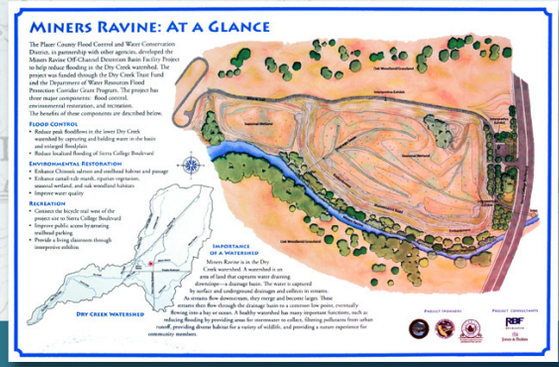
Miners Ravine Off-Channel Detention Basin Hydrology & Hydraulic Design Report



SEPTEMBER 2007

Placer County Flood Control and Water Conservation District

RBF CONSULTING

MINERS RAVINE OFF-CHANNEL DETENTION BASIN HYDROLOGY AND HYDRAULIC DESIGN REPORT

TABLE OF CONTENTS

EXECUTIVE SUMMARY I

SETTING I
BACKGROUND II
PROJECT DETAILS III
Existing Conditions III
Proposed Conditions III
Analyses III

1.0 INTRODUCTION 5

1.1 BACKGROUND 5
1.2 PURPOSE 6
1.2.1 Project Purpose 6
1.2.2 Report Purpose 7
1.3 HISTORY 7
1.4 CONFIGURATION CONCEPT 7
1.5 PREFERRED CONFIGURATION 7
1.6 DIVISION OF SAFETY OF DAMS CONSIDERATIONS 9
1.7 FEMA CONSIDERATIONS 10

2.0 BASELINE HYDROLOGY 12

2.1 PREVIOUS HYDROLOGIC MODELS 12
2.2 PROJECT BASELINE HYDROLOGIC MODEL DEVELOPMENT 14
2.2.1 100 Year Discharges 14
2.2.2 Range of Design and Evaluation Storm Events 14
2.2.3 Hydrologic Parameters 15
2.2.4 Precipitation for Spillway Analysis 16
2.3 PROJECT BASELINE DISCHARGES FOR COMPARATIVE ANALYSIS 17
2.3.1 Modifications to Flow Routing Parameters 17
2.3.2 Modeling Process 18
2.5 PEAK DISCHARGES AT SIERRA COLLEGE BOULEVARD 21

3.0 HYDRAULIC ANALYSES 23

3.1 EXISTING CONDITIONS 23
3.2 BASIN CAPACITY 24
3.2.1 Minimum Basin Elevation 24
3.2.2 Elevation verses Capacity Relationship 25
3.3 SYSTEM CONFIGURATION 26
3.3.1 Initial Concepts 26
3.3.2 Key Design Considerations 26
3.3.3 Alternatives Analysis 27
3.3.4 System Performance 28
3.4 FINAL DESIGN CONFIGURATION EXPECTED PERFORMANCE 30

MINERS RAVINE OFF-CHANNEL DETENTION BASIN HYDROLOGY AND HYDRAULIC DESIGN REPORT

3.4.1 Final System Configuration with Road Widening Project Culvert *30*
3.4.2 Final Design Expected Benefit *31*
3.4.3 Final Design Operation *33*
3.4.4 Site Stream Flow Conditions *35*
3.5 BASIN DRAWDOWN 35
3.6 SPILLWAY CONFIGURATION 36
3.7 EMBANKMENT FAILURE 39

4.0 SEDIMENT TRANSPORT 45

4.1 ANNUAL SEDIMENT YIELD ESTIMATE 45
4.2 CHANNEL STABILITY ANALYSIS 46
4.2.1 Channel Hydraulics *46*
4.2.2 Sediment Continuity Analysis *47*

5.0 CONCLUSIONS 49

EXHIBITS

EXHIBIT ES-1: VICINITY MAP ..... ES-I
EXHIBIT ES-2: PROJECT AND DRY CREEK WATERSHEDS ..... ES-II
SHEET 1: PROJECT LAYOUT ..... ENCLOSED
EXHIBIT 1: VICINITY MAP 5
EXHIBIT 2: PROJECT AND DRY CREEK WATERSHEDS 6
EXHIBIT 3: EMBANKMENT FAILURE – PIPING SCENARIO 41

PHOTOGRAPHS

Photograph 1: Flooding At Sierra College Boulevard (1995) 13

CHARTS

CHART 1: DSOD JURISDICTIONAL DAM SIZE 9
CHART 2: SPILLWAY EVALUATION PRECIPITATION PATTERN 17
CHART 3: FLOW PROBABILITY PLOT FOR MINERS RAVINE AT SIERRA COLLEGE BLVD. 22
CHART 4: RATING CURVES AT KEY SECTIONS 24
CHART 5: ELEVATION-AREA-CAPACITY CURVES 25
CHART 6: STREAM AND BASIN STAGE HYDROGRAPHS 33
CHART 7: BASIN FLOW HYDROGRAPHS 34
CHART 8: 100-YEAR STREAM FLOW ATTENUATION 34

MINERS RAVINE OFF-CHANNEL DETENTION BASIN HYDROLOGY AND HYDRAULIC DESIGN REPORT

CHART 9: BASIN DRAWDOWN RATE 36
CHART 10: 1000 YEAR DISCHARGE HYDROGRAPHS 38
CHART 11: SPILLWAY RATING CURVES 38
CHART 12: BASIN STAGE HYDROGRAPHS FOR FAILURE ANALYSIS 42
CHART 13: NEAR BASIN STREAM STAGE HYDROGRAPHS FOR FAILURE ANALYSIS 42
CHART 14: DOWNSTREAM STREAM STAGE HYDROGRAPHS FOR FAILURE ANALYSIS 43
CHART 15: BASIN FLOW HYDROGRAPHS FOR FAILURE ANALYSIS 43
CHART 16: NEAR BASIN STREAM FLOW HYDROGRAPHS FOR FAILURE ANALYSIS 44
CHART 17: DOWNSTREAM STREAM FLOW HYDROGRAPHS FOR FAILURE ANALYSIS 44
CHART 18: MINERS RAVINE SEDIMENT GRADATION 48

MINERS RAVINE OFF-CHANNEL DETENTION BASIN HYDROLOGY AND HYDRAULIC DESIGN REPORT

TABLES

TABLE 1: MODEL FLOWS AT KEY LOCATIONS 14
TABLE 2: INITIAL LOSS AND BASE FLOW CONDITIONS 15
TABLE 3: SIX-HOUR PRECIPITATION DEPTHS FOR MINERS RAVINE ABOVE SIERRA COLLEGE BOULEVARD 16
TABLE 4: RAINFALL STATION STATISTICAL 1000-YEAR DEPTHS (INCHES) 16
TABLE 5: KEY LOCATION SUMMARY 18
TABLE 6.A: 100-YEAR BASELINE FLOW COMPARISON (CUBIC FEET PER SECOND) 20
TABLE 6.B: 50-YEAR BASELINE FLOW COMPARISON (CUBIC FEET PER SECOND) 20
TABLE 6.C: 25-YEAR BASELINE FLOW COMPARISON (CUBIC FEET PER SECOND) 20
TABLE 6.D: 10-YEAR BASELINE FLOW COMPARISON (CUBIC FEET PER SECOND) 20
TABLE 6.E: 5-YEAR BASELINE FLOW COMPARISON (CUBIC FEET PER SECOND) 21
TABLE 6.F: 2-YEAR BASELINE FLOW COMPARISON (CUBIC FEET PER SECOND) 21
TABLE 7: EXISTING CONDITIONS WATER SURFACE ELEVATION (FEET) 23
TABLE 8.A: CONFIGURATION A1, DOWNSTREAM CONNECTION, FIXED CONTROL, PEAK DISCHARGE REDUCTION (CUBIC FEET PER SECOND) 28
TABLE 8.B: CONFIGURATION A1, DOWNSTREAM CONNECTION, FIXED CONTROL, PEAK STAGE REDUCTION (FEET) 29
TABLE 8.C: CONFIGURATION A2, DOWNSTREAM CONNECTION, LOW FLOW GATE CONTROL, PEAK DISCHARGE REDUCTION (CUBIC FEET PER SECOND) 29
TABLE 8.D: CONFIGURATION A2, DOWNSTREAM CONNECTION, LOW FLOW GATE CONTROL, PEAK STAGE REDUCTION (FEET) 29
TABLE 8.E: CONFIGURATION B1, UPSTREAM CONNECTION, FIXED CONTROL, PEAK DISCHARGE REDUCTION (CUBIC FEET PER SECOND) 29
TABLE 8.F: CONFIGURATION B1, UPSTREAM CONNECTION, FIXED CONTROL, PEAK STAGE REDUCTION (FEET) 29
TABLE 8.G: CONFIGURATION B2, UPSTREAM CONNECTION, LOW FLOW GATE CONTROL, PEAK DISCHARGE REDUCTION (CUBIC FEET PER SECOND) 30
TABLE 8.H: CONFIGURATION B2, UPSTREAM CONNECTION, LOW FLOW GATE CONTROL, PEAK STAGE REDUCTION (FEET) 30
TABLE 9: BASELINE (CASE 5) DISCHARGES (CUBIC FEET PER SECOND) 31
TABLE 10: DESIGN CONFIGURATION DISCHARGES (CUBIC FEET PER SECOND) 31
TABLE 11: DESIGN CONFIGURATION FLOW REDUCTION (CUBIC FEET PER SECOND) 32
TABLE 12: DESIGN CONFIGURATION STAGE REDUCTION (FEET) 32
TABLE 13: STREAM FLOW RATE SUMMARY 35
TABLE 14: STREAM STAGE AND VELOCITY SUMMARY 35
TABLE 15: BREACH PARAMETERS 39
TABLE 16: SUMMARY OF PEAK CONDITIONS FROM FAILURE ANALYSIS 40
TABLE 17: SEDIMENT YIELD AND DEPOSITION SUMMARY 46
TABLE 18: 2-YEAR EVENT HYDRAULIC PARAMETERS FOR SEDIMENT TRANSPORT 47
TABLE 19: SEDIMENT TRANSPORT ANALYSIS SUMMARY 47

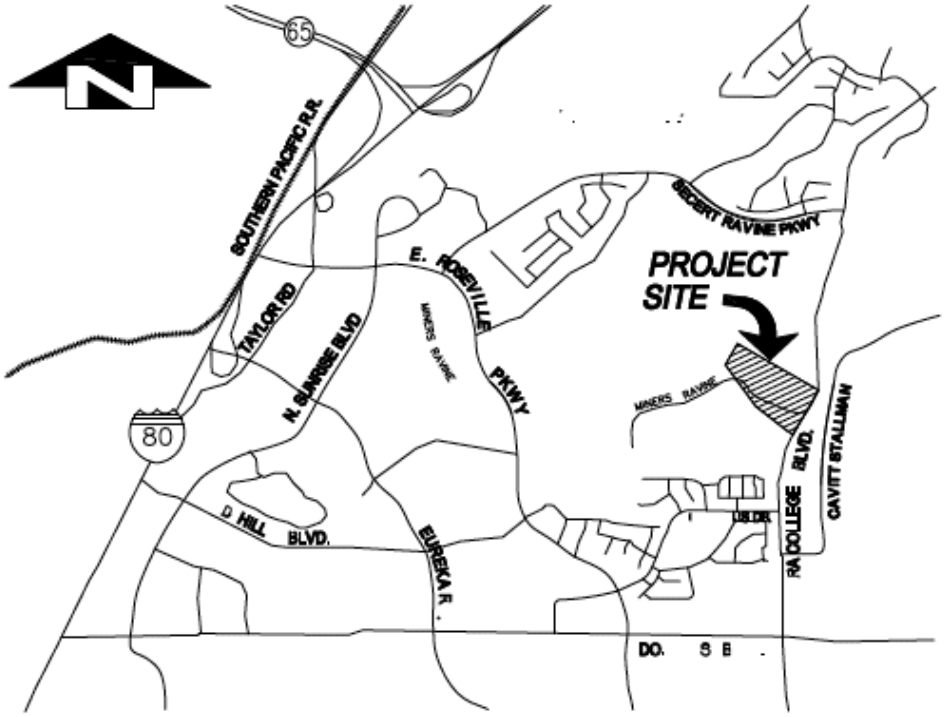
MINERS RAVINE OFF-CHANNEL DETENTION BASIN HYDROLOGY AND HYDRAULIC DESIGN REPORT

EXECUTIVE SUMMARY

Setting

The Miners Ravine Off-Channel Detention Basin Project (the Project) is a proposed regional flood control facility within the Dry Creek Watershed. The Project is located on a 26-acre site that extends approximately 1,600-feet west from Sierra College Boulevard within the City of Roseville. The Project area includes the main channel of Miners Ravine and the 12-acre area of what had been sewage treatment basins operational from the early 1960s to the mid 1980s. The Project involves construction of an off-channel detention basin within the existing FEMA 100-year floodplain. The Project also includes stream and wetlands restoration and recreation components.

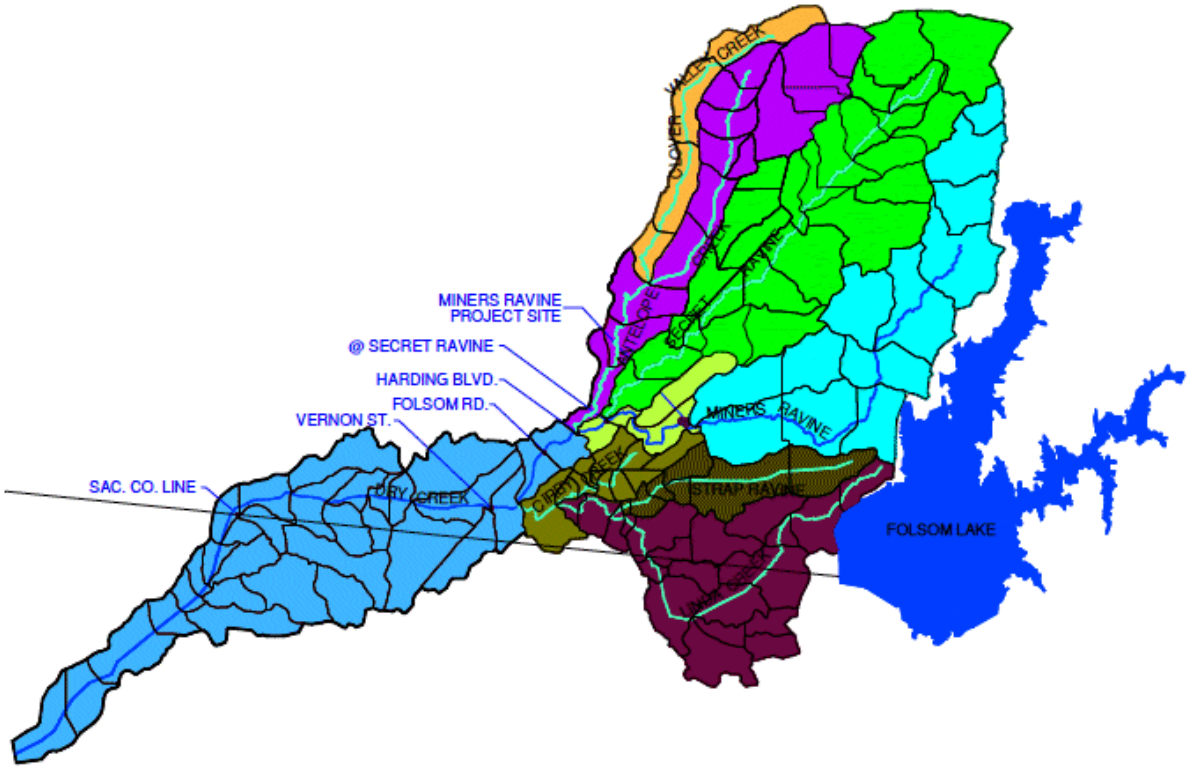
Exhibit ES-1: Vicinity Map



The portion of the Miners Ravine watershed upstream from the Project is 17.6 square-miles and the potential hydrologic impacts of the Project are being considered in the context of the 101 square-mile Dry Creek watershed. Potential

benefits are being evaluated at multiple locations over design flood conditions from a 2-year through a 100-year flood event.

Exhibit ES-2: Project and Dry Creek Watersheds



Background

The Project would be the first regional flood control project in the Dry Creek Watershed and is considered critical to mitigating impacts from new development since 1989. By reducing peak flows it would also help prevent damaging flood events through the Roseville area such as the federal disasters that were declared in 1986 and 1995.

The multi-objective project is funded in part by fees on new development but also from a significant 1 million dollar grant awarded by the State Department of Water Resources (DWR) through their Flood Corridor Protection Grant Program. The Division of Flood Management within DWR is an advocate for this project and is partnering with the Placer County Flood Control and Water Conservation District (District) on the design and implementation. The project has also received strong support from an active stakeholder committee comprised of the public, local creek activists and multiple local, state and federal agencies

including the State Department of Water Resources, the California Department of Fish and Game, National Marine Fisheries Service, Sacramento County and the City of Roseville.

Project Details

Existing Conditions

Miners Ravine runs along the southern edge of the project site. Frequent flows, and flows up to a point between a 10 and 25 year storm event, are contained generally south of an existing embankment adjacent to the Project site. At higher discharges, flows spread out into the floodplain through notches in what had been sewage treatment basin embankments. The existing site storage conditions provide some flood reduction benefits. The limited flood reduction benefits from existing site storage conditions were considered in determining potential added benefit gained from the Project.

Proposed Conditions

The Project calls for grading the site and construction of flow control facilities to improve the flood attenuation characteristics of the site. The potential flood control benefit of the Project is limited by its maximum feasible storage capacity. Storage capacity is constrained by available area and functional limitations on minimum and maximum storage levels. The recommended Project includes an inlet/outlet facility connecting the basin to Miners Ravine on the upstream side of Sierra College Boulevard. This connection allows the Project to provide significantly more flood control benefit than if it were to be connected to the downstream side because of higher water levels at the point of connection.

Analyses

Hydrologic, hydraulic and sediment transport analyses were performed as part of the project design process. Baseline existing conditions were established and alternatives were evaluated. Anticipated benefits of a preferred alternative were identified. The anticipated benefits include reduced peak flood discharges and stages in Miners Ravine and Dry Creek over a wide range of events and reduced frequency of overtopping of Sierra College Boulevard. The preferred alternative was further refined to improve overall system function in the process of integrating final design of fish passage enhancements to the Sierra College Boulevard widening project with the basin improvements. The road widening and detention basin projects are anticipated to be constructed simultaneously during the summer of 2006 and are being considered together for regulatory flood control purposes.

The proposed project includes fill within a regulatory floodway. Specifically, culvert improvements, roadway fill, and an embankment parallel to the channel will be constructed in areas shown as floodway on FEMA map panel 06061C0479G, dated November 21, 2001. Portions of the project are also within the 100-year floodplain shown on panel 06061C0477G. The project is shown in relationship to the FEMA floodplain on Exhibit ES-3. The project is configured to provide a reduction in peak flood stage during a range of design storm events up to a 100-year event. The community does not plan to revise the flood insurance mapping as a result of the project because the reductions in peak stage upstream and downstream from the project site are expected to be relatively small. This report provides documentation of hydrologic and hydraulic analysis used to demonstrate that the project would not result in any increase in flood levels.

The project is within the jurisdiction of the Division of Safety of Dams (DSOD) because the project involves construction of an embankment with a height over six feet and has the potential to impound more than 50 acre-feet. The spillway and low level outlet were evaluated to demonstrate adequacy relative to DSOD regulatory requirements. Failure analyses were performed to support a conclusion that the proposed facilities would not introduce a substantial risk.

1.0 INTRODUCTION

1.1 Background

The Miners Ravine Off-Channel Detention Basin Project (the Project) is a proposed regional flood control facility within the Dry Creek watershed. The location of the site is shown on Exhibit 1, Vicinity Map and it is shown in relationship to the Dry Creek watershed on Exhibit 2. The Project is located on a 26-acre site that extends approximately 1,600 feet west from Sierra College Boulevard within the City of Roseville. The Project area includes the main channel of Miners Ravine and the 12-acre footprint of what had been sewage treatment basins from the early 1960s to the mid 1980s. The Project involves construction of an off-channel detention basin and includes stream and wetlands restoration and recreation components. The Project Layout is included on Sheet 1, enclosed.

Exhibit 1: Vicinity Map

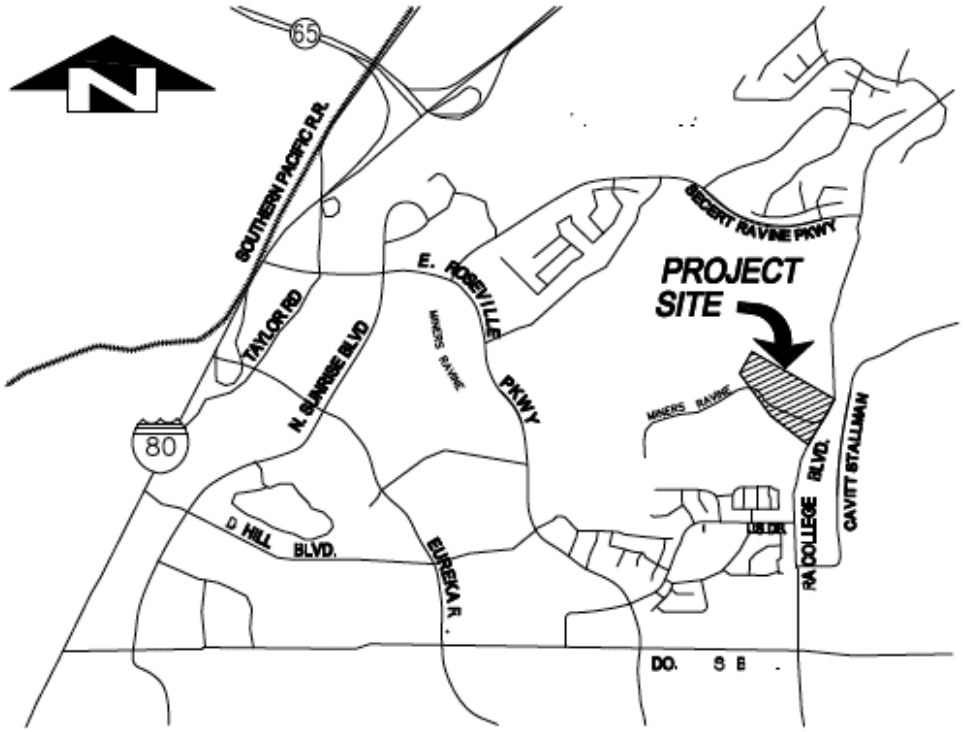
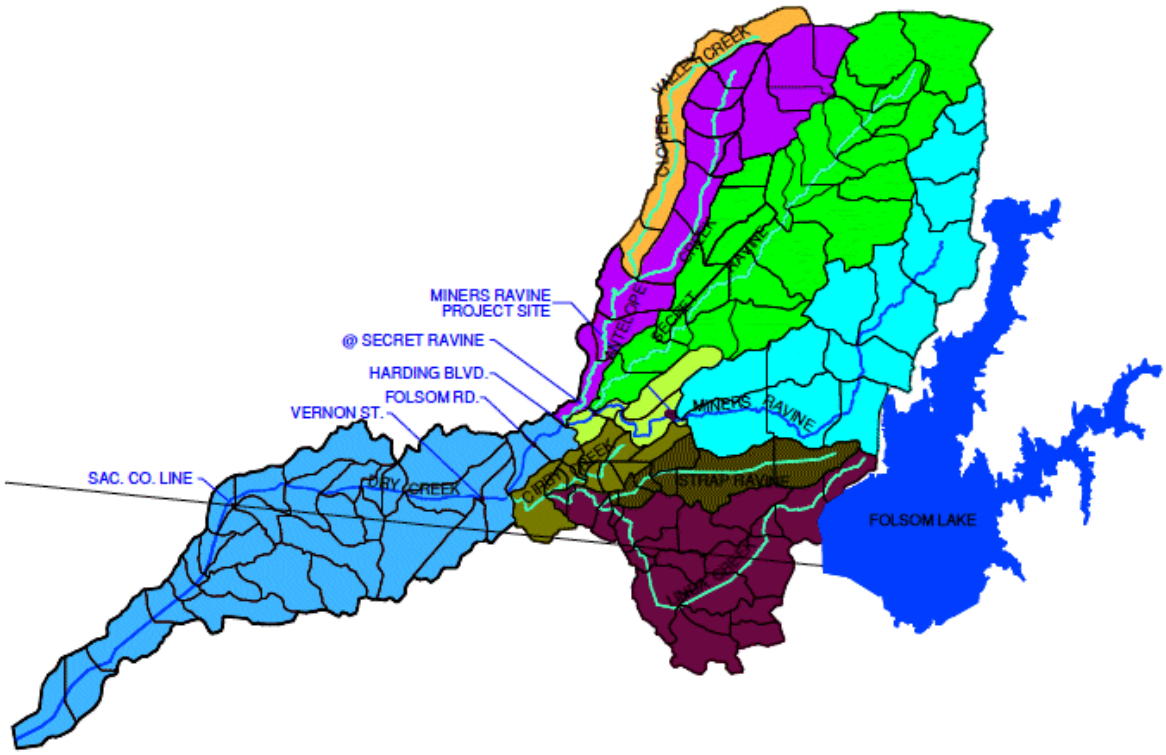


Exhibit 2: Project and Dry Creek Watersheds



1.2 Purpose

1.2.1 Project Purpose

The primary objective of the Project is to reduce peak flood flow rates downstream from the Project to mitigate for increases resulting from development. The Project will be configured considering more frequent events, including 2, 5, 10, 25 and 50 year flows, as well as the 100 year event. The Project will include a setback area between the existing low flow channel and the embankment of the proposed detention basin to provide an enhanced floodplain area. An existing multi-use recreation trail will be extended from its current end on the west side of the project to a new parking lot off of Sierra College Boulevard.

Key considerations include:

- Public Safety,
- Balanced flood control benefit over a range of design events,
- Protection of sensitive species including minimizing potential for fish stranding,
- Recreational and Educational Opportunities, and
- Environmental Enhancements.

1.2.2 Report Purpose

The purpose of this report is to document Project design hydrology and expected hydraulic performance of the final project configuration. This report also provides comparative analysis of alternatives that form a basis for the final configuration. This report also provides information related to both flood control and restoration design elements to address issues that may be of concern to regulatory agencies.

1.3 History

Damaging floods have occurred within the Dry Creek watershed in December 1955, April 1958, October 1962, December 1964, March 1983, February 1986, and January 1995. Placer and Sacramento Counties adopted the Dry Creek Watershed Flood Control Plan prepared by James M. Montgomery in 1992 to provide a comprehensive approach to reducing flood damages. Part of this plan includes regional detention basins upstream from the City of Roseville. A report prepared in 1999 concluded that an on-channel detention facility on Miners Ravine would be feasible. However, following public and environmental community protest, the District Board determined that while an on-channel facility may be feasible it would not be pursued and other alternatives would be examined.

In July 2001, the District prepared a Preliminary Feasibility Report that evaluated the feasibility of construction of a regional, off-channel detention basin at the current Project site. The report concluded that an off-channel detention basin adjacent to Miners Ravine west of Sierra College Boulevard would be feasible from a technical, financial, environmental and permitting standpoint.

1.4 Configuration Concept

The basic concept of an off-channel detention basin is to have normal flows remain confined to the stream and pass by the project without being intercepted. Portions of the high flows are diverted from the stream channel into the storage area by using a system of weirs, gates or other flow control mechanisms to achieve the desired system response. The same and additional connections between the basin and the channel are used to drain the basin. Off-channel detention basins can provide more efficient flood control than on-channel basins because storage capacity is not used during low flows making more storage available to attenuate peaks of more severe events.

1.5 Preferred Configuration

Numerous alternative configurations were investigated during the development of the Project. Technical analyses and a stakeholder group decision making

process were used to establish a preferred configuration from a set of options. Subsequent to the selection of a preferred alternative, additional refinements to the design were made to satisfy DSOD requirements and to integrate fish passage enhancements within the main channel Miners Ravine culvert at Sierra College Boulevard.

The potential flood control benefit of any off-channel detention configuration is limited by the effective storage capacity. The available area, the bottom elevation of (or initial stage in) the basin, and the maximum stage, limit the maximum effective storage capacity during an event. The efficiency of the configuration at using the available storage capacity is dependent on the physical connections between the channel and basin and actual flow conditions.

The effectiveness of the basin also depends on the system draining rapidly enough after the peak of a storm for the storage to be available for a subsequent storm. The bottom elevation of the basin was established to allow the basin to drain by gravity. Due to pumping costs to recover flood control storage, as well as groundwater level issues, it was determined that additional basin capacity, which would need to be pumped to be effective, would not be feasible. A low level, gravity draining, outlet will connect the basin to the stream channel where frequent stream flow levels are expected to be below the bottom elevation in the basin. The size of the low level outlet is set as the minimum required to drain the basin because flow through the low level outlet reduces system effectiveness by discharging during the peak of the storm.

The maximum basin stage is limited by the water surface elevation in the channel at the point of the inlet connection and how the water surface elevation responds to the diversion system. As long as the flows are detained up to the higher elevation behind a high enough embankment, moving the connection point upstream, where the stream water surface would be higher, can increase potential storage in the basin.

The Project site is located immediately downstream from Sierra College Boulevard. The existing box culverts on Miners Ravine at Sierra College Boulevard experience a significant water surface elevation drop at high flows. By connecting the proposed basin to the upstream side of Sierra College Boulevard, the water surface at the connection point could be five feet higher than if the basin were to be connected to the downstream side. Another advantage of connecting the basin to the upstream side of Sierra College Boulevard is that the location experiences a greater change in water surface elevation over the design range of flows than that immediately downstream from the culvert, allowing better control and predictability of system response.

The preferred configuration includes flap gates that allow flows to return from the basin into Miners Ravine at the point of connection upstream from Sierra College

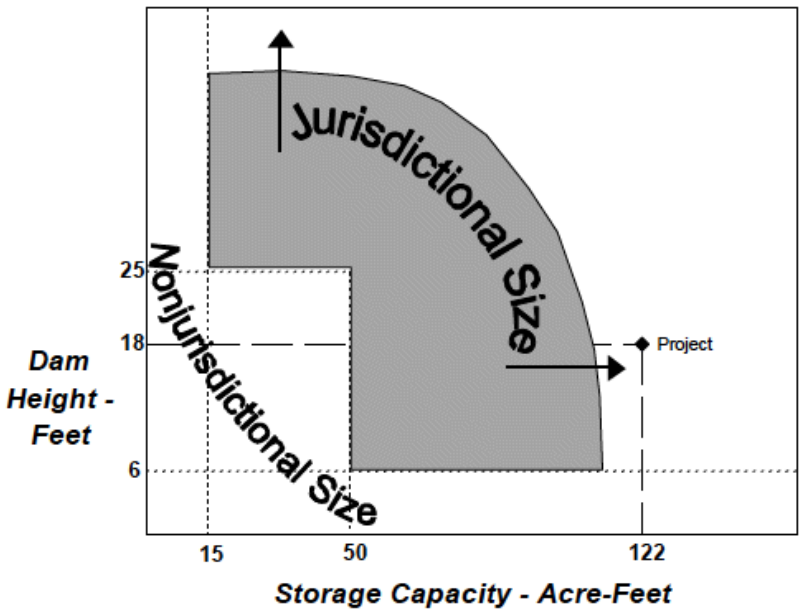
Boulevard. This allows the basin level to drop rapidly with receding flood levels in the channel without potential high outflows during the peak of design storm events.

The roadway widening project includes lengthening the existing boxes. The box extensions will be higher than the existing boxes, which tends to limit the impact of the extensions. However, the center box, including the existing portion, will include baffles and low flow obstructions will be added to the outer boxes to direct low flows to the center box with fish passage enhancements. The fish passage enhancement measures tend to cause an increase in upstream flood levels. This report includes documentation of analysis that concludes the flood control attenuation capacity of the basin, connected through a new culvert to the upstream side of Sierra College Boulevard can mitigate for the potential rise in flood levels due to the fish passage enhancements.

1.6 Division of Safety of Dams Considerations

The Division of Safety of Dams (DSOD) determined that the proposed facility would be within their jurisdiction based on a dam height over 6 feet and storage capacity over 50 acre-feet. DSOD considers dam height to be the vertical distance from spillway crest to the lowest elevation of fill along the downstream toe. For this project the dam height is approximately 18 feet from the extreme event spillway crest at elevation 250 feet down to the toe at the low level outlet at approximately elevation 232 feet. The storage capacity up to the spillway crest is approximately 122 acre-feet. Chart 1 is the DSOD jurisdictional dam size chart that indicates that the proposed project is within their jurisdiction.

Chart 1: DSOD Jurisdictional Dam Size



Specific design requirements of DSOD can vary depending on project specific considerations. This report provides information about the proposed project function as it relates to design considerations including:

1. The expected frequency and duration of inundation;
2. The unregulated outlet at the location of the inlet weir approximately four feet above the invert of the low level outlet; and
3. Self-regulating inflows limited to the maximum stream stage at the point of connection.

This report also provides documentation of analysis associated with evaluating the low risk associated with embankment failure and parameters to demonstrate compliance with DSOD *Guidelines for Small Dam Design*:

1. A minimum spillway design flood return period of 1,000 years where the downstream hazard from dam failure is minor as is the case for the proposed project;
2. Minimum freeboard (vertical distance from spillway crest to dam crest) of 4 feet; and
3. Minimum residual freeboard (distance from maximum reservoir stage for spillway design flood and dam crest) of 1.5 feet.

1.7 FEMA Considerations

The portion of the Project site that generally covers the basin area is within the FEMA 100-year floodplain. The Project would modify the timing and depth of flooding within the floodplain to improve the ability of the floodplain to attenuate peak flood flows. The Project is shown in relationship to the FEMA 100-year floodplain, as shown on the effective Flood Insurance Rate Maps, on Exhibit 3.

FEMA regulations require if fill is placed within the regulatory floodway, it must be demonstrated that the project will not cause a rise in base flood elevations within the community. For the purpose of addressing FEMA regulatory considerations, the Miners Ravine Off-Channel Detention Basin and the Sierra College Boulevard Widening Projects are being considered together. The Widening Project included extending the triple box culvert on Miners Ravine and adding fish passage enhancements to the existing portion of the culvert. The Detention Basin Project includes a flow control structure that is partially within the mapped floodway, though it is outside of the effective flow area upstream from the culvert boxes and would not obstruct flow over the roadway. The Detention Basin Project also includes removal of an existing berm that is within the mapped floodway and a new embankment, setback farther from the existing berm, but still partially within the mapped floodway. The net effect of the grading along the stream corridor is an increase in floodway conveyance. Detailed analysis

demonstrated that, when taken together, the detention basin and culvert projects would not cause a rise in regulatory flood levels except within the Project property limits, behind the embankment, where the rise is desired for increased detention to reduce downstream peak discharges.

2.0 BASELINE HYDROLOGY

Hydrologic analyses of the Dry Creek watershed that includes Miners Ravine were performed to evaluate conditions local to the basin and determine its expected function from a watershed perspective. The portion of the Miners Ravine watershed upstream from the Project is 17.6 square-miles and the potential hydrologic impacts of the Project are being considered in the context of the 101 square-mile Dry Creek watershed. Potential benefits were evaluated at multiple locations over design flood conditions from a 2 year through a 100 year flood event.

The Project hydrological evaluation included a review of baseline data. The review of previous models resulting in a determination that updated models would be necessary to make valid comparisons to quantify anticipated Project performance. This section provides an explanation of the development of the hydrologic models used as a basis of design.

2.1 Previous Hydrologic Models

The District provided RBF with HEC-1 hydrologic computer models of the Dry Creek Watershed for use in developing a basis of design. RBF reviewed these models and the information in the 1992 James M. Montgomery (JMM) *Dry Creek Watershed Flood Control Plan*, the US Army Corps of Engineers (USACE) report titled *Dry Creek Hydrology* (revised April 1988) and other sources of hydrologic data. This review identified a significant variation in what has been estimated to be the peak 100 year discharge in Miners Ravine. Peak flow rates at Sierra College Boulevard from various sources include:

1. Table 5 on page 15 of the Flood Insurance Study that indicates a 100-year peak discharge of 4,900 cubic feet per second at Sierra College Boulevard.
2. The HEC-2 file (MINERS.H2O) that calculates a water surface profile that appears to match that in the Flood Insurance Study (251.2 feet just upstream from Sierra College Boulevard) shows the discharge at Sierra College Boulevard to be 4,300 cubic feet per second.
3. The District provided baseline HEC-1 100-year model (HNBDVRNN.HC1) lists a flow rate of 4,329 cubic feet per second at Sierra College Boulevard.
4. The *Dry Creek Watershed Flood Control Plan*, by JMM dated April 1992, lists 100-year discharges of 3,847 cubic feet per second for 1989 land use conditions and 4,465 cubic feet per second for future land use conditions. (The tabulated peak discharges in the 1992 JMM report were based on a large number of input files associated with the storm centering procedures used, whereas the analysis for this study was based on the Vernon Street HEC-1 model.)

The District also provided an HEC-1 file (HNBDMINR.CA3) from a Miners Ravine floodplain re-study that contained precipitation values that resulted in higher flows at the project site than the baseline 100-year model (HNBDVRNN.HC1) provided by the District. The intent of the re-study model was to develop peak discharges that would result in peak flow conditions that correspond closely to the observed overtopping of Sierra College Boulevard (see Photograph 1) during the January 1995 flood event. The re-study flow at Sierra College Boulevard is 4,757 cubic feet per second.

Photograph 1: Flooding at Sierra College Boulevard (1995, looking south, project on right)

However, based on a review of measured precipitation, the 1995 flood event, shown above, may have been more severe than that expected to be exceeded on an average of once every 100 years. The Moss Lane rain gage within the Miners Ravine watershed upstream from Sierra College Boulevard recorded 3, 6 and 12 hour precipitation depths of 2.85, 3.60 and 5.10 inches, respectively. These depths, at the durations indicated, may be close to approximately 500 year recurrence interval depths, based on a review of available local rain gage statistics. Precipitation statistics from the CAClimate CD (see Section 2.2.4 for reference information) for the Roseville Filter Plant indicate 500 year recurrence interval depths of 2.70, 3.47, and 4.90 inches for the 3, 6 and 12 hour durations, respectively. These statistics are, however, based on only 24 years of record.

2.2 Project Baseline Hydrologic Model Development

2.2.1 100 Year Discharges

RBF identified that the HEC-1 Dry Creek watershed models provided by the District did not include zero storage/outflow values in the reaches that used the Modified Puls routing method. This method was used predominantly in the Miners Ravine portion of the model, but not throughout the entire computer model. The missing values resulted in significant anomalies in low flow hydrographs (i.e. 2-year flows), but are not readily apparent when reviewing only 100-year peak discharges. Zero storage/outflow values were inserted into the HEC-1 models, except for the one from the floodplain re-study, with the District's concurrence. This modification resulted in a significant reduction in calculated peak discharges in Miners Ravine, but had only a relatively small impact on the flow results that had been used to validate the overall Dry Creek model. Table 1 lists peak 100-year discharges at key locations from USACE study, the HNBDVRNN.HC1 file and the HEC-HMS model prepared for this study.

Table 1: Model Flows at Key Locations

Location	USACE, 1988		Baseline HEC-1 HNBDVRNN.HC1		Project HEC-HMS
	sq. mi	cfs	sq. mi	cfs	cfs
Antelope Creek at Mouth	14.85	2900	14.78	2998	3001
Secret R. above Sucker Ravine	18.1	4200	17.8	3615	3619
Secret Ravine at Mouth	22	4800	22.52	4469	4457
Miners R. at Sierra College Blvd	Not listed		17.6	4329	3788
Miners R. above Secret Ravine	20.05	5300	1931	4447	3827
Miners R. above Antelope Creek	42.39	9900	42.37	8907	8306
Miners R. below Antelope Creek	57.24	12000	57.82	11497	10975
Dry Creek above Cirby Creek	58.63	11200	58.42	10050	10999
Linda Creek at Strap Ravine	11.26	2950	11.38	2887	2878
Strap Ravine at Mouth	4.02	1260	4.07	1000	988
Linda Creek above Cirby Creek	16.4	3100	16.33	3646	3639
Cirby Creek above Linda Creek	2.09	710	2.09	948	952
Cirby Creek above Dry Creek	19.12	2950	19.54	3963	3956
Dry Creek below Cirby Creek	77.75	14300	77.96	15447	14874
Dry Creek at Vernon Street	78.2	13400	78.68	15051	14556
Dry Creek at Treatment Plant	79.6	13300	79.57	15120	14629
Dry Creek at Sac. Co. Line	88.4	12000	88.7	15561	15082

2.2.2 Range of Design and Evaluation Storm Events

A wide range of modeled storm events was used in the design and evaluation of the Project. The purposes of using this wide range of events included:

- Demonstration of flood reduction benefit from 2 year through 100 year storm events,
- Satisfying FEMA regulatory 100 year flood requirements,

- Designing the spillway to meet DSOD criteria for 1000 year conditions,
- Evaluation of the more frequent flow conditions for stream restoration design,
- Calculating flows for sediment transport analysis.

Precipitation patterns for the 2, 5, 10, 25, 50 and 100 year storm events that were used in the Project hydrologic models were the same as those used in previous models, or were provided by the District for the purposes of the Project. Differences in the shape of various recurrence interval flow hydrographs used in this study (which may result in unexpected comparative results between different recurrence intervals) are due to the basis of the assumed precipitation patterns. The 10, 25, and 100 year event models used sets of precipitation distributions (rainfall varied by sub-watershed) based one storm centering (Vernon Street) condition. The 50 year event model used a different storm centering condition which resulted in a set of hydrographs that are not entirely consistent with the other models. The 2 and 5 year event models were based on general storm precipitation patterns (identical rainfall from each sub-watershed) provided by the District. These differences in storm centering are significant only to understanding some of the result presented herein, and are not significant to the design of the project.

2.2.3 Hydrologic Parameters

Rainfall to runoff transformation and system wide hydrologic routing was performed using the District's HEC-1 model converted to HEC-HMS. Key hydrologic parameters that vary between the Dry Creek hydrologic models for the various recurrence intervals include:

1. Rainfall depths,
2. Initial loss rates, and
3. Base flow rates.

Base flow and initial loss rates were taken from the values in the 1992 JMM report. Table 2 lists the initial loss and base flow conditions used in the models.

Table 2: Initial Loss and Base Flow Conditions

Recurrence Interval (years)	Initial Loss (inches)	Base Flow (cfs/sq. mi)
1000	0.10	23
100	0.10	23
50	0.10	16
25	0.10	11
10	0.38	7
5	0.38	4.5
2	0.41	2.5

The basin models for the 100, 50, 25 and 10 year events use storm centering that applied 10 different precipitation depths depending on location within the Dry Creek Watershed. Five different depths were applied within the drainage areas in the watershed tributary to the project site. Area weighted average 6-hour precipitation depths were calculated for the watershed tributary to the project site based on the values in the models. Table 3 lists the 6-hour weighted average and general storm precipitation values.

Table 3: Six-Hour Precipitation Depths for Miners Ravine above Sierra College Boulevard

Recurrence Interval (years)	Precipitation Depth (inches)
100	2.41
50	2.29
25	1.92
10	1.62
5	1.40
2	1.06

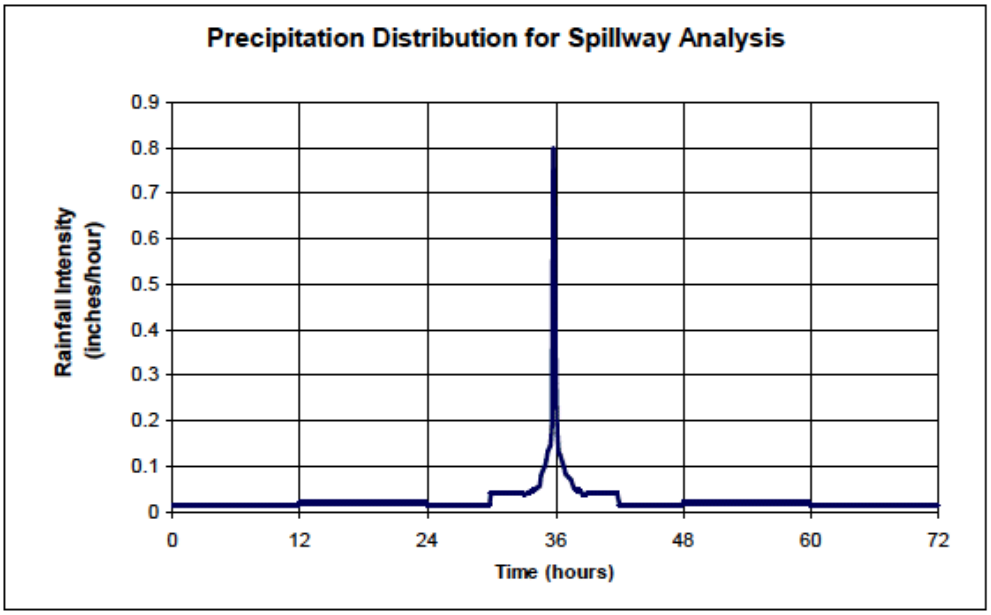
2.2.4 Precipitation for Spillway Analysis

For the project spillway evaluation, a hydrologic model of the project watershed was created using the HEC-HMS model that had been developed based on the District's Dry Creek HEC-1 model. Precipitation for spillway analysis was taken from the 1,000 year, 72-hour duration depth – duration - frequency data on the CAClimate CD provided by Mr. Jim Goodridge, formerly with the State Department of Water Resources. This data supersedes Bulletin 195 and is used by DSOD for spillway evaluations. A 10 minute interval precipitation pattern was developed that matches statistics from Roseville Filter Plant (Station Number A00 7565 30) for durations up to 24 hours and Loomis (Station Number A00 5096 00) for 2 and 3 day durations. Table 4 summarizes 1, 2 and 3 day precipitation depths at rainfall station locations in the vicinity of the project. Chart 2 illustrates the 72 hour precipitation pattern used for the spillway evaluation.

Table 4: Rainfall Station Statistical 1000-year Depths (inches)

Station	1 Day	2 Day	3 Day
Loomis 3 ENE	5.73	9.14	11.31
Loomis	5.87	9.4	11.49
Newcastle Fowler	5.85	8.95	10.88
Rocklin	5.14	8.29	10.09
Roseville Filter Plant	6.31	9.13	10.40

Chart 2: Spillway Evaluation Precipitation Pattern



2.3 Project Baseline Discharges for Comparative Analysis

HEC-HMS computer models were setup to provide a basis for comparing the potential effectiveness of alternative configurations. The flow rates presented as part of the configuration selection process are not directly comparable to discharges in previous studies by others because of the revised baseline, but the information presented summarizes how the models have been updated and integrated with the hydraulic HEC-RAS computer model to provide a consistent basis for the analysis presented herein. The following information describes the significance of the model updates and how considerations related to a potential Secret Ravine project are addressed.

2.3.1 Modifications to Flow Routing Parameters

The computer program HEC-HMS was used to calculate flow hydrographs throughout the Dry Creek watershed using a model based on the HEC-1 file HNBDVRNN.HC1. As previously discussed, data points were added to the storage-discharge flow routing curves in the original model to include a point of zero flow at zero storage. Additionally, data points were extrapolated above the high end of the previous model curve to allow the model to run for the more extreme events that resulted in discharges that exceeded the range included in the original HEC-1 file. (This was necessary to perform the 1000 year storm analysis for spillway design.)

For comparison of conditions with and without a proposed project on Secret Ravine, storage – discharge curves for the Secret Ravine Alternative 1 project site and adjacent reach routing parameters were added based on information in the *Secret Ravine – Floodplain and Restoration Feasibility Study*, dated August 2003 by HDR and the HEC-HMS basin model named "Sr 100Yr Alt 1" provided by the District.

2.3.2 Modeling Process

The complete Dry Creek watershed HEC-HMS model was used to calculate peak values and runoff hydrographs at locations throughout the watershed. Flow hydrographs on Miners Ravine at Sierra College Boulevard were used as the upstream boundary condition for detailed flow routing in unsteady HEC-RAS along the Miners Ravine project reach from Sierra College Boulevard to False Ravine. The output hydrographs from HEC-RAS were then used as flow into the HEC-HMS model to evaluate impacts on peak flow rates at key locations throughout the Dry Creek watershed for the range of alternative Miners Ravine detention basin project configurations considered. The development of the unsteady-state HEC-RAS existing conditions model and the evaluation of alternatives are described in the *Hydraulic Analysis* section of this report.

Peak flows and selected hydrographs were extracted from the HEC-HMS and HEC-RAS output for comparison at key locations. Table 5 summarizes the key locations and the corresponding model locations.

Table 5: Key Location Summary

Location	Tributary Area (sq. mi)	HEC-HMS Node	HEC-RAS Cross Section
Miners Ravine above Sierra College Blvd	17.6	SCB MRC	
Miners Ravine above Secret Ravine	19.31	MR37 RO	7849.9
Miners Ravine at Harding Blvd	42.37	MINERS M	111
Dry Creek Ravine at Folsom Rd	57.82	DCC1 – C	79852.1
Dry Creek and Vernon St	78.68	VERNON-	70110.5
Dry Creek at Sacramento Co Line	88.7	DCC8 – C	

Tables 6.A through 6.F list peak flows from the HEC-HMS model at key locations for the evaluated recurrence intervals. The implications of the various Secret Ravine routing conditions are presented at the request of the District to evaluate the anticipated effect of the proposed Miners Ravine project in addition to the anticipated effects of a proposed future Secret Ravine project on the watershed. It is necessary to consider the following set of models to attribute calculated flow changes to their cause and validate the comparative analyses.

Case 1: SR-OrigHMS – MR-OrigHMS
All routing in HEC-HMS, original model uses HNBDVRNN.HC1 routing on Secret Ravine (basin model names include "DC ORIG").

Case 2: SR-ExHMS – MR-OrigHMS
All routing in HEC-HMS, Secret Ravine routing based on existing conditions storage – outflow curve provided in the *Secret Ravine – Floodplain and Restoration Feasibility Study*, dated August 2003 by HDR (basin model names include "DC SR ExCurve"). It was necessary to develop the *SR-ExHMS – MR-OrigHMS* model to provide an appropriate baseline to evaluate the potential benefit of the Secret Ravine project because the routing parameters in the original HEC-1 model did not accurately represent the existing conditions storage-outflow relationship at the Alternative 1 site as presented in the 2003 report.

Case 3: SR-Alt1HMS – MR-OrigHMS
All routing in HEC-HMS, Secret Ravine routing based on proposed conditions storage – outflow curve (basin model names include "DC SR Alt1"). Comparison of *SR-Alt1HMS – MR-OrigHMS* model results to *SR-ExHMS – MR-OrigHMS* model results identifies the expected benefit of the Alternative 1 Secret Ravine project based on the curve included in the 2003 report.

Case 4: SR-Alt1HMS – MR-ExRAS
Routing along Miners Ravine above False Ravine based on existing conditions HEC-RAS model. Secret Ravine routing based on proposed conditions storage – outflow curve (basin model names include "DC SRA1 ExM"). The *SR-Alt1HMS – MR-ExRAS* model provides the baseline to which the expected impacts of Miners Ravine projects evaluated using HEC-RAS can be compared with the Secret Ravine project as anticipated in the 2003 report.

Case 5: SR-ExHMS – MR- ExRAS
Routing along Miners Ravine above False Ravine based on existing conditions HEC-RAS model. Secret Ravine routing based on existing conditions storage – outflow curve (basin model names include "DC SRExCu ExM"). The *SR-ExHMS – MR-ExRAS* model provides the baseline to which the expected impacts of Miners Ravine projects evaluated using HEC-RAS can be compared without the Secret Ravine project as anticipated in the 2003 report and allows the anticipated benefit of the Miners Ravine project to be considered separately from or in combination with the feasibility level anticipated benefits of the Secret Ravine project.

The process of evaluating the listed models provides a baseline so that the incremental benefit of the proposed Miners Ravine project by itself, or above that expected from a future Secret Ravine project, can be determined.

It is recognized that the precision listed in the flow rate table is greater than the accuracy of these values from an absolute perspective. However, by maintaining the high level of precision by not rounding the results, valid conclusions may be drawn based on the differences between specific cases.

Table 6.A: 100-Year Baseline Flow Comparison (cubic feet per second)

Location	Case 1	Case 2	Case 3	Case 4	Case 5
Miners Ravine above Sierra College Blvd	3,788	3,788	3,788	3,788	3,788
Miners Ravine above Secret Ravine	3,827	3,827	3,827	3,784	3,788
Miners Ravine at Harding Blvd	8,306	8,070	7,979	7,930	8,024
Dry Creek at Folsom Rd	10,975	10,758	10,670	10,630	10,718
Dry Creek and Vernon St	14,556	14,384	14,313	14,273	14,344
Dry Creek at Sacramento Co Line	15,082	14,922	14,855	14,815	14,882

Table 6.B: 50-Year Baseline Flow Comparison (cubic feet per second)

Location	Case 1	Case 2	Case 3	Case 4	Case 5
Miners Ravine above Sierra College Blvd	3,420	3,420	3,420	3,420	3,420
Miners Ravine above Secret Ravine	3,446	3,446	3,446	3,385	3,385
Miners Ravine at Harding Blvd	7,274	7,070	6,986	6,927	7,012
Dry Creek at Folsom Rd	9,928	9,726	9,645	9,618	9,699
Dry Creek and Vernon St	13,243	13,047	12,965	12,923	13,004
Dry Creek at Sacramento Co Line	13,656	13,476	13,399	13,354	13,431

Table 6.C: 25-Year Baseline Flow Comparison (cubic feet per second)

Location	Case 1	Case 2	Case 3	Case 4	Case 5
Miners Ravine above Sierra College Blvd	2,627	2,627	2,627	2,627	2,627
Miners Ravine above Secret Ravine	2,635	2,635	2,635	2,544	2,544
Miners Ravine at Harding Blvd	5,798	5,675	5,598	5,519	5,595
Dry Creek at Folsom Rd	7,681	7,543	7,469	7,391	7,465
Dry Creek and Vernon St	10,235	10,096	10,017	9,943	10,013
Dry Creek at Sacramento Co Line	10,556	10,429	10,361	10,291	10,359

Table 6.D: 10-Year Baseline Flow Comparison (cubic feet per second)

Location	Case 1	Case 2	Case 3	Case 4	Case 5
Miners Ravine above Sierra College Blvd	1,684	1,684	1,684	1,684	1,684
Miners Ravine above Secret Ravine	1,650	1,650	1,650	1,680	1,680
Miners Ravine at Harding Blvd	3,878	3,829	3,768	3,810	3,872
Dry Creek at Folsom Rd	5,175	5,133	5,087	5,073	5,125
Dry Creek and Vernon St	6,997	6,950	6,895	6,917	6,974
Dry Creek at Sacramento Co Line	7,276	7,231	7,180	7,190	7,241

Table 6.E: 5-Year Baseline Flow Comparison (cubic feet per second)

Location	Case 1	Case 2	Case 3	Case 4	Case 5
Miners Ravine above Sierra College Blvd	1,252	1,252	1,252	1,252	1,252
Miners Ravine above Secret Ravine	1,249	1,249	1,249	1,277	1,277
Miners Ravine at Harding Blvd	2,894	2,742	2,742	2,706	2,875
Dry Creek at Folsom Rd	4,309	4,154	4,154	4,127	4,267
Dry Creek and Vernon St	5,843	5,628	5,628	5,648	5,828
Dry Creek at Sacramento Co Line	6,082	5,883	5,883	5,897	6,061

Table 6.F: 2-Year Baseline Flow Comparison (cubic feet per second)

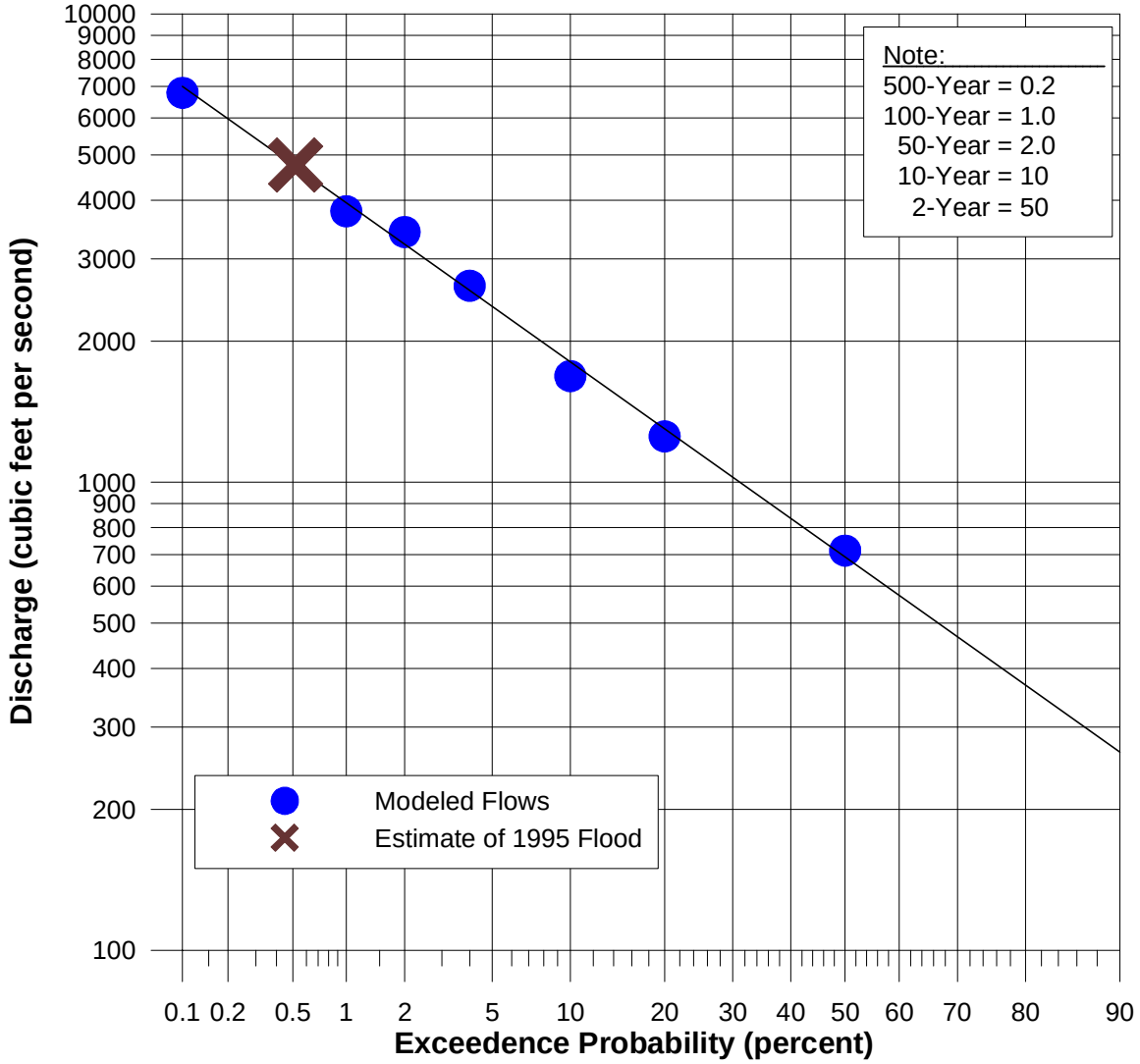
Location	Case 1	Case 2	Case 3	Case 4	Case 5
Miners Ravine above Sierra College Blvd	714	714	714	714	714
Miners Ravine above Secret Ravine	701	701	701	757	757
Miners Ravine at Harding Blvd	1,677	1,593	1,584	1,606	1,654
Dry Creek at Folsom Rd	2,404	2,346	2,323	2,321	2,390
Dry Creek and Vernon St	3,391	3,309	3,298	3,314	3,371
Dry Creek at Sacramento Co Line	3,531	3,447	3,433	3,442	3,509

2.5 Peak Discharges at Sierra College Boulevard

The 1000-year discharge at Sierra College Boulevard calculated using the HEC-HMS model is 6,782 cfs. The peak discharge from the HEC-1 model that was set up to approximate the 1995 event shows a peak discharge of 4,757 cubic feet per second (cfs) in Miners Ravine upstream from Sierra College Boulevard.

Chart 3 shows a probability plot of flows in Miners Ravine upstream from Sierra College Boulevard using the HEC-HMS results. Based on the model results, the discharge of 4,757 cubic feet per second at Sierra College Boulevard appears to be on the order of a 200-year recurrence interval event.

Chart 3: Flow Probability Plot for Miners Ravine at Sierra College Blvd.



3.0 HYDRAULIC ANALYSES

Hydraulic analyses were performed to establish baseline conditions, evaluate alternative improvements and design project features through the use of detailed computer models configured to simulate the effects of the project's physical configuration on flows along Miners Ravine. The flows along Miners Ravine were calculated as described in the Hydrology section. The following sections describe how these flows were used to evaluate conditions at the site. Hydraulic analyses were also used to investigate failure scenarios for risk considerations and to demonstrate the adequacy of the design as related to Division of Safety of Dams requirements.

3.1 Existing Conditions

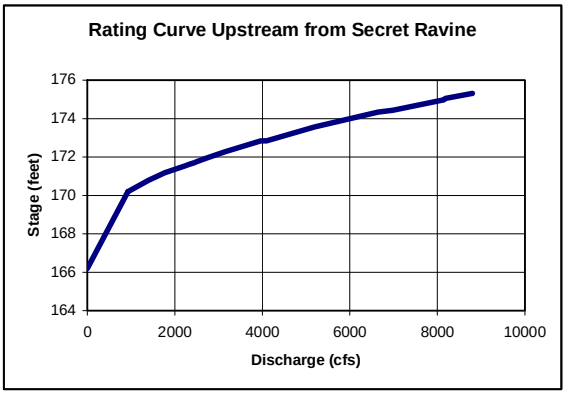
A HEC-RAS model of the project area was developed to provide a consistent baseline to which the effects of site modifications could be evaluated. The existing conditions unsteady-state HEC-RAS model developed for this study was based on the URS "R04 Existing Conditions" geometry modified in the vicinity of the project using project survey information. The updated existing conditions model defined the area of the old sewage treatment basins as storage areas connected to the channel with a series of lateral connections, instead of being part of the channel overbank. Additionally, refinements were made to the parameters used to define how ineffective flow areas and the Sierra College Boulevard culvert function.

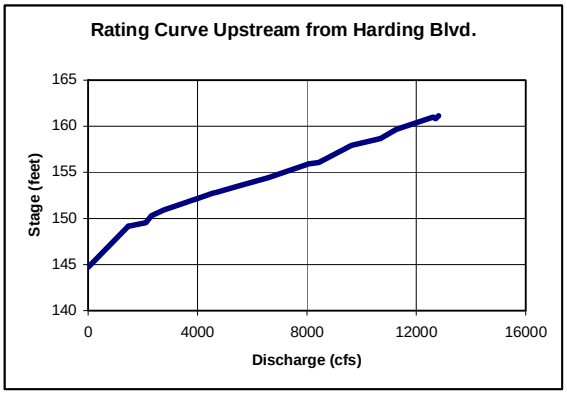
The Dry Creek HEC-RAS hydraulic model was used to calculate flood depth versus discharge rating curves at key locations downstream from the proposed project. These rating curves, shown on Chart 4, were extracted at cross sections just upstream from the Miners Ravine confluence with Secret Ravine, and along Dry Creek at Harding Boulevard, Folsom Street, and Vernon Street. These rating curves provided the means to correlate the discharges calculated in the HEC-HMS models to flood stages to calculate anticipated flood elevation reductions at key locations based on the various project configuration alternatives. Table 7 lists the baseline existing conditions water surface elevations determined from the Case 5 (i.e. no Miners Ravine or Secret Ravine project) flows and these rating curves.

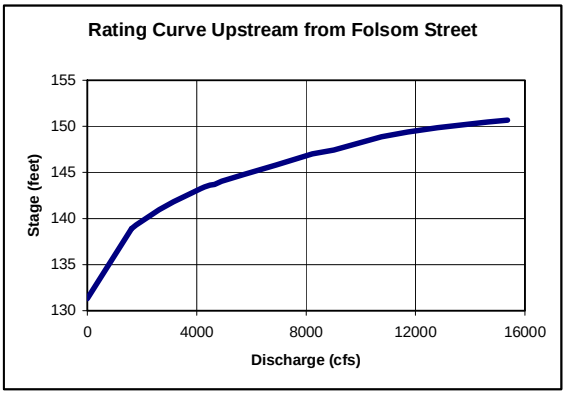
Table 7: Existing Conditions Water Surface Elevation (feet)

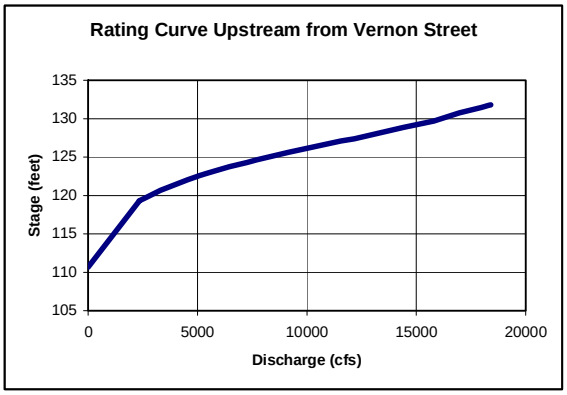
Location	**Recurrence Interval (years)**					
	2	*5*	*10*	*25*	*50*	*100*
Secret Ravine	169.5	170.6	171.1	171.8	172.4	172.7
Harding Blvd	149.3	151.0	152.0	153.6	154.9	155.9
Folsom Rd	140.5	143.4	144.2	146.3	148.0	148.8
Vernon St	120.7	123.2	124.1	126.1	127.9	128.8

Chart 4: Rating Curves at Key Sections









3.2 Basin Capacity

3.2.1 Minimum Basin Elevation

One of the major factors that will determine the effectiveness of the detention basin is its capacity. Because the area of the site is limited, the capacity is largely determined by the lowest practical bottom elevation and the maximum flood stage during an event. Pumping was determined to not be feasible due to cost and environmental considerations. Therefore, the minimum effective storage elevation in the basin was determined by that elevation which would drain by gravity and could be relied upon as being available at the onset of the design event.

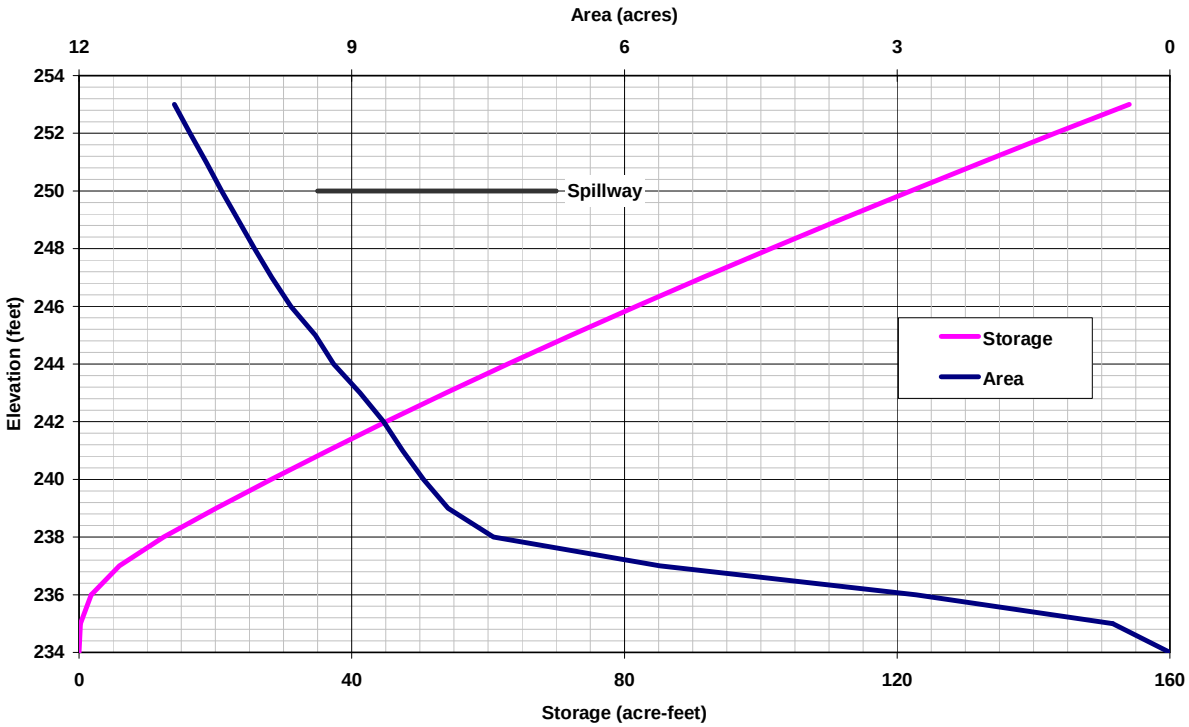
Stream stage at the low level outlet connection point controls the minimum level of effective storage because any water in the basin below the water level in the stream can not drain by gravity. A flap gate was originally proposed on the low level outlet pipe, however, due to fish passage considerations and detailed analysis that showed the flood control advantage of a flap gate with the final basin configuration was minimal, no flap gate is included in the final design. The Dry Creek hydrologic model assumes a base flow of 23 cubic feet per second per

square-mile before a 100-year storm. This corresponds to a base flow condition of 400 cubic feet per second past the project site. Any storage below the stage corresponding to 400 cfs in Miners Ravine might not be effective, even though flows would not be expected to remain at that level for extended durations. Based on an analysis of stream stage at the expected low level outlet location, the minimum practical effective stage in the basin was determined to be approximately elevation 235 feet. The proposed minimum basin elevation is slightly lower based on the design consideration that the bottom of the basin must be sloped for positive drainage. Having a small amount (0.3 acre-feet) of potentially ineffective storage between elevations 234 feet and 235 feet allows the bottom to be graded adequately and increases effective storage above 235 feet.

3.2.2 Elevation verses Capacity Relationship

Various elevation-area-capacity curves were developed during the design process. Chart 5 shows the elevation-area-capacity curves used for the hydraulic and hydrologic analyses of the design configuration. A slightly different curve was used in the alternatives analysis.

Chart 5: Elevation-Area-Capacity Curves



3.3 System Configuration

3.3.1 Initial Concepts

Initially, three general configurations were considered. These configurations included:

- Connecting the basin to the downstream side of Sierra College Boulevard,
- Connecting the basin to the upstream side of Sierra College Boulevard, and
- Connecting the facility to the upstream side of Sierra College Boulevard with the basin split into one area that would flood in more frequent events and one area with storage for more severe storms.

3.3.2 Key Design Considerations

Preliminary analysis concluded that there would not likely be significant potential benefit from splitting the basin. The effectiveness of the available storage could be better controlled through the selection of an appropriate system of weirs, openings and gates. The most significant factors related to the effectiveness of the available storage at attenuating the peak from any given event were determined to be:

- How much conveyance from the stream to the basin is available,
- What elevation the conveyance becomes effective,
- The shape of the stage and flow hydrographs at the point of connection between the stream and the basin, and
- When tailwater (water level in the basin) limits inflow.

Optimization of the facility for a particular event would involve diverting flows so that the entire available storage is utilized to detain flows above some flow rate. This would truncate the peak from the flow hydrograph to the lowest possible downstream peak rate. However, this idealization cannot be achieved because:

- It is preferable that the basin must provide benefit over a wide range of events,
- Fixed systems require increasing head to add conveyance (that is, a passive system cannot physically achieve the optimum and it would be preferable to not rely on a mechanical system), and
- There is uncertainty, and variability over time, in the rating curve for the stream channel at the point, or points, of connection.

Mechanical systems that were considered to help optimize the basin configuration within the practical constraints of the project included: inflatable weirs, automatic upstream level control gates, and motor driven gates that would

open and close based on stream gage set points. Only motor driven gates were determined to have practical application to this project. This is because they help to improve performance of the basin during the lower range of events (2- to 10-year events) for which flood attenuation is desired, while withholding potential flood detention capacity for more extreme events. A fixed, non-mechanical, system would be used to control the majority of the diversion during 25- to 100-year events.

In addition to much greater storage capacity, connection of the basin to the upstream side of Sierra College Boulevard has the advantages of:

- Greater change in stage over the range of flows resulting more head being available to convey flows over a fixed system, and
- Greater predictability because the culvert generally controls flows instead the natural stream, thereby eliminating some uncertainty induced by variability in, and accuracy estimating, stream roughness.

A system that includes one relatively small motor driven gate was selected to control a limited amount of flow into the basin at lower stream levels without diverting too much, too fast, at higher stages, as would be the case with a fixed weir at that preset level.

3.3.3 Alternatives Analysis

Preliminary analysis was performed to compare upstream and downstream connections, with and without motor driven gate(s) to control inflow during the more frequent attenuated events. This analysis was performed based on preliminary configurations. The final design configuration is a refinement of configuration B2 describe below.

Configuration A1 is a basin with the inlet/outlet structure downstream from Sierra College Boulevard without mechanical controls. Specific features include:

1. A 60 foot long trapezoidal broad-crested weir at elevation 245 with 15 percent end slopes; and
2. Three 3 foot and two 4 foot diameter culverts with inverts at elevations 239.0, 239.5, 240.0, 241.0 and 241.5 feet, respectively.

Configuration A2 is a basin with the inlet/outlet structure downstream from Sierra College Boulevard with a motor driven slide gate. Specific features include:

1. A 90 foot long triangular broad-crested weir with a low point and elevation 243 feet and high points at elevation 248 feet; and

2. A 3.5 foot square slide gate with an invert elevation of 237 feet set to open when the streamside water surface reaches elevation 240.0 feet and to close at 239.7 feet.

Configuration B1 is a basin with the inlet/outlet structure upstream from Sierra College Boulevard without mechanical controls. Specific features include:

1. A 40-foot long weir with a 10-foot wide base at elevation 241.75 feet with upward slopes to elevation 246 feet over a horizontal distance of 2.5 feet and additional upward slopes up to elevation 248 feet over a horizontal distance of 12.5 feet.
2. A 12-foot wide by 8-foot high culvert under Sierra College Boulevard connecting the structure with the weir to the basin.

Configuration B2 is a basin with the inlet/outlet structure upstream from Sierra College Boulevard with a motor driven slide gate. Specific features include an inlet/outlet control structure on the eastern end of a 12 foot wide by 8 foot high culvert with an invert of 238 feet under Sierra College Boulevard connecting the stream to the basin with:

1. A 40 foot long stepped weir with 10-feet at elevations 245, 246, 247, and 248 feet;
2. Two 6.5 foot square flap gates with inverts at 238 feet that allow flow only in the direction from the basin to the stream; and
3. Two 2.5 foot square motor driven slide gates with inverts at 238 feet that open at streamside water surface elevations of 242.0 and 243.5 feet, respectively, and close three-tenths of a foot lower.

3.3.4 System Performance

The Table 8.A through 8.H list the peak discharge and peak stage reduction at key downtown Roseville locations compared to the Case 4 (no Miners Ravine project) baseline conditions.

Table 8.A: Configuration A1, Downstream Connection, Fixed Control, Peak Discharge Reduction (cubic feet per second)

Location	**Recurrence Interval (years)**					
	2	*5*	*10*	*25*	*50*	*100*
Secret Ravine	33	33	73	79	99	138
Harding Blvd	28	22	79	86	152	163
Folsom Rd	0	22	43	89	159	106
Vernon St	26	32	63	87	174	100

Table 8.B: Configuration A1, Downstream Connection, Fixed Control, Peak Stage Reduction (feet)

Location	Recurrence Interval (years)					
	2	*5*	*10*	*25*	*50*	*100*
Secret Ravine	0.14	0.04	0.07	0.07	0.07	0.09
Harding Blvd	0.02	0.03	0.08	0.07	0.15	0.16
Folsom Rd	0.00	0.03	0.04	0.08	0.13	0.09
Vernon St	0.03	0.03	0.04	0.05	0.12	0.07

Table 8.C: Configuration A2, Downstream Connection, Low Flow Gate Control, Peak Discharge Reduction (cubic feet per second)

Location	Recurrence Interval (years)					
	2	*5*	*10*	*25*	*50*	*100*
Secret Ravine	5	91	98	25	26	85
Harding Blvd	-1	59	108	25	83	138
Folsom Rd	0	67	69	31	207	197
Vernon St	-1	89	93	34	151	126

Table 8.D: Configuration A2, Downstream Connection, Low Flow Gate Control, Peak Stage Reduction (feet)

Location	Recurrence Interval (years)					
	2	*5*	*10*	*25*	*50*	*100*
Secret Ravine	0.02	0.11	0.10	0.02	0.02	0.06
Harding Blvd	0.001	0.08	0.11	0.02	0.08	0.14
Folsom Rd	0.00	0.09	0.06	0.03	0.17	0.16
Vernon St	0.001	0.07	0.06	0.02	0.10	0.08

Table 8.E: Configuration B1, Upstream Connection, Fixed Control, Peak Discharge Reduction (cubic feet per second)

Location	Recurrence Interval (years)					
	2	*5*	*10*	*25*	*50*	*100*
Secret Ravine	8	6	49	118	328	347
Harding Blvd	4	8	45	131	303	395
Folsom Rd	0	7	48	182	147	104
Vernon St	2	9	44	171	271	203

Table 8.F: Configuration B1, Upstream Connection, Fixed Control, Peak Stage Reduction (feet)

Location	Recurrence Interval (years)					
	2	*5*	*10*	*25*	*50*	*100*
Secret Ravine	0.03	0.01	0.05	0.10	0.23	0.24
Harding Blvd	0.00	0.01	0.05	0.11	0.30	0.40
Folsom Rd	0.00	0.01	0.04	0.17	0.12	0.09
Vernon St	0.00	0.01	0.03	0.10	0.18	0.14

Table 8.G: Configuration B2, Upstream Connection, Low Flow Gate Control, Peak Discharge Reduction (cubic feet per second)

Location	Recurrence Interval (years)					
	2	*5*	*10*	*25*	*50*	*100*
Secret Ravine	8	39	68	13	227	396
Harding Blvd	4	46	53	29	258	449
Folsom Rd	0	47	78	78	288	245
Vernon St	2	49	60	73	280	269

Table 8.H: Configuration B2, Upstream Connection, Low Flow Gate Control, Peak Stage Reduction (feet)

Location	Recurrence Interval (years)					
	2	*5*	*10*	*25*	*50*	*100*
Secret Ravine	0.03	0.05	0.07	0.01	0.16	0.27
Harding Blvd	0.00	0.06	0.05	0.02	0.26	0.45
Folsom Rd	0.00	0.07	0.07	0.07	0.24	0.20
Vernon St	0.00	0.04	0.04	0.04	0.19	0.18

The results show that there would be a clear advantage to connecting the system to the upstream side of Sierra College Boulevard. Whether or not a gate system should be used would depend on what is ultimately desired as a system response and whether or not the cost of a gate is worth the benefit of it.

It may be noted that the benefit of the configurations may not appear consistent over the range of events that were evaluated. This is partially due to the existing site already acting as an off-channel detention basin to a limited degree. During events when the existing basins would provide substantial benefit, such as during a 25-year event, the project may show a relatively lower net benefit. Total stream peak discharge attenuation from flows above Sierra College Boulevard to flows below the project site show consistent results and the higher total attenuation of the site, but were not used to calculate project benefit.

3.4 Final Design Configuration Expected Performance

3.4.1 Final System Configuration with Road Widening Project Culvert

The preferred alternative configuration includes:

1. A structure upstream from Sierra College Boulevard with:
    a. Four weir crests, at elevations 245.67, 246.67, 247.67, and 248.67 feet, each with a length on 10 feet;

b. Two openings fitted with flap gates to allow rapid draining of the basin as stream level recedes, each opening being 3 feet square with an invert at elevation 238 feet;
c. An opening 3 feet high by 4 feet wide with an invert at elevation 238.5 covered by a motor drive slide gate set to open when the local stream stage reaches elevation 242.0 feet and close once stream level recedes to 241.7 feet.

2. An inlet/outlet culvert connecting the structure upstream from Sierra College Boulevard to the basin that is 6 feet high by 10 feet wide with an invert at elevation 237 feet (+/-) with a length of 168 feet.
3. A low level outlet with a diameter of 1.5 feet, and invert elevation of 234 feet, and a flap gate to preclude flow from Miners Ravine into the basin.
4. A spillway at elevation 250 feet to protect the embankment for flood event up to at least a 1000-year storm.

3.4.2 Final Design Expected Benefit

The net benefit of the preferred alternative can be computed by identifying flood reduction from the Case 5 scenario described in the Hydrology section. The anticipated benefit was evaluated using case 5 as a baseline condition to account for the Miners Ravine benefit without a Secret Ravine Project. Table 9 summarizes the Case 5 flows, Tables 9 and 10 show baseline and final design flow rates. Tables 11 and 12 summarizes the flow and stage reductions expected to result from the preferred alternative.

Table 9: Baseline (Case 5) Discharges (cubic feet per second)

Location	**Recurrence Interval (years)**					
	2	*5*	*10*	*25*	*50*	*100*
Secret Ravine	757	1,277	1,680	2,544	3,385	3,788
Harding Blvd	1,654	2,875	3,872	5,595	7,012	8,024
Folsom Rd	2,390	4,267	5,125	7,465	9,699	10,718
Vernon St	3,371	5,828	6,974	10,013	13,004	14,344

Table 10: Design Configuration Discharges (cubic feet per second)

Location	**Recurrence Interval (years)**					
	2	*5*	*10*	*25*	*50*	*100*
Secret Ravine	749	1202	1594	2496	3148	3374
Harding Blvd	1654	2769	3778	5535	6747	7587
Folsom Rd	2389	4161	5044	7381	9422	10475
Vernon St	3370	5701	6884	9934	12731	14081

Table 11: Design Configuration Flow Reduction (cubic feet per second)

Location	Recurrence Interval (years)					
	2	*5*	*10*	*25*	*50*	*100*
Secret Ravine	8	75	86	49	236	414
Harding Blvd	1	106	94	60	265	437
Folsom Rd	0	106	81	84	277	243
Vernon St	1	127	90	80	273	263

Table 12: Design Configuration Stage Reduction (feet)

Location	Recurrence Interval (years)					
	2	*5*	*10*	*25*	*50*	*100*
Secret Ravine	0.03	0.09	0.09	0.04	0.16	0.28
Harding Blvd	0.00	0.11	0.09	0.05	0.27	0.44
Folsom Rd	0.00	0.14	0.07	0.08	0.23	0.20
Vernon St	0.00	0.11	0.06	0.05	0.18	0.18

3.4.3 Final Design Operation

Charts were prepared to illustrate the design function of the proposed off-channel detention basin system. Chart 6 shows the design basin stage hydrograph in response to the design 100 year storm event. The graph shows how basin stage would rise in response to stream stage and then fall rapidly following the receding limb of the stream stage hydrograph. The basin stage continues to fall below the stream stage upstream from Sierra College Boulevard due to low level outlet flow.

Chart 6: Stream and Basin Stage Hydrographs

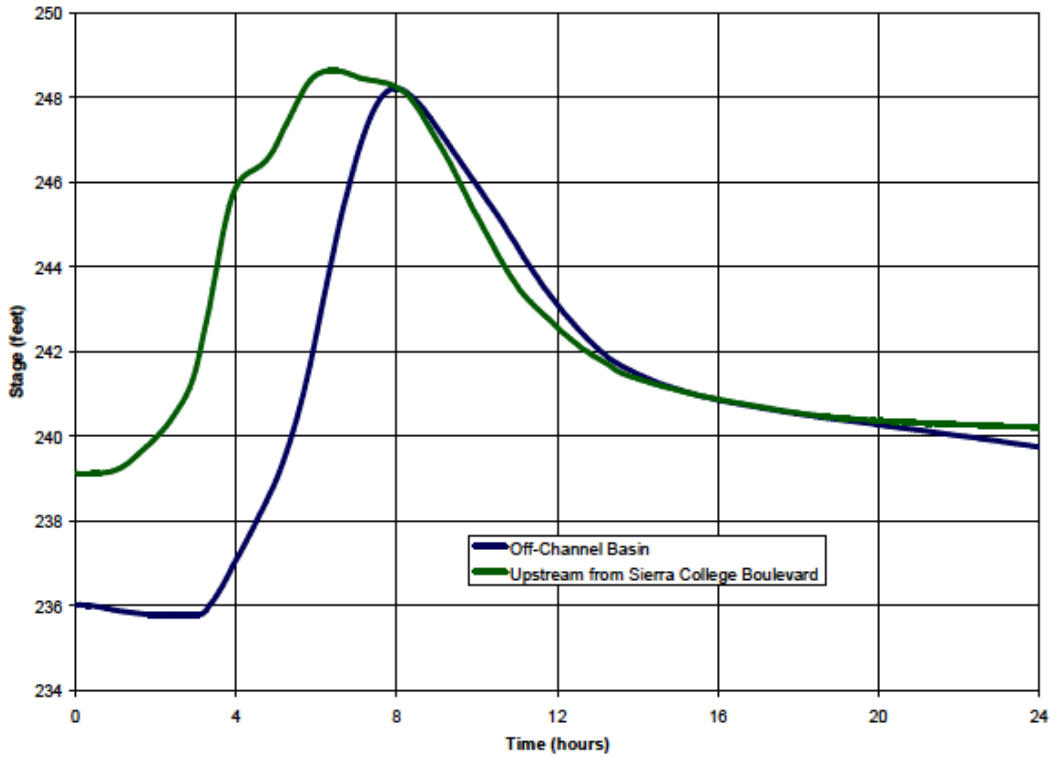


Chart 7 shows 100 year design flows through the inlet/outlet culvert and the low level outlet. High flows into and out from the basin provide peak flow attenuation and rapid recovery of storage for back-to-back storms.

Chart 7: Basin Flow Hydrographs

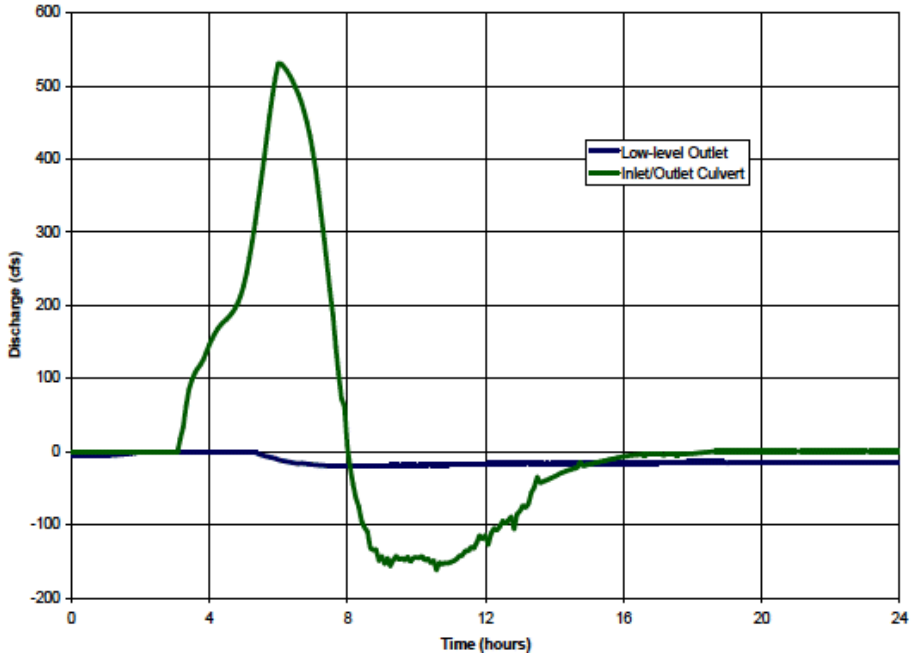
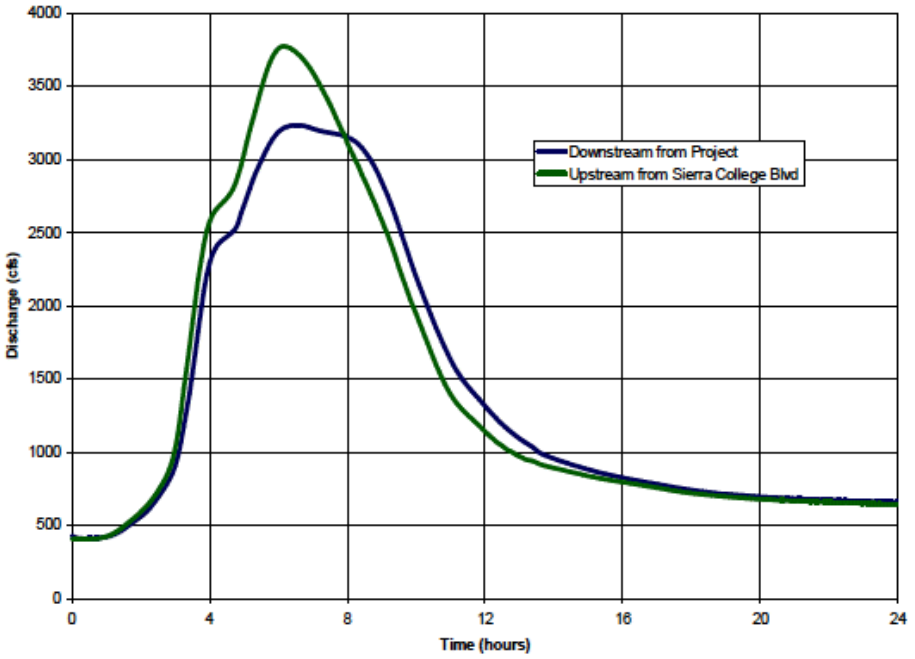


Chart 8 shows the effectiveness of the project area at attenuating peak discharges by comparing the flow hydrographs upstream and downstream from the site.

Chart 8: 100-Year Stream Flow Attenuation



3.4.4 Site Stream Flow Conditions

Stream flow conditions in the vicinity of the project site influence environmental enhancement and restoration planning, embankment erosion control measures, and basin operation.

Table 13 summarizes existing and design peak discharges along Miners Ravine downstream from Sierra College Boulevard. Table 14 lists peak water surface elevations just downstream from Sierra College Boulevard and near the westerly end of the proposed embankment. Table 14 also includes the maximum main channel velocity calculated by the model for the channel adjacent to the embankment. Overbank velocities are expected to be significantly less, but will vary with the state of vegetation. Additional stream parameters can be extracted, as needed, from the computer models.

Table 13: Stream Flow Rate Summary

Recurrence Interval (yrs)	Flow Rate Downstream from Sierra College Blvd.	
	Existing Conditions (cfs)	Design Conditions (cfs)
1000	6800	6300
100	3800	3200
50	3400	3000
25	2600	2500
10	1700	1600
5	1200	1100
2	700	700

Table 14: Stream Stage and Velocity Summary

Recurrence Interval (yrs)	Water Surface Elevation (ft)		Channel Velocity (fps)
	East End	West End	
1000	246.7	244.9	9.1
100	242.8	240.3	8.3
50	242.6	240.0	8.1
25	241.8	239.2	7.4
10	240.6	238.0	6.2
5	239.8	237.2	5.6
2	238.8	236.2	4.6

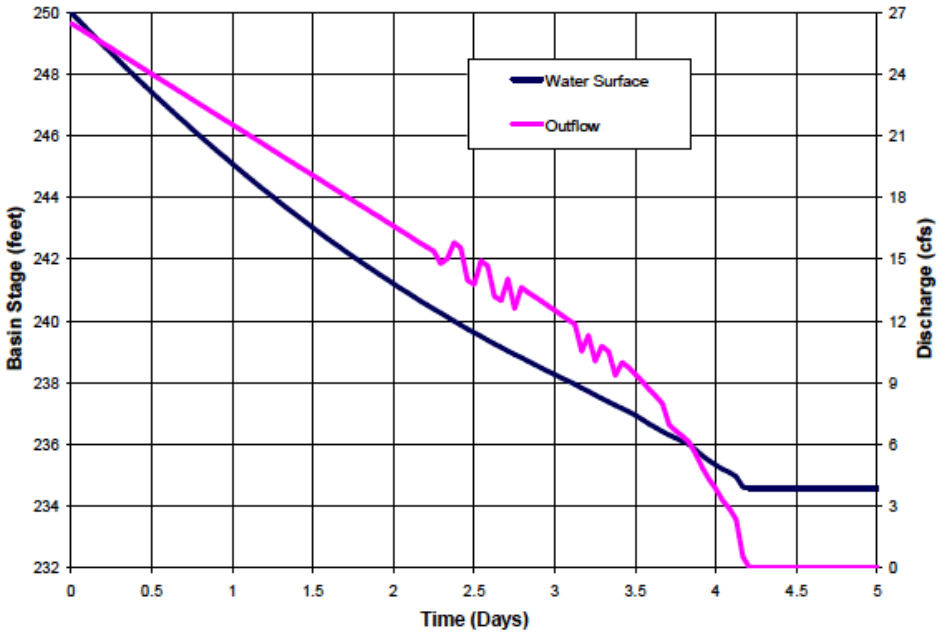
3.5 Basin Drawdown

The proposed configuration includes a low level outlet to provide positive drainage from the basin. The proposed configuration calls for an unregulated outlet consisting of an 18-inch diameter reinforced concrete pipe through the embankment. The pipe would be fitted with a flap gate to preclude flows from the stream to the basin.

HEC-RAS was used to calculate how long it would take to empty the proposed basin through the low level outlet. The analysis assumed that the initial stage in

the basin was elevation 250 feet, at the spillway crest. No flow through the inlet/outlet culvert was assumed. A base flow of 200 cfs was assumed in Miners Ravine. Chart 9 shows the outflow rate and indicates that the basin would completely drain in less than five days.

Chart 9: Basin Drawdown Rate



3.6 Spillway Configuration

The proposed spillway configuration has a trapezoidal crest with a horizontal length of approximately 90 feet at elevation 250 feet and slopes to conform to the abutment at the northern end and to the bike path at the southern end. Flow over the spillway would pass onto the bike path that is configured as a side channel spillway. Beyond the west end of the embankment, flows would drain to the south, across the existing small basin area, and return to the main channel of Miners Ravine.

As an off-channel facility, the basin interior would only be exposed to a fraction of the peak discharge from a 100-year event. As the water level in the basin would rise in response to rising water levels upstream from Sierra College Boulevard, backwater conditions would reduce flows through the inlet/outlet culvert into the basin. Unlike an on-channel basin where an infinite duration of peak stream from would result in peak stream flow over the spillway, basin peak inflow rate while the off-channel basin level is rising is higher than that which would occur at conditions based on an infinite duration of peak stream flow.

A three day, 1000 year recurrence interval storm was developed and used to evaluate spillway performance. The spillway was modeled two different ways. One model was set up to evaluate the spillway and side channel simultaneously and does not model the basin or stream. The primary system model assumes a weir coefficient, C, of 2.6 ($Q=CLH^{3/2}$) but does not provide analysis of the side channel and potential backwater effects on spillway discharge.

Chart 10 shows 1000 year flow hydrographs with a peak stream discharge of 6,800 cfs, a peak basin inflow of 870 cfs and a peak spillway flow of 440 cfs. Peak stream stage upstream from Sierra College Boulevard was calculated to be 253.2 feet and peak basin stage was calculated to be 251.4 feet, relative to a spillway crest at elevation 250.0 feet and an embankment crest at elevation 254.0 feet. Chart 11 illustrates spillway rating curves based on both the hydraulic models and demonstrates that the proposed system would have ample capacity for the design event with more than 1.5 feet of freeboard.

Peak conditions of basin stage spillway flow for the proposed off-channel detention basin result from peak stage upstream from Sierra College Boulevard and are not otherwise linked to stream flow or runoff volume. Peak stage upstream from Sierra College Boulevard and that within the basin will be dependent on peak stream discharge and the design of the proposed system's inlet/outlet works and spillway. The 72-hour distribution developed for spillway analysis includes short duration peak intensities that result in peak discharges that would be expected to control the peak conditions for the spillway design recurrence interval.

Chart 10: 1000 Year Discharge Hydrographs

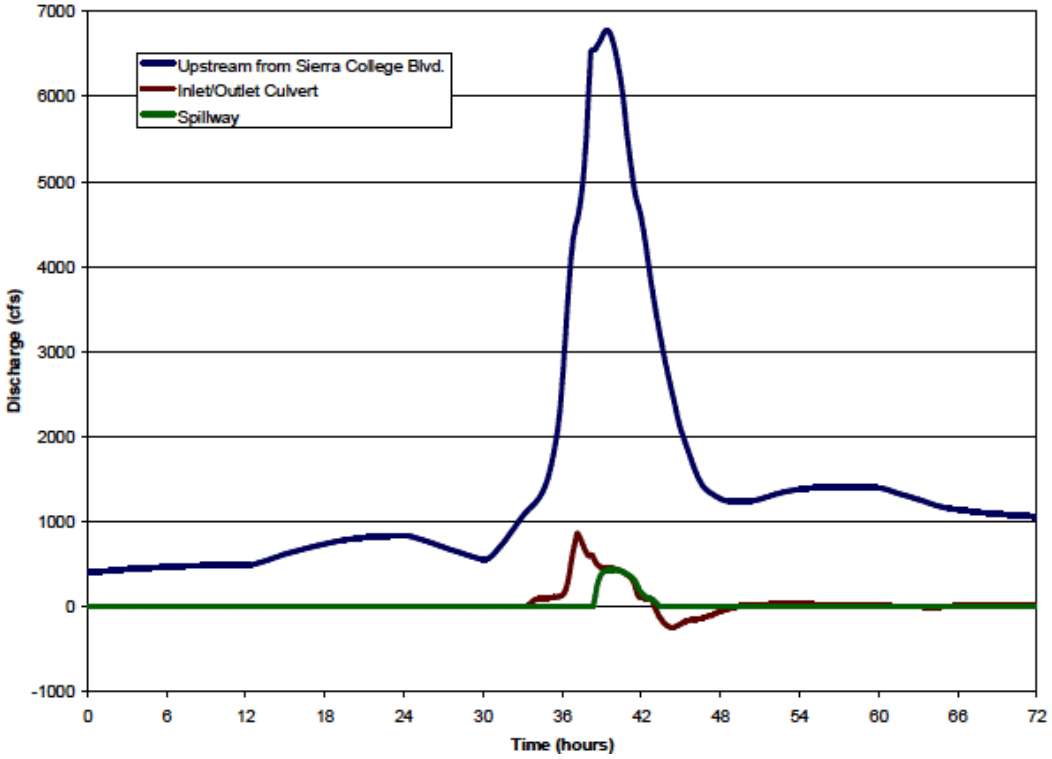
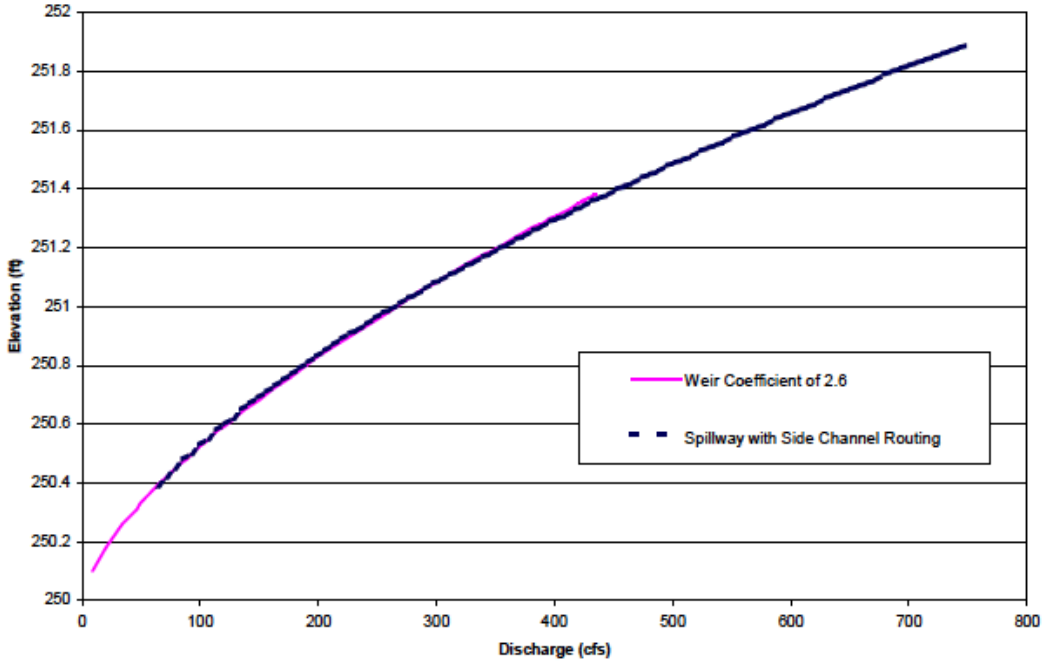


Chart 11: Spillway Rating Curves



3.7 Embankment Failure

For many dams, two modes of embankment failure are considered. Piping failure can occur due to erosion of embankment material from excessive seepage due to embankment porosity or holes, such as those made by burrowing animals. Overtopping failure can occur when inflows exceed the capacity of the spillway and flows pass over and erode the unprotected, or inadequately revetted, portions of the embankment. The likelihood of either of these modes of failure is minimal given the design and operation of the proposed facility. Seepage damage generally results from long durations of saturation and the proposed facility would detain flows infrequently and only for short durations. Overtopping is unlikely because flows would not be expected to reach the spillway crest elevation in a 100-year event, there would be more than 1.5 feet of freeboard during the design 1000-year conditions, and the spillway crest and side channel are proposed to be cut into the Mehrten Formation in the hillside along the north side of the basin. Parameters used to define the failure scenarios are listed in Table 15.

(Seismic induced failure scenarios are not considered due to the remote probability of an earthquake simultaneous with a severe flood.)

The embankment failure analysis for this study considers a design storm that approximates conditions experienced during the January 1995 flood. Based on estimated conditions and the hydrologic models, the January 1995 event may have been on the order of a 200-year event. During this event, peak flows were passing over Sierra College Boulevard.

Table 15: Breach Parameters

Parameter	Unit	Piping	Overtopping
Crest Elevation at Breach	feet	253	250
Final Bottom Width	feet	35	35
Final Bottom Elevation	feet	238	241
Left Side Slope	H:V	1	1
Right Side Slope	H:V	1	1
Full Formation Time	hours	0.5	1
Piping Coefficient		0.8	N/A
Initial Piping Elevation	feet	244	N/A
Trigger Failure at	Mode	WS Elev + Duration	WS Elev + Duration
Threshold WS	feet	248	251
Duration above Threshold	hours	1.0	0.5

Table 16 summarizes changes in peak conditions based on the modeled failures. Differences between No Project conditions and No Failure conditions are shown

to be insignificant. Failure scenario flows are confined to undeveloped open space along the stream past the confluence of Miners Ravine with Secret Ravine. The first structures that could potentially be impacted by Project failure are downstream from Harding Boulevard where the calculated increase in stage resulting from the piping failure scenario would be approximately 6-inches. Exhibit 3 illustrates the floodplain and the locations where potential impacts were evaluated. Charts 12 through 17 compare basin and stream stage and discharge hydrographs based on the failure analyses.

Table 16: Summary of Peak Conditions from Failure Analysis

Location	**Near Basin**		**1.5 mi Downstream**		**3.0 mi Downstream**	
	Stage	Discharge	Stage	Discharge	Stage	Discharge
	feet	cfs	feet	cfs	feet	cfs
No Project	238.7	4722	196.7	4714	154.7	11754
No Failure	238.7	4695	196.7	4691	154.7	11763
Piping Failure	239.5	6512	198.0	6216	155.2	13183
Overtopping Failure	239.1	5590	197.4	5484	154.9	12526

LEGEND

APPROXIMATE FEMA SPECIAL FLOOD HAZARD AREA

N.T.S.

NO.	REVISIONS	DATE	APP'D

RBF JOB NO: 60-100078

DRAWN BY: B. BROWN — DATE

DESIGNED BY: H. OSLICK — DATE

CHECKED BY: P. HEGEDUS — DATE

RBF CONSULTING — PLANNING ■ DESIGN ■ CONSTRUCTION

2351 ARENA BOULEVARD, SUITE 200
SACRAMENTO, CALIFORNIA 95834-2503
916.928.1700 FAX: 916.928.1701 WWW.RBF.COM

REVIEWED BY: PAL A. HEGEDUS

DATE:

R.C.E. # 33865

EMBANKMENT FAILURE - PIPING SCENARIO

MINERS RAVINE OFF-CHANNEL DETENTION BASIN FACILITY

PLACER COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

SHEET EX3 3 OF 3

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Chart 12: Basin Stage Hydrographs for Failure Analysis

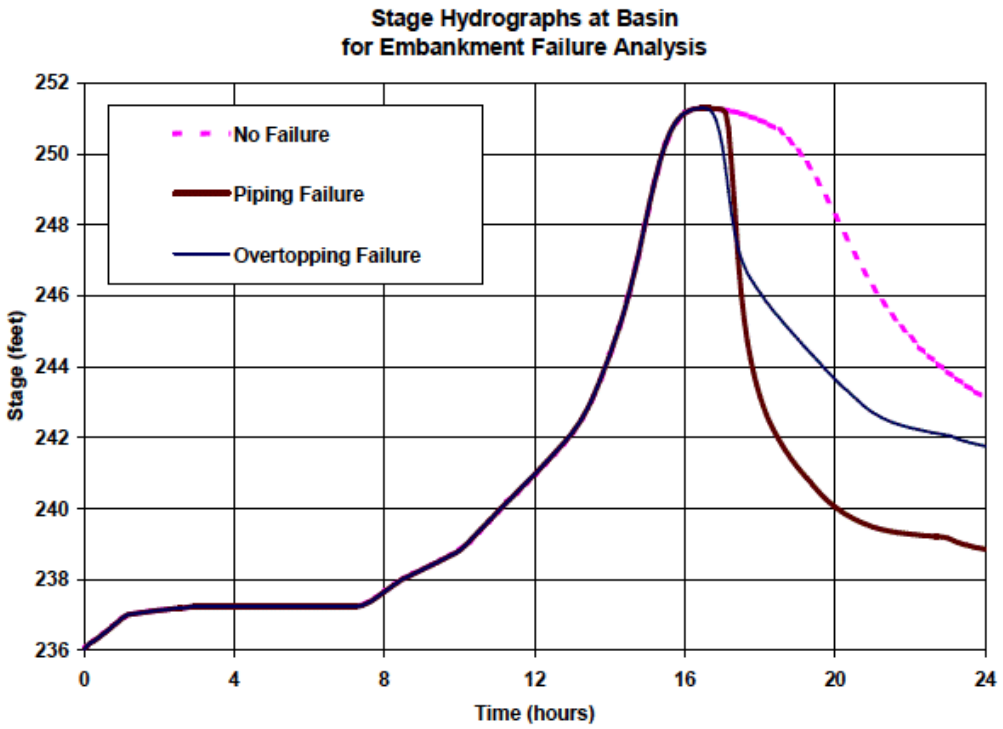


Chart 13: Near Basin Stream Stage Hydrographs for Failure Analysis

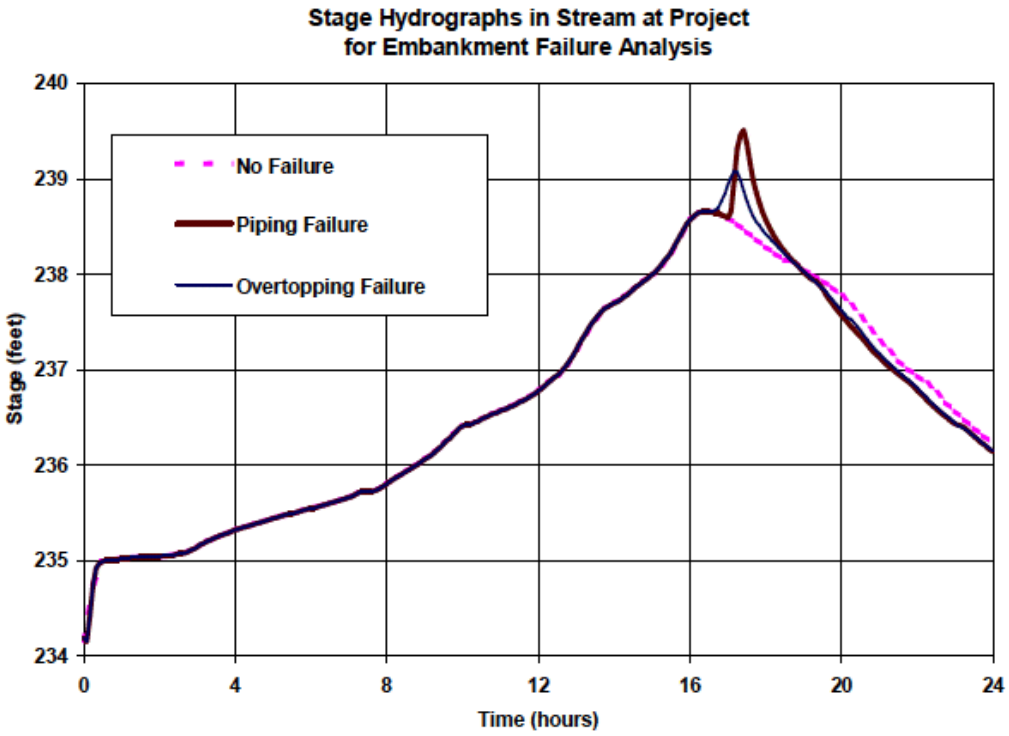


Chart 14: Downstream Stream Stage Hydrographs for Failure Analysis

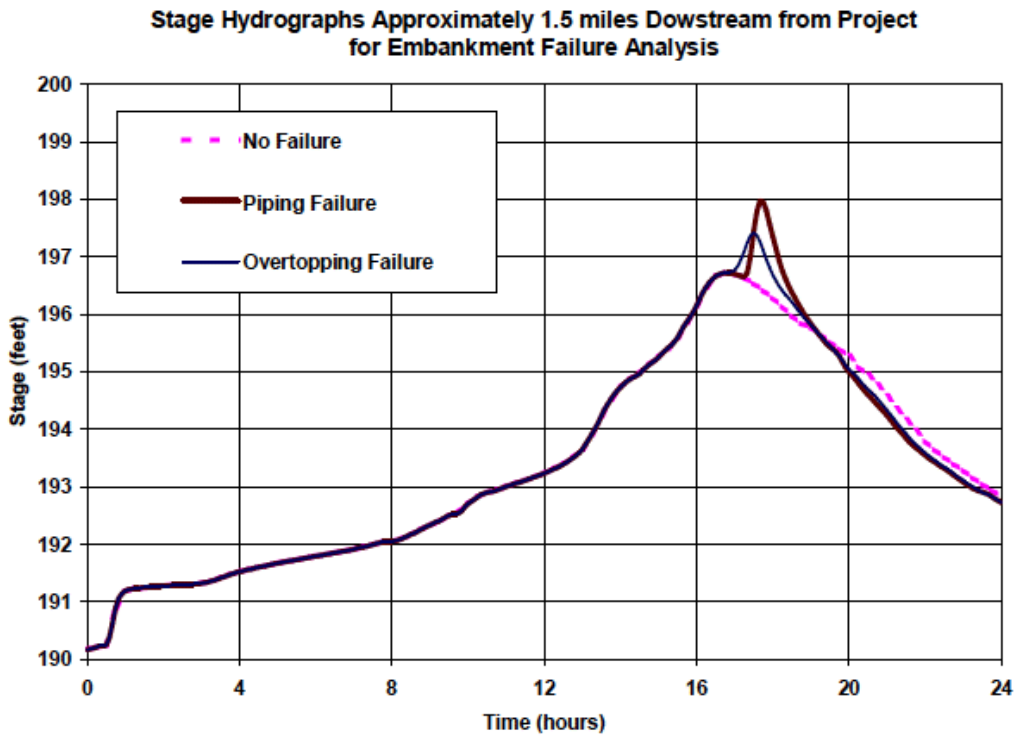


Chart 15: Basin Flow Hydrographs for Failure Analysis

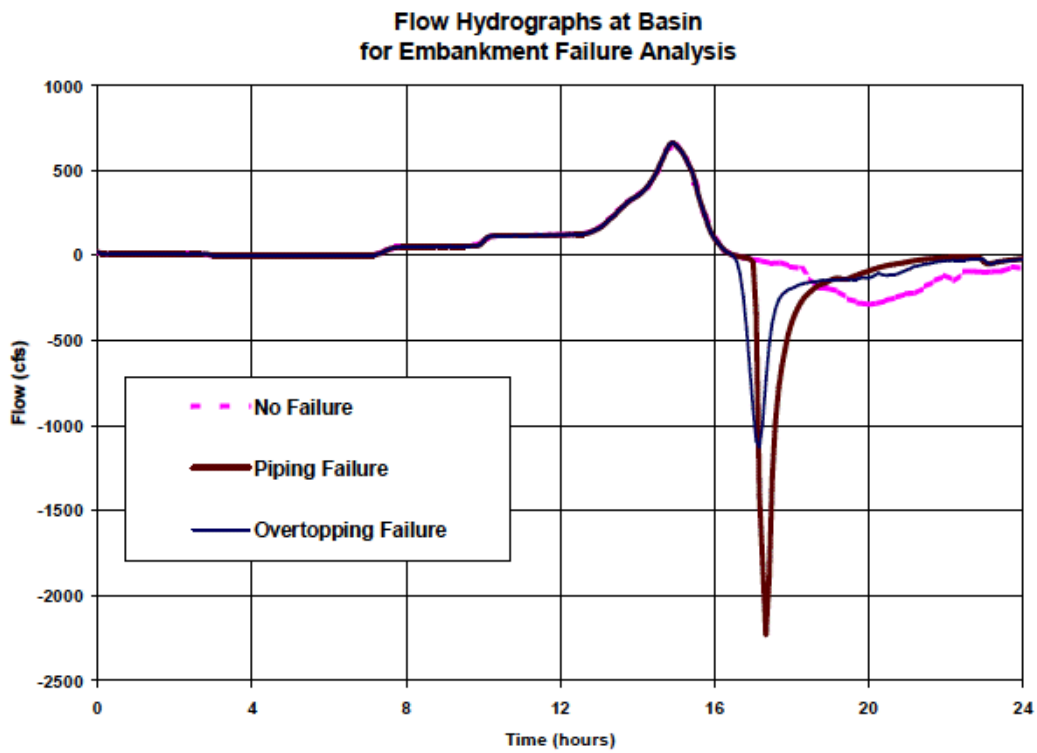


Chart 16: Near Basin Stream Flow Hydrographs for Failure Analysis

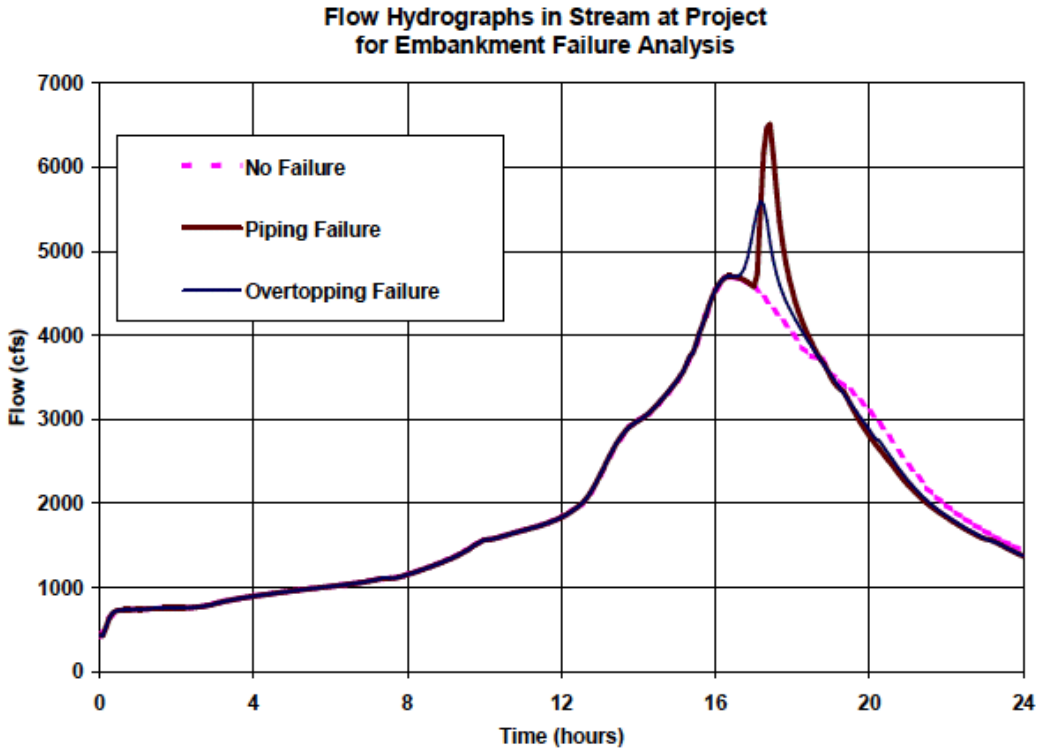
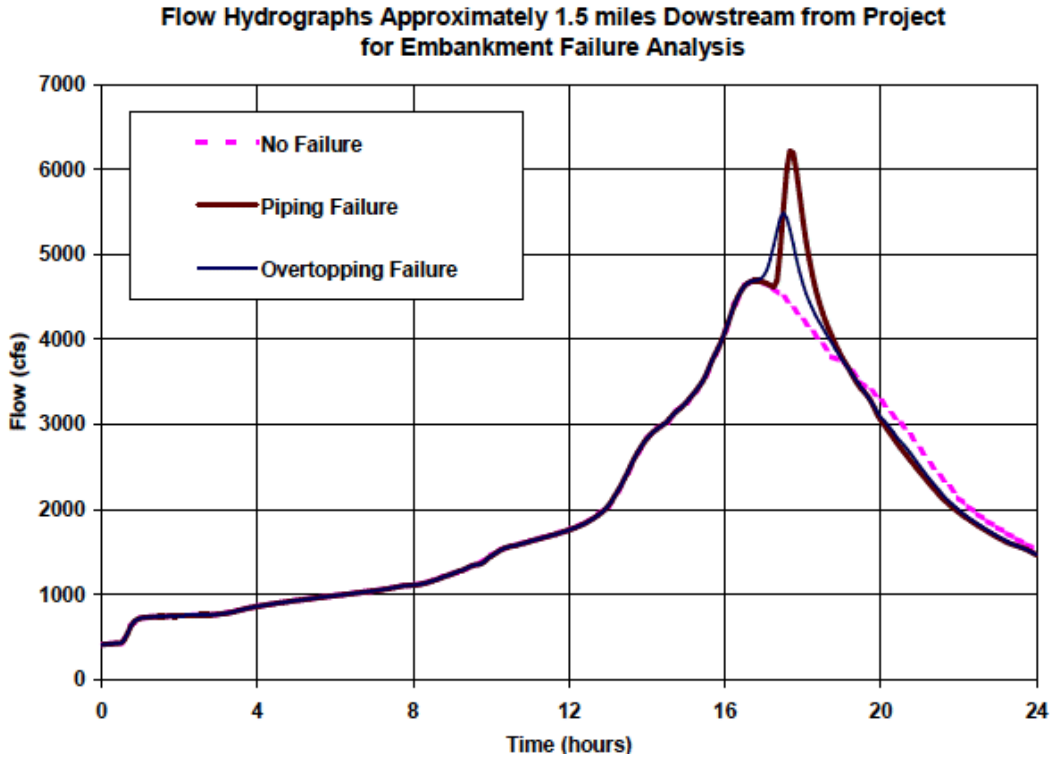


Chart 17: Downstream Stream Flow Hydrographs for Failure Analysis



4.0 SEDIMENT TRANSPORT

The two major issues regarding sediment transportation that were evaluated include:

1. Potential frequency for sediment removal maintenance activities from the proposed detention basin, and
2. The stability of the Miners Ravine streambed along the southern edge of the proposed detention basin. The SAM computer program was used to evaluate potential changes to the creek.

4.1 Annual Sediment Yield Estimate

The universal soil loss equation was used to estimate the potential single event and the annual average sediment yield of Miners Ravine at the project site. The main reference documents used for the calculation were the USACE TD-36, *Application of Methods and Models for Prediction of Land Surface Erosion and Yield* and *Erosion and Sediment Control Handbook* by Steven J. Goldman, Katharine Jackson and Taras A. Bursztynsky.

The following is the general form of the universal soil loss equation:

$$A = R \times K \times LS \times C \times P$$

Where:
- A = soil loss, tons/(acre) (year)
- R = rainfall erosion index,
- K = soil erodibility factor
- LS = slope length and steepness factor
- C = vegetative cover factor
- P = erosion control practice factor

In order to evaluate potential deposition within the basin, we also needed to evaluate the impact of major storm events. Table 17 summarizes the sediment yield and the potential maximum depth of sediment deposition caused by different frequency flood events:

Table 17: Sediment Yield and Deposition Summary

Storm Event	Total Sediment Yield (tons)	Total Sediment Yield (ac-ft)	Total Storm Volume (ac-ft)	Basin Storage (a-cft)	Basin Storage (%)	Estimated Maximum Sediment in Basin (aft)	Average Depth of Sediment in Basin (in)
100 year	12,447	4.76	1,747	113	6.47	0.308	0.41
50 year	11,212	4.29	1,645	97	5.90	0.253	0.34
10 year	5,964	2.28	888	38	4.28	0.098	0.13
5 year	5,103	1.95	722	15	2.08	0.041	0.05

The average annual yield is calculated from the single event estimates with the following formula:

$$Y_{avg} = 0.02Y_{100} + 0.04\ Y_{50} + 0.09Y_{10} + 0.015Y_5 = 0.042 \text{ in/year}$$

This estimate should also considered as conservative, since it assumes that all the sediment transported will have adequate time to settle within the basin. Sediment removal maintenance requirements are expected to be negligible because only approximately 2 inches are expected over a 50 year period.

4.2 Channel Stability Analysis

The SAM computer was used to analyze Miners Ravine channel stability along the reach immediately south of the proposed project. SAM is an integrated system of programs developed to aid engineers in analyses associated with designing, operating, and maintaining flood control channels and stream restoration projects. The following fundamental sediment processes are considered: erosion, entrainment, transportation, and deposition. Compaction of the deposited bed sediment is not accounted for in the design of stable channels.

The three (3) main modules—SAM.hyd, SAM.sed, and SAM.yld—can be used in series or used separately, to assist in various hydraulic design situations.

4.2.1 Channel Hydraulics

The calculations were completed for a two-year design event. It is generally accepted that two-year events that are also close to the bank-full flows, as is the case of Miners Ravine in the vicinity of the proposed project, can be considered as the channel forming flows.

The study reach was divided into six (6) sediment reaches. Sediment reach 1 is just downstream of the project area. Sediment reaches 2-5 run from Sierra College Blvd. to the end of the project. Sediment reach 6, the most upstream, was included as a supply reach. Average hydraulic parameters (i.e., hydraulic

depth, velocity, top width, and energy gradient) were calculated for each designated subreach and discharge. Six (6) sets of average hydraulic parameters were determined. Each set represents a constant discharge associated with a particular event. Table 18 lists the 2-year event parameters for the study reaches.

Table 18: 2-Year Event Hydraulic Parameters for Sediment Transport

Reach	HEC-RAS Station Range	Channel Velocity	Depth	Top Width	Energy Gradient
		(ft/s)	(ft)	(ft)	(ft/ft)
6	18667 – 18310.19	2.79	3.61	200	0.0044
5	18222.35 – 17872.38	3.41	3.23	77	0.0018
4	17773.82 – 17619.65	4.09	3.46	62	0.0033
3	17356.92 – 16947.5	3.36	3.69	63	0.0019
2	16884.9 – 16496.92	3.36	2.92	84	0.0032
1	16408.83 – 16172.89	3.96	2.28	82	0.0068
Average		3.49	3.20	94	0.0036

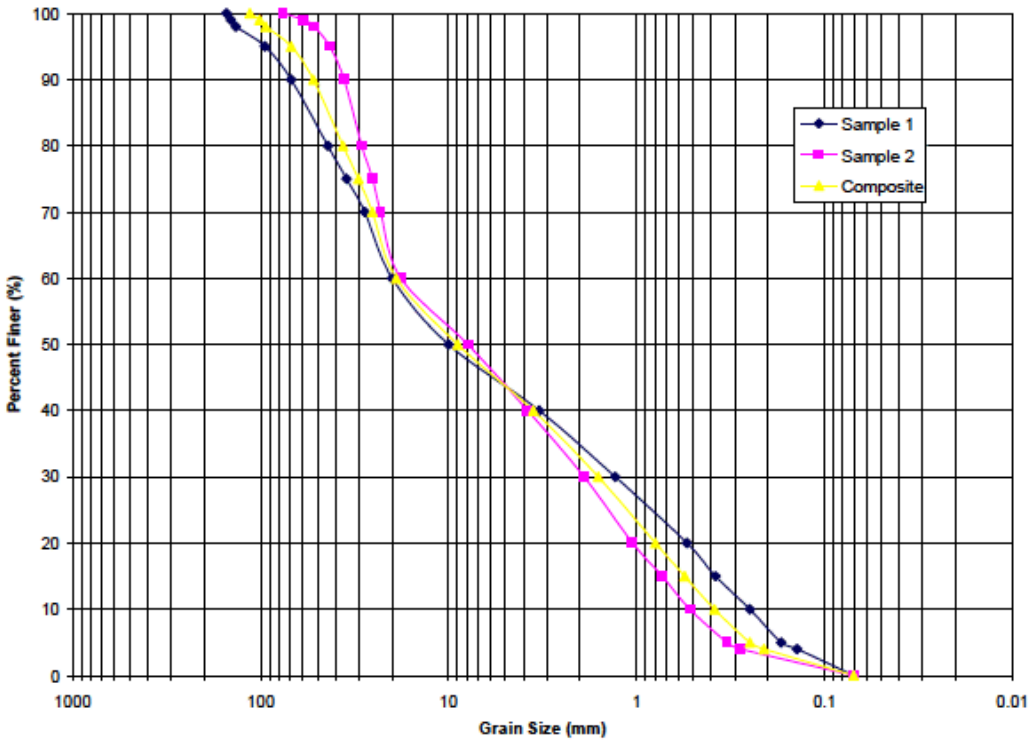
4.2.2 Sediment Continuity Analysis

For each sediment reach, a characteristic rating curve was developed for each of the five (5) hydraulic parameters: water discharge, hydraulic depth, velocity, top width, and energy gradient. A representative sediment gradation curve was produced from the boring results of the geotechnical investigation. The composite gradation curve is shown on Chart 18. Sediment transport models were based on the average hydraulic parameters of each sediment reach. The sediment transport capacities for each sub-reach were calculated for each of the selected sediment transport models. The results of the analysis for the 2-year event are included in Table 19.

Table 19: Sediment Transport Analysis Summary

Sediment Reach	Transport Capacity	Scour/Aggradation
	(tons)	(ft)
6	521	-------
5	238	0.18
4	440	-0.17
3	175	0.19
2	351	-0.09
1	1504	-0.74

Chart 18: Miners Ravine Sediment Gradation



The results of the sediment continuity analysis are valid for both existing and proposed project conditions because only localized modifications expected below the banks of the existing channel. The results show the streambed to be stable for the reach along the proposed project. Only minor long-term effects on the channel through the project reach (sediment reaches 3-5) are expected. Scour and aggradation magnitudes of less than two tenths (0.2) of a foot can be expected as the channel moves toward a state of equilibrium. It is expected the channel will remain stable following the completion of the proposed improvements.

5.0 CONCLUSIONS

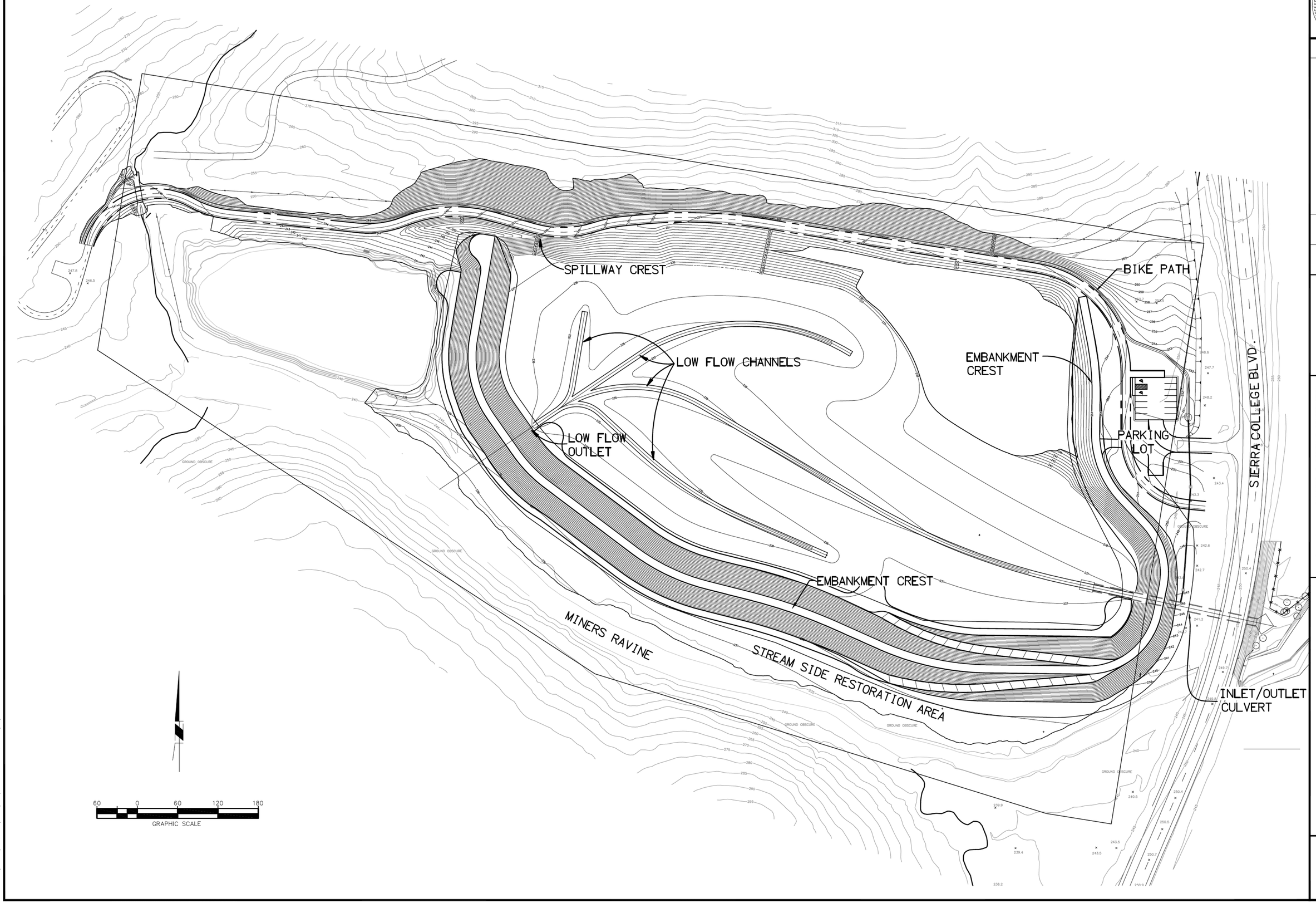
Hydrologic analysis was performed to develop a consistent baseline for comparison of alternatives and calculation of expected benefit. The evaluation of alternatives resulted in a recommended system configuration for an off-channel basin connected through a culvert to Miners Ravine on the east side of Sierra College Boulevard. The features of the recommended configuration were refined to develop a preferred alternative that includes:

1. An inlet/outlet structure east of Sierra College Boulevard;
2. A 6' high by 10' wide box culvert under Sierra College Boulevard connecting the basin to the inlet/outlet structure;
3. A stepped inlet weir on the inlet/outlet structure with four crests, one at each elevation of 245, 246, 247, and 248 feet, each with a crest length of 10 feet;
4. Two 3' high by 3' wide flap gates in the inlet/outlet structure that allow flow from the basin to the stream;
5. A 3' high by 4' wide opening in the inlet/outlet structure with a motor driven gate to admit some more frequent flows;
6. A 1.5' diameter low level outlet with a flap gate to preclude flows from Miners Ravine to the basin capable of draining the basin in less than 5 days;
7. A spillway crest four feet below the embankment crest capable of passing the 1000 year flow with more that 1.5 feet of freeboard.

The preferred alternative would reduce peak flow rates downstream from the project over a wide range of design events without causing an increase in peak discharges during more frequent events, as is often the case with off-channel detention facilities. One of the potential benefits of the project can be expressed by the expected flood reduction of 0.22 feet during a 100 year event. The reduction will be most notable in the vicinity and on the structures immediately downstream of the preferred alternative. Though this may seem small from an absolute perspective, it may be considered to be significant benefit achieved by a detention basin with a surface area of only 12 acres downstream of a watershed that exceeds 11,000 acres where the benefit is being measured at a location with a tributary area of 37,000 acres.

Failure analysis concluded that the proposed facility would not introduce a significant risk.

Sediment transport analysis concluded that the adjacent stream channel is and will remain stable and sediment deposition within the basin is expected to be low and should not be a long-term maintenance problem.



H:\PDATA\60100078\CADD\EXH\078EX1.DWG HOSLICK 3/21/08 10:52 am

REGISTERED PROFESSIONAL ENGINEER
PAL A. HEGEDUS
No. #33865
Exp. 6-30-09
CIVIL
STATE OF CALIFORNIA

NO.	REVISIONS	DATE	APP'D

RBF JOB NO: 60-100078

DRAWN BY: B.RUNKE	DATE 5/06	
DESIGNED BY: H.OSLICK	DATE 5/06	
CHECKED BY: P.HEGEDUS	DATE 5/06	

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DATE:
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PROJECT LAYOUT
MINERS RAVINE
OFF-CHANNEL DETENTION BASIN FACILITY
PLACER COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

SHEET
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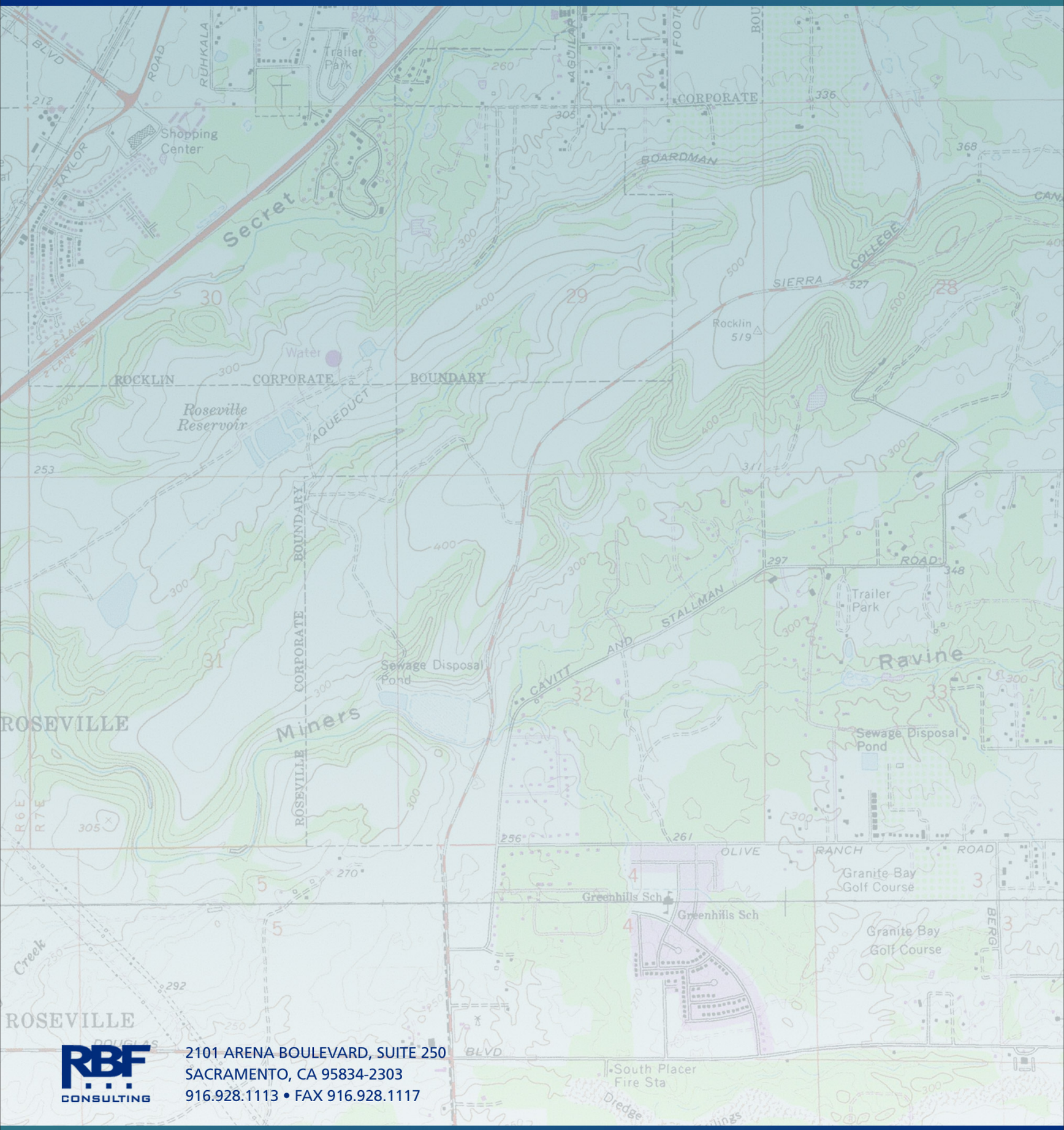

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