single detention basin at Site D with levees to confine inundation to primarily agricultural land.
5. Prepare new maps of inundation at the basin sites for the 200-year flood event (equivalent to Figure 4-2 of the main report).
6. Prepare a new figure showing hydrographs with & without projects for the 200-year flood event (equivalent to Figure 4-4 of the main report).
7. Prepare new tables presenting facility sizes and costs for 200-year flood protection (equivalent to Tables 4-1 and 4-2 of the main report).
8. Prepare a new table that compares the three 200-year flood protection alternatives (equivalent to Table 6-1 of the main report).
9. Prepare an addendum to the main report to include the above analyses, tables and figures.
10. Provide an Independent Technical Review (ITR) and Project Management services for this scope of work.

2.0 ANALYSIS RESULTS

2.1 Two Hundred-Year, 24-Hour Precipitation Amount and Temporal Distribution

Precipitation-duration amounts for the 200-year, 24-hour storm event were obtained from the DWR website (http://www.weather.water.ca.gov/engineering/) for the Merced Airport location. Precipitation amounts for 5-minute and 15-minute and 1-hour, 3-hour, 6-hour, 12-hour, and 24-hour durations were estimated for the 2-year, 5-year, 10-year, 25-year, 50-year and 100-year return frequency storm events using procedures presented in NOAA Atlas 2. These values were plotted as shown in Figure A-1 as return frequency versus precipitation amount for each of the durations. The plots were extrapolated assuming a linear-log fit to estimate the 200-year precipitation amounts for each of the durations. The results of these estimates are presented in Table A2-3 and Figure A2-2. Also included in Table A2-3 and Figure A2-2 are the precipitation-duration amounts for the 100-year storm events that are presented in the main report, Table 2-3 and Figure 2-2. The NOAA Atlas 2 precipitation-duration estimates presented in Table A2-3 for the 200-year storm event were used in subsequent analyses for this addendum (the 100-year NOAA Atlas 2 precipitation amounts were used in the alternatives analyses presented in the main report).

The temporal distribution of the 200-year precipitation amount was determined using the same methodology as was used for the main report analyses of the 100-year flood event. The temporal distribution is illustrated in Figure A-2.

Figure A-1 Plot of Precipitation Depth versus Return Period for Estimated Storm Durations and Volumes from NOAA Atlas 2

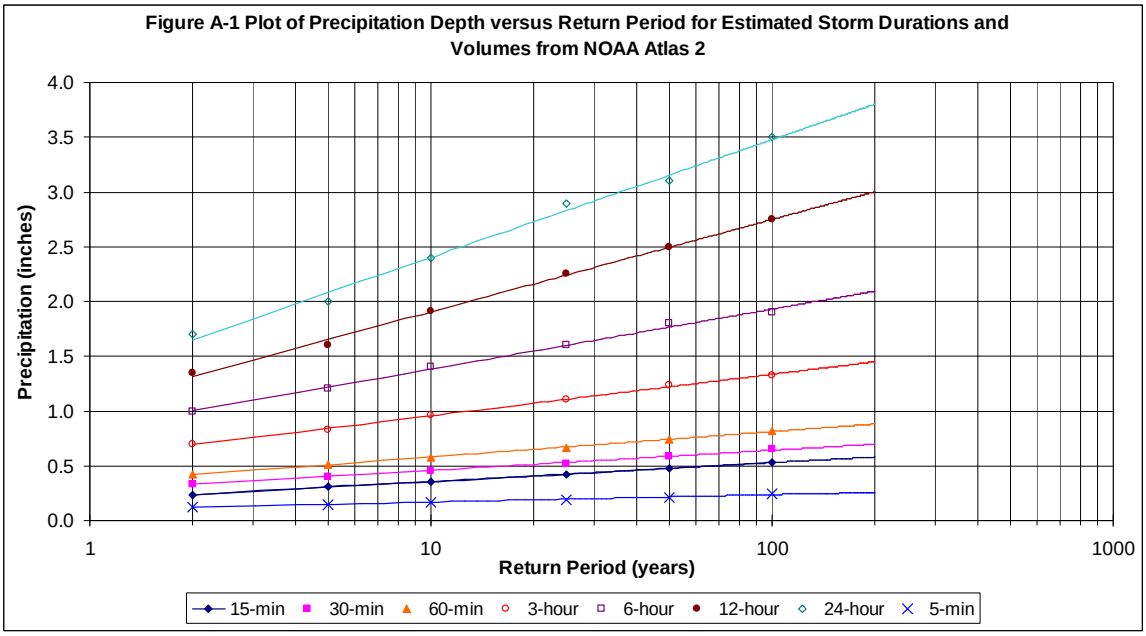


Table A2-3 Precipitation Volume for 100 Year and 200 Year Event(s)

Duration		DWR Merced Precipitation Frequency		NOAA Atlas #2 Precipitation-Frequency	
Hours	Minutes	(100-Year)	(200-Year)	(100-Year)	(200-Year)
0.083	5	0.35	0.38	0.23	0.26
0.25	15	0.54	0.58	0.46	0.58
1	60	0.9	0.98	0.80	0.88
2	120	1.19	1.29	1.06	1.20
3	180	1.38	1.50	1.30	1.45
6	360	1.78	1.93	1.88	2.09
12	720	2.31	2.50	2.75	3.00
24	1440	2.81	3.05	3.50	3.80

FIGURE A2-2: Comparison of 100-Year and 200-Year Precipitation Amounts - DWR's Merced Estimates and NOAA's Atlas #2 Estimates

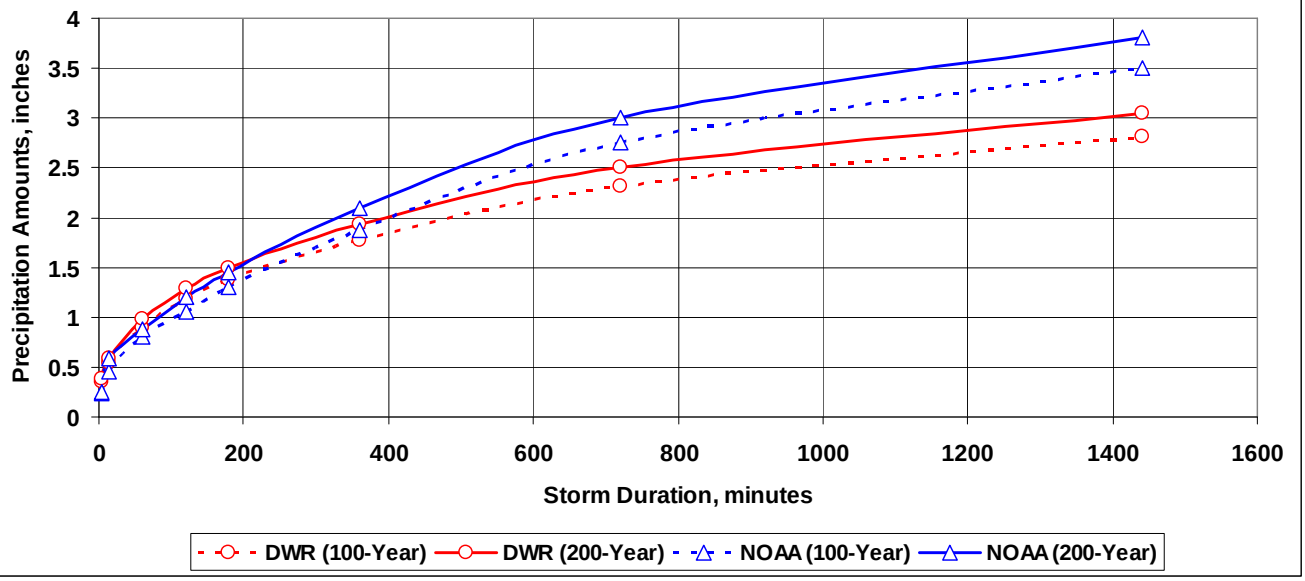
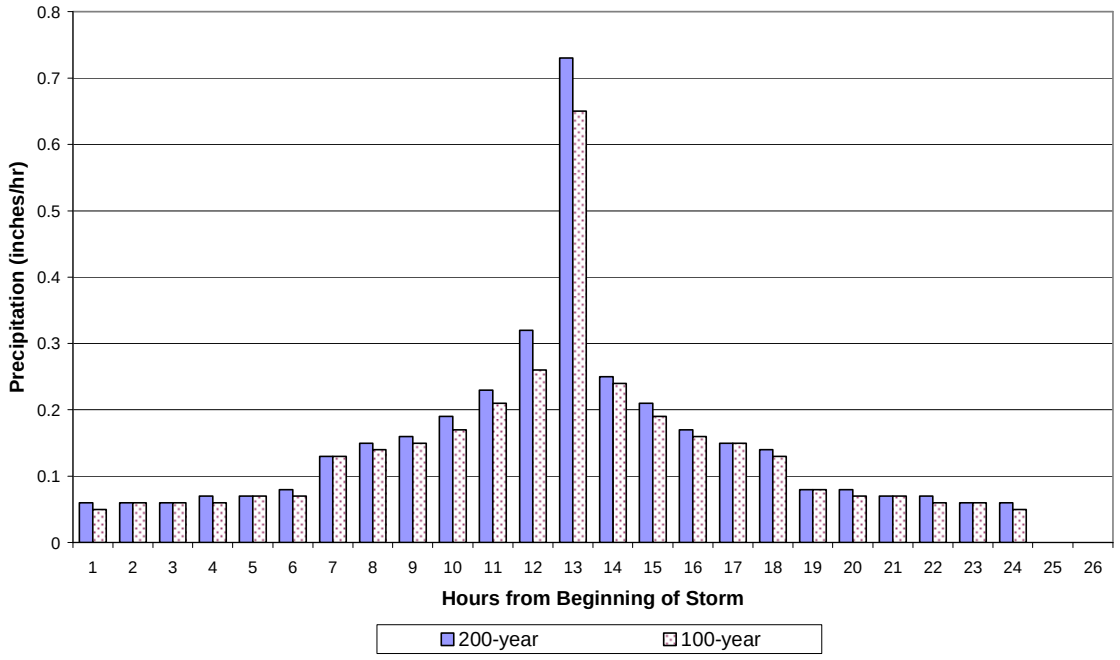


Figure A-2 Hyetograph for 200-year Storm Event used in Black Rascal Creek Detention Basin Study

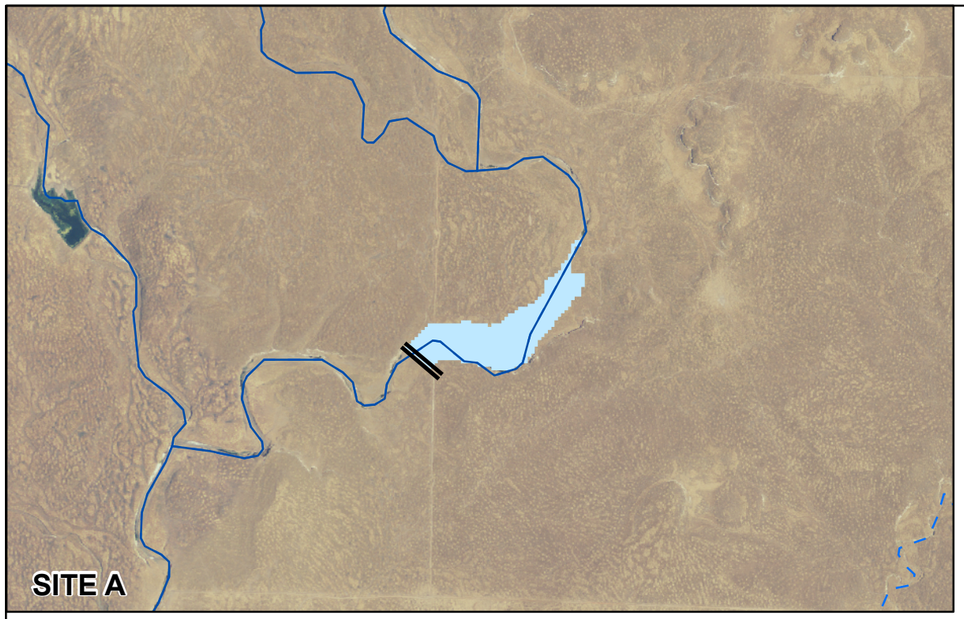


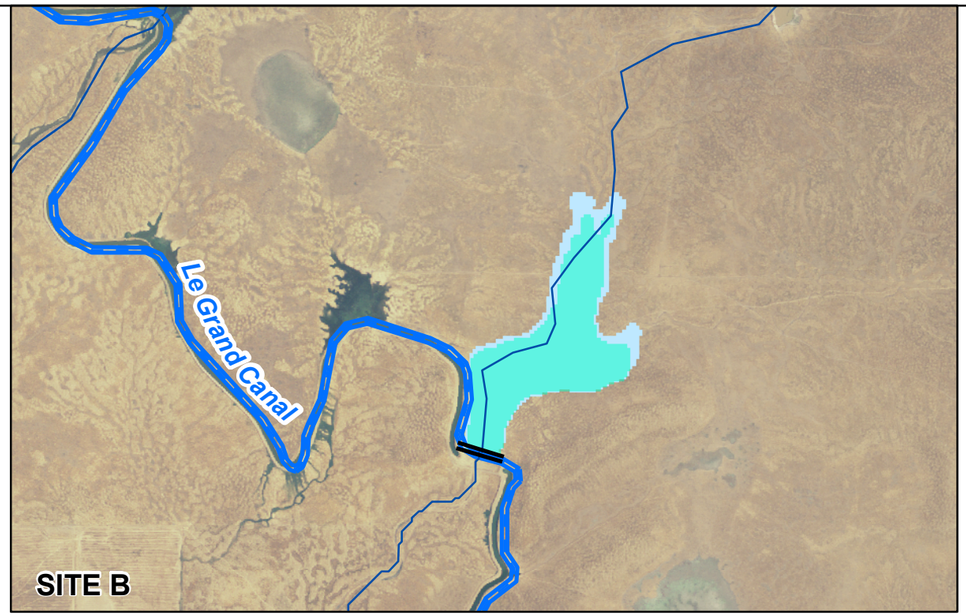
2.2 Inundation Maps and Outflow Hydrographs

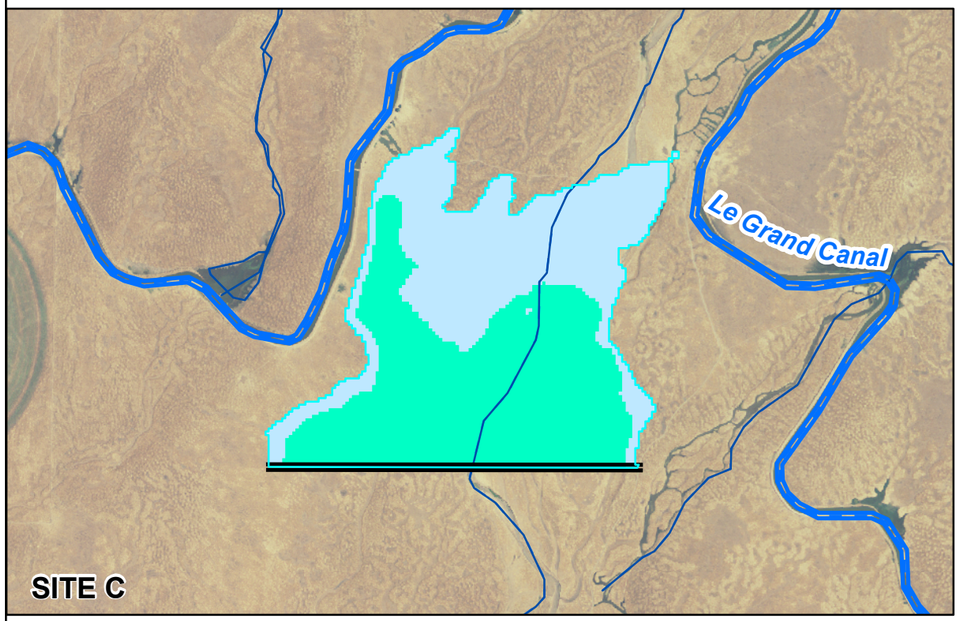
The same three alternative detention basin projects analyzed in the main report (see Section 4.2) plus a modification to the project at site D to reduce environmental impacts were analyzed in this addendum. These analyses resulted in the required detention basin sizes presented in Table A4-1 for each of the alternative projects. As noted in Table A4-1, the outlet for the basin at Site B was sized to limit outflows from sub-area BR6 to a practical minimum, about 100 cfs.

Figure A4-2 shows the inundated area for each of the alternatives. For sites A and B the inundated area is about the same for both the 100-year and 200-year events. The resolution of the topographic data is not sufficient to distinguish the areas. In the main report Figure 4-2 shows results using a curve number of 91 and 97 since there was some uncertainty in the actual measured flow rate in the diversion. However, all results in the main report for costs and design are for the curve number of 91 only since it was considered to be the more likely value. Therefore, Figure A4-2 shows results using a curve number of 91 only.

Figure A4-4 presents the discharge hydrographs at the Black Rascal Creek diversion during the design flood for existing conditions (no detention basins) and for each of the three alternative detention basin projects. As shown by Figure A4-4, all of the alternative detention basin projects reduce the peak flow at the diversion to about 3,000 cfs.







Flood inundation areas

100-yr floodplain

200-yr floodplain

Detention basin embankment

1 inch = 1,500 feet (AT 11" X 17" PAGE SIZE)

0 1,250 2,500 5,000 Feet

N

URS

Black Rascal Creek

Project no. 18715153

Detail of Detention Basins at Locations A, B, C

Figure A4-2
Sheet 1 of 2

Flood inundation areas

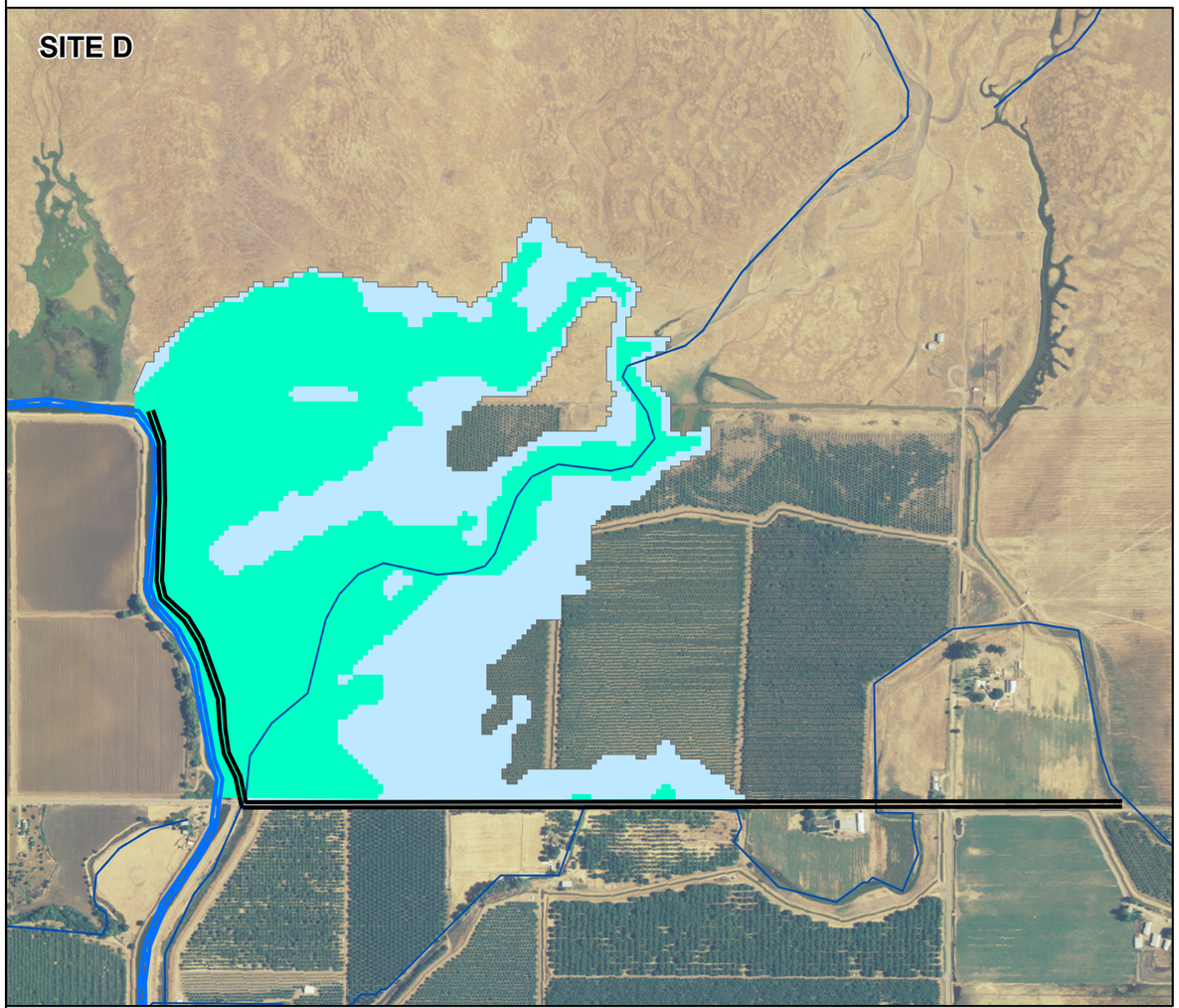
100-yr floodplain

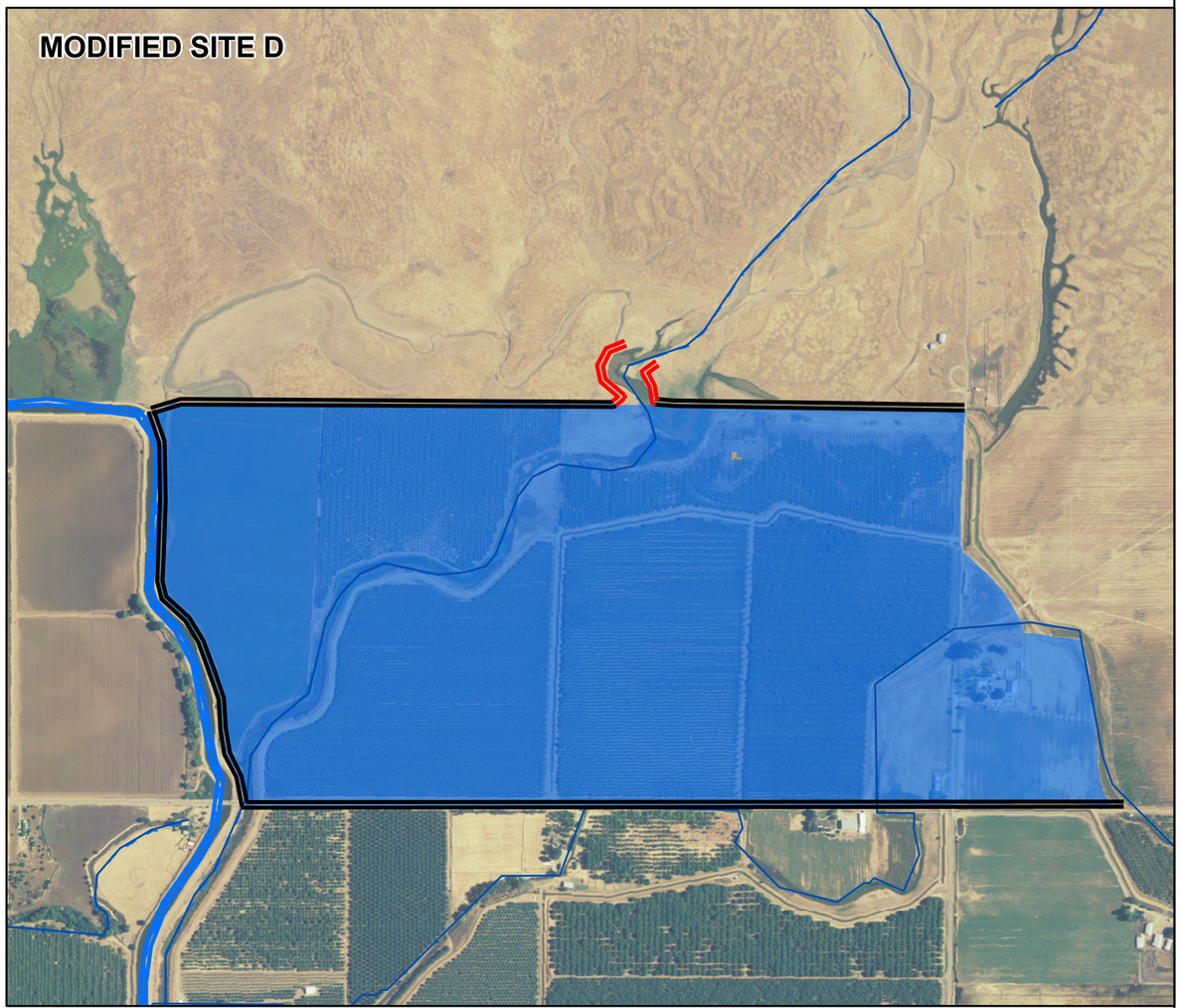
200-yr floodplain

200-yr floodplain, modified site D

Detention basin embankment

Training Berms





1 inch = 1,000 feet (AT 11" X 17" PAGE SIZE)

0 1,250 2,500 5,000 Feet

N

URS

Black Rascal Creek

Project no. 18715153

Detail of
Detention Basins (continued)
Location D

Figure
A4-2
Sheet 2 of 2

The goal of reducing Black Rascal Creek peak flows to about 3,000 cfs by use of the detention basin alternative projects examined in these studies can only be achieved by providing a relatively large detention basin at either Site C or Site D. Modifying the basin at Site D to eliminate the inundation of potentially sensitive habitat results in the same amount of storage as in the unmodified basin. However, the storage that occurs to the north of the agricultural area (in an area that could potentially contain vernal pools) with the unmodified basin occurs within the orchard located on the east side of the site when the basin is modified to contain water only on agricultural lands. The lower end of the Black Rascal Creek watershed is very flat. Water contained within the detention basin would backwater up Black Rascal Creek and spill onto land that could potentially contain vernal pools without the training berms. These berms would be short (a few feet tall) located along the creek to prevent the backwater from overtopping the creek banks. The available topographic data are not sufficient to define these berms accurately. Another issue associated with the modified basin is local drainage. Runoff that collects on the outside the berms on the north side of the agricultural lands would need to be diverted around the berms. This may require construction of a small drainage ditch along the edge of the agricultural lands.

Figure A4-4 Effect of Detention Basin in Black Rascal Creek Watershed at the Black Rascal Creek Diversion during a 200-year Precipitation Event

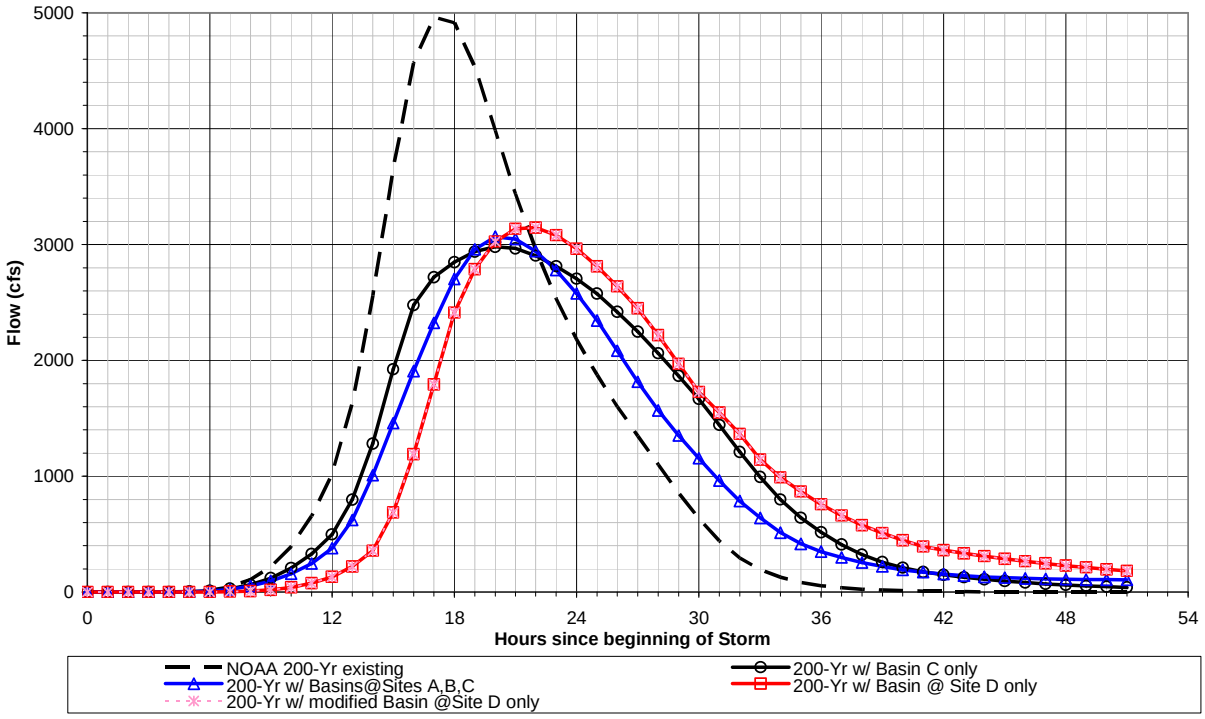


Table A4-1 Alternative Detention Basin Projects

Project Alternative	Culvert Outlets	Height - culvert floor to spillway crest	Height - culvert floor to embankment crest	Basin storage @ spillway crest (acre-feet)	Basin storage @ dam crest (acre-feet)
Alternative 1 - A single large detention basin at Site C	3 - 5' x 10' culverts	14 feet	17 feet	1136	1438
Alternative 2 - Three detention basins:					
Site A Basin	2 - 5' x 10' culverts	10 feet	13 feet	202.7	319
Site B Basin	limit outflow to 100 cfs	11 feet	14 feet	306.9	486.9
Site C Basin	5 - 5' x 10' culverts	9 feet	12 feet	676.3	945.2
Alternative 3 - A single large detention basin at Site D	2 - 10' x 12' culverts	12.6 feet	15.6 feet	1,711	2,374
Alternative 4 - A single large detention basin at Site D restricted to agricultural land only	2 - 10' x 12' culverts	14.5 feet	17.5 feet	1,711	2,534

2.3 Cost of Alternative Detention Basins

URS developed concept-level cost estimates to construct each of the alternative detention basin configurations listed in Table A4-1. Actual costs would be determined during final design when requirements imposed by DSOD, environmental requirements, and site-specific conditions are better known. Assumptions used in the cost estimate are the same as in the main report and are repeated below:

- The embankment of the dam could be constructed from onsite materials.
- Three feet of material would be excavated for the foundation.
- The general layouts of the impoundment structure, outlet, and spillway are as shown on Figures A4-2 and 4-3.
- The spillway for each detention basin is sized to pass the 200-year flood event with 3 feet of freeboard. However, since all the basins have a hydraulic height greater than 6 feet, DSOD could require more stringent spillway requirements even though the reservoirs are in a relatively undeveloped area. DSOD often will require that an allowance for wind-waves also be included in the freeboard estimates. Since these basins are not designed to hold water only to reduce peak flows for the 200 year event, water levels are only expected to be near their peak elevations for a few hours then quickly recede so additional freeboard for wind-waves was not included

For purposes of the feasibility cost estimate it is assumed that the reservoir lands will be purchased in fee. A small cost savings may be realized if flood easements can be obtained. This is an important assumption for the modified basin at Site D (Alternative 4 in Table A4-2) since all the storage is assumed to occur on agricultural lands, and the cost of orchard land is assumed to be high.

- Environmental costs are assumed to consist of mitigation for loss of habitat due to the dam footprint and possible damage to vernal pools within the inundation area. Construction of the dam is not assumed to destroy the vernal pool habitat but may change the characteristics of the pools that are inundated. Therefore, a lower cost was assigned to the pool impact.

Construction quantities, project costs, and environmental impacts and their costs are presented in Table A4-2 for the alternative projects. In addition, unit costs used in the estimate as well as assumptions associate with environmental impacts are presented as footnotes on Table A4-2.

The alternative projects listed in Table A4-1 were qualitatively evaluated based on their performance in relation to addressing the following four issues:

- Effectiveness in Reducing Black Rascal Creek Flows
- Environmental Acceptability
- Project Costs

The relative advantages and disadvantages of the detention basins and combinations of detention basins in addressing these issues are summarized in Table A6-1.

Table A4-2: Black Rascal Creek Project Cost Estimate (Sheet 1 of 5)

Project Element	Alternative 1	Alternative 2				Alternative 3	Alternative 4
	Single Basin @ Site C	Basin @ Site A	Basin @ Site B	Basin @ Site C	Total of Sites A,B & C	Single Basin @ Site D	Single Basin @ Site D
Embankment Fill:							
Emb. Crest Width, ft. =	15	15	15	15		15	15
Height to 200-Year Water Surface, ft. =	14	10	11	9		12.6	14.5
Freeboard Above 200-Year Water Surface, ft. =	3	3	3	3		3	3
Emb. Height, ft. =	17	13	14	12		16	18
Upstr. Emb. Slope, H:1V =	2.5	2.5	2.5	2.5		2.5	2.5
Dwnstr. Emb. Slope, H:1V =	2.5	2.5	2.5	2.5		2.5	2.5
Emb. Length (excl. outlet), ft. =	4,520	408	380	3,146		8,029	11,973
Emb. X-Sect. Area, sq.-ft. =	456	284	413	100		842	1,028
Emb. Vol. (excl. outlet), CY =	**76,260**	**4,285**	**5,819**	**11,627**	**21,731**	**250,505**	**455,916**
Foundation:							
Foundation Excavation Depth, ft. =	3	3	3	3		3	3
Emb. Base Width, ft. =	67.25	48.5	58	29.5		93	102.5
No. Outlet Culvert Barrels, # =	3	2	1	5		2	2
Outlet/Spillway Width, ft. =	34	23	12	56		27	27
Embankment & Outlet Length, ft. =	4,554	431	392	3,202		8,056	12,000
Embankment & Outlet Footprint, sq.-ft. =	306,257	20,904	22,736	94,459		749,208	1,230,000
Foundation Vol., CY =	**34,029**	**2,323**	**2,526**	**10,495**	**15,344**	**83,245**	**136,667**
Culvert Concrete:							
Culvert Length, ft. =	15	15	15	15		15	15
Wall, Roof, Floor Thickness, ft. =	1.0	1.0	1.0	1.0		1.0	1.0
Barrel Width, ft. =	10	10	10	10		12	12
Barrel Height, ft. =	5	5	5	5		10	10
X-Sect. Concrete, sq.-ft. =	88	61	34	142		84	84

Table A4-2: Black Rascal Creek Project Cost Estimate (Sheet 2 of 5)

Project Element	Alternative 1	Alternative 2				Alternative 3	Alternative 4
	Single Basin @ Site C	Basin @ Site A	Basin @ Site B	Basin @ Site C	Total of Sites A,B & C	Single Basin @ Site D	Single Basin @ Site D
Culvert Concrete, CY =	**49**	**34**	**19**	**79**	**132**	**47**	**47**
Spillway Crest Concrete:							
Crest Elevation Above Culvert Floor, ft. =	14	10	11	9		13	15
Crest Height Above Culvert Roof, ft. =	8	4	5	3		2	4
Crest Length, ft. =	32	21	10	54		25	25
Crest Thickness, ft. =	1.0	1.0	1.0	1.0		1.0	1.0
Spillway Crest Concrete, CY =	**1**	**1**	**0**	**2**	**3**	**1**	**1**
Inlet/Outlet Apron Concrete:							
Width @ Culvert, ft. =	34	23	12	56		27	27
Width @ Emb. Toe, ft. =	119	88	82	116		105	114.5
Upstr. & Dwnstr. Apron Length, ft. =	85	65	70	60		78	87.5
Total Apron Area, sq.-ft. =	6,503	3,608	3,290	5,160		5,148	6,191
Apron Thickness, ft. =	0.7	0.7	0.7	0.7		0.7	0.7
Apron Concrete, CY =	**161**	**89**	**81**	**127**	**298**	**127**	**153**
Wingwall Concrete:							
Wall Thickness, ft. =	0.7	0.7	0.7	0.7		0.7	0.7
Wall Height at Culvert (one side), ft. =	11.0	7.0	8.0	6.0		4.6	6.5
Concrete Above Culverts (two sides), CY =	8	5	6	4		3	5
Wall Height (@ Apron), ft. =	17	13	14	12		15.6	17.5
Wall Base Length (one side/end), ft. =	60	46	49	42		55	62
Area - 4 walls, sq.-ft. =	2,044	1,195	1,386	1,018		1,721	2,166
Total Wingwall Concrete, CY =	**59**	**35**	**40**	**30**	**104**	**46**	**58**

Table A4-2: Black Rascal Creek Project Cost Estimate (Sheet 3 of 5)

Project Element	Alternative 1 Single Basin @ Site C	Alternative 2 Basin @ Site A	Alternative 2 Basin @ Site B	Alternative 2 Basin @ Site C	Alternative 2 Total of Sites A,B & C	Alternative 3 Single Basin @ Site D	Alternative 4 Single Basin @ Site D
Total Concrete, CY =	**269**	**158**	**141**	**238**	**537**	**221**	**259**
Land Requirements: (inundated area)							
Undeveloped Land, acres =	193	40	65	86	191	76	0
Agricultural Land, acres =	0	0	0	0		70	70
Orchard Land, acres =	0	0	0	0		70	282
Unit Costs:							
Embankment Fill, $/CY =	$20	$20	$20	$20		$20	$20
Foundation, $/CY =	$9	$9	$9	$9		$9	$9
Concrete, $/CY =	$600	$600	$600	$600		$600	$600
Undeveloped Land, $/ac =	$3,200	$3,200	$3,200	$3,200		$3,200	$3,200
Agricultural Land, $/ac =	$3,250	$3,250	$3,250	$3,250		$3,250	$3,250
Orchard Land, $/ac =	$42,000	$42,000	$42,000	$42,000		$42,000	$42,000
Project Construction Costs:							
Embankment Cost	$1,525,195	$85,708	$116,373	$232,530	$434,611	$5,010,096	$9,118,326
Foundation Cost	$306,257	$20,904	$22,736	$94,459	$138,099	$749,208	$1,230,000
Concrete Cost	$161,541	$95,059	$84,384	$142,729	$322,173	$132,360	$155,239
Total Construction Costs	**$1,992,993**	**$201,671**	**$223,493**	**$469,719**	**$894,883**	**$5,891,664**	**$10,503,565**
Contingencies							
Engineering @ 10% =	$199,299	$20,167	$22,349	$46,972	$89,488	$589,166	$1,050,357
Contingencies @ 50% =	$996,497	$100,835	$111,747	$234,859	$447,441	$2,945,832	$5,251,783
Construction Costs with Contingencies	**$3,188,789**	**$322,673**	**$357,589**	**$751,550**	**$536,930**	**$9,426,663**	**$16,805,705**
Undeveloped Land Cost	$617,600	$128,000	$208,000	$275,200	$611,200	$243,200	$0
Agricultural Land Cost	$0	$0	$0	$0	$0	$227,500	$227,500

Table A4-2: Black Rascal Creek Project Cost Estimate (Sheet 4 of 5)

Project Element	Alternative 1 Single Basin @ Site C	Alternative 2 Basin @ Site A	Alternative 2 Basin @ Site B	Alternative 2 Basin @ Site C	Alternative 2 Total of Sites A,B & C	Alternative 3 Single Basin @ Site D	Alternative 4 Single Basin @ Site D
Orchard Land Cost	$0	$0	$0	$0	$0	$2,940,000	$11,844,000
Total Land Costs	**$617,600**	**$128,000**	**$208,000**	**$275,200**	**$611,200**	**$3,410,700**	**$12,071,500**
Total Construction Cost Including Land =	**$3,806,389**	**$450,673**	**$565,589**	**$1,026,750**	**$2,043,013**	**$12,837,363**	**$28,877,205**
Environmental Impacts:							
Direct Environmental Impacts, acres =	7.0	0.5	0.5	2.2	3.2	17.2	28.2
Indirect Environmental Impacts, acres =	193	40	65	86	191.0	76	0
Environmental Impacts Unit Costs							
Wetland/vernal pool density	0.2	0.2	0.2	0.2		0.2	0.2
Direct (vernal pools) (3:1 mitigation)							
Preservation of Vernal pools (cost/acre) (2:1)	$65,000	$65,000	$65,000	$65,000		$65,000	$65,000
Creation of new Vernal Pools (1:1)	$130,000	$130,000	$130,000	$130,000		$130,000	$130,000
Indirect Environmental Costs (vernal pool habitat)							
Preservation of Vernal pools (cost/acre) (2:1)	$65,000	$65,000	$65,000	$65,000		$65,000	$65,000
Environmental Review/Permitting (per alternative)	$500,000			$500,000		$500,000	$500,000
Direct Environmental Impacts for Agricultural Land	$15,000	$15,000	$15,000	$15,000		$15,000	$15,000
Environmental Costs:							
Direct Environmental Costs =	$365,595	$24,954	$27,141	$112,761	$164,856	$481,903	$423,554
Indirect Environmental Costs =	$5,018,000	$1,040,000	$1,690,000	$2,236,000	$4,966,000	$695,259	$0

Table A4-2: Black Rascal Creek Project Cost Estimate (Sheet 5 of 5)

Project Element	Alternative 1	Alternative 2				Alternative 3	Alternative 4
	Single Basin @ Site C	Basin @ Site A	Basin @ Site B	Basin @ Site C	Total of Sites A,B & C	Single Basin @ Site D	Single Basin @ Site D
Total Environmental Costs =	**$5,883,595**	**$1,064,954**	**$1,717,141**	**$2,848,761**	**$5,130,856**	**$1,677,162**	**$923,554**
Total Including Land and Environmental Costs =	**$9,689,984**	**$1,515,627**	**$2,282,730**	**$3,875,511**	**$7,673,868**	**$14,514,525**	**$29,800,759**
Total Costs Without Land Costs =	**$9,072,384**	**$1,387,627**	**$2,074,730**	**$3,600,311**	**$7,062,668**	**$11,103,825**	**$17,729,259**

NOTES:

(1) Area of direct impact is assumed to be equal to foot print of the dam.

(2) Indirect impacts are assumed equal to the inundated area.

(3) Costs of impacts are based on a 3:1 mitigation ratio for direct impacts to wetlands. Wetland density is assumed to be 20 percent of total grassland area affected. Mitigation for direct impacts would include 2:1 preservation at $65,000 per impact acre and 1:1 creation at $130,000 per acre of impact. Mitigation for indirect impacts is assumed to be preservation credits at a 2:1 ratio based on a cost of $65,000 per acre of indirect impact. A flat cost of $500,000 is included for each site that would include all environmental review and permitting.

(4) Basin BR10b is located on land that is currently cultivated with low potential for vernal pool species. Cost estimate is based on a 1:1 mitigation ratio for direct loss of potential foraging habitat for Swainson's hawks and San Joaquin kit fox and 0.2:1 mitigation for indirect effects at $15k per acre. There may also be costs associated with obtaining a flood easement.

Table A6-1

Comparison of Alternative Projects

Evaluation Criteria	Basin/Project Capabilities	Comments
Potential DSOD Jurisdiction:	All basins, regardless of whether or not they are provided in combination with other basins or as the only basin, will probably be under DSOD jurisdiction.	Based on comparison to Burns Dam, the spillways for the larger basins at Sites C & D may be adequate.
Effectiveness In Reducing BRC Flows:	All Alternatives are equally effective in reducing BRC flows.	
Environmentally Acceptable:		
Site C - Alternatives 1 & 2	Has Known Adverse Environmental Impacts - **Probably Not Permitable**	If Permitted, Environmental Mitigation May Be Very Costly
Site A - Alternative 2	Probably Has Adverse Environmental Impacts But Needs Investigations (not previously studied in detail)- Possibly Permitable	Will Probably Incur Significant Environmental Mitigation Cost. Requires long access road and associate impacts
Site B - Alternative 2	May have least adverse environmental impacts, needs more investigation (not previously studies in detail) - Probably Permitable	Will Probably Have Some Environmental Mitigation Cost. Requires long access road and associated impacts.
Site D - Alternative 3	May have least environmental impacts - impacts primarily to agricultural land	May be one house relocation - no other known social impacts. Environmental impacts could possibly be reduced further. Detailed topographic data should be collected for final design if this option is selected.
Relative Project Costs:		
Alternative 1 - Site C Only	$9,689,984	Construction Cost = 33%, Land Cost = 6%, Environmental Cost = 61%
Alternative 2 - Sites A, B, & C	$7,673,868	Construction Cost = 17%, Land Cost = 8%, Environmental Cost = 75%
Alternative 3 - Site D Only	$14,514,525	Construction Cost = 65%, Land Cost = 23%, Environmental Cost = 12%
Alternative 4 - Site D Only, Modified Basin	$29,800,759	Construction Cost = 56%, Land Cost = 41%, Environmental Cost = 3%