Loss Avoidance Study

Southern California Flood Control Mitigation
Part Two: Detailed Methodology

April 2007

FEMA

Federal Emergency Management Agency
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500 C Street, Southwest
Washington, DC 20472

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Each year, natural disasters produce tens of billions of dollars in direct damages to the built environment and as much or more in indirect damages and economic losses. As the nation's population continues to grow and migrate to hazard-prone regions, disaster related losses continue to escalate. In response, mitigation actions to reduce or eliminate long-term risk to life, property, and infrastructure are being taken in communities around the country.

In Southern California, tens of millions of dollars have been invested in mitigation projects in an effort to reduce the region's risk to flood hazards. The projects analyzed in this study were funded as a result of presidential disaster declarations between 1992 and 1995. Various post-project flooding events provided an opportunity for the projects to be evaluated and assess the project's effectiveness.

Several individuals made up the Loss Avoidance Team for this study. John Rowden and David Kennard envisioned the need for this study following the 2005 disaster declarations in Southern California. Shabbar Saifee and L. Gina White led the effort to define the scope of the study, collect data, guide the analysis, and develop the report. Daniel Powell and Dennis Quan provided technical expertise and were instrumental in collecting data for the analysis. Alan Springett provided technical support and review of the analysis and draft documents. Christina Finch and Robert Patten provided GIS, graphics design and technical writing support throughout the process. URS participated in data collection, completed the analysis and aided report development.

FEMA Region IX would like to take this opportunity to thank the State of California for their participation and support throughout the study. Special thanks is extended to the local governments in Los Angeles, Orange, Riverside, San Bernardino, Santa Barbara, San Diego, and Ventura counties who spent many hours assisting the Loss Avoidance Team in data collection and whose participation in the study was tireless.

Table of Contents:

List of Figures and Tables

Executive Summary:

Each year federal, state, and local agencies, as well as private entities contribute funds towards mitigation in order to reduce the nationwide exposure of people, the built environment, and the economy to hazards. In California alone, various entities have invested more than $1.4 billion dollars in reducing or eliminating California's long-term risk to hazards through mitigation activities.

The Federal Emergency Management Agency (FEMA) awards mitigation grants, through various programs, on the basis of whether proposed projects are cost-effective. Tools that have been utilized by FEMA in the past, for determining the effectiveness of a project are based on the analysis of a probabilistic hazard event, completed prior to project funding and prior to project construction. However, with such significant investment in mitigation be made, policy makers have taken great interest in the effectiveness of mitigation. In response, FEMA developed methodology utilizing a quantitative approach to assess the performance of mitigation projects based on actual post-construction hazard events.

FEMA partnered with the State of California and recently utilized this quantitative approach by completing a loss avoidance study in Southern California. By conducting this type of study, FEMA identified the benefits of the project in terms of actual economic performance. Such results demonstrate the effectiveness of the project and can be used to promote the value of investing in mitigation measures.

Two documents were completed as a result of the Southern California Loss Avoidance Study. Part One presents an overview of the loss avoidance study methodology and describes its application to structural flood control projects. It additionally, summarizes the application of the methodology to flood control mitigation projects in Southern California and the results of the study. This report, Part Two, provides detailed documentation of the methodology implemented during the Southern California Study and can be used as guidance for the preparation of future loss avoidance studies specific to structural flood control mitigation projects. Additionally, it describes considerations and recommended practices that were identified during the completion of the Southern California Study. The appendices to this report describe the specific application of the methodology to the six projects selected for the loss estimation analysis in the Southern California Study herein detailed.

While the results of the Southern California Loss Avoidance Study provide a means to demonstrate the nominal effectiveness of the selected projects for the flood event(s) analyzed, a comparison of the results with the cost of the original project demonstrates the return on investment. For the projects assessed in the Southern California Study, the aggregate construction cost was $19.6[1] million and aggregated losses avoided were $7.3 million. This equated to a 37 % return on investment.

[1] All figures in this document are adjusted and reported in 2006 dollars.

Section One:

Introduction

1.1 Background

Mitigation is defined by FEMA as any sustained action to reduce or eliminate long-term risk to people and property from hazards and their effects. It is an activity that is practiced within numerous federal, state and local entities and is identified as one of the primary missions of FEMA. Through three nationwide programs – the Hazard Mitigation Grant Program (HMGP), the Pre-Disaster Mitigation Program (PDM), and the Flood Mitigation Assistance Program (FMA) – FEMA annually provides states and communities with substantial financial assistance for projects to reduce or eliminate risks of natural hazards. In California alone, multiple entities have contributed more than $1.4 billion to reducing or eliminating long-term risks through mitigation activities.

With this type of investment, policy makers take great interest in the effectiveness of mitigation. In response a study was performed by the Multihazard Mitigation Council (MMC) under the direction of FEMA. The MMC Study: *NATURAL HAZARD MITIGATION SAVES: An Independent Study to Assess the Future Savings from Mitigation Activities* indicated that natural hazard mitigation saves an average of $4 for every $1 of investment (MMC, 2005). However, the MMC study used methods that assess project effectiveness for probabilistic events. While this provides a theoretical measure of effectiveness, it does not demonstrate the effectiveness of mitigation projects for reducing or eliminating damage during actual hazard events.

The MMC determined that natural hazard mitigation saves an average of $4 for every $1 invested.

To determine the effectiveness of mitigation during actual events, FEMA developed loss avoidance methodology which is based on the analysis of actual events. By utilizing this methodology, FEMA (or any project sponsor) can quantitatively assess the benefits of the project in terms of its actual performance. Such results demonstrate the effectiveness of the project and can be used to promote the value of investing in mitigation measures.

1.2 Purpose

The purpose of this study is to verify potential effectiveness and document economic performance of structural flood control mitigation projects in Southern California. In doing so, this study will answer the question "how much damage could have occurred from a storm event if the flood control mitigation project had not been in place?" Further, the study will provide comprehensive documentation of "losses avoided" (damages avoided or benefits) utilizing quantitative methods. The methods incorporated will provide a reproducible and verifiable methodology so that results of this study are meaningful and defensible.

Often verifiable tools utilized in loss avoidance analyses include tools such as Hazards U.S. – Multihazard (HAZUS-MH) or the FEMA Benefit-Cost Analysis (BCA) Modules. HAZUS-MH is primarily a planning tool that estimates damages in general terms (census block) for existing site conditions. On the other hand, BCA provides a more narrowed focus and requires specific assumptions in order to determine the cost effectiveness of the project. Both HAZUS-MH and BCA are tools that look into the future. They are completed prior to project funding and prior to project construction. The most visible use of these tools was by the MMC during the completion of their study: *NATURAL HAZARD MITIGATION SAVES: An Independent Study to Assess the Future Savings from Mitigation Activities.*

Terminology

Two different scenarios are required for a loss avoidance study. The first is the existing project and will be identified as the Mitigation Project Complete (MP_C). The second is to determine how the area would respond without a project in place, or Mitigation Project Absent (MP_A).

In contrast to the previously mentioned tools, this loss avoidance study provides an alternative methodology for project analysis. Its approach quantifies losses avoided of completed mitigation projects using actual post-construction storm events for two separate scenarios, Mitigation Project Absent (MP_A) and Mitigation Project Complete (MP_C). This approach provides a comprehensive and detailed methodology that can be utilized as a template for additional studies throughout the nation in order to show the effectiveness of mitigation programs and the importance of these programs in reducing damages.

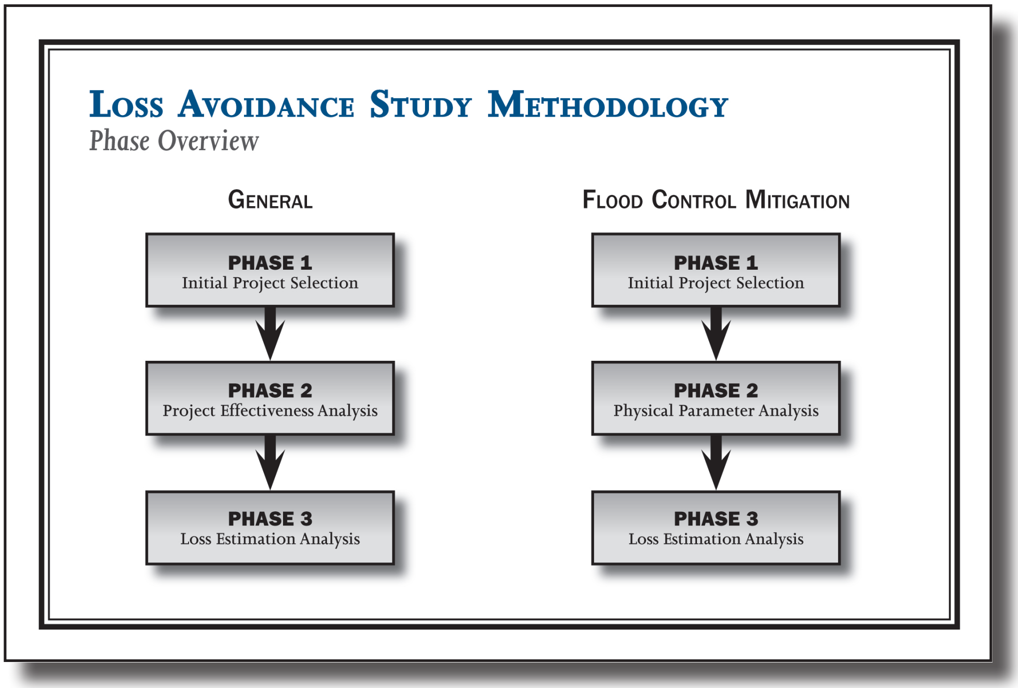
1.3 Loss Avoidance Methodology Overview

Figure 1.1 illustrates the phases of the general methodology for loss avoidance studies and the methodology specific to flood control mitigation projects. While Phase 1 and Phase 3 would be the same regardless of the type of mitigation project or type of disaster being evaluated, Phase 2 would vary depending upon the type of disaster and project. This study specifically focuses on the methodology utilized when assessing flood control mitigation projects. Figure 1.2 illustrates this methodology in more detail.

Phase 1 focuses on the selection of initial projects and the development of the initial project list. First, projects are selected based on parameters established for the study. This initial selection of projects is then screened based on the availability of data necessary to complete the study. This process determines the projects that will be placed on the initial project list and will advance to the analysis phases of the study.

As previously indicated, the purpose of the Southern California Loss Avoidance Study is to verify the effectiveness and document

Figure 1.1



economic performance of structural flood control mitigation projects in Southern California. Although the projects reviewed for inclusion in the initial list of projects were funded by FEMA through the HMGP, this type of study can be implemented for any mitigation project regardless of funding source. Several parameters were established to guide the selection of projects for the initial list: projects had to be flood control mitigation projects, had to have a construction completion date prior to 2005, and had to be located in a county designated under 1577-DR-CA or 1585-DR-CA. Utilizing these parameters, 37 projects located in seven Southern California counties were selected for review and inclusion in the initial list of projects. From this selection, 17 projects were selected for further analysis based on the type of data available.

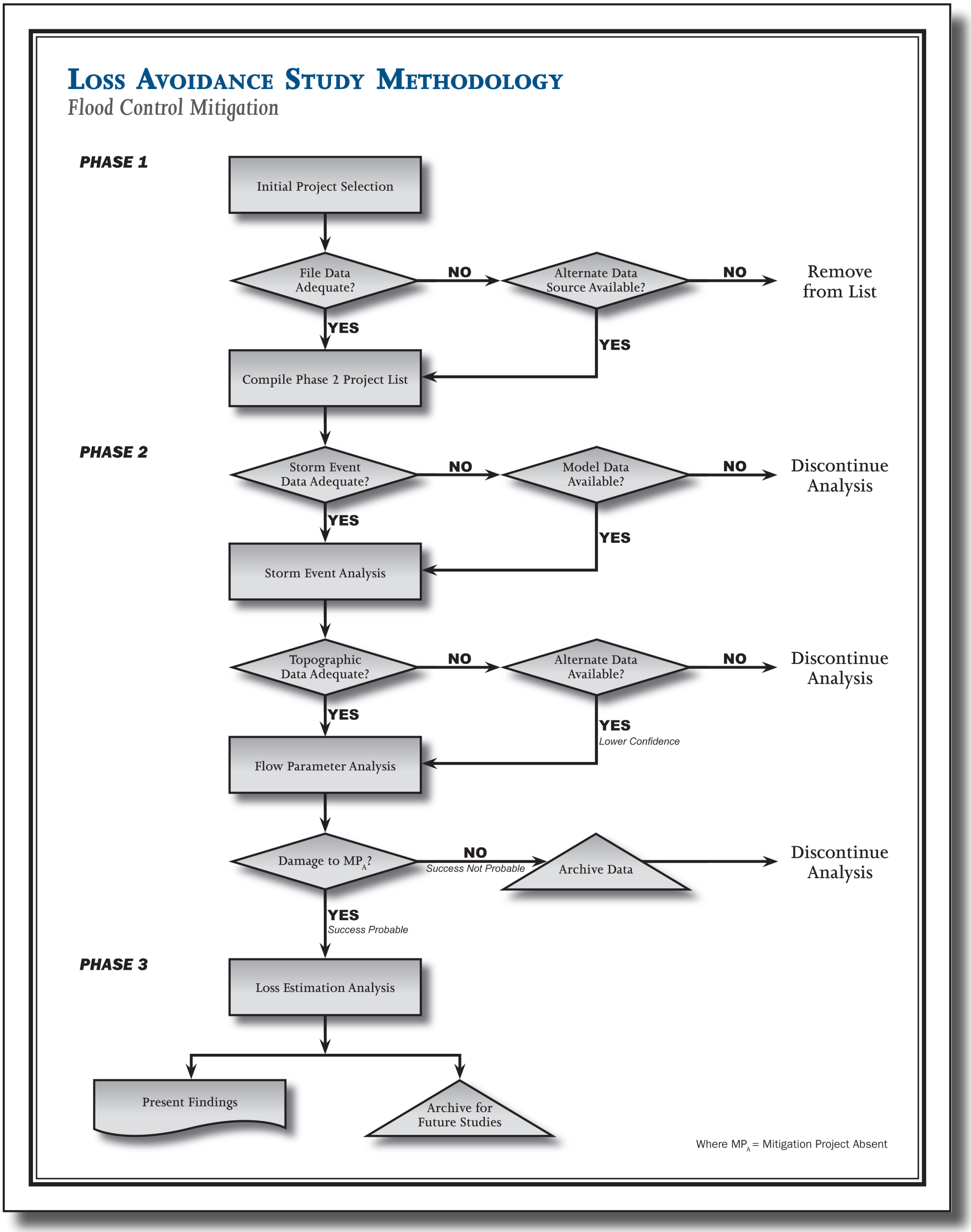
The second phase of the methodology includes multiple analyses to determine if there were avoided losses to measure since the project's completion. As the analyses are completed, projects are eliminated from further evaluation based on data availability and analytic results.

To fully analyze flood control mitigation projects a Storm Event Analysis and Flow Parameter Analysis is completed as the second phase of the methodology. During these analyses an estimate is made of the depth and extent of inundation from an actual storm event(s) that occurred since project completion. The first task for Phase 2 is to determine if there are recorded precipitation event(s) of a size to have caused damages if the mitigation project had not been constructed. The second task is to map the MP_A and MP_C

HAZARD MITIGATION GRANT PROGRAM (HMGP)

The HMGP is authorized by the Robert T. Stafford Disaster Relief and Emergency Assistance Act, and is administered by FEMA to provide funding for eligible mitigation activities following a presidential disaster declaration. The intent of the program is to prevent or reduce losses and protect life and property during future disasters. State, local, and tribal governments, and some private non-profit organizations, are eligible applicants for HMGP funds.

Figure 1.2


LOSS AVOIDANCE STUDY METHODOLOGY
Flood Control Mitigation
PHASE 1
Initial Project Selection
File Data Adequate?
NO
Alternate Data Source Available?
NO
Remove from List
YES
YES
Compile Phase 2 Project List
PHASE 2
Storm Event Data Adequate?
NO
Model Data Available?
NO
Discontinue Analysis
YES
YES
Storm Event Analysis
Topographic Data Adequate?
NO
Alternate Data Available?
NO
Discontinue Analysis
YES
YES
Lower Confidence
Flow Parameter Analysis
Damage to MP_A?
NO
Success Not Probable
Archive Data
Discontinue Analysis
YES
Success Probable
PHASE 3
Loss Estimation Analysis
Present Findings
Archive for Future Studies
Where MP_A = Mitigation Project Absent

damages for the event(s). In order to compare the area inundated by flooding from the event, detailed topographic data for the area impacted in both scenarios is required. This flood boundary limit is used to estimate the number and types of structures and facilities flooded.

As a result of the Phase 2 analyses for the Southern California Loss Avoidance Study several projects were eliminated from the study. Seven were eliminated from consideration based on lack of data and four were eliminated based on analysis results that indicated no damage from the MP_A event. This resulted in six projects advancing to Phase 3 of the study for Loss Estimation Analysis.

The final phase of the methodology is the Loss Estimation Analysis. There are two steps to this phase. First an economic evaluation of the projects is completed for the two scenarios, MP_A and MP_C. The difference between the two scenarios is calculated and losses avoided (LA) are determined. Secondly the return on investment (ROI) is assessed by computing the difference between project investment (PI) and LA.

In Phase 3 of the Southern California Loss Avoidance Study the remaining six projects were analyzed for flood damage loss. During this analysis, losses were estimated using the relationship between the type of structure or facility flooded, the depth and duration of the flood event impacting that structure, and the damage amount (in dollars) for both the MP_A and MP_C scenarios. The calculations included physical damage costs, loss of function costs, and emergency management costs. Once the MP_A and MP_C damages were estimated, the difference between the two scenarios was calculated to assess the losses avoided. The total LA for the projects analyzed in the Southern California Loss Avoidance Study was $7,309,402 with an average ROI of 37%.

The total losses avoided for the six projects analyzed in this study was $7,309,402 which yielded an average return on investment of 37%.

Section Two:

Phase 1 - Project Selection

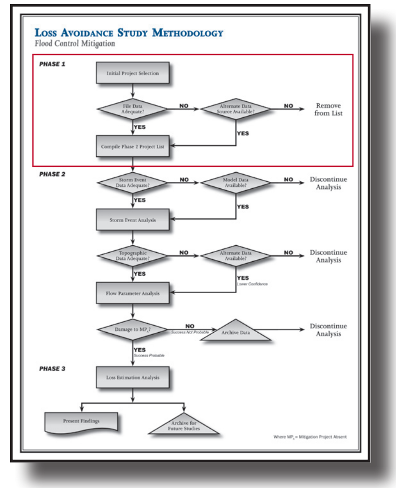


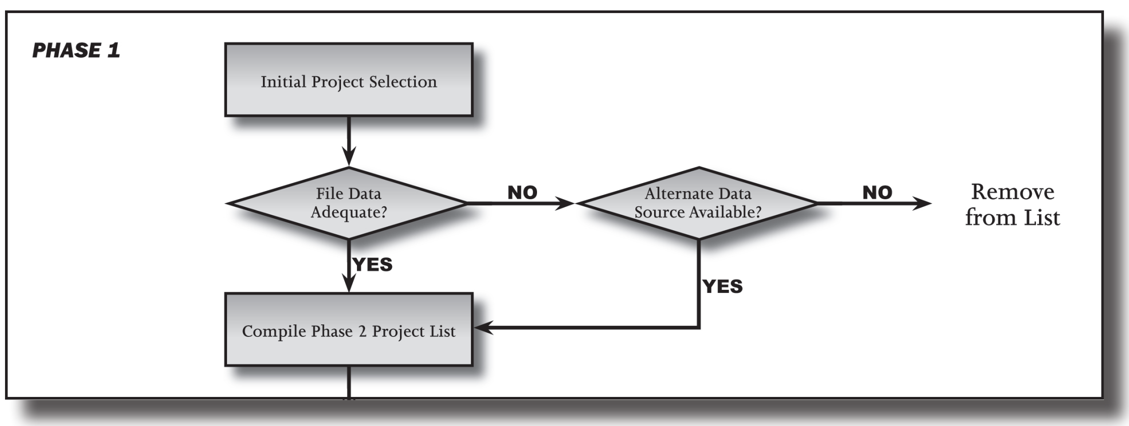
Figure 1.2 provides a detailed illustration of each of the methodology phases for flood control mitigation projects. Section Two provides a full synopsis of the process for Phase 1 as illustrated in that figure. This section will utilize examples from, and provide summaries of, the Southern California Loss Avoidance Study in an effort to better illustrate the process.

As illustrated in Figure 2.1, there are two tasks completed as a part of Phase 1 in order to develop an initial project list:

1. **Identifying a list of candidate mitigation projects** and
2. **Eliminating projects based on available data.**

Once the initial project list has been completed the projects are prioritized in order for the analysis to be completed efficiently and for the project to maintain cost effectiveness.

Figure 2.1



2.1 Initial Project Selection

The initial project selection is based on parameters established by the organization conducting the loss avoidance study. These parameters could include but are not limited to area of interest, hazard type, project type, and project baseline.

Area of Interest

The Area of Interest may vary greatly from study to study. For example, the area of interest could be a single community, a region within a state, or a watershed. Because of the extreme variance of the area of interest, it should be clearly defined by the organization considering the study prior to project selection.

Hazard Type

Projects may also be screened by general hazard type. Care should be taken, to avoid inadvertently removing a multihazard project from consideration. For example, a dam may have been mitigated for earthquake hazards, yet part of the project may have been to increase overall capacity to lower pressure on the dam face while retaining reservoir capacity. This would increase the amount of water the dam could hold for a temporary period, reducing flash flood risk.

Project Type

Selection may also be based on project type. For example, while the hazard type chosen may be flooding or multihazard (included flooding) and the project type may be flood control, the organization completing the project may want to specifically focus on acquisitions instead of brick and mortar flood control projects. The type of project greatly impacts the type of analytical techniques utilized in the study which could become an additional factor in selecting projects.

Project Baseline

The date of construction completion may have a significant impact on the decision to include a project in an analysis as it creates the necessary baseline for analysis. Projects with an older construction completion date have a higher likelihood of being tested by a potentially damaging event than a project with a more recent construction completion date. Consequently, it is more likely that losses avoided can be estimated for an older project. However, certain types of information such as digital topography may be difficult to obtain for older projects which could hinder the ability to assess losses avoided. In addition, phased construction projects, where conditions are modified several times over a period of years, increase the difficulty in assessing the project's performance for a single event.

2.2 Project Screening

The data necessary for implementation of specific methodology is a primary determining factor when screening projects for inclusion in a study. The initial list of projects must be evaluated to identify projects with characteristics necessary for the methodology being applied. If specific data and characteristics are not available for a project, that project should be removed from the project list. There are three primary considerations for the project screening process: initial site visit, local preferences, and project file components.

Initial Site Visit

An initial site visit should be completed in order to conduct a preliminary assessment of the project, meet local and state officials, and initiate the more detailed data collection for Phase 2 and 3. The site visit may reveal a lack of available data necessary to conduct a study or other resources available for detailed data collection. Further, the site visit may reveal the complexity of a project and potential difficulty with conducting the physical parameter and loss estimation analyses.

Local Preferences

Local and State officials may have predetermined preferences to assess certain projects over others. For example, a project may be in the vicinity of a critical facility, and therefore may have a higher profile than another project in a remote area. Similarly, a project that provides protection to a densely developed neighborhood may be of greater importance than a project that protects few residences. The organization conducting the study should account for these considerations in selecting projects.

Project File Components

Some of the projects on the initial project list may not have adequate information in project files to proceed to Phase 2. Since the inception of mitigation programs, FEMA and other contracting agencies have had different long-term data storage requirements. Basic information, such as the original funding application and financial reports, are routinely kept in FEMA files. However, detailed engineering design drawings and digital data are not often kept in the same files. As a result, the Loss Avoidance Team (LAT) may be required to utilize other resources, such as local governments or contracting consultants to retrieve the information. The process of collecting specific data elements, such as topographic data, typically occurs when the Physical Parameter Analysis is prepared during Phase 2. However, it is advisable to determine whether critical hazard-specific data is available early in the process, to determine whether projects should be removed from the project list. If the necessary information is not in the FEMA file and not available through other resources, the list of all possible projects that could be included in a loss avoidance study may be reduced.

2.3 Prioritizing Projects

Once the initial project list is created, it should be maintained in some type of priority order throughout the loss avoidance study. All studies have time and resource limitations and maintaining a prioritized project list promotes efficiency. As a result, less time should be spent on projects with possible issues related to calculating the losses avoided. The prioritization should reflect the judgment of the LAT on the following factors: data availability, occurrence of a damaging event, and analysis potential.

Data Availability

Several of the screening calculations may indicate certain data have limited availability. If certain critical data are known to be readily available for a community, then projects in that community would be given a higher priority than those in communities where critical data may not be readily available.

Damaging Event

Mitigation projects are designed to provide a specific level of protection from damaging events. The effectiveness of a project is determined by comparing the damage that would have occurred MP_A with the damage that actually occurred MP_C. Consequently, the occurrence of a damaging event MP_C is critical to loss avoidance methodology. As a result, the initial data collection process should include an assessment of whether a potentially damaging event has occurred MP_C. In some cases, local observations of a recent event may indicate that the event was of sufficient magnitude to have caused damage. For example, if a flood event occurred in an area affected by a mitigation project, but there was actual damage to a number of structures, then losses avoided might be expected for this project. This project would then be given a higher priority than projects where the occurrence of an event with losses avoided is unknown.

Analysis Potential

The initial data collection may also indicate whether sufficient information is available to conduct the Physical Parameter Analysis. For example, a project file that contains electronic versions of hydraulic modeling that can be easily modified for the event of interest would be given higher priority than projects where this data is not available. A project located on a river or stream where detailed Flood Insurance Studies (FIS) were prepared might be given a higher priority than projects in areas with limited or no flood studies.

All of these factors should be considered jointly to give each project an overall priority. A project that has been subject to a known damaging event would likely be given a high priority, even if the availability of detailed data was limited. A project for which modeling data are not available may be given a lower priority unless data are available to develop new models, in which case the project would be given a higher priority. The assigned priorities must be reevaluated regularly throughout the data collection process, until the desired number of projects is reached, or analysis is completed on all projects with sufficient data.

2.4 Southern California Study: Project Selection

FEMA Region IX and the California Office of Emergency Services (OES) initiated the Southern California Loss Avoidance Study following the flooding that occurred during December 2004, January 2005, and March 2005, leading to Presidential Disaster Declarations 1577-DR-CA and 1585-DR-CA in Southern California. The scope of work for this study required the identification of six to eight projects in Southern California that could proceed through all three phases of the study. Officials noted that the flood losses from the 1577-DR-CA and 1585-DR-CA events were less than the 1995 California Winter Storms (1044-DR-CA and 1046-DR-CA). Additionally they believed that the flood control mitigation implemented since the early 1990s was responsible for the reduction of out-of-bank flooding and the reduction in damages. As a result, the parameters established for this loss avoidance study included:

1. **Area of Interest** - Southern California counties designated in 1577-DR-CA or 1585-DR-CA,
2. **Hazard Type** - flood or multihazard (including flood),
3. **Project Type** - structural flood control mitigation projects, and
4. **Baseline** - project construction completion date prior to 2005.

The initial project selection seen in Table 2.1 included a total of 37 projects. These projects were located in Los Angeles, Orange, Riverside, San Bernardino, San Diego, Santa Barbara, and Ventura counties and were funded through HMGP under disasters 0935-DR-CA, 0979-DR-CA, 1008-DR-CA, 1044-DR-CA, and 1203-DR-CA.

Following the initial project selection a review of the FEMA HMGP project files was completed in order to identify the data that had to be collected from alternate resources. Contacting alternate sources for hydrologic data, hydraulic data, and engineering drawings was necessary for all 37 projects. This task proved difficult for the Southern California Study as many local officials and engineering firms did not maintain digital files as needed. As illustrated in Table 2.1 and Figure 2.2, 17 of the 37 projects advanced to Phase 2 for a Physical Parameter Analysis following this data collection process.

After the 17 projects were identified, site visits were complete, and the project files were reviewed, the projects received an initial

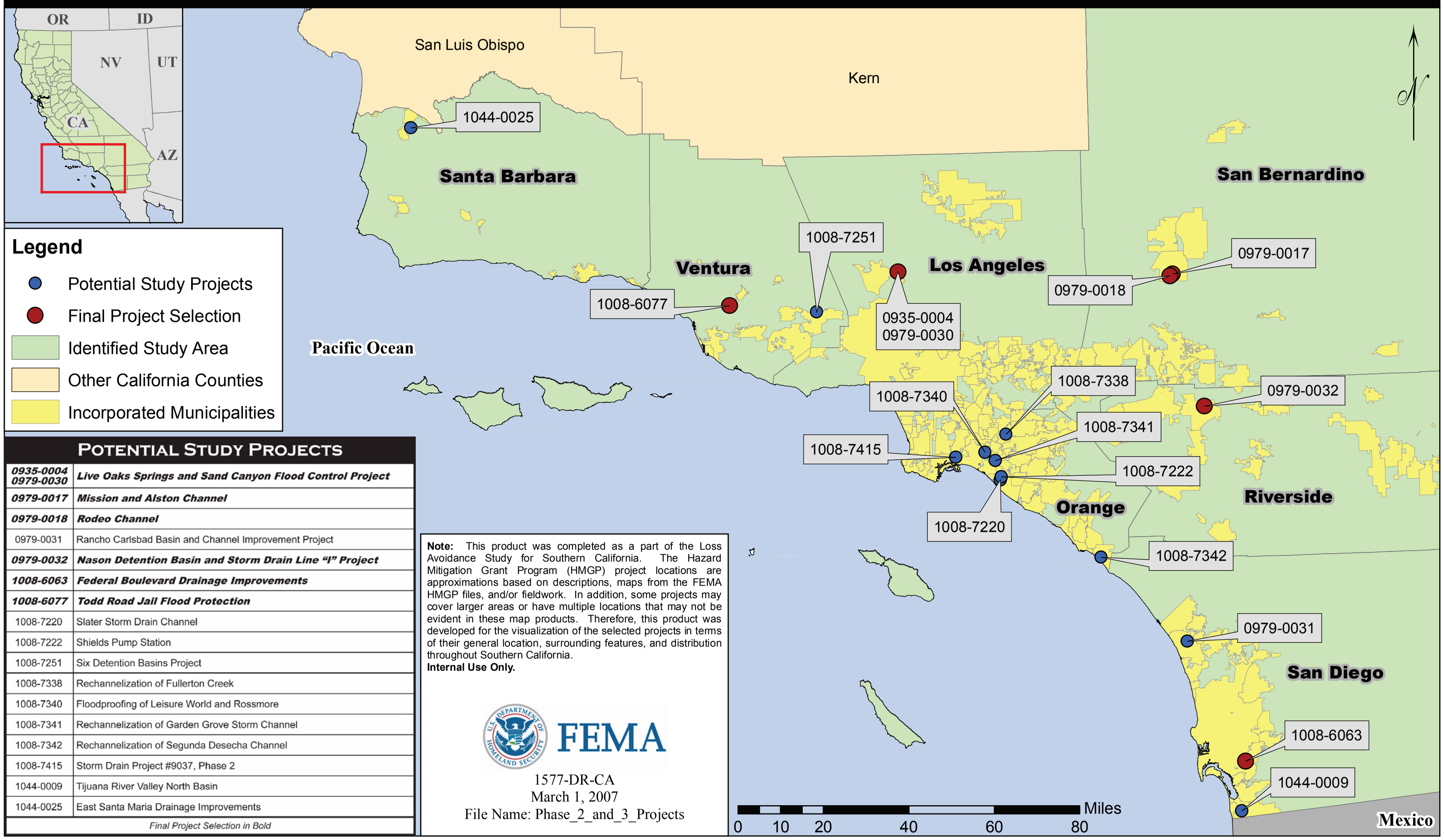
Table 2.1

Project List

County	Disaster and Project Number	Project Name	Phase 1	Phase 2	Phase 3
Los Angeles	0935-0004 0979-0030	Live Oaks Springs and Sand Canyon Project			
	0979-0022	Western Avenue Storm Drain			
	0979-0023	Grand Avenue Storm Drain			
	1008-6056	23rd Place Storm Drain			
	1008-7003	Mainview Drain			
	1008-7415	Long Beach Storm Drain Project #9037			
Orange	0935-0008	Flounder Pump Station Upgrade			
	0935-0009	Flounder Pump Station Controls			
	0979-0013	E01 P25 Storm Drain			
	1008-7219	Corsican Storm Drain Improvement			
	1008-7220	Slater Storm Drain Channel			
	1008-7222	Shields Pump Station			
	1008-7338	Fullerton Creek Rechannelization			
	1008-7340	Rossmoor (Leisure World) Floodproofing			
	1008-7341	Bolsa Chica Rechannelization			
	1008-7342	Segunda De Schecha Rechannelization			
	1008-7844	Serrano Creek Erosion Control			
	1008-7845	Serrano Creek Erosion Control			
Riverside	0935-0005	Pipeline Avenue Storm Drain			
	0979-0032	Nason Detention Basin			
San Bernardino	0979-0009	Dry Well Installation			
	0979-0010	Middle School Detention Basin			
	0979-0011	Rimrock Detention Basin			
	0979-0017	Mission and Alston Channel			
	0979-0018	Rodeo Channel			
San Diego	0979-0003	Troy Street Culvert			
	0979-0004	Harbison Avenue Storm Drain			
	0979-0031	Ranchero Carlsbad Basin and Channel			
	1008-6063	Federal Boulevard Drainage Improvements			
	1044-0009	Tijuana River North Berm			
Santa Barbara	1044-0024	Via Regina Interceptor Channel			
	1044-0025	East Santa Maria Project			
	1203-4443	Veloz Drive RCB Culvert Replacement			
Ventura	0935-0003	Amlit Way Storm Drain			
	1008-6077	Flood Protection for Todd Road Jail Facility			
	1008-7251	Simi Valley Detention Basins			

Figure 2.2

PHASE 2 AND PHASE 3 PROJECT LOCATIONS
LOSS AVOIDANCE STUDY FOR SOUTHERN CALIFORNIA



Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California.
Internal Use Only.

FEMA
1577-DR-CA
March 1, 2007
File Name: Phase_2_and_3_Projects

POTENTIAL STUDY PROJECTS

0935-0004 0979-0030	***Live Oaks Springs and Sand Canyon Flood Control Project***
0979-0017	***Mission and Alston Channel***
0979-0018	***Rodeo Channel***
0979-0031	Rancho Carlsbad Basin and Channel Improvement Project
0979-0032	***Nason Detention Basin and Storm Drain Line "I" Project***
1008-6063	***Federal Boulevard Drainage Improvements***
1008-6077	***Todd Road Jail Flood Protection***
1008-7220	Slater Storm Drain Channel
1008-7222	Shields Pump Station
1008-7251	Six Detention Basins Project
1008-7338	Rechannelization of Fullerton Creek
1008-7340	Floodproofing of Leisure World and Rossmore
1008-7341	Rechannelization of Garden Grove Storm Channel
1008-7342	Rechannelization of Segunda Desecha Channel
1008-7415	Storm Drain Project #9037, Phase 2
1044-0009	Tijuana River Valley North Basin
1044-0025	East Santa Maria Drainage Improvements

Final Project Selection in Bold

ranking of high, medium, and low based on the availability of the type of data needed to perform the physical parameter and loss estimation analysis.

- **High** – A project was ranked with high priority if it appeared the appropriate topographic data and hydrologic and hydraulic models were available to represent the MP_A scenario.
- **Medium** – A project was ranked with medium priority for multiple reasons:
  - Only minor (non-structural) damage was recorded from past flood events.
  - The LAT was awaiting data that had been requested for review.
  - No hydraulic model data was available, but topography that could be used to create the model was available.
  - Digital topography was available, but with a less-detailed contour interval than desired. There was no indication that a floodplain hydraulic model was created for the project area.
- **Low** – A project was ranked with low priority if:
  - The site was shown on the community's Flood Insurance Rate Map (FIRM) to be in Zone X (an area of minimal to non-existent flood hazard), indicating that no detailed flood hazard data was readily available, or
  - There was no digital topography indicated in the file.

The initial ranking indicated that 12 projects were likely to have sufficient data for the physical parameter analysis. The remaining five projects continued to be lower priority candidates for analysis.

Following the initial ranking, an evaluation of storm events was completed to determine whether a storm event had occurred MP_C that was at a threshold to have caused flooding MP_A. This ranking was conducted using the following categories:

- **High** – Projects with sufficient data and analysis results to calculate losses avoided.
- **Low** – Projects with insufficient data and/or analysis results, which precluded the calculation of losses avoided.

Table 2.2 identifies the 17 projects that advanced to Phase 2 of the analysis with their initial and final ranking. The analyses used to determine these rankings were conducted in Phase 2, and are described in more detail in Section Three of this document.

Table 2.2

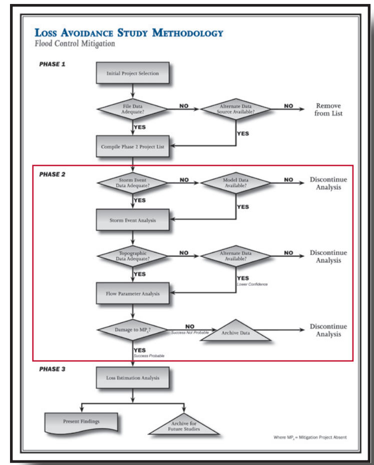
Phase 2 Project List with Priority Rank

General Project Information				Project Priority	
Project Number	Project Name	County	Project Type	Initial Rank[1]	Final Rank[1]
0935-0004 0979-0030	***Live Oaks Springs and Sand Canyon***	Los Angeles	Detention basin and channel rerouting	**M**	**H**
0979-0017	***Mission and Alston Channel***	San Bernardino	Detention basin, channel improvements (with storm and drain pipe), and improved outlet	**H**	**H**
0979-0018	***Rodeo Channel***	San Bernardino	Channel improvements and new storm drain outlet pipe	**M/L**	**H**
0979-0032	***Nason Detention Basin***	Riverside	Detention basin and new storm drain pipe	**M**	**H**
1008-6063	***Federal Boulevard Drainage Improvements***	San Diego	New storm drain pipes and street curb inlets	**M**	**H**
1008-6077	***Flood Project for Todd Road Jail Facility***	Ventura	Channel armoring	**M/H**	**H**
0979-0031	***Ranchero Carlsbad Basin and Channel***	San Diego	Detention basin and channel improvements	**H**	**L**
1008-7220	***Slater Storm Drain Channel***	Orange	Channel and culvert improvements	**M**	**L**
1008-7222	***Shields Pump Station***	Orange	New pump station	**L**	**L**
1008-7251	***Simi Valley Detention Basins***	Ventura	Detention basins	**H**	**L**
1008-7338	***Fullerton Creek Rechannelization***	Orange	Channel and culvert improvements	**L**	**L**
1008-7340	***Rossmoor (Leisure World) Floodproofing***	Orange	New pump station and channel rerouting	**L**	**L**
1008-7341	***Bolsa Chica Rechannelization***	Orange	New storm drain pipe and channel rerouting	**L**	**L**
1008-7342	***Segunda De Schecha Rechannelization***	Orange	Detention basin and channel improvements	**M/H**	**L**
1008-7415	***Long Beach Storm Drain Project #9037***	Los Angeles	New storm drain pipe and pump improvements	**M/L**	**L**
1044-0009	***Tijuana River North Berm***	San Diego	Berm	**H**	**L**
1044-0025	***East Santa Maria Project***	Santa Barbara	New detention basin, storm drain pipe, basin channel improvements	**L**	**L**

[1] **H** = High; **M** = Medium; **L** = Low

Section Three:

Phase 2 - Physical Parameter Analysis

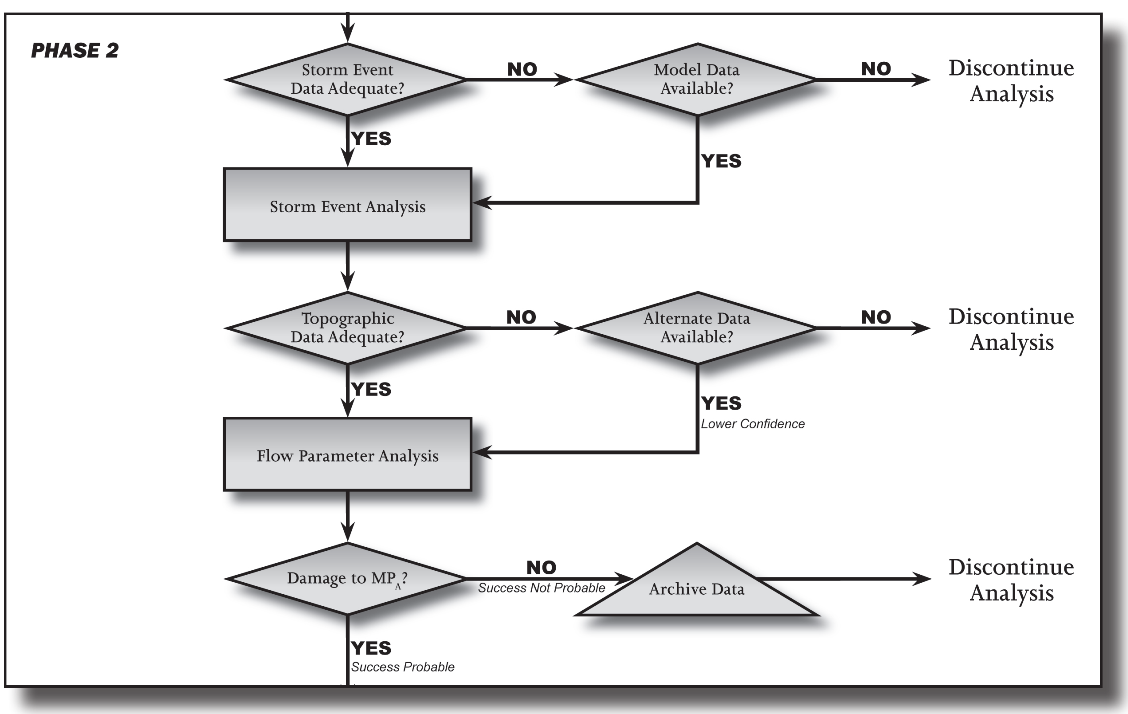


Section Three provides a full synopsis of the process for Phase 2, the Physical Parameter Analysis, as illustrated in Figure 3.1. This section utilizes examples from, and provides summaries of, the Southern California Loss Avoidance Study in an effort to better illustrate the process.

During Phase 2 the physical parameter for the storm event(s) of interest is determined for both the MP_A and MP_C scenarios. There are two major tasks in Phase 2 that must be completed when analyzing flood control mitigation projects.

1. **Storm Event Analysis** to identify potential storm events and assess data availability for flood flow determination.
2. **Flow Parameter Analysis** which includes:
   - **Hydrologic Modeling** to determine runoff amounts for the storm event of interest,
   - **Hydraulic Modeling** to determine flood elevations at modeled cross-sections, and
   - **Flood Boundary Analysis** to determine the flood inundation boundary and flood depth at any point.

Figure 3.1



Each of the steps within the tasks listed above is described in detail in the subsections that follow. Projects that were not eliminated during the Phase 1 screening process may be eliminated during any of these steps, either due to lack of data or because a storm of sufficient magnitude to cause MP_A damage has not occurred since project construction.

3.1 Storm Event Analysis

Storm Event Analysis Data Sources

For loss avoidance studies, local regional, state, and federal weather and conservation agencies are the primary source for data.

State and Federal Agencies That Operate Gage Networks Include:

- Local or regional agencies
- State departments of water resources
- National Weather Service (NWS), National Climatic Data Center (NCDC)
- U.S. Geological Survey (USGS)
- U.S. Army Corps of Engineers (USACE)
- U.S. Forest Service (USFS)

3.1.1 Data Collection

A loss avoidance study for a flood control mitigation project is dependent upon the occurrence of a storm event significant enough to have produced MP_A damage. To identify the storm events for analysis the project baseline must be established. This baseline is based on the date of project completion which may be obtained from the HMGP project files, community officials or their consultants.

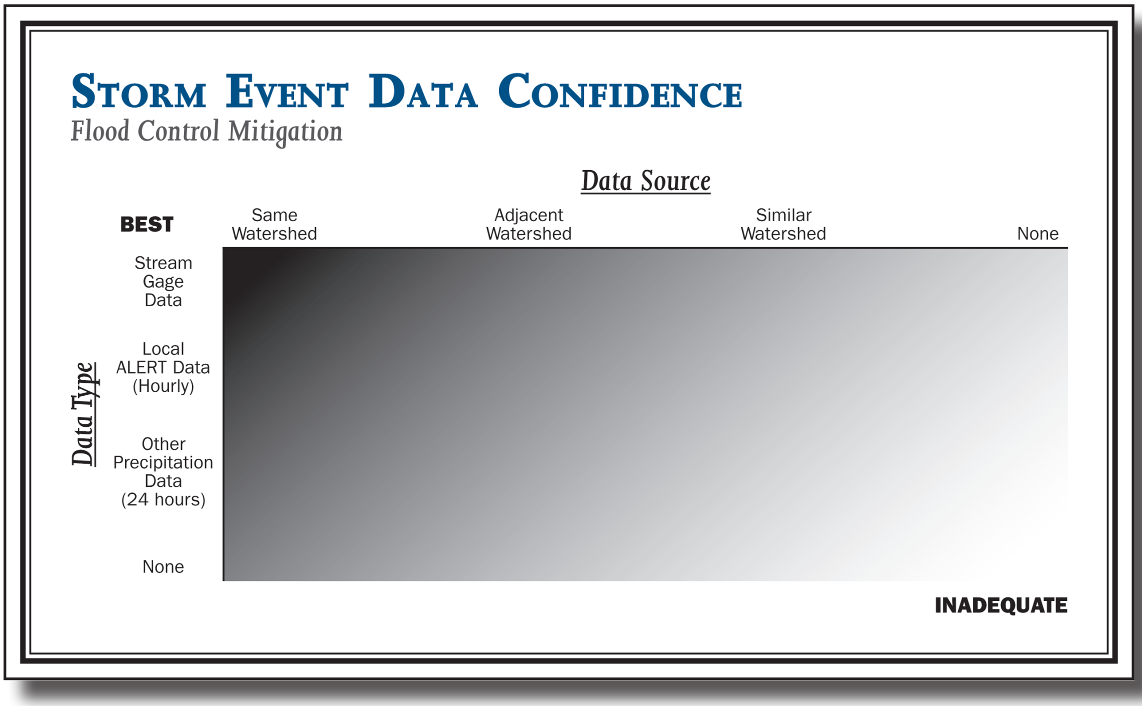
For some projects, one or more storm events may have occurred during the project baseline that might have caused damages (or did cause damages) in the study area. In such situations, if all the required data are available losses avoided can be calculated. To do this, both the MP_A and MP_C scenarios must be modeled for each event.

The main components of gage data are location, type (rainfall or stream gage), and interval (daily, hourly, event-based). Collection of gage data is typically accomplished by working with federal, state, and local agencies to obtain text or spreadsheet files of raw recorded gage data or reports where data is summarized for the required storm durations (such as the 6-hour or 24-hour storm for precipitation).

The key data required for the storm event analysis are stream or rainfall gage records for the watershed within which the mitigation project is located. Data for a Storm Event Analysis can vary in confidence based on the type of data and the data source. As illustrated in Figure 3.2 the best available data to complete the Storm Event Analysis are stream or rainfall gage records for the watershed in which the mitigation project is located, where as general precipitation data in a similar watershed have a lower confidence.

Project background data includes information about the geographic and physical conditions of the study area and project site. If at all possible, information should be collected in electronic formats, such as Geographic Information System (GIS) data, that can be used to prepare hydrologic and hydraulic analyses. Like gage data, this information comes from a variety of local, state, and federal sources. Many regions may have GIS organizations that compile these datasets. There may also be a state GIS organization, state

Figure 3.2



agencies or contractors that have most of these datasets available. Although more expensive, many agencies now provide basic data to commercial enterprises who post-process the data and provide enhanced data for sale.

The specific requirements (and detail level) needed for both gage and background data determine how the next steps of the storm event analysis occur. It is very likely that the data collection and analysis steps of the storm event analysis may need to be repeated several times until either sufficient data has been collected or it is determined that the data is not available. Projects with insufficient data should be eliminated from the project list.

Project background data elements include:

- Aerial Photography
- Transportation networks
- Drainage networks and watersheds
- Topography
- Municipal boundaries
- Project site information
- Flood history

3.1.2 Identify Analysis Information

The storm event data collected must be evaluated for watershed information and study area. This evaluation is used to determine the location of gages that might provide data applicable to the study.

Effective Watershed Area

The first step is determining the effective watershed drainage area for the study area. The project files often contain maps and information about the watershed drainage area. In other cases, this must be derived. Drainage networks are a part of an effective watershed analysis. A natural watershed is defined by the watershed divide. A watershed divide is that area where a hypothetical drop of water falling on one side of the divide runs into the watershed and an identical drop falling on the other side runs to another watershed.

In urban areas or some areas of the west with large ditch networks, drainage networks may revise the natural watershed area. This fact may lead to increased or decreased delivery of water to the project site, resulting in the effective watershed for the project. A combination of drainage network information and topographic information can be used to derive the effective watershed area. In areas with low topographic relief, such as Piedmont areas or North Dakota, the detail level of this data needs to be greater than in areas with high relief. The effective watershed area is used as part of the evaluation of the gage data. For the remainder of this document, the effective watershed will be simply referred to as the watershed.

Study Area

The study area is defined as that area affected by the mitigation project. Typically this area encompasses the floodplain from the project location downstream to the point where the impact of the project on flooding conditions is negligible. Often this downstream limit is where the drainage enters a larger drainage channel. Some projects may also have upstream impacts if they cause backwater effects, however these impacts should have been accounted for during initial project calculations. In some cases, the study area is identified in the project files. However, in other cases, the study area must be determined from available data and reassessed after the flood boundary analysis has been conducted. This scenario may occur if the project has led to enhanced development in the study area.

3.1.3 Stream Gage Event Analysis

The availability of sufficient stream gage data for event analysis should be determined. If a stream gage is available in or near the watershed and has a period of record covering the event of interest, then a stream gage event analysis can be conducted. If stream gage data are available for only a part of the project baseline, this information may also be useful in the hydrologic analysis.

If sufficient stream gage data are available, the storm event of interest can be identified using the following method:

- If an event with known MP_C damages occurred, determine the peak stage (water elevation height above the stream bed) for that event.
- Rank all stream gage data by stage height and determine the dates of the maximum peak stage event(s).
- If gage records are stored as average stages (typically, daily or hourly periods), determine the method to calculate peak stage from average stage values.

Stream gages typically record the stage. This stage data must be converted to obtain the actual flow of the stream. Most streams vary in cross sectional area. This means that for any unit in elevation change of the stream, more or less water will be flowing past the gage. If a stream stage is rising, typically the stream will experience more flow per foot of increased stage. This does not apply if the channel has been modified by man. In any case, each stream gage has had the flow calculated for each stage of that stream. This value will be re-verified periodically and after any flood to ensure the cross section has not been modified by erosion or other impacts.

In most cases, the stream gage data can simply be ranked and the dates of events determined. However, the stream gage data may not represent peak runoff, but may instead be some type of average stage value over an interval (hour or day). This happens if a stream is subject to very rapid stage increases (flash flood conditions). For such data, the gage data source may have information on methods (such as line fitting techniques) that were used to determine peak flow rates. Weather research literature and texts can also be sources for these methods.

3.1.4 Precipitation Event Analysis

If stream gage data is not available, then the storm event of interest must be identified through analysis of precipitation gage data. The gage must have a period of record that sufficiently covers the project baseline and it must be applicable to the watershed in which the study area is located. For larger watersheds, this may require using data from multiple gages. The hydrologic model that is used later in the analysis (see Section 3.2) must be considered when determining the proper gage coverage of the watershed area.

The hydrologic model to be used also affects the storm duration that is selected for the analysis. If there is an existing hydrologic model, the model storm duration should be evaluated to determine which duration to use for storm event selection. Existing hydrologic models were developed for these projects to account for all upstream drainage networks and structures that impact runoff response. The original model creators chose appropriate storm duration for their model(s) to maximize peak runoff rates so their project designs would have sufficient capacity. In many cases, the hydrologic models use 24-hour rainfall duration as their basis for design. For systems with detention structures, the storage in these structures is often required by local and state regulations to be designed for 24-hour accumulations, which commonly produce the largest peak runoff rates downstream. In other cases, the creators of these models may have considered a variety of storm durations and their associated rainfall intensities, and selected the duration that produced the highest peak runoff rates.

When new hydrologic models are required, the storm duration of interest must be determined through the hydrologic modeling process. In many cases, sufficient information is not available to adequately model the MP_A scenario, since this represents a pre-project condition that no longer exists. When there is sufficient information, the hydrologic analysis must be prepared using an appropriate method for that location. The choice of hydrologic analysis method determines the storm duration (see Section 3.2). Precipitation gage data may require screening for peak rainfall rates or multiple durations (6-, 12-, or 24-hour) to be modeled, and then the peak runoff is selected from all model runs.

If sufficient data is available to determine the storm duration of interest and sufficient precipitation gage coverage of the study area exists, the storm event of interest can be identified using the following method:

- Summarize the data according to storm duration intervals.
- If an event with known MP_C damages occurred, determine the precipitation total for the storm duration causing that event.
- Rank all storm duration interval totals and determine the dates of the maximum precipitation event(s).

If sufficient gage or hydrologic analysis information is not available to complete the storm event analysis or if the gage data do not show the occurrence of a significant storm during the project baseline, the project is eliminated from the study list. Care should be taken to archive all data developed up to the point the project is removed from the project list to reduce time and cost for future studies of this project.

3.1.5 Southern California Study: Storm Event Analysis

Detailed results of the storm event analysis for the Southern California Loss Avoidance Study are illustrated in Table 3.1. In the Southern California Study only one of the projects analyzed in Phase 2 had stream gage data for the reach of interest. The runoff for all the other project sites was estimated from rainfall data. The county-based Automated Local Evaluation in Real Time (ALERT) systems and the National Weather Service (NWS) were the primary sources for the rainfall data. In general, the ALERT system has more extensive gages throughout this region and was the best available data source for most of the project sites. However, since ALERT is used primarily for real-time flood forecasting, the availability of long-term ALERT data was limited. For those projects with inadequate ALERT data,

Table 3.1

STORM EVENT ANALYSIS RESULTS

Project Number	Project Name	Greatest Post-Construction Event	Frequency
0935-0004 0979-0030	Live Oaks Springs and Sand Canyon Project	February 12, 2003 (5.81 inches)	Between 25-year (5.31 inches) and 50-year (6.05 inches)
0979-0017	Mission and Alston Channel	February 23, 1998 (2.29 inches)	Damaging events (close gage) ~ 0.91 inches Between 5-year (2.0 inches) and 10-year (2.5 inches)
0979-0018	Rodeo Channel	February 23, 1998 (2.29 inches)	Damaging events (close gage) ~ 2 inches Between 5-year (2.0 inches) and 10-year (2.5 inches)
0979-0032	Nason Detention Basin	March 16, 2003 (2.81 inches)	Between 2-year (2.0 inches) and 5-year (3.0 inches)
1008-6063	Federal Boulevard Drainage Improvements	February 23, 2004 (2.32 inches)	Between 2-year (1.8 inches) and 5-year (2.5 inches)
1008-6077	Flood Protection for Todd Road Jail Facility	January 10, 2005 (5.31 inches)	Between 10-year (4.5 inches) and 25-year (5.8 inches)

long-term weather data from the NWS, or state and local sources, were used.

For example, no damage was observed from storm events in the study area of the Live Oaks Springs and Sand Canyon Drainage Improvement Project during the project baseline, so it was not necessary to analyze the MP_C scenario for this study. Weather data were available from the Los Angeles County Fire Department and Los Angeles County ALERT. Rainfall data for the project site were obtained from Los Angeles County Fire Department Station Camp 9, approximately 1.2 miles from the project site and located within the watershed area. The existing hydrologic model for this project used a 24-hour storm duration. The maximum project baseline event was a 24-hour rainfall of 5.81 inches that occurred on February 12, 2003 (see Table 3.1). Appendix A contains more detailed information about this project.

3.2 Hydrologic Analysis

A hydrologic analysis is used to determine the amount of runoff for the event of interest. Between the storm event analysis and the hydrologic analysis, the decision is made to analyze either both the MP_C and MP_A scenarios or the MP_A scenario alone. This decision is based on whether actual damages occurred for the storm event of interest. In addition, the overall loss avoidance study scope determines if loss avoidance calculations are conducted for the MP_C storm event with the greatest rainfall or for all MP_C storm events that potentially produced losses avoided. For example, the study sponsor may be interested only in the most severe event that occurred during the project baseline; therefore, that event is used to model the MP_A scenario. In other cases, several events may be modeled for the MP_A scenario.

HYDROLOGIC ANALYSIS DATA SOURCES

Mitigation Project Data:

- HMGP Project Files
- FEMA Databases
- Construction Drawings and Specifications
- GIS Data (Aerial Photography and Political Boundary Mapping)

Hydrologic Modeling Data:

- HMGP Project Files
- Pre- and Post-Construction Hydrology Design and Model Reports
- Local Drainage Plans
- NOAA Design Storm Maps
- FEMA Data (FIRM, DFIRM, FIS, LOMC)
- GIS Data (Streams, Rivers, Watersheds, Land Cover, and Soils)

3.2.1 Data Collection

The type of data and detail required is driven by the results of the storm event analysis. If stream gage data were available, then these gage data may be used to calculate the peak runoff directly. If precipitation gage data had to be analyzed in the previous step, then some type of existing or new hydrologic model is needed in order to calculate the peak runoff. In addition to the results of the storm event analysis, drainage data, infiltration information, and hydrologic model data are required.

Drainage Data

Common sources for drainage data include the following:

- *Existing hydrologic and hydraulic models* - project files; project design report; Master Plan for the study area; the state National Flood Insurance Program (NFIP) coordinator; and NFIP mapping information maintained by FEMA, including the FIS for the study area and Letters of Map Revision (LOMR) and Conditional Letters of Map Revision (CLOMR) that FEMA may have issued for the study area. NFIP mapping information can be obtained from FEMA's Resource Management Center, located in each FEMA region.
- *Topography* – U.S. Geological Survey (USGS) Digital Elevation Model (DEM) data, project site survey and construction plans, master plans, the topographic data that was used to prepare the FIRM for the study area, and local officials.
- *Flood mapping* - FIRM showing the study area, local hazard mitigation plans, master plans, and flood insurance studies.
- *Locally available information* - local or regional GIS data.

The key to collecting the proper drainage data is to determine which of the analysis "paths" the hydrologic analysis will follow. New models require the most extensive drainage data; analysis of stream gage data requires the least. Details on specific drainage information needed for any given model should be provided in the model documentation.

Infiltration Information

Infiltration information is necessary to determine if rainfall will become runoff or infiltrate (soak) into the soil. Typical data sources include the following:

- Existing hydrologic and hydraulic models: Project Report, Master Plan, FIS, CLOMR, LOMR, the state
- U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) soils mapping
- Community land use mapping

Like drainage data, the anticipated modeling approach will dictate the information and data format needed.

Hydrologic Model Data

The parameters necessary to prepare the hydrologic analysis must be identified. For example, many models use the National Resources Conservation Service (NRCS)-Curve Number (CN) approach, where the CN is based on a combination on land use, soils, and antecedent moisture conditions. If the hydrologic model uses this approach, then information about how to calculate the CN is required to develop and run the model. Some data sources for this hydrologic model data type of information include the following:

- Regional regression equations for flow rates: USGS, state or local departments of transportation
- County and state hydrologic design standards, such as standards published by local flood control or watershed management districts
- Public and private hydrologic model software vendors

As with storm event analysis data, any project with insufficient hydrologic data is eliminated from study consideration at this time. If stream gage data are not available, there may need to be several rounds of data collection and analysis before it can be determined whether sufficient data exist to create new, or modify existing, hydrologic analysis.

3.2.2 Identify Analysis Information

To proceed with hydrologic analysis, the data collected must be analyzed for the sub-watershed delineation and parameters as well as hydrologic model configuration parameters.

Sub-watershed Delineation and Parameters

Most existing and new hydrologic models require that sub-watersheds are delineated and that model parameters are determined for those sub-watersheds. Sub-watersheds are delineated using drainage network and topographic data, along with hydrologic model guidelines regarding delineation of small sub-watersheds to adequately represent runoff response. Once the sub-watershed boundaries are known, hydrologic model parameters are generalized for each of the sub-watersheds, typically based on area-weighted averages.

Hydrologic Model Configuration Parameters

Hydrologic models also have specific configuration parameters, apart from those parameters entered for the sub-watersheds, that control how the model runs and the system defaults. For example, event-based hydrologic models often require information about antecedent conditions, such as soil moisture, to provide starting conditions for various model process equations.

3.2.3 Stream Gage Hydrologic Analysis

The availability of sufficient stream gage data for hydrologic analysis is determined during the initial data collection process. If sufficient data is available, the runoff peak can be identified by identifying the peak runoff value for the date of the event of interest. In some cases, the source stream gage data may represent an average runoff over some interval, such as an hour or a day. Statistical methods for analyzing data, in which the flow data is normalized using a standard distribution, may be required to estimate an instantaneous peak when only time-averaged peak data are available.

3.2.4 Modifying Existing Hydrologic Models for Analysis

If stream gage data are not available, then a hydrologic model must be prepared to determine peak runoff. For some projects, the project files may contain existing models that represent the MP_A and/or MP_C scenarios. When these models are available, they can be modified to represent the event of interest. This may involve simply replacing the input design rainfall distribution with the distribution for the event of interest. In other cases, only portions of the original model can be retained, because the model makes use of iterative solutions or calibration to determine certain parameters. The difficulty of modifying a model for a given project is highly dependent upon both the model and the type of project. Also, the hydrologic modeling software that is used by engineers tends to change over time, so it may be difficult to obtain the original model runtime programs to go with the original model input files. It may be necessary to modify model inputs so that they are compatible with the latest model version. Obviously, any modifications to existing model runs should be carefully documented and full runs made with the revisions.

3.2.5 Creating New Hydrologic Models for Analysis

Because of the difficulties associated with modifying existing hydrologic models, creating a new model may be less time consuming even when existing models are available. If a new model must be created without any existing model information, model selection should be matched to the data available and standard practices for similar modeling situations, such as floodplain modeling. For example, FEMA floodplain modeling guidelines allow the use of regional regression equations to determine peak runoff for different recurrence intervals. A relationship can be developed from the design rainfall amount at different recurrence intervals and the resulting runoff. For event of interest rainfall, runoff can be estimated based on a line-fitting statistical process. More sophisticated hydrologic modeling may be needed when the watershed and drainage network contain impoundment structures or flow-restricted drainage networks that will alter runoff response. An example of a flow-restricted drainage network would be a culvert under a road. Culverts are often designed for higher frequency flow of 30 to 50 year events. A culvert capable of only carrying a 30-year flow will restrict the delivery of some of the runoff, reducing the overall runoff curve. This will result in local flooding, but will reduce flooding downstream of the culvert. Likewise, any restriction of upstream flood retention project outfalls will reduce downstream flow.

This analysis may also result in project elimination from the study list when there are insufficient data to conduct hydrologic analysis. However, by using simple methods, such as regression equations, new hydrologic models can often be developed without excessive effort. This holds true only if watershed drainage networks are not too complex or affected by control structures.

3.2.6 Southern California Study: Hydrologic Analysis

Hydrologic analyses were conducted for most of the projects evaluated in Phase 2 of this case study. The HMGP files did not contain detailed project design or construction information. As a result, local communities provided the information for the study. Access to this data was limited and often only available in hardcopy formats. However, many of the project analyses used county-specific hydrologic models that were still available. Therefore, when the required information about the watershed and drainage network upstream from the project site was available, a hydrologic model was created for the project site.

Most projects contained sufficient information to approximate the hydrologic response for the event of interest. For example, the Todd Road Jail Facility Access Road Flood Protection Project had available MP_A hydrologic modeling that was prepared using a Modified Rational Method (MRM) model developed by the Los Angeles County Department of Public Works. This analysis had been prepared for

Two projects were removed from the Phase 2 project list because there was insufficient information available to model the complex upstream drainage network.

- 1008-7340 Rossmore (Leisure World) Flood Proofing
- 1044-0025 East Santa Maria Project

the 24-hour, 100-year design storm of 9.0 inches. To predict the runoff from the event of interest, the information contained in the available hydrologic modeling output was used to develop a new Hydrologic Engineering Centers – "Flood Hydrograph Package" (HEC-1) model. This information included a unit hydrograph, temporal rainfall distribution, and watershed response factors. The temporal rainfall distribution from the original model was scaled to represent the 5.31-inch rainfall from the event of interest, which occurred in 2005. The HEC-1 model was first run for the original 100-year storm event and matched the MRM within 1%. The second run of the new HEC-1 model used the 5.31-inch rainfall to produce a resulting peak runoff of 2,325 cfs. More detailed information on this project can be found in Appendix E.

3.3 Hydraulic Analysis

The second step of the flow parameter analysis is to estimate the water surface (flood) elevation for a series of cross-sections based on the peak runoff for an event of interest. Water surface elevations will always be estimates for MP_A scenarios, and will also be estimated for the MP_C when actual damages occurred. Like the hydrologic analysis, a separate hydraulic analysis is required for each combination of event and scenario. This may be more difficult to do when there are both MP_C and MP_A scenarios, since the channel configurations and conditions may have changed between the two scenarios, unless the flood control project is exclusively a detention facility.

3.3.1 Data Collection

In addition to the hydrologic analysis results, channel topographic data and hydraulic model data are required to conduct the hydraulic analysis.

Hydraulic Analysis Data Sources

Topographic Data:

- Digital Elevation Data (Contours, LIDAR, and TIN)
- NOAA IfSAR Data
- USGS Topographic Mapping
- Paper Drawing Contours

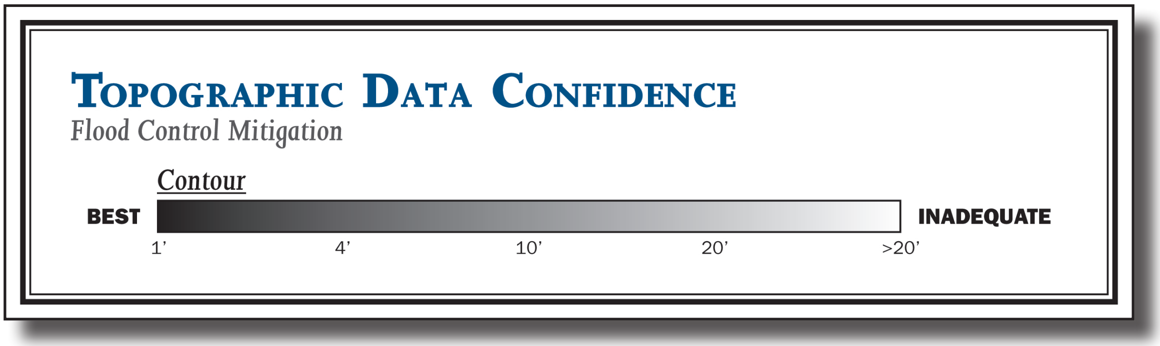
Hydraulic Modeling Data:

- HMGP Project Files
- Pre- and Post-Construction Hydrology Design and Model Reports
- Local Drainage Plans
- NOAA Design Storm Maps
- FEMA Data (FIRM, DFIRM, FIS, LOMC)
- GIS Data (Streams, Rivers, Watersheds, Land Cover, and Soils

Channel Topographic Data

Channel topographic data is needed to represent the profile of the flood channel for MP_A and MP_C conditions. For the MP_A scenario, this often requires finding, or approximating, channel topography prior to project construction. The MP_C can often be based on recent topographic data. As illustrated, in Figure 3.3 the confidence of the topographic data varies depending upon the contour intervals. One to 4-foot contour intervals is the best data to have when completing a loss avoidance study. However, if contour intervals up to 10 feet are available, they can be interpolated to four feet or less which increases its resolution. Confidence in the data is drastically decreased if contour levels are greater than 10 feet.

Figure 3.3



The source and data collection method for topographic data will affect the detail level and usefulness for hydraulic analysis. The major topographic data collection techniques are as follows:

- Photogrammetric – Digital topography produced from aerial photogrammetry with ground control and survey
- Topography generated by Airborne Light Detection and Ranging Systems (LIDAR)
- Surveyed and hardcopy topographic data
- USGS DEM and contour data

Photogrammetric and LIDAR

Both of these collection techniques have similar sources. These include the following:

- *Project-specific topographic data from a city, county, FEMA, or other federal agency* - Digital topographic data may be available for the project site and surrounding area or from a neighboring project. The data may be in the form of a FIRM revision (such as a CLOMR or LOMR) with pre- and post-project topographic data submitted with project plans, or the data may be from neighboring public works or private development projects.
- *Sub-regional level data available through local and federal agencies* - For example, in some cases, local or federal agencies may have produced digital topography for post-fire conditions, levee analysis, hydrologic master planning studies, or similar projects.
- *Regional, citywide, or countywide data available through City Engineering, Public Works, Flood Control, or GIS Departments* - Some cities have recent, readily available citywide topographic data. Many counties do not have sufficiently accurate countywide digital topographic data but may have localized coverage developed for particular regional watershed studies.

Surveyed and Hardcopy Topographic Data

Surveyed and hardcopy topographic data are the second, and typically less preferable, type of topographic data that may be available for a particular project. These data are less preferable due to the time and effort that is typically required to obtain, copy, interpret, and compile this data into a usable and accurate format, particularly in conjunction with readily available aerial photography and land use maps. These topographic data often require a significant amount of manual data interpretation and adjustment. The typical sources and limitations of these data include the following:

- *Ground survey data without digital elevation contours* - Point survey data for the project for MP_A and/or MP_C scenarios may be available for roadway surfaces, top of levee elevations, structure elevations, etc.; this information is available from the project construction files or construction drawings on file at the city/county/agency
- *'As-built' construction drawings (typically grading plans)* for the project or neighboring projects typically with top of channel and pad elevations on file at the city/county/agency
- *Hardcopy City or County topographic maps (typically 1980s 100 to 200 ft per inch scale 4- to 5-foot contour interval)* – These are available from city or county engineering/public works/flood control departments.

As indicated above, survey data and hardcopy topographic data may require significant time to obtain, process, and utilize for current studies. Survey data may provide limited local elevation data that can potentially be used for levee/channel overtopping elevations, but will not typically provide information required to determine flooding limits or depths within the floodplain or upstream/downstream locations. 'As-built' construction drawings typically focus on the specific project locations and do not provide topographic data for the floodplains, or upstream/downstream of the project.

USGS DEM and Contour Data

This is the least preferred source of topographic data, because of issues with the quality and date of collection. Typical the data is available on a 30-meter (in some cases 10-meter) digital DEM format. While these data are readily available across the United States, often, they are not sufficiently detailed or accurate enough for hydraulic analysis, particularly in areas of flat terrain or areas with significant recent floodplain development that has resulted in changes in drainage patterns or channelization. For example, projects located within recently developed areas not reflected in the DEM data that have constructed detention basins, channels or levees will not accurately reflect flood level conditions in the vicinity of the development.

Regardless of the source for topographic data, the information is used to create elevation cross-sections to enter in a hydraulic model. The only exception is when this cross-section information has been provided in an existing hydraulic model, which may be the case when a LOMR has been done in conjunction with a mitigation project.

Hydraulic Model Data

The parameters necessary to prepare the hydrologic analysis must be identified. For example, many models use Manning's Roughness Coefficient to represent the resistance of the channel lining to water flow. This usually is required for each cross-section, with variation noted across the cross-section. Cross-sections are commonly placed at locations along a stream channel where the flow changes for some reason. Often, this will result in a differing channel roughness. If the hydraulic model uses this approach, then information about how to derive this information is needed to develop and run the model. Some data sources for this type of information include the following:

- County and state engineering departments (county and state hydraulic design standards)
- Public and private hydraulic model software vendors

As with previous data analysis, any project with insufficient hydraulic data is eliminated from study consideration. When a new model is needed, lack of sufficiently detailed topographic data is often the reason a project cannot be adequately modeled.

3.3.2 Identify Analysis Information

To proceed with the hydrologic analysis, the collected data needs to be analyzed for cross-section and structure data as well as hydraulic model configuration parameters

Cross-Section and Structure Data

Extracting elevation and parameter information for each model cross-section is needed for new hydraulic models and possibly for modifying existing models. There are numerous tools available, mostly GIS-based, for cutting cross-section elevation and parameter information from digital data. Most of these tools work with the Hydrologic Engineering Centers – River Analysis System (HEC-RAS) model, however other data input tools also come with most private vendor software hydraulic models. In many cases, the platform for conducting a hydraulic model is a GIS or Computer-Assisted

Drafting and Design (CADD) environment, where automated routines extract the required data from input data formatted in a certain way.

If a model has to represent a structure other then typical open-channel flow, such as a bridge or culvert, then these data are converted to the proper format for entry into the model. For example, HEC-RAS has special data input screens for bridges and culverts requiring elevation data on both the structure and roadway above the structure.

Hydraulic Model Configuration Parameters

Hydraulic models also have specific configuration parameters, in addition to those parameters entered for the cross-sections. These parameters include: peak runoff; boundary conditions; and model runtime control settings. This information must be determined to successfully create a working hydraulic model.

3.3.3 Observed Data Analysis

The availability of observed flood elevation (that is, high-water mark) data to represent hydraulic conditions should be determined. The MP_A water surface elevation cannot be measured, since this event never actually occurs. Therefore, it needs to be estimated from flow and topography. In some cases it may be possible to use historical data and information to estimate the water surface elevation. It is more likely that water surface elevation information is available for the MP_C scenario, usually in the form of measured high-water marks. A hydraulic model must be used to approximate flood elevations between the high-water marks.

3.3.4 Modifying an Existing Hydraulic Model for Analysis

For most projects, hydraulic modeling is needed to develop the flood elevations required for flood boundary mapping. These models must be modified to represent each of the scenarios. For the MP_A scenario, possible approaches include the following:

- If an existing hydraulic model is available and represents the scenario, it can be used to calculate the water surface elevation.

OR

- Flood profiles can be used to estimate the water surface elevation (for example, current FIS profiles) if profiles representing the MP_A scenario are available.
- If no model or historical data are available, interviews or discussions with community representatives can be used to

estimate water levels for different historical flood events. This information is then used to estimate what the likely water surface elevation would have been.

Likewise, for the MP_C scenario, the approach for using existing models includes the following:

- Use current site conditions hydraulic model, if appropriate.

OR

- Use flood profiles (for example, current FIS profiles) if MP_C high-water marks are available. A recurrence interval could be approximated based on the high-water mark data. The Flood Information Tool (FIT) in FEMA's HAZUS-MH MR2 model uses a similar approach to approximate flood elevations and boundaries when information is entered for several known flood recurrence intervals (FEMA, 2006a).

3.3.5 Creating a New Hydraulic Model for Analysis

When a new model is required, several approaches can be taken before a detailed model such as HEC-RAS may be needed. If a published rating curve that compares flood stage to flow rate is available (such as from the USGS), or if historical data are available to develop a rating curve, then the rating curve is used to estimate the water surface elevation from the estimated or measured flow rate. In addition, a normal depth calculation can also be used to calculate the water surface elevation. Existing channel cross-sections are estimated from measurements collected in the field, such as channel width, depth, and shape. If a detailed hydraulic model is needed and required information is not available, then some projects are eliminated.

3.3.6 Southern California Study: Hydraulic Analysis

Most of the project files did not include hydraulic models that described the pre- and post-construction hydraulic conditions of the floodplain. Most often the hydraulic information included in the project file was for the flood control structure only and not the floodplain (i.e., storm sewer hydraulic model). If topographic data were available new hydraulic models were created by extracting cross-section elevations from the topography.

When the topographic data was adequate, the model results sometimes indicated that all flows would have been contained by the drainage system, so there would have been no MP_A damages. For example, the Tijuana River Valley North Berm Project had sufficient data (including stream gage data and a detailed 2-foot topographical map) to conduct a hydraulic model, but the hydraulic model results

Five projects that did not have sufficient topographic data to create hydraulic models were eliminated from the Phase 2 project list.

- 1008-7220 Slater Storm Drain Channel
- 1008-7222 Shields Pump Station
- 1008-7338 Fullerton Creek Rechannelization
- 1008-7342 Segunda De Schecha Rechannelization
- 1008-7415 Long Beach Storm Drain Project

After the Hydraulic Analysis, two projects indicated no out-of-bank flooding and were removed from the project list.

- 1008-7341 Bolsa Chica Rechannelization
- 1044-0009 Tijuana River North Berm

indicated that the event of interest was too limited and would not have reached the berm and project area. Therefore, this project was eliminated due to lack of a damaging event.

There were eight projects that had sufficient data to produce hydraulic models, and when modeled, it was indicated that there would have been out-of-bank flooding. For example, the project file for the Federal Boulevard Drainage Improvement Project had MP_C hydraulic data, but did not have any MP_A hydraulic modeling for out-of-pipe flooding. Using the MP_A 1-foot contour interval hard copy construction drawings, a new HEC-RAS model was created. The modeling was performed only within the study area from the drainage improvement until the confluence of a much larger watershed. The hydraulic analysis results of the event of interest found that MP_A scenario flow depths would have been between approximately six and 24 inches, and flow velocities between one and 10 feet per second. Slight out-of-bank flooding was shown at many cross-sections, so a flood boundary analysis was needed to determine if there would have been any damage for the MP_A scenario. Details on the Federal Boulevard project can be found in Appendix D.

3.4 Flood Boundary Analysis

The final step of the flow parameter analysis is to determine the flood boundary and associated flood depths to determine if there would have been impacted structures for each event and scenario. Analysis results provide: flood boundaries; flood depth information; and a list of the types of potentially damaged properties for MP_A and MP_C scenarios.

Flood Boundary Analysis Data Sources

Topographic Data:

- Digital Elevation Data (Contours, LIDAR, and TIN)
- NOAA IfSAR Data
- USGS Topographic Mapping
- Paper Drawing Contours

Flood Boundary Analysis Data:

- HMGP Project Files
- FEMA Data (FIRM, DFIRM, FIS, LOMC)
- GIS Data (Streams, Rivers, Watersheds, Land Cover, and Soils)

3.4.1 Data Collection

In many cases, most of the data required for the flood boundary analysis will have been collected during previous analysis steps. Besides the hydraulic modeling results and all the previously collected data, this analysis will also require existing floodplain modeling data, supplemental topographic data, and asset location and elevation data.

Existing Floodplain Modeling Data

The review for floodplain data begins by determining whether the project is located in a floodplain shown on a FIRM. If the FIRM shows the project to be in the floodplain, then the FEMA Map Service Center is checked for any LOMRs or CLOMRs that include data for the study area. If there was a CLOMR or LOMR prepared for the project, then it will likely provide most of the data necessary for the inundation analysis, including hydrologic and hydraulic models and topography. In some cases, this type of data may be available for the original models used to create the FIRM or when models were converted to digital formats through the FEMA Map Modernization process. The presence or absence of this data should be determined early in the analysis process to possibly shorten data collection efforts.

Supplemental Topographic Data

For some studies, the topographic data collected for the hydraulic modeling are sufficiently detailed and cover the entire area where flood inundation would occur. If not, supplemental topographic data are needed to produce the flood boundary and depth information. The various topographic sources described in the hydraulic analysis can be explored to find these supplemental data.

As with previous analysis steps, some projects may be eliminated due to lack of data. However, if detailed information, such as topographic data, is lacking for the flood boundary analysis, a lower quality source of data may be used to provide some idea of flood extent (rather than eliminate the project). This analysis will have a documented lower confidence level.

Asset Location and Elevation Data

To determine if an asset would have been damaged from flooding, the location of the structure and the elevation offset above the ground elevation needs to be known. For structures, this is the first floor elevation (FFE); for roads and bridges, it is the top of the road. Direct data sources for this information include the following:

- Obtain surveyed elevations
  - If the local government has prepared a flood elevation certificate for a structure, then survey-quality data should be available.
  - Global Positioning System (GPS) data points can be obtained in the field.
- Non-survey methods
  - Measuring the offset between the lowest adjacent grade and the FFE with a tape measure
  - Taking site photos and estimating FFE offset based on house characteristics (such as counts of steps or bricks)
  - Offset from surveyed high-water marks

These site methods can be done fairly quickly, but can be very time consuming when working with a large number of structures or with complex structures, such as commercial or industrial sites, that have large square footages on several different levels.

For projects where there is larger number of structures or limited data, there are different calculation methods that can be used. These methods rely on an available dataset and a specific attribute associated with a type of structure, where that attribute is used to assign an FFE or flood depth. Methods include the following:

- **Location methods:** ground elevation topographic data is compared to the flood elevation to produce a flood depth surface. The way a flood elevation is assigned to a structure is based on how the structure position is located. If a building footprint or center point is available, the flood depth is determined from the flood surface. If only a tax parcel boundary is available, then flood elevation over the parcel is averaged before it is assigned to the structure on the parcel. Aerial photography often allows a method for locating position of a structure within a tax boundary. Many localities now use GIS for tax map purposes and this will provide moderate to good structure location determinations.
- **Elevation methods:** group structures according to relative ground elevation and assign flood depth uniformly to structures in the group. For example, all houses with ground elevations between 70 and 72 feet National Geodetic Vertical Datum (NGVD) for a site with 75-foot flood elevations are assigned four-foot flood depths.
- **The HAZUS model** uses approximate surface topography (such as a 10- or 30-meter DEM) and flood elevation data to calculate percent of census block flooding. If 20% of a census block is flooded, then it is assumed that 20% of the structures are flooded. The difference between the flood elevation and the topography is used to assign various flood depths to the 20% of structures estimated to be flooded.

All of these methods are highly dependent upon data availability, especially high-quality topographic data. The actual method used for each site will likely be a balance between site and remote data acquisition methods depending upon number of structures and data availability.

3.4.2 Typify Analysis Information

This step of the flood boundary analysis will usually consist of converting various source data into the format of the tool being used to produce the boundary and depths. For example, GIS-based tools that use raster grids will require that flood elevations at each cross-section be converted to a "grid surface" to cover all areas between cross-sections. The topographic data must also be converted to a raster grid before the analysis is conducted. Other tools have similar data conversion process requirements.

3.4.3 Existing Observed Flood Boundary Data

For some MP_C scenarios, there is observed flood boundary data. Ideally, flood maps based on quality current site condition topographic data (at least 4-foot contours) would be available. However, there may be aerial photography taken during the peak of flooding that could be digitized to develop a flood boundary. For MP_A scenarios, there may be past events that closely approximate the event of interest where flood boundaries were determined. Care should be taken to ensure the site condition, land use, and drainage area have not been altered significantly since that historical event.

3.4.4 Modifying an Existing Flood Boundary and Depth Analysis

For some projects, existing flood boundary models can be modified to provide an event of interest scenario. For example, if the hydraulic model found that flood elevations had changed for only a subset of all modeled cross-sections from an existing model, then new flood boundaries would only need to be determined for this subset. Tools like the FIT in HAZUS-MH MR2 can also make use of existing data to simplify the analysis of the flood boundary and depth.

3.4.5 Creating a New Model for Analysis

When a new flood boundary and depth need to be calculated, all approaches determine flood depths and then the flood boundary. Flood depth is calculated as the difference between the water surface elevation of the flood event being analyzed and the ground surface elevation. The flood boundary is the zero flood depth contour line. GIS and CADD tools exist that perform this calculation.

3.4.6 Asset Damage

Any assets located within the flood boundary are assessed to determine of they would have had flood damage. While knowing an asset's elevation, such as FFE, can indicate a flood depth for each asset, the loss avoidance analysis calculation must still be done to determine if the depth relates to damage. For example, elevated structures may experience damages several feet below the first floor elevation. The key finding from the asset damage assessment is a list of the possible assets that appear to be flooded for inclusion in the loss avoidance analysis. Any project with results that indicate no damage MP_A would be eliminated from further consideration.

Since most of the data collection needed for a future loss avoidance analysis has been accomplished, these studies should be archived for future reference.

After the Flood Boundary Analysis, two projects indicated no MP_A inundation and were removed from the project list.

- 0979-0031 Ranchero Carlsbad Basin and Channel
- 1008-7251 Simi Valley Detention Basins

3.4.7 Southern California Study: Flood Boundary Analysis

Six of the eight projects that underwent flood boundary analysis indicated that there would have been damages MP_A. The Simi Valley Six Detention Basin Project is an example of a project where the flood boundary results did not indicate MP_A damage for the event of interest. The hydraulic modeling indicated that certain locations would have experienced some out-of-bank flooding. When the flood boundary analysis was conducted, it was determined that flooding would have only produced slight out-of-bank flooding, not damaging any roads or structures. Therefore, this project was eliminated from the study list. A summary of the Phase 2 analysis for the final six projects is provided in Table 3.2 and the locations are illustrated in Figure 2.2. These six projects advanced to Phase 3 for the Loss Estimation Analysis.

The six projects that remained on the study list all indicated that flood damages would have occurred for the MP_A scenario. For example, a new flood boundary analysis was conducted for the Nason Detention Basin Project based on the results of a HEC-RAS hydraulic model for the event of interest. Flood elevations were mapped on a combination of the 1-foot contour and 4-foot contour data based on the mapped water surface elevations from the HEC-RAS model. Flood depth mapping indicated that one structure would have had approximately 1.0 feet of flooding and another would have had approximately 0.1 feet of flooding; and that 0.5 miles of Nason Street would have flooded. More detailed information on the Nason Detention Basin project is available in Appendix C.

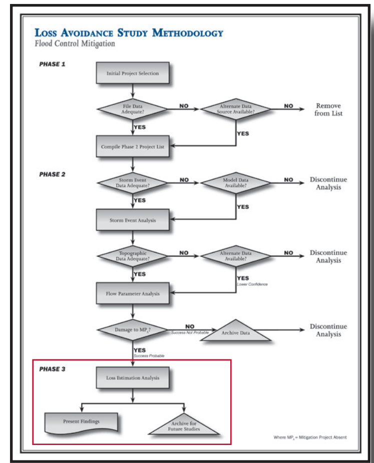
Table 3.2

Project Analysis Summary

General Project Information				Phase 2 and Phase 3 Results	
Project Name	Community	County	Project Type	Phase 2 Physical Parameter Analysis	Phase 3 Loss Estimation Analysis
Live Oaks Springs and Sand Canyon Project	Santa Clarita	Los Angeles	Detention Basin and Channel Rerouting	*Storm Event Analysis:* February 12, 2003, Event from Los Angeles County Fire Department Data *Hydrologic Analysis:* Modified version of model in project files *Hydraulic Analysis:* New model based on topographic data *Flood Boundary Analysis:* Mapping based on hydraulic model results and topographic data	*Primary Loss Categories:* Residential Structural Damage, Road Closure
Mission and Alston Channel	Hesperia	San Bernardino	Detention Basin, Channel Improvements (with storm drain pipe), and Improved Outlet	*Storm Event Analysis:* February 23, 1999, Event from San Bernardino County ALERT Data *Hydrologic Analysis:* Modified version of model in project files *Hydraulic Analysis:* New model based on topographic data *Flood Boundary Analysis:* Mapping based on hydraulic model results and topographic data	*Primary Loss Categories:* Residential Structural Damage, Extensive Road Closures
Rodeo Channel	Hesperia	San Bernardino	Channel Improvements and New Storm Drain Outlet Pipe	*Storm Event Analysis:* February 23, 1999, Event from San Bernardino County ALERT Data *Hydrologic Analysis:* Modified version of model in project files *Hydraulic Analysis:* New model based on topographic data *Flood Boundary Analysis:* Mapping based on hydraulic model results and topographic data	*Primary Loss Categories:* Residential Structural Damage, Extensive Road Closures
Nason Detention Basin	Moreno Valley	Riverside	Detention Basin and New Storm Drain Pipe	*Storm Event Analysis:* March 16, 2003, Event from Riverside County ALERT Data *Hydrologic Analysis:* Modified version of model in project files *Hydraulic Analysis:* New model based on topographic data *Flood Boundary Analysis:* Mapping based on hydraulic model results and topographic data	*Primary Loss Categories:* Residential Structural Damage, Road Closure, Business Interruption
Federal Boulevard Drainage Improvements	Lemon Grove	San Diego	New Storm Drain Pipes and Street Curb Inlets	*Storm Event Analysis:* February 23, 2004, Event from San Diego County ALERT Data *Hydrologic Analysis:* Modified version of model in project files *Hydraulic Analysis:* New model based on topographic data *Flood Boundary Analysis:* Mapping based on hydraulic model results and topographic data	*Primary Loss Categories:* Business Structural Damage, Road Closure, Business Interruption
Flood Protection for Todd Road Jail Facility	Santa Paula	Ventura	Channel Armoring	*Storm Event Analysis:* January 10, 2005, Event from Ventura County ALERT Data *Hydrologic Analysis:* Modified version of model in project files *Hydraulic Analysis:* New hydraulic and stream erosion models based on topographic data *Flood Boundary Analysis:* Mapping based on hydraulic model results and topographic data	*Primary Loss Categories:* Channel Erosion Damage, Road Closure, Prison Operations Interruption

Section Four:

Phase 3 - Loss Estimation Analysis

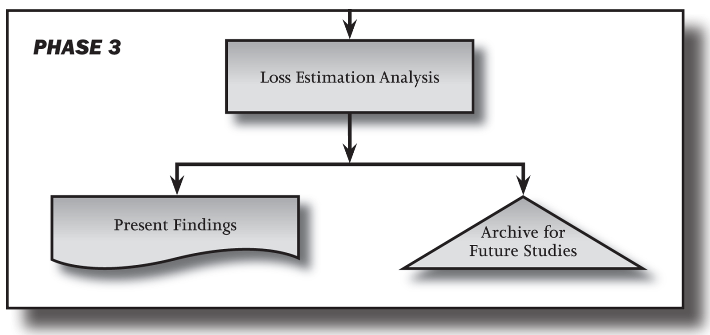


The final phase of a loss avoidance study is to estimate the amount of losses that were avoided based on the effectiveness of the mitigation project during the modeled storm event. Section four provides a full synopsis of the process for Phase 3, the Loss Estimation Analysis. The methodology is illustrated in Figure 4.1. Examples are given from the Southern California Loss Avoidance Study to better illustrate the process.

There are two major tasks in Phase 3 that must be completed:

1. **Calculating losses avoided** and
2. **Calculating return on investment**.

Figure 4.1



4.1 Calculating Losses Avoided

Calculating losses avoided requires knowledge of damages MP_A and MP_C. Figure 4.2 illustrates the formula utilized to compute losses avoided.

4.1.1 Formulating MP_A and MP_C Damages

For each of the Phase 3 projects selected for the Loss Estimation Analysis, the following information was determined as part of Phase 2 of the loss avoidance study:

- The most extreme post-construction storm event analyzed either caused damages or would have caused damages using MP_A and MP_C scenarios.
- The number and type of assets impacted by the storm event being analyzed for both MP_A and MP_C scenarios.
- The flood depth at each impacted asset estimated from the hydraulic analysis.

Figure 4.2

Loss Estimation Analysis

$$MP_A - MP_C = LA$$

Where MP_A = Mitigation Project Absent
Where MP_C = Mitigation Project Completed
Where **LA** = Losses Avoided

The result of this information is a list of impacted assets and the depth of the flooding at each asset for each project, for both MP_A and MP_C scenarios. Often the damages from the flood event MP_C (in dollars) would be available from the community directly (these are the damages, if any, for the right side of the equation).

Estimated flood depths MP_A provide the basis for the damages on the left side of the equation. Asset damage estimates were based on flood depth-damage relationships published nationally or estimated from more relevant local information. The type of depth-damage information used is dependent upon the type of asset. For example, the depth-damage curve for a residential structure is dependent upon the type of construction, number of floors, and the square footage.

4.1.2 Loss Categories

Once the Flood Boundary Analysis is complete and potentially affected assets have been inventoried, the asset data collected regarding the impacted areas must be evaluated. As illustrated in Table 4.1, asset damages such as structural, infrastructure, and displacement costs are divided into loss categories. Loss categories generally include physical damage, loss of function, and emergency management costs all which contain multiple loss types.

4.1.2.1 Physical Damage

Physical damage is direct damage that impacts assets such as buildings, contents, and roads and bridges. The types of physical losses resulting from a given flood event vary based on the land use and the flood area. Flooding in residential areas tends to result in structure and content damage. Flooding in industrial areas could result in extensive infrastructure and environmental damage. Flooding in commercial areas, such as downtown areas, could result in a wide variety of impacts due to the mixed usage of

Table 4.1

Loss Estimation Categories and Types

Loss Category	Loss Types
Physical Damage	Structure Contents Roads and Bridges Infrastructure Landscaping Environmental Impacts Vehicles/Equipment
Loss of Function	Displacement Expense Loss of Rental Income Loss of Business Income Lost Wages Disruption Time for Residents Loss of Public Services Economic Impact of Utility Loss Economic Impact of Road/Bridge Closure
Emergency Management	Debris Cleanup Governmental Expense

the area. These costs can be established by determining the actual damages (repair costs) that were incurred by a flooding event; or by estimating the damages based on structure replacement value and depth-damage curves. However, to ensure that the results of the loss avoidance study are meaningful, detailed data regarding land use must be obtained using aerial photographs, community tax and parcel data, or GIS-based land use information.

Calculating Structural Damage

In General, actual repair costs or replacement costs (if the structure was substantially damaged) should be used to estimate losses, if a flood event of similar magnitude occurred in the past. If this information in not available, the following process should be used for each structure inundated in order to estimate damages.

- Inventory the structure to determine characteristics, such as type of structure, living area, number of floors, and first floor elevation (FFE). This type of information is generally obtained through site visits or by researching community databases such as tax assessment and parcel data.
- Determine the replacement value for each structure inundated by:
  - Estimating replacement value based on local tax assessment values, or

Physical Damage Data Sources

- Depth-damage curves obtained from HAZUS-MH or USACE
- Insurance information
- HMGP or FMA project files and BCA's
- Public assistance program project worksheets for permanent repair work
- Historical flood damage information

  - Calculating replacement value by using valuation guides such as Marshall & Swift or RSMeans.

- Estimate the content-to-structure ratio.
- Identify appropriate structure and content depth-damage curves.
- Correlate the flood depth and duration with the appropriate percent damage ratio from the depth-damage curve to estimate the percent damage to each structure.
- Multiply the percent damage ratio by the replacement value to calculate the damage from the flood event. The same calculation should be completed for the content damages.

Depth-Damage Curves

Established depth-damage relationships for different asset types, such as buildings of varying construction types and building contents, are a common source of information for determining physical destruction caused by hazards. These relationships, which have been developed by FEMA, the United States Army Corps of Engineers (USACE), and other agencies using observed data from historical events, generally identify the percentage of damage that is likely to occur at certain intervals (i.e. flood depths). The flood depth-damage relationships are either nationally published estimates or are estimated from local damage information. The specific depth-damage relationship used for the analysis is dependent upon the characteristics of the given asset. For example, the depth-damage curve for a residential structure is dependent upon the type of construction, number of floors, and square footage.

The FEMA BCA Modules, which were developed to standardize determinations of cost-effectiveness for mitigation projects, include methods for determining damage based on the severity of an event and can be adapted to the loss avoidance study (FEMA, 2006c). For the flood module these relationships are based on historical data taken from flood insurance claims under NFIP. Table 4.2, taken from the BCA Riverine Flood Full-Data Module, illustrates the depth-damage curve for structural damage to different types of residences.

In addition to the FEMA BCA Module, depth-damage relationships are also used to estimate physical damage costs in the HAZUS-MH flood module. The *HAZUS-MH Technical Manual* includes depth damage curves for 28 general building stock categories (6 residential, 10 commercial, six industrial, and six other) from flood depths ranging from -4 to 24 feet. Further, the USACE has depth-damage and content-to-structural ratios tables that are used for preparing economic analyses for USACE flood control and floodplain management projects. However, if the flow and resulting damages are known for particular flood events from another source (such as a detailed FEMA BCA), a depth-damage relationship can be constructed for the study area to estimate the total damages for any event. In this case, the damages for a particular flood depth would be estimated by interpolating between the previously estimated damages for both the MP_A and MP_C scenarios. The resulting estimates would be reviewed for validity.

Table 4.2

Depth-Damage Data

Building Type	1 Story, without Basement	2 Story, without Basement	Split Level, without Basement	1 or 2 Story, with Basement	Split Level, with Basement	Mobile Home	Other
Flood Depth (ft)	Percent Damaged (% of Building Value)						
-2	0	0	0	4	3	0	0
-1	0	0	0	8	5	0	0
0	9	5	3	11	6	8	0
1	14	9	9	15	16	44	0
2	22	13	13	20	19	63	0
3	27	18	25	23	22	73	0
4	29	20	27	28	27	78	0
5	30	22	28	33	32	80	0
6	40	24	33	38	35	81	0
7	43	26	34	44	36	82	0
8	44	29	41	49	44	82	0
>8	45	33	43	51	48	82	0

Source: FEMA BCA Riverine Flood Full-Data Module

Structural Data Sources

Data for structures can be obtained from a multitude sources. However, it is important to ensure the source used is credible and that the data maintained by that source is as up-to-date as possible. Below are a few of the more common sources used for obtaining structural data:

- *Data on historical damage can be obtained utilizing primary sources such as interviews with building owner, local contractors, and homeowner interviews.* Further, secondary and tertiary sources such as homeowners' insurance claims, flood insurance claims, the NFIP's BureauNet database, and Small Business Administration (SBA) loan application databases. Additionally, the BCA was developed to approve the mitigation project may also contain the necessary historical damage data. Additionally, FEMA may have provided grant funds under the Public Assistance Program (PA) for repairs to buildings owned by public entities and certain private non-profit organizations for events that received disaster declaration. Damage and repair information may be obtained from Project Worksheets (PW) that FEMA prepared to document eligible costs under PA.

- *Tax assessment databases and tax parcel mapping* may be used to obtain assessed or market value for a structure. Some communities store this information digitally using GIS and provide the data online while others still maintain hard data making it difficult to collect.

- *Construction valuation guides, such as RSMeans or Marshall & Swift* take into account building type, size, and geographic location and can be used to determine Structural replacement value. However when looking at flood impact for larger areas, nationally available databases, such as those previously discussed, can be used to estimate replacements values.

Calculation of Content Damage

As with structure damage, actual repair costs or replacement cost (if substantially damaged) should be used for contents damage. However, if actual repair costs are not available, content damage can be estimated using the following steps.

- Estimate the replacement value of the structure, as described in calculating structural damage.

- Multiply the replacement value by the appropriate content-to-structure value ratio to determine content value.

- Multiply the content value by the percentage of damage, as determined from the depth-damage curve and depth of flooding, to estimate damages to content.

Content Data Sources

- Direct content value, may be obtained through owner interviews, insurance information, and tax records. Further, the BCA developed to approve the mitigation project may also contain historical damage data,

- The FEMA BCA document "How to Determine Cost-Effectiveness of Hazard Mitigation Projects," also known as the "Yellow Book."

- The *HAZUS-MH Technical Manual*, and

- The USACE depth-damage curves, which include content-to-structure value ratios.

Infrastructure

Infrastructure includes transportation, water, wastewater, electric transmission, gas transmission, and telecommunications systems. Systems to be considered for analysis can be identified by comparing the available data on infrastructure with the flooding limits for the event of interest. Damage to infrastructure, like structure and contents damage, can be estimated either by using actual costs from past events; or by using depth-damage relationships or other estimating methods. To the extent practicable, actual damage costs for previous events should be used to estimate infrastructure damages. Local officials and infrastructure owners, such as state departments of transportation and utility companies, generally maintain and will provide data on damage from previous events. Further, repairs to disaster-related damage may have been funded under PA and PWs documenting damage to public infrastructure may be available. For those roads identified as Federal-aid routes, the Federal Highway Administration (FHWA) may have documented disaster-related damage and repair costs under the Emergency Relief Program; the grant documents for this program may also provide actual cost information.

If actual damage information is not available, damage may be estimated using the following:

- *Tables from the HAZUS-MH Technical Manual*. For example, Chapter 7 provides details on methods based primarily on scour and direct damage estimates to infrastructure components that can be used as guidelines for the specific infrastructure components (FEMA 2006a).
- *Cost estimates based on engineering estimates of expected damage*. For example, for roads, the following method can be used:
  - Determine the length of roadways impacted in the MP_A and MP_C scenarios.
  - Estimate the potential damage and average repair costs for a length of road in the affected area.
  - Multiply the average repair cost by the length of the affected road for both scenarios.
- *"Rule of thumb" repair estimates from damage experts based on flood depths for certain road types.*
- *"How to Determine Cost-Effectiveness of Hazard Mitigation Projects,"* provides guidance on estimating infrastructure damage.

Landscaping

According to "What Is a Benefit?" there are no typical or default damage functions available for estimating landscaping repair or damage costs (FEMA, 2006c). However, these damages can be identified separately if historical information is available or professional judgment can be used to estimate the amount.

Environmental Impacts

Assessment of environmental impacts is conducted on a project-specific basis, but may include multiple assessments such as impacts to water quality, drinking water, outdoor recreation, hospitals and hazardous waste, wetlands, and cultural and historical resources. Environmental impacts of flooding can be difficult to project and impacts can vary greatly from site to site depending upon the area. For example, environmental impacts for flooding would be much greater if a wastewater treatment plant or chemical manufacturer were located in the floodplain, than if the floodplain consisted primarily of residential areas or open space.

Evaluating environmental damages or the benefits of reducing or avoiding such damages are not included in "What Is a Benefit?" However, environmental impacts may be partially considered in the calculation of the loss of function of facilities, such as wastewater treatment plants. "What Is a Benefit?" goes further to say that the estimated regional economic impact (the loss of function for the wastewater treatment plant) may be equal to or greater than possible environmental damages (FEMA, 2006c).

In general the damages from environmental concerns should be based on the cost of remediation. Information on historical environmental cleanup costs due to flooding may be available through interviews with local and state environmental protection officials, as well as, with the U.S. Environmental Protection Agency (EPA). Additionally, research on relevant literature to determine the monetary value that is placed on local environmental characteristics could potentially be available from environmental impact statements or environmental impact reports. These reports are often the result of research conducted for the study area or for other existing and/or proposed projects that may have an environmental impact on the study area.

Vehicles/Equipment

Physical damages to vehicles and equipment include repair or replacement costs for damages incurred during a flood event. The types of vehicles and equipment in the impacted area of a selected project will vary by site. Information on vehicles and equipment in the project area may be gathered during site visits. For larger areas, assumptions may be required on the number and type of vehicles and equipment expected, based on the land use or building type (such as residential, commercial, industrial, agricultural, public, or academic). This evaluation is difficult as, in many cases, vehicles and equipment can be moved prior to a flooding event, unless it is an event with little or no warning (such as a flash flood). Ideally insurance information could be used to estimate damage costs. As with other types of physical damage, actual costs for damage during previous events may be valuable, particularly for special types of vehicles or equipment. PWs that FEMA prepared for repairs to vehicles and equipment may include this information. If specific information for vehicles and equipment in the impacted area are is not available, physical damages to vehicles and equipment may be expressed as a percentage of the building replacement value. The *HAZUS Technical Manual* and FEMA guidance on calculating benefit-cost ratios can be consulted to determine available depth-damage curves for vehicle and equipment damage.

4.1.2.2 Loss of Function

Loss of function damages are those damages that occur indirectly because of the damage to an asset. Loss of function damages can vary extensively depending upon the type of asset damage. For example indirect costs associated with damage to a residence could be costs associated with moving to another residence while flooding subsides and repairs occur. Indirect costs associated with damages to a business could be lost business, temporary relocation to another structure, and lost wages for employees. Indirect costs resulting from damages to public facilities could be maintenance of critical public services, such as police and fire departments. Indirect costs associated with road damages could be costs due to traffic rerouting while road repairs are being completed.

Overall Methodology

Most methods used to calculate loss of function quantify the stoppage or delay in delivery of services, in terms of days or units of delivery (i.e. kilowatt hours for electrical service). These estimates are typically based on the amount of destruction to the physical asset, so the physical damages must be estimated before the loss of function estimates can be calculated. For example, residential displacement time can be estimated based on the percent of damage to the residence – that is, the displacement time increases with the severity of damage to the structure.

Loss of function often includes displacement costs, loss of rental income, loss of business income, lost wages, disruption time for residents, loss of public services, economic impact of utility loss, and the economic impact of road/bridge closure. Whether costs from loss of function for each of these types can be calculated depends

Loss of Function Data Sources

- Factors used in HAZUS-MH for loss of function calculations
- FEMA BCA loss of function calculations
- Highway mapping and traffic counts
- Utility and infrastructure use information
- Historical flood damage information

upon the severity of flooding and the type(s) of assets flooded. Typically, roads and bridges flood first, resulting in loss of function costs associated with traffic disruption. Increased depths may affect residential and commercial structures, resulting in costs associated with the displacement of residents and closure of businesses.

As with depth-damage relationships, published relationships between flood depth and duration and loss of function costs can be used to identify these costs. For example, "What Is a Benefit?" contains guidance on methods that can be used to calculate loss of function for each of the types listed above (FEMA, 2006c). Most of these methods start by calculating a time delay based the percentage of damage to an asset then calculate costs for this delay in function. However the default values listed are national averages. Further, the *HAZUS-MH Technical Manual* has similar methods to FEMA BCA guidance, with regional adjustments to various loss of function methods. Additionally, The USACE publications on post-disaster impacts from flooding contain information about loss of function from specific locations. For specialized loss of function costs, such as those associated with critical facilities, communities may provide costs from past events that demonstrate the impact of the event. In these cases local values better represent a project area than the national or regional values from tools such as FEMA BCA or HAZUS.

Displacement Costs

According to "What is a Benefit?" displacement time is "the time period during which occupants are displaced from a building in order for repairs to be made" (FEMA, 2006c). The FEMA BCA Modules calculate displacement time as a function of the structural damage and building type (residential, business and commercial). When damage is below a certain threshold (approximately 10% of replacement value) it is considered minimal and business operation can resume quickly. When damage is more significant (greater than 10% and less than 50% of the replacement value) the module calculates a value between a month and year. If damage is substantial (greater than 50% of the replacement value), then a year displacement is the default time for the structure owner to find a new location. Loss of function costs for displacement can be calculated as follows:

- Calculate the number of days a structure occupant would be expected to be displaced.
- Determine the cost per day for displaced occupants.
- Multiply the number of displaced days by the economic impact of each day. Actual historic information may also be useful. For

example, if a public facility lies within the area of flooding and has experienced closure due to flooding in the past, information regarding the cost of relocating the function of that building may be available. Because such costs may be eligible for PA, PWs prepared under a disaster declaration may include this information. Additionally, emergency assistance organizations such as the American Red Cross may have information regarding the costs associated with displacement of residents during previous flood events.

Loss of Rental Income

The owner of residential or commercial rental property may lose income when tenants of a rented property are displaced because of damages resulting from flood losses. Computing loss of rental income should be considered on a site-by-site basis. Most often, the loss of rental income is not calculated; instead, displacement costs are estimated for all tenants of a property (as discussed above). Care should be taken to avoid "doubly counting" in order to accurately assess losses avoided.

Loss of Business Income

Functional downtime is the time period during which services are lost for either a business or public service. A loss of business income can occur when business function is interrupted due to flooding. Business losses can be estimated using the following methods. However results should be validated through field observation and discussion with local representatives.

- Calculate the number of days that business interruption would occur due to flooding. Both the *HAZUS Technical Manual* and the FEMA BCA "Yellow Book" provide guidance for determining business interruption time based on percentage of structure damage.
- Determine the economic impact of each lost day of operation (annual net profits or annual budget divided by 365). The FEMA BCA Modules estimate business loss based on the annual net profits of the business. For non-profits and government agencies, this is based on the annual budget.
- Multiply the number of lost days by the economic impact of each day.

Lost Wages

Lost wages can occur when there is a loss of function for any structure where people are employed. Similar to the loss of business income for the owner, hourly employees can experience a loss of wages when a business closes. In accordance with "What Is a Benefit?," lost wages are counted for only short-term losses due to temporary business closure and are counted for hourly employees (FEMA, 2006c). Wages are not counted for salaried employees, unless employees are laid off without pay; or for public employees.

Lost wages are calculated by adding the employee's base pay and benefits. "What Is a Benefit?" provides a national average for wages and benefits at $21.16 per hour (FEMA, 2006c). Because this average was developed in 2001, it should be adjusted to account for inflation. However, in place of the national average, regional or local averages can also be used. In order to compute total lost wages for employees of an impacted business, various types of information are required.

- *Per hour average wages and benefits,* based either on national averages or local data
- *Number of places of employment in the impacted project area,* which is generally available from local officials
- *Number of hourly personnel employed by each employer affected,* which is generally available from local officials or from the employer directly
- *Loss of function for the business,* which can be determined using the *HAZUS Technical Manual* data or historic losses

Disruption Time for Residents

Disruption time for residents is the economic value of a person's time spent conducting activities associated with the event, such as preparing for potential evacuations, the act of evacuating, cleaning and repairing property following the event, and making insurance claims. As described in "What Is a Benefit?" a person's time has value, whether or not that person is formally compensated by employment (FEMA, 2006c). The FEMA BCA Modules relate the percentage of structure damage to structure repair time. As a result, the number of days for repair time is based on the depth of flooding and the structure type.

Loss of Public Service

If a public building temporarily closes due to a flooding event, there is a potential for a loss of public service to occur. Public buildings include public services (such as public works departments, police stations, fire departments, and the like). Additionally, private non-profit organizations such as schools and hospitals that are essentially providing public services are classified as public services.

The loss of public service calculation will vary by site. If a building housing a public service is located in an impacted area. Local officials or the operators of private non-profit entities can provide information on the annual operating budget for the agencies in question. This information may also be available on the agency/ service web site. A loss of public service is assigned an economic value that is equal to the costs necessary to provide that public service. The daily cost of providing service is considered the value for loss of public service. Determining loss of public function is determined by using the following methods.

- Identify the number of days the public service would be closed due to flooding.
- Establish the economic impact of each lost day of operation. Generally, the daily cost of providing service is estimated using the annual operating budget for the particular service (if a building houses many public services, it is the annual operating budget of all the services).
- Multiply the number of lost days by the economic impact of each day to accurately compute loss of public service.

Economic Impact of Loss of Utility Service

Utility services include electric power, gas transmission, potable water, and wastewater services. Economic impact of loss of utility service is the economic value assigned when a utility service is down following a flooding event. Due to the importance of these services, the economic impact of loss of service is generally much greater than the physical damages to the facility. Various data sources can be used to determine the economic impact of loss of utility service.

- *Functional downtime of the utility expressed in system days which is the number of days the entire system is down, or fractions thereof.* The downtime can be estimated based on past flooding events or interviews with utility providers.
- *The total number of people serviced by the utility line.* Interviews with utility providers can also provide information on the number of people serviced by a particular component (note that the entire serviced area will not be used, only that percentage of the area serviced by a line in the study area).
- *Values for per capita economic impacts per day of lost service.* "What Is a Benefit?" provides values for the per capita economic impacts per day of lost service as follows (FEMA, 2006c):
  - Loss of electrical power: $188/person/day of lost service
  - Loss of potable water: $103/person/day of lost service
  - Loss of wastewater service: $33.50/person/day of lost service

Economic Impact of Road/Bridge Closure

The most important step in estimating transportation-related impacts is to determine the roads that were actually impacted MP_C and those that would have been impacted MP_A. Following determination of the area of inundation, the following steps should be used to estimate the losses due to transportation rerouting and delay:

- Estimate the duration of flooding on impacted roads, through either anecdotal information or the Flood Boundary Analysis.
- Estimate the number of vehicles that travel on impacted roads using one-way traffic counts from local and state data sources.
- Estimate detour distance and time to travel on alternative routes around the impacted area, either by discussing detours with local officials or reviewing local maps.
- Multiply the additional distance traveled for each vehicle by the Federal mileage allowance. Sum the additional costs for additional distance for all vehicles impacted by flooded roads.
- Multiply additional time of alternative route by number of vehicles by the value of delay.
- Sum the costs to all vehicles to determine the total transportation related impacts.

4.1.2.3 Emergency Management

Emergency management costs are those costs related to response and recovery activities conducted by local, state, and federal government agencies as a result of a hazard event. These estimates are primarily obtained from historic damage records, such as PWs prepared by FEMA. If a mitigation project under evaluation significantly reduces these emergency management costs, then the benefits of reduced emergency management costs should be counted. Since many of the projects evaluated affect small areas, there may be little difference between MP_A and MP_C for emergency management costs. Like loss of function costs, these estimates are dependent upon the results of the physical damage estimates. For example, the community will experience costs for ensuring public safety, evaluating the road damage, developing a repair plan, and managing the rerouting during repair. Care should be taken, however, to ensure these costs are not doubly counted as part of the physical damage costs.

Emergency Management Data Sources

- Public assistance program project worksheets for emergency work
- Interviews with local public safety officials
- Historical flood damage information

If actual costs from previous events are known, they should be used. If FEMA previously provided PA funds for emergency work, PWs prepared to document emergency work costs may provide relevant information. The following steps can be used to calculate impacts of other emergency response measures:

- Interview local representatives to identify the types of services required and the level of effort required in delivering those services.
- Use the duration of the flood and the appropriate salary categories to estimate the costs for first responders. This may include costs for rescue, traffic control, and flood-fighting.
- Use the estimated flood recovery time and the appropriate salary categories to estimate the impact to other municipal employees. This may include cleanup and costs associated with implementing repairs.

Alternatively, methods from the FEMA BCA Modules can be used. BCA uses a factor referred to as Post Disaster Continuity Premium to express the additional cost of making sure critical facilities can operate. Continuity premiums of 50% to 100% of the normal daily costs of providing services may be appropriate for services that are moderately important in the post-disaster environment. Continuity premiums of several times normal daily costs may be appropriate for emergency response services. Continuity premiums of five or 10 times the normal daily costs may be appropriate for services which are critical to the disaster response. PA records from past disasters can provide a good estimate of this premium for a community.

4.1.3 Southern California Study: Calculating Losses Avoided

The six projects that advanced to Phase 3 are summarized in Table 3.2, and their locations are shown on Figure 2.2. It is important to note that five of these project sites did not actually experience any out-of-bank damage during the event being analyzed. As a result, the flood mitigation project was completely effective for that event, and no actual damages (zero dollars) accrued for these projects. The Todd Road Jail Facility had minor out-of-bank flooding, and experienced minor damage to the channel armoring which led to MP_C damages. All of the projects experienced MP_A damage conditions. Some of the areas evaluated had residential structure damages and all had road closure issues.

- Regarding the Live Oaks Springs and Sand Canyon, Nason Detention Basin, and Federal Boulevard Drainage Improvements projects, when larger events occurred, the roadway became the overflow channel, flooding structures along the roads and requiring the rerouting of traffic to neighboring roads.
- Two projects (Rodeo Channel and Mission and Alston Channel projects) experienced flooding through a residential neighborhood involving a number of structures and roadways.

- The hydraulic models for the Flood Protection for Todd Road Jail Facility project showed minor out-of-bank MP_C flooding and indicated some in-stream bank erosion.

The types of damages (losses) that were estimated for each of the six projects included in this phase of the study are shown on Table 4.1.

Part of the data collection for this analysis included a final field visit to the six project sites. This visit focused on the assets, shown by the inundation boundary, to be at risk from MP_A flooding. Photos of each asset that would have been impacted were taken, and the type and condition of the asset was noted.

Avoided losses were calculated for each of the loss types listed in Table 4.1. The detailed depth-damage relationships in FEMA HAZUS-MH for different residential and commercial construction types were used for the structural and content damages and displacement. The traffic delay cost methodology from FEMA BCA guidance documents was used for the loss of function costs (flooded roads). The HMGP project files were used to estimate other loss types by noting the date of the original damage and the flood depth that caused the damage. The damages were calculated by interpolating the previous data and converting the result into 2006 dollars.

As noted above, with the exception of the Todd Road Jail Facility, there were no actual MP_C damages from the storm events analyzed. Therefore, the MP_C was $0.00. The benefits are then the damages that would have occurred from a storm event MP_A. The results of the avoided losses for each type of damage for the projects analyzed in Phase 3 are summarized in Table 4.3 by loss category. Based on these results, the total amount of damages avoided from one event for these six projects is approximately $7,309,402 with the most significant losses avoided being in the physical damage category.

For the events analyzed in Southern California, five of the projects evaluated were *completely effective*, resulting in *no damages*.

4.2 Calculating ROI

The final task in determining losses avoided is to calculate the return on investment. Care should be taken to remember the results on a per project basis could vary depending upon the number of events being analyzed for each project and the level of MP_A damage. Figure 4.3 provides an illustration of the formula utilized in calculating return on investment.

The bottom portion of the equation is the total investment for the project being calculated. It is important to remember that project

Table 4.3

Loss Estimation Analysis Results

General Project Information				Results by Loss Category						Losses Avoided Total
				MP_A Scenario Damages			MP_C Scenario Damages			
Project Name	Community	County	Project Type	Physical Damage Subtotal	Loss of Function Subtotal	Emergency Management Subtotal	Physical Damage Subtotal	Loss of Function Subtotal	Emergency Management Subtotal	
Live Oaks Springs and Sand Canyon	Santa Clarita	Los Angeles	Detention basin and channel rerouting	$167,920	$512,856	$11,079	$0	$0	$0	**$691,855**
Hesperia Projects: Mission and Alston Channel and Rodeo Channel	Hesperia	San Bernardino	**Mission and Alston Channel:** Detention basin, channel improvements (with storm and drain pipe), and improved outlet **Rodeo Channel:** Channel improvements and new storm drain outlet pipe	$4,452,784	$244,133	$725,996	$0	$0	$0	**$5,422,913**
Nason Detention Basin	Moreno Valley	Riverside	Detention basin and new storm drain pipe	$178,100	$78,093	$4,511	$0	$0	$0	**$260,704**
Federal Boulevard Drainage Improvements	Lemon Grove	San Diego	New storm drain pipes and street curb inlets	$507,483	$220,568	$3,093	$0	$0	$0	**$731,144**
Flood Project for Todd Road Jail Facility	Santa Paula	Ventura	Channel armoring	$251,720	$0	$27,969	$69,213	$0	$7,690	**$202,786**
			Total	**$5,558,007**	**$1,055,650**	**$772,648**	**$69,213**	**$0**	**$7,690**	**$7,309,402**

Figure 4.3

RETURN ON MITIGATION INVESTMENT

$$\frac{\$\,LA}{\$\,PI} = \%\,ROI$$

Where **LA** = Losses Avoided
Where **PI** = Project Investment
Where **ROI** = Return on Investment

investment does not represent the federal investment alone. Rather, it is the total investment for the project from all parties involved. Care should be taken to insure the investment total is representative of the project area only and does not include work outside the identified project bounds.

4.2.1 Southern California Study: Calculating ROI

All of the projects analyzed in the Southern California Study utilized multiple sources of funding. The aggregated project investment ranged from a few hundreds of thousands of dollars to millions of dollars. Table 4.4 illustrates the amount of investment and provides details on the percent of ROI for each individual project. The total investment for the six projects that advanced to Phase 3 was $19,575,932 and the average ROI was 37%.

The Federal Boulevard Drainage Improvements project yielded the highest ROI with approximately 118%. As a result, the investment in the project was fully recovered with one event. The Hesperia and the Todd Road Jail Facility projects also yielded a higher than average ROI. However the Live Oaks Springs and Sand Canyon and the Nason Detention Basin projects were determined to have a lower than average ROI with the Nason Detention Basin project yielding a 4% ROI. Nonetheless, all projects included in the Southern California Loss Avoidance Study were completed within the last five to 10 years. Since their completion the projects were impacted by only one storm event that caused inundation. If similar events occur during the next 10 to 20 years, the ROI will likely exceed 100%. As a result, project investment could be fully recovered well within the intended lifespan of the projects.

Table 4.4

Return on Mitigation Investment

General Project Information			Results by Loss Category			Losses Avoided Total	Project Investment Adjusted for 2006 Dollars	Current ROI
Project Name	County	Date of Project Completion	Physical Damage Subtotal	Loss of Function Subtotal	Emergency Management Subtotal			
Live Oaks Springs and Sand Canyon	Los Angeles	**07/17/2002**	$167,920	$512,856	$11,079	**$691,855**	**$6,436,509**	**10.75%**
Hesperia Projects: Mission and Alston Channel and Rodeo Channel	San Bernardino	**11/21/1997 and 08/14/1995**	$4,452,784	$244,133	$725,996	**$5,422,913**	**$6,251,954**	**86.74%**
Nason Detention Basin	Riverside	**01/14/2003**	$178,100	$78,093	$4,511	**$260,704**	**$5,957,151**	**4.38%**
Federal Boulevard Drainage Improvements	San Diego	**04/17/2002**	$507,483	$220,568	$3,093	**$731,144**	**$621,619**	**117.62%**
Flood Project for Todd Road Jail Facility	Ventura	**12/14/2001**	$182,507	$0	$20,279	**$202,786**	**$308,699**	**65.69%**
		Total	**$5,488,794**	**$1,055,650**	**$764,958**	**$7,309,402**	**$19,575,932**	**37.34%**

Section Five:

Considerations And Recommended Practices

The Southern California Study yielded findings that are of potential value to future loss avoidance studies. Many of these findings could be incorporated into the planning and implementation of mitigation projects so that loss avoidance studies can be completed more efficiently once those projects are constructed. Section Five provides a discussion about considerations and recommended practices that were developed based on the findings of the study. These considerations and recommended practices are grouped under two separate categories: Data and Analysis.

5.1 Data

Multiple types of data were collected for each phase of the analysis and different challenges were experienced with each type of data (see Table 5.1). In working through these challenges a list of considerations and recommended practices were developed that address data collection and long-term storage.

5.1.1 Data Available from HMGP Project Files

HMGP project files typically contain basic information about a project, including funding applications, financial reports, and basic engineering design information. Additionally, many older reports only include hard copies and not the original digital input and output model files. However, detailed engineering drawings and design reports are needed for a Physical Parameter Analysis. To support future loss avoidance studies, state and federal officials should require that the digital files created throughout the project design and construction process, including hydrologic and hydraulic modeling and topographic data, be stored with the project files or retained in searchable archives.

5.1.2 Planning Data Collection

Data not available from project files must be collected from other sources. These sources may include local governments; state and federal agencies; and private companies, such as engineering and mapping firms. The older the project, the less likely it is that the original agencies and firms involved with the project have retained detailed information. In addition, data such as topographic or community parcel data may require a special data release that may take a significant period of time to process through local government

Table 5.1

DATA COLLECTION SUMMARY		
DATA TYPE	**DESCRIPTION**	**CHALLENGES**
Project Data	Background information for each project, including HMGP project files, Construction Drawings and Plans, GIS data and aerial photography	Completeness of project files; coordination with multiple data sources
Topographic Data	Data describing the terrain for each project area - gathered from paper files of site plans and in GIS and CADD digital formats	Data availability especially for pre-project conditions, data detail (contour interval), aerial extent of data (often did not include downstream areas)
Storm Event Data	Rainfall or stream gage data describing severity of storm events	Completeness of data for post-construction time period, different data collection intervals, lack of stream gages
Flow Parameter Data	Data required to conduct hydrologic modeling, hydraulic modeling, and flood boundary analysis	***Hydrologic***: Availability of model input and output files ***Hydraulic:*** Lack of models for the downstream reaches affected by flooding ***Flood Boundary:*** Lack of topographic data to produce detailed inundation boundaries
Field Data	Information gathered from site visits including photography and structure data	Visit final projects for structure information after completion of inundation mapping
Asset Data	Data used to determine value of different assets affected by flooding, including structure replacement values, road repair costs, and traffic count data	Have completed inundation analysis to determine specific at-risk locations where asset data would be required for analysis

channels. Therefore, the data collection process should have a clearly identified plan and priority list for different datasets.

5.1.3 Availability of Storm Event Data

Southern California is a highly populated area, sensitive in the extreme to storms. Accordingly, multiple sources were identified for the data necessary to complete a Storm Event Analysis. It is highly unlikely that areas more rural in nature will have appropriate data availability. Analysis methods that use modeling of precipitation over a wide area may be required for rural areas.

5.1.4 Availability of Topographic Data

Topographic data with the vertical resolution and format suitable for computer modeling is often difficult to obtain. During the Southern California Study, obtaining such data for the pre-construction MP_A scenario proved difficult, and resulted in the elimination of a number of projects from further consideration. Topographic data should have detailed contours of four feet or less. If this data is not available and interpolation of the available data is not possible then the project should be removed from the project analysis list.

5.1.5 Data Collection Archive

The data collected and the analyses completed for any project in a study should be maintained and easily accessible once the project has been removed from the study or once the study has been completed. Care should be taken to remember that projects may be a part of more than one study and maintaining the information collected and analyzed could greatly reduce the cost of future studies of which the project is a part.

5.2 Analysis

The study consisted of various types of analysis and modeling. The challenges experienced when completing these tasks assisted in the LAT identifying processes and methods that can improve the efficiency of future loss avoidance studies.

5.2.1 Damage Thresholds

Where the Southern California Loss Avoidance Study focused heavily on the most significant storm event, future studies should consider identifying and analyzing the threshold storm event and use it as a filter to determine if a project moves forward in the analysis. Establishing a threshold will assist in determining if the project had post-construction impact by more than one event, thereby, having more significant losses avoided and potentially having a total return on investment. Additionally, this practice will assist in establishing parameters for the project's participation in future studies which will greatly assist in reducing the cost of the future studies.

5.2.2 Evolving Computer Models

Computer models used for hydrologic, hydraulic, and flood boundary analyses evolve over time. Any analysis conducted for a loss avoidance study should electronically store the properly formatted input and output files for the particular model used in the analysis. The input and output information should be stored in "common" formats, such as spreadsheets or text files. This will aid future studies that may not have the original models available and will need to create new models. This type of data storage especially applies to any mapping or digital drafting and design data that are in a special format.

5.2.3 Use of Methods Based on National Data

Many of the methods currently available for calculating flood damages for certain features, such as infrastructure, are usually obtained from regional or national averages. If the project files contain actual damage amounts from past events, the loss avoidance study should make use of these locally-based values. The damage estimates can be scaled or interpolated from these actual damage amounts and converted to current dollars. However, care must be taken that local inflationary or deflationary factors are still applicable.

Appendix A:

Live Oaks Springs and Sand Canyon Drainage Improvement Project

Projects: 0935-0004 and 0979-0030

Table of Contents:

List of Figures and Tables

Appendix A:

Projects: 0935-0004 and 0979-0030

Live Oaks Springs and Sand Canyon Drainage Improvement Project

A.1 General Project Information

A.1.1 Project Location

As illustrated in Figure A.1, the Live Oaks Springs and Sand Canyon Drainage Improvement project is located in the City of Santa Clarita, Los Angeles County, CA. More specifically, the project site is located along Sand Canyon Road south of SR 14 (the Antelope Valley Freeway). The northern, downstream extent of the project is located near the Santa Clara River with the southern, upstream extent located at Robinson Ranch Road (see Figure A.2).

A.1.2 Project Description

Sand Canyon Road is the primary access route to central Santa Clarita and SR 14 for residents of Sand Canyon. Prior to project construction the natural drainage of Sand Canyon and the Live Oaks Springs Canyon Wash, its tributary, had limited channel capacity and carried a significant amount of sediment and debris. This resulted in frequent flooding of the canyon and floodwater often flowed down Sand Canyon Road. In addition, a ground elevation dip under the Southern Pacific Railroad trestle, across Sand Canyon, periodically caused ponding on the road of up to four feet. Flooding events of this nature frequently forced a detour of traffic from Sand Canyon Road (5 miles back to SR 14) to Placerita Canyon Road. Further, the Placerita Canyon Road detour was subject to washouts and landslides, forcing traffic to a 25-mile detour on Little Tujunga Canyon Road.

The frequent closures on Sand Canyon Road in conjunction with increasing development around the watershed, prompted the City of Santa Clarita to design drainage improvements in an effort to enhance the conveyance of floodwaters through the canyon to the Santa Clarita River. The project consisted of the construction of a discharge structure, debris containment structure, and new drainage system on the Live Oaks Springs Canyon Wash north of Robinson Ranch Road (see Figure A.3). The debris containment structure is an inlet debris basin with a capacity of 500 cubic yards that traps debris that would otherwise flow into Sand Canyon. The structure also redirects drainage into a new underground drainage system. The primary drain, aligned with Sand Canyon Road is routed 0.7 miles north to an outlet structure that discharges directly into the Santa Clara River. This new system is a gravity-flow system which

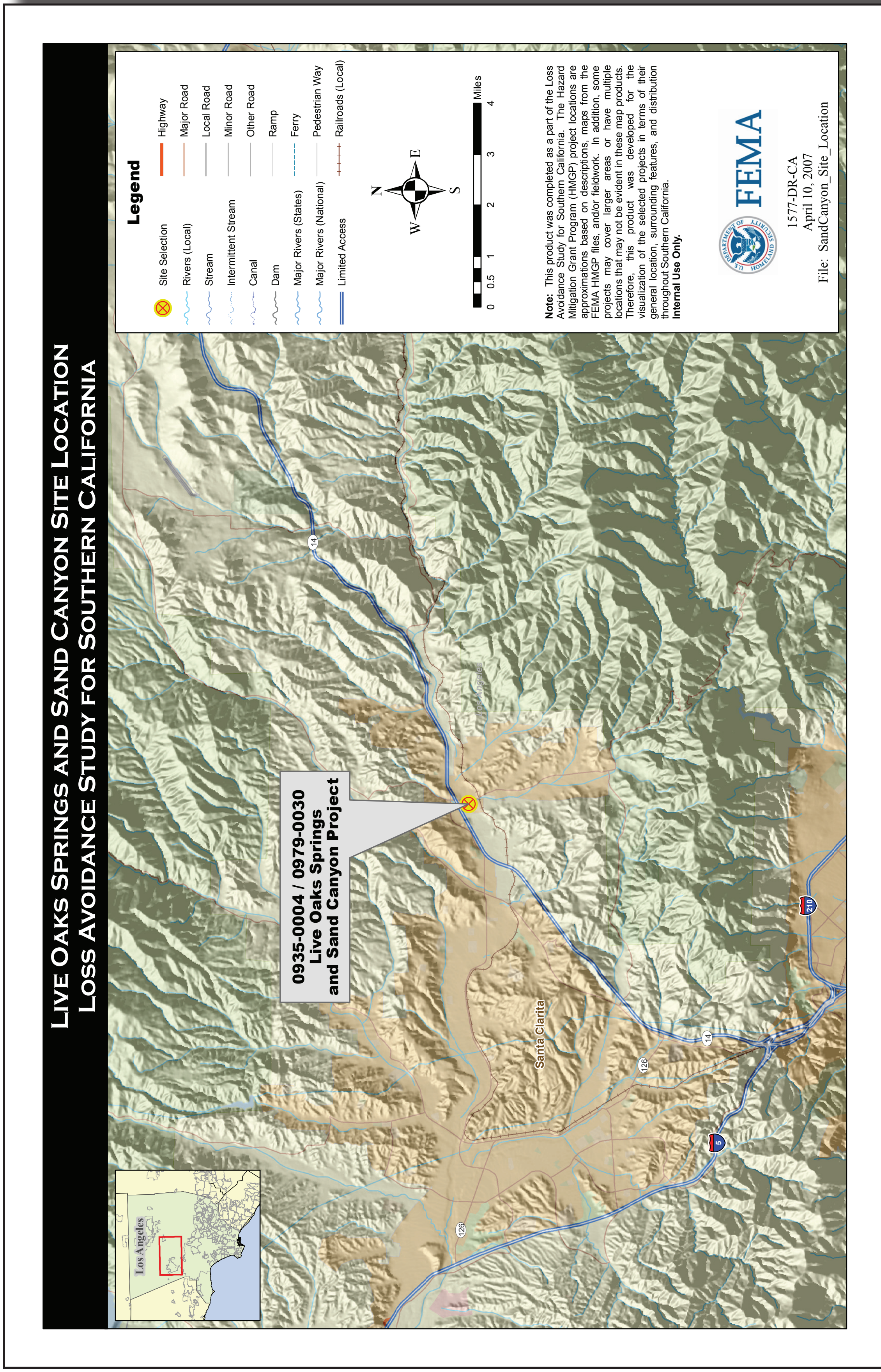

Live Oaks Springs and Sand Canyon Site Location
Loss Avoidance Study for Southern California
0935-0004 / 0979-0030
Live Oaks Springs
and Sand Canyon Project
Santa Clarita
Los Angeles
Legend
Site Selection
Rivers (Local)
Stream
Intermittent Stream
Canal
Dam
Major Rivers (States)
Major Rivers (National)
Limited Access
Highway
Major Road
Local Road
Minor Road
Other Road
Ramp
Ferry
Pedestrian Way
Railroads (Local)
N
E
S
W
0 0.5 1 2 3 4
Miles
Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California.
Internal Use Only.
FEMA
1577-DR-CA
April 10, 2007
File: SandCanyon_Site_Location

Figure A.1

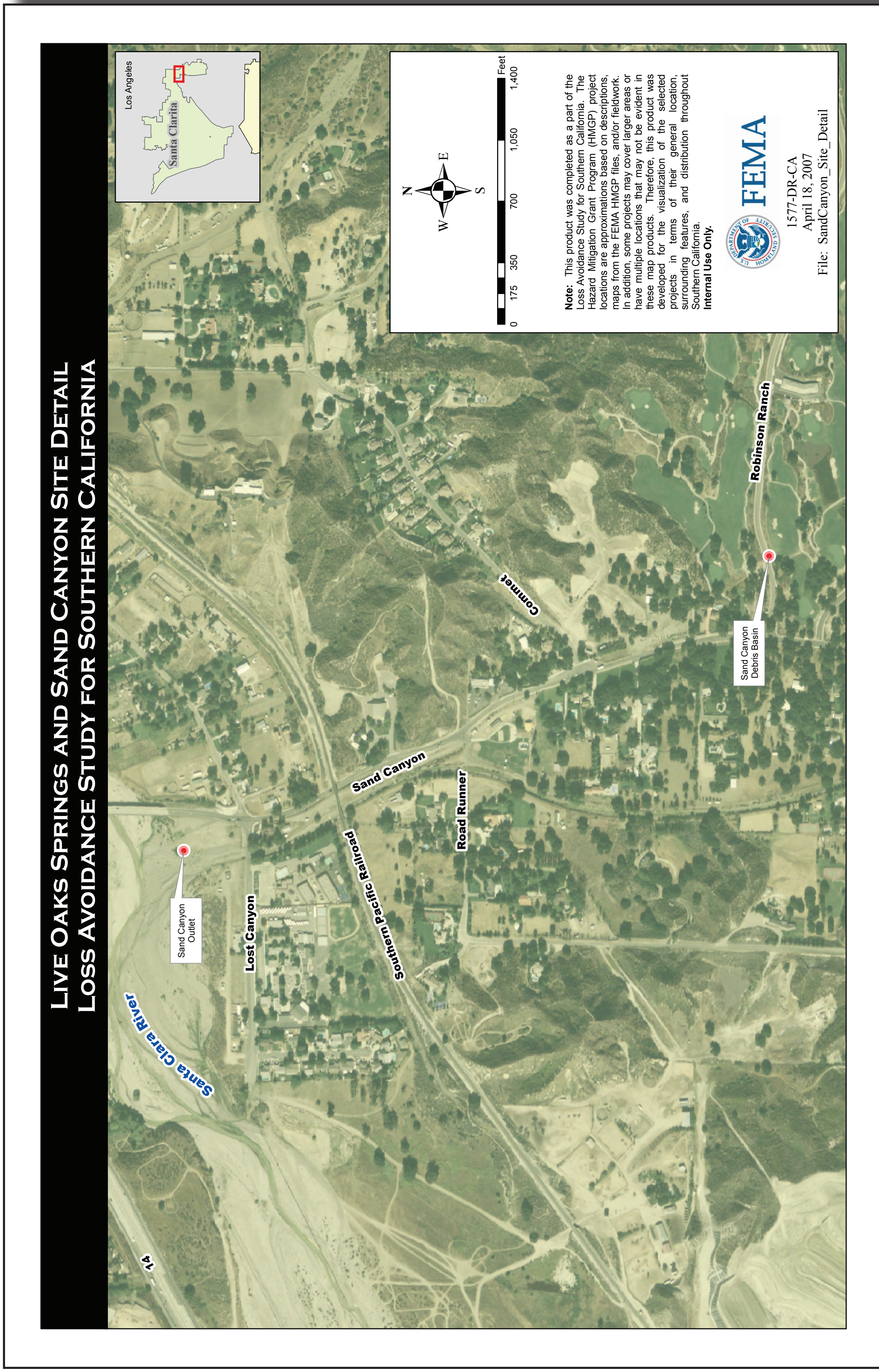

Live Oaks Springs and Sand Canyon Site Detail
Loss Avoidance Study for Southern California
Los Angeles
Santa Clarita
N
E
S
W
0
175
350
700
1,050
1,400
Feet
Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California.
Internal Use Only.
FEMA
1577-DR-CA
April 18, 2007
File: SandCanyon_Site_Detail
Robinson Ranch
Sand Canyon Debris Basin
Commet
Sand Canyon
Road Runner
Southern Pacific Railroad
Lost Canyon
Sand Canyon Outlet
Santa Clara River
14

Figure A.2

Figure A.3

carries flow that previously passed through the natural drainage channel from Robinson Ranch Road to Comet Way and small roadside ditches from Comet Way to Lost Canyon Road.

A.1.3 Project Funding and Construction Time Line

The total project cost was $6,436,506. FEMA provided 40% of the cost under HMGP Project Number 0935-0004 and under a supplemental HMGP grant, 0979-0030 (FEMA, 2006b). The remainder of the project was funded through the Los Angeles County Department of Public Works, Hazard Elimination Grant Program and a local government general fund for flood control projects.

The project was completed in two phases. The first phase consisted of completion of the discharge structure and 1,350 feet of the underground RCB with a temporary drain inlet for Live Oaks Sands Wash, located at the intersection of Comet Way and Sand Canyon Road. The second phase consisted of completion of the remainder of the RCB drain and the debris containment structure on Robinson Ranch Road at the upstream end of the system. FEMA approved the grant for the project in August 1993, and the City of Santa Clarita completed all phases of construction before the end of July 2002. Subsequent closeout of the project was completed on January 7, 2003.

A.2 Data Collection

In order to prepare for the analysis of the Live Oaks Springs and Sand Canyon Drainage Improvement project, the LAT completed a detailed review of the HMGP project file, noting the data that was available and the data that required additional research. Additionally, the LAT conducted an initial site visit with City of Santa Clarita personnel to gather site-specific information related to past flooding, discuss the project with city personnel, assess the site condition (topography, drainage features, and structure types), and obtain photo documentation of the site. One significant data source that was provided for this project was the 2005 restudy of the drainage for Sand Canyon and several tributaries. The restudy contained topographic data, hydrologic data, and hydraulic model data that were utilized during project analysis.

A.3 Physical Parameter Analysis

A.3.1 Storm Event Analysis

Two sources were utilized in identifying candidate storm events, weather data were obtained from the Los Angeles County Fire Department as well as the Los Angeles County ALERT system. Los Angeles County ALERT data was obtained from Los Angeles County Fire Department station Camp 9, located at latitude 34.4020, longitude -118.4020, approximately 1.2 miles from the project site. The maximum post-project, 24-hour rainfall recorded at this gage MP_C was 5.81 inches on February 12, 2003. Using NOAA's 1973 *Precipitation Frequency Atlas of the Western United States,* the LAT estimated this event to have a recurrence interval between 25 and 50 years (Miller et al., 1973). However, local officials did not observe any actual damage during this event.

A.3.2 Hydrologic Analysis

The hydrologic analysis, representing MP_A conditions, was available from a restudy of the Sand Canyon drainage, including the Live Oaks Spring Wash, that was completed in 2005. This analysis was available electronically and was based on the Los Angeles County Flood Control District Modified Rational Method (MRM). It included modeling for 10-, 100-, and 500-year events, and provided information on modeling storms of different frequencies.

A new hydrologic analysis was conducted to determine peak runoff generated by the February 12, 2003, storm event. The MRM analysis was revised to reflect MP_A conditions, and the runoff was recalculated with the actual storm event rainfall values. This analysis resulted in a maximum peak flow rate 826 cubic feet per second (cfs) for the MP_A scenario. Because the February 12, 2003, storm would have resulted in runoff exceeding channel capacity in the MP_A scenario, loss avoidance would be expected for this project.

A.3.3 Hydraulic Analysis

A hydraulic model representing the MP_A scenario was not available. Therefore, a hydraulic model was developed using HEC-RAS to determine if the channel had sufficient capacity for the February 12, 2003, event, and to determine the depth and extent of out-of-bank flooding. To prepare this analysis, topographic data were obtained from the Los Angeles County digital elevation data (originally collected in 2004 for the 2005 restudy), and the 1-foot contour interval mapping derived from this data (FEMA 2005). Because the topographic data represented MP_C conditions, it was necessary to modify the data to reflect MP_A conditions. Within HEC-RAS, roadside ditches that had been present for the MP_A scenario were added to the appropriate cross-sections. Ditch specifications were based on conversations with Los Angeles County and Santa Clarita officials.

Based on available data, the natural drainage channel that previously carried flow from Robinson Ranch Road to Comet Way was found to have sufficient capacity to carry runoff from the February 12, 2003, storm. Therefore, the HEC-RAS model included only the reach extending from the vicinity of Comet Way and Sand Canyon Road to the intersection of Lost Canyon Road and Sand Canyon Road. The hydraulic analysis for the MP_A scenario showed that, for the February 12, 2003, storm:

- Flooding would have occurred along the entire length of Sand Canyon Road from Comet Way to Lost Canyon Road.
- Sand Canyon Road would have served as the main channel, with flooding outside of the road right-of-way near the Comet Way intersection.
- Flood depths would have reached 4.5 feet, with the maximum depth occurring under the Union Pacific Railroad trestle in the elevation dip.
- Flow velocities would have been between two and seven feet per second.

A.3.4 Flood Boundary Analysis

There was no flood boundary analysis available in either project file for either of the MP_A or MP_C scenarios. Existing flood boundary information is shown on the existing *Flood Insurance Rate Map (FIRM) for the City of Santa Clarita*. The study area is shown on FIRM Number 0607290480C, dated September 29, 1989, as Zone A (an area subject to inundation during the 100-year flood) and Zone AO (an area subject to shallow flooding with depths of up to three feet). Additionally, the 2005 restudy was available to provide new 100-year floodplain information. However, neither the existing FIRM nor the restudy provided information that could be used for the MP_A scenario. The existing FIRM does not show flood hazard data for the Live Oaks Springs Canyon Wash separately from the flood hazard data shown for the main Sand Canyon floodplain. The draft Flood Insurance Study (FIS) represented MP_C conditions, including the new improvements. Consequently, a flood boundary analysis for the MP_A scenario was performed using the hydraulic model for the February 12, 2003, storm event for the area of Sand Canyon Road from Comet Way to Lost Canyon Road. Flood elevations were mapped using the above-referenced 1-foot contour mapping.

Figure A.4 provides an illustration of the MP_A flood boundary analysis results. As illustrated, street flooding would have occurred along the entire length of Sand Canyon Road from Comet Way to Lost Canyon Road, with structure flooding near the intersection of Sand Canyon Road and Comet Way. The analysis also indicated that flooding could be expected in residential structures located at the following addresses:

- 27865 Sand Canyon Road – approximately 1.2 feet
- 27901 Sand Canyon Road – approximately 0.5 feet

All other structures within the study area are located sufficiently above and away from the flooding and would not have been impacted.

A.4 Loss Estimation Analysis

Table A.1 displays the results of the loss estimation analysis for both the MP_A and MP_C scenarios by loss category and loss type. Various methods were utilized and are detailed below to determine MP_A damages. However, since the project was found to be completely effective in the February 2003 storm, there were no MP_C damages. Details on the figures provided in Table A.1 are discussed in the following sections, with calculation details being provided in the Attachments.

Figure A.4

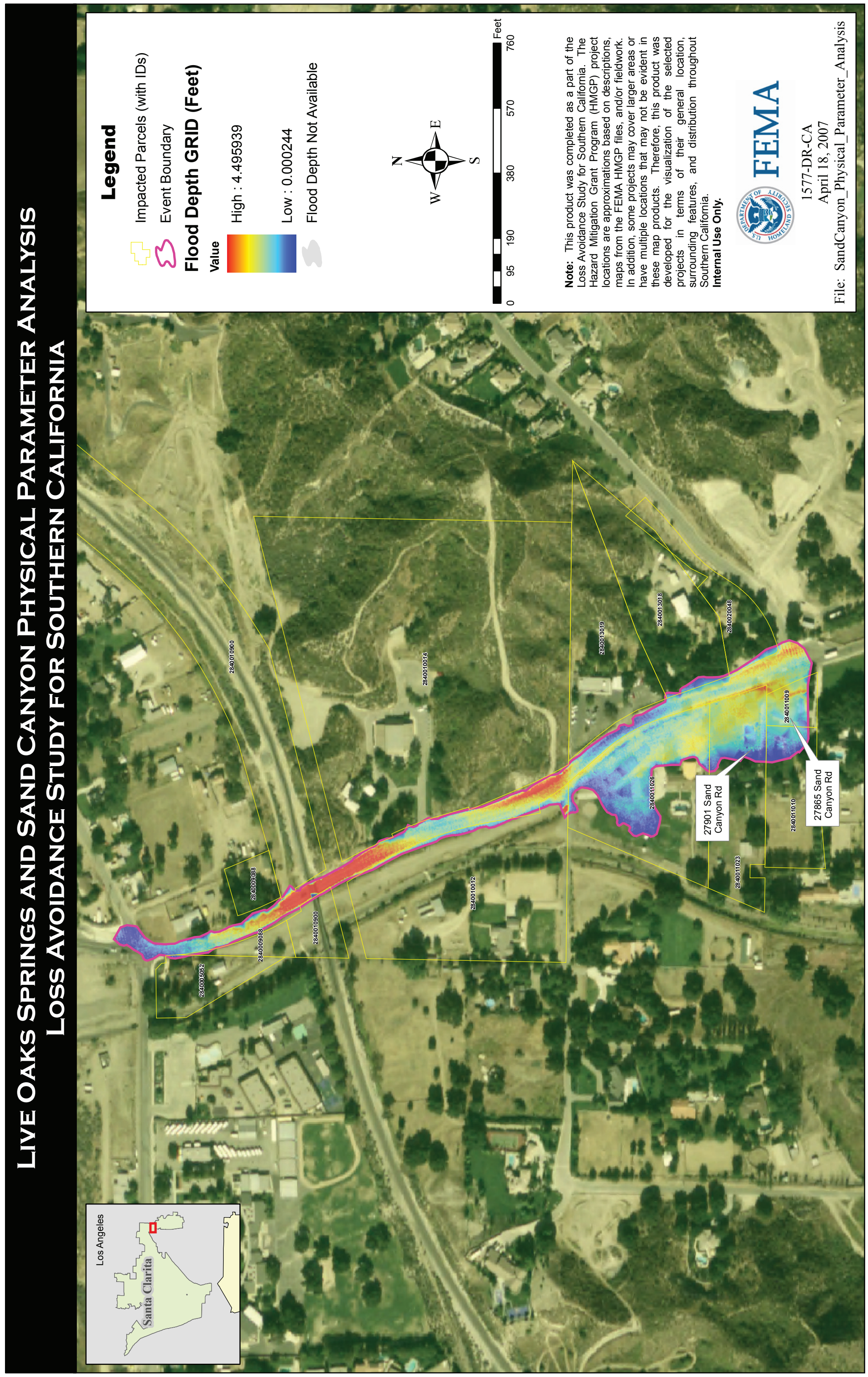

Live Oaks Springs and Sand Canyon Physical Parameter Analysis
Loss Avoidance Study for Southern California
Legend
Impacted Parcels (with IDs)
Event Boundary
Flood Depth GRID (Feet)
Value
High : 4.495939
Low : 0.000244
Flood Depth Not Available
N
E
S
W
0 95 190 380 570 760
Feet
Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California.
Internal Use Only.
FEMA
1577-DR-CA
April 18, 2007
File: SandCanyon_Physical_Parameter_Analysis
27901 Sand Canyon Rd
27865 Sand Canyon Rd
Los Angeles
Santa Clarita

Table A.1

Loss Estimation Analysis Results
Live Oaks Springs and Sand Canyon

Loss Type	MP_A Scenario Losses[1]	MP_C Scenario Losses[1]	Losses Avoided[1]	Comments
Physical Damage				
Structure	$93,656	$0	**$93,656**	• 1.2 ft flooding at 27865 Sand Canyon Road • 0.5 ft flooding at 27901 Sand Canyon Road • Applied HAZUS-MH depth-damage curve for RES1[2] • Replacement value based on RSMeans (Mewis, 2006)
Contents	$42,145	$0	**$42,145**	• Contents estimated at 30% of the structure replacement value based on FEMA BCA defaults (FEMA, 2006c) • Damage assumed to be 1.5 times structure damage
Roads and Bridges	$32,119	$0	**$32,119**	• Damages scaled from historical damages in project file
Infrastructure	$0	$0	**$0**	• Not predicted, not indicated in project file
Landscaping	$0	$0	**$0**	• Not predicted, not indicated in project file
Environmental Impacts	$0	$0	**$0**	• Not predicted, not indicated in project file
Vehicles/Equipment	$0	$0	**$0**	• Not predicted, not indicated in project file
Subtotal	***$167,920***	***$0***	***$167,920***	
Loss of Function				
Displacement Expense	$5,822	$0	**$5,822**	• Based on HAZUS-MH and FEMA BCA methods
Loss of Rental Income	$0	$0	**$0**	• No residential rental properties impacted
Loss of Business Income	$0	$0	**$0**	• No businesses impacted
Lost Wages	$0	$0	**$0**	• Not predicted, not indicated in project file
Disruption Time for Residents	$3,897	$0	**$3,897**	• Based on HAZUS-MH and FEMA BCA methods
Loss of Public Services	$0	$0	**$0**	• Not predicted, not indicated in project file
Economic Impact of Utility Loss	$0	$0	**$0**	• Not predicted, not indicated in project file
Economic Impact of Road/Bridge Closure	$503,137	$0	**$503,137**	• FEMA BCA traffic delay method based on delay time, number of vehicles, and lost income per vehicle • Average delay estimated at 45 minutes
Subtotal	***$512,856***	***$0***	***$512,856***	
Emergency Management				
Debris Cleanup	$6,083	$0	**$6,083**	• Costs scaled from historical damages in project file
Governmental Expense	$4,996	$0	**$4,996**	• Costs scaled from historical damages in project file
Subtotal	***$11,079***	***$0***	***$11,079***	
Total	***$691,855***	***$0***	***$691,855***	

[1] All amounts rounded to the nearest dollar
[2] Residential Type 1 (Single Family Dwelling)

A.4.1 Physical Damage

Physical damage costs were calculated for the structure and contents of the residences that were determined to be at risk of MP_A damage, and for damage to Sand Canyon Road itself.

The structure and contents damages for the MP_A scenario were estimated based on the flood depths at each structure (provided in Section A.3.4, above). Both residences are one-story, wood frame residential structures. Estimates for structure replacement values were based on RSMeans square footage values, Los Angeles County tax parcel data (2006), and observations obtained during a site visit by the LAT (see Attachments A.1 and A.2). Estimates for content values were based on the FEMA BCA default for residential structures. Under this option, the value of contents is 30% of the structure replacement value. The HAZUS-MH MR2 depth-damage function for damage to Residential Type 1 (Single Family Dwelling) was used to estimate the percent of damage associated with the flood depths at each structure. The FEMA BCA and HAZUS default for content damage percentage is 1.5 times the structural damage percentage (see Attachment A.3). These methods estimated structure damages to be $93,656 and content damage to be $42,145 (see Table A.1).

Damage to the pavement and drainage ditches on Sand Canyon Road due to flooding was based on information provided in the project files for a 1992 flood event. Road repair costs for that event were estimated to be $32,119 (see Table A.1).

Total estimated physical losses for the MP_A scenario were calculated at $167,920. There was no observed physical damage for the February 2003 MP_C event. As a result, estimated physical losses for the MP_C scenario were determined to be $0. Therefore, the avoided losses for physical damage were $167,920 (see Table A.1).

A.4.2 Loss of Function

Costs due to loss of function result from displacement of the occupants of flooded residences, disruption to the lives of those occupants, and costs associated with the closure of Sand Canyon Road. The estimation of losses for each of these elements is described below.

The flooding of residences, and the time necessary to repair the damage to the residences, would result in displacement of the occupants and costs to them as a result of this disruption. Using the FEMA BCA Module, which relates percentage of structure damage to structure repair time, the displacement at 27865 Sand Canyon Road was estimated to be 68.1 days, and the displacement at 27901 Sand Canyon Road was estimated to be 51.9 days. Using HAZUS-MH MR2 methods, displacements costs for the two flooded structures were estimated to be $5,822, and disruption costs to the residents were estimated to be $3,897 (see Table A.1).

According to local officials, flooding on Sand Canyon Road under the MP_A scenario would have produced road closures for two days – one day while the flooding occurred and one day for debris cleanup. Such closures would have forced residents to detour to Placerita Canyon Road, approximately five miles or 20 minutes, and then back to SR 14. As previously noted, this detour was also subject to washouts and landslides, forcing a detour to Little Tujunga Canyon Road. This would have resulted in a 25-mile (70-minute) detour for residents. For the loss estimation analysis, it was assumed that residents would have to detour to Little Tujunga Canyon Road for one day and to Placerita Canyon Road for one day. This would have resulted in an average delay of 45 minutes. According to local officials, Sand Canyon Road carries 8,400 vehicles per day. Using the FEMA BCA Module, which estimates lost wages to people in delayed vehicles, loss of function costs due to traffic delays were estimated to be $503,137 (see Attachment A.4).

There was no loss of function costs for the January 2003 MP_C event. Therefore, total losses avoided for loss of function costs were determined to be $512,856 (see Table A.1).

A.4.3 Emergency Management

Emergency management costs include debris cleanup and governmental expense. The project files indicated that, for the 1992 flood event, debris cleanup on Sand Canyon Road was completed at a cost of $6,083 (minus 10% for governmental cost). In addition, the cost for the local government to provide police personnel to close off the road was estimated to be 10% of total local government costs for debris cleanup and road repair, or $4,996. Flooding conditions and emergency management costs expected for the MP_A scenario were assumed to be similar to those experienced during the 1992 event. There were no MP_C emergency management costs for the January 2003 event. Therefore, losses avoided for emergency management were $11,079 (see Table A.1).

A.4.4 Results Summary

For the January 2003 MP_C storm event, losses avoided due to the construction of the project total $691,855 (see Table A.1). When compared to the project cost of $6,436,509 this represents a ROI of 11%, which is below the average ROI of 37%. However, it is expected that the ROI will increase as additional storm events, above the threshold, test the project's effectiveness.

Losses in Project File and Loss Calculations, Part 1
Live Oaks Springs and Sand Canyon

Event	Loss Type: Physical Damage							Comments
	Structure	Contents	Roads and Bridges	Infrastructure	Landscaping	Environmental Impacts	Vehicles/ Equipment	
February 1992 (MP_A)	$93,656	$42,145	$43,198 ($32,119)	$0	$0	$0	$0	***Structure*** • 27865 Sand Canyon Road 22.7% damaged, $47,144 • 27901 Sand Canyon Road 20.9% damaged, $46,512 ***Contents*** • 27865 Sand Canyon Road 34.0% damaged, $21,215 • 27901 Sand Canyon Road 31.4% damaged, $20,930 ***Roads and Bridges*** • Total cost of labor, materials, equipment rental, debris cleanup, and governmental expense
February 2003 (MP_C)	$0	$0	$0	$0	$0	$0	$0	

Event	Loss Type: Loss of Function								Comments
	Displacement Expense	Loss of Rental Income	Loss of Business Income	Lost Wages	Disruption Time for Residents	Loss of Public Services	Economic Impact of Utility Loss	Economic Impact of Road/Bridge Closure	
February 1992 (MP_A)	$5,822	$0	$0	$0	$3,897	$0	$0	$503,137	***Displacement Expense*** • $0.020645161 per square foot per day • 27865 Sand Canyon Road, 68.1 days, $2,943 • 27901 Sand Canyon Road, 51.9 days, $2,879 ***Disruption Time for Residents*** • $0.815483867 per square foot • 27865 Sand Canyon Road, $1,706 • 27901 Sand Canyon Road, $2,191 ***Economic Impact of Road/Bridge Closure*** • See *Travel Delay Calculations* attachment
February 2003 (MP_C)	$0	$0	$0	$0	$0	$0	$0	$0	

Losses in Project File and Loss Calculations, Part 2
Live Oaks Springs and Sand Canyon

Event	Loss Type		Comments
	Emergency Management		
	Debris Cleanup	*Governmental Expense*	
February 1992 (MP_A)	$6,083	$4,996	***Debris Cleanup*** • Scaled from project files and subtracted from road and bridge repair costs ***Governmental Expense*** • 10% of road and bridge repair costs and debris cleanup costs are assumed to be governmental expenses
February 2003 (MP_C)	$0	$0	

All amounts are adjusted for 2006 dollars and rounded to the nearest dollar.

Study Area Parcel Information, Part 1
Live Oaks Springs and Sand Canyon

Parcel ID	Address	TRA	Admin Region No	Recording Date	Land Value	Improvement Value	Built sq ft Main	Effective Year	Year Built	Homeowner Exempt Value	LDLL Narrative	LDLL Lott	LDLL Division	LDLL Region	LD Line1	LD Line2	LD Line3	LD Line4	LD Line5	Zoning Code	Use Code
2840011009	27865 Sand Canyon	00547	B1	20050412	$234,600	$438,600	1937	1937	1937	$7,000	OF SE 1/4 OF	23	4N	15	*LOT (EX OF ST) COM N 89>36' E 292.56 FT	AND N 0>28' E 122.83 FT AND N 84>33'16"	E 296.53 FT AND N 89>36' E 119.12 FT	FROM NW COR OF LOT 3 PM 121-30-31 TH N	89>36' E 170.88 FT TH N 18>41' W 156.82	LCA12*	0101
2840011023	27901 Sand Canyon	00547	B1	19920226	$322,524	$322,854	2488	2488	2488	$0	OF SEC 23 TN R15W				FOR DESC SEE ASSESSOR'S MAPS POR SE 1/4					LCA12*	0101

Study Area Parcel Information, Part 2
Live Oaks Springs and Sand Canyon

Parcel ID	Address	Replacement Value	Contents Value	Flood Depth (ft)	Structure Damage Ratio	Contents Damage Ratio	Structure Damage	Contents Damage	Displacement Time (days)	Displacement Costs	Disruption Costs
2840011009	27865 Sand Canyon	$208,011	$62,403	1.2	0.23	0.34	$47,144	$21,215	68.1	***$2,943***	***$1,706***
2840011023	27901 Sand Canyon	$222,146	$66,644	0.5	0.21	0.31	$46,512	$20,930	51.9	***$2,879***	***$2,191***
TOTAL		***$215,079 (avg)***	***$64,524 (avg)***				***$93,656***	***$42,145***		***$5,822***	***$3,897***

HAZUS-MH Damage - RES1
Live Oaks Springs and Sand Canyon

Occupancy	Specific Occupancy ID	Source	Description	Stories	Comment	Default Function	Editable	Selected	-4 ft -4.00	-3 ft -3.00	-2 ft -2.00	-1 ft -1.00	0 ft 0.00	1 ft 1.00	2 ft 2.00	3 ft 3.00	4 ft 4.00	5 ft 5.00	6 ft 6.00	7 ft 7.00	8 ft 8.00	9 ft 9.00	10 ft 10.00	11 ft 11.00	12 ft 12.00	13 ft 13.00
RES1	R11N	FIA	one floor, no basement, structure, A-Zone	1 Story		1			0.00	0.00	0.00	0.00	18.00	22.00	25.00	28.00	30.00	31.00	40.00	43.00	43.00	45.00	46.00	47.00	47.00	49.00
RES1	R11B	FIA (Mod.)	one floor, with basement, structure, A-Zone	1 Story		1			7.00	7.00	7.00	11.00	17.00	21.00	29.00	34.00	38.00	43.00	50.00	50.00	54.00	55.00	55.00	57.00	58.00	60.00
RES1	R12N	FIA	two floor, no basement, structure, A-Zone	2 Story		1			0.00	0.00	0.00	0.00	11.00	12.00	14.00	18.00	20.00	22.00	24.00	26.00	30.00	34.00	38.00	39.00	40.00	42.00
RES1	R12B	FIA (Mod.)	two floor, with basement, structure, A-Zone	2 Story		1			4.00	4.00	8.00	14.00	19.00	21.00	26.00	29.00	34.00	39.00	44.00	50.00	55.00	57.00	59.00	61.00	63.00	65.00
RES1	R13N	FIA	three or more floors, no basement, structure, A-Zone	3 Story		1			0.00	0.00	0.00	0.00	5.00	8.00	12.00	17.00	19.00	22.00	24.00	25.00	30.00	35.00	38.00	39.00	40.00	42.00
RES1	R13B	FIA (Mod.)	three or more floors, with basement, structure, A-Zone	3 Story		1			3.00	3.00	6.00	10.00	12.00	14.00	20.00	25.00	31.00	36.00	38.00	41.00	44.00	48.00	50.00	52.00	54.00	56.00
RES1	R1SN	FIA	split level, no basement, structure, A-Zone	Split Level		1			0.00	0.00	0.00	0.00	3.00	9.00	13.00	25.00	27.00	28.00	33.00	34.00	41.00	43.00	45.00	46.00	47.00	48.00
RES1	R1SB	FIA (Mod.)	split level, with basement, structure, A-Zone	Split Level		1			6.00	6.00	9.00	14.00	15.00	24.00	27.00	30.00	35.00	400.00	43.00	44.00	52.00	56.00	58.00	60.00	62.00	64.00

Occupancy	Specific Occupancy ID	Source	Description	Stories	Comment	Default Function	Editable	Selected	14 ft 14.00	15 ft 15.00	16 ft 16.00	17 ft 17.00	18 ft 18.00	19 ft 19.00	20 ft 20.00	21 ft 21.00	22 ft 22.00	23 ft 23.00	24 ft 24.00	ID	Basement	Hazard Riverine	Hazard CV	Hazard CA
RES1	R11N	FIA	one floor, no basement, structure, A-Zone	1 Story		1			50.00	50.00	50.00	51.00	51.00	52.00	52.00	53.00	53.00	54.00	54.00	105		1		1
RES1	R11B	FIA (Mod.)	one floor, with basement, structure, A-Zone	1 Story		1			62.00	63.00	65.00	67.00	69.00	70.00	72.00	74.00	76.00	77.00	79.00	106	1	1		1
RES1	R12N	FIA	two floor, no basement, structure, A-Zone	2 Story		1			43.00	44.00	45.00	47.00	48.00	49.00	50.00	52.00	53.00	54.00	56.00	107		1		1
RES1	R12B	FIA (Mod.)	two floor, with basement, structure, A-Zone	2 Story		1			66.00	68.00	69.00	71.00	72.00	74.00	75.00	77.00	79.00	80.00	82.00	108	1	1		1
RES1	R13N	FIA	three or more floors, no basement, structure, A-Zone	3 Story		1			43.00	44.00	45.00	47.00	48.00	49.00	50.00	52.00	53.00	54.00	56.00	109		1		1
RES1	R13B	FIA (Mod.)	three or more floors, with basement, structure, A-Zone	3 Story		1			57.00	59.00	61.00	63.00	65.00	67.00	69.00	71.00	73.00	75.00	77.00	110	1	1		1
RES1	R1SN	FIA	split level, no basement, structure, A-Zone	Split Level		1			49.00	50.00	51.00	52.00	53.00	54.00	55.00	56.00	57.00	58.00	59.00	111		1		1
RES1	R1SB	FIA (Mod.)	split level, with basement, structure, A-Zone	Split Level		1			66.00	68.00	70.00	72.00	74.00	76.00	78.00	81.00	83.00	85.00	87.00	12	1	1		1

Travel Delay Calculations[1]
Live Oaks Springs and Sand Canyon

1. Daily Volume of Traffic Flow[2]

Detour: Sand Canyon Road South of Lost Canyon Road to Live Oaks Springs Road - **8,400 VPD**

2. Average Delay or Detour Time per Vehicle

Sand Canyon Road Delay
Time in transit from Google Earth (placemarks entered to gain segment times and distances)

Segment	*Time*	*Distance*	*Speed*	**3. Economic Impact of Delay**
Sand Canyon Road from Lost Canyon intersection to Placerita Canyon *(major local road)*	*3 minutes*	2.8 Miles	56 mph	
Placerita Canyon to California Highway 14 *(secondary road)*	*7 minutes*	5 Miles	43 mph	***$39.9314704227 per vehicle hour***
California Highway 14 to Sand Canyon Road *(highway)*	*5 minutes*	5.4 Miles	65 mph	
Normal Travel Time	***15 minutes***	**13.2 Miles**		
Congestion Factor: Additional delay based on traffic capacity of detour *(delays on Placerita Canyon and decreased speed on Sand Canyon*	*5 minutes*			***Delay Cost:***
Delay Duration: 1 day flooding, 1 day debris cleanup = *2 days* **Delay Time per Day**	***20 minutes***			***$111,808.12***
Sand Canyon Road from Lost Canyon intersection to Little Tujunga Canyon Road *(major local road)*	*3 minutes*	2.8 Miles	56 mph	
Little Tujunga Canyon Road to I-210 *(secondary road)*	*39 minutes*	14.6 Miles	22 mph	
I-210 to I-5/SR-40 intersection *(highway)*	*10 minutes*	9.9 Miles	59 mph	
I-5/SR-40 intersection to Sand Canyon Road *(highway)*	*8 minutes*	8.1 Miles	61 mph	***$39.9314704227 per vehicle hour***
Normal Travel Time	***60 minutes***	**35.4 Miles**		
Congestion Factor: Additional delay based on traffic capacity of detour *(delays on Little Tujunga Canyon and decreased speed on Sand Canyon*	*10 minutes*			***Delay Cost:***
Delay Duration: 1 day flooding, 1 day debris cleanup = *2 days* **Delay Time per Day**	***70 minutes***			***$391,328.41***
			Total Delay Cost (2006 $)	***$503,136.53***

[1] General Methodology from "What is a Benefit?" document in FEMA BCA Toolkit, Version 3.0
[2] Vehicles per day from year 2000 traffic data

Appendix B:

Mission and Alston Channel and Rodeo Channel

Projects: 0979-0017 and 0979-0018

Table of Contents:

List of Figures and Tables

Appendix B:

Projects: 0979-0017 and 0979-0018

Mission and Alston Channel and Rodeo Channel

B.1 General Project Information

B.1.1 Project Location

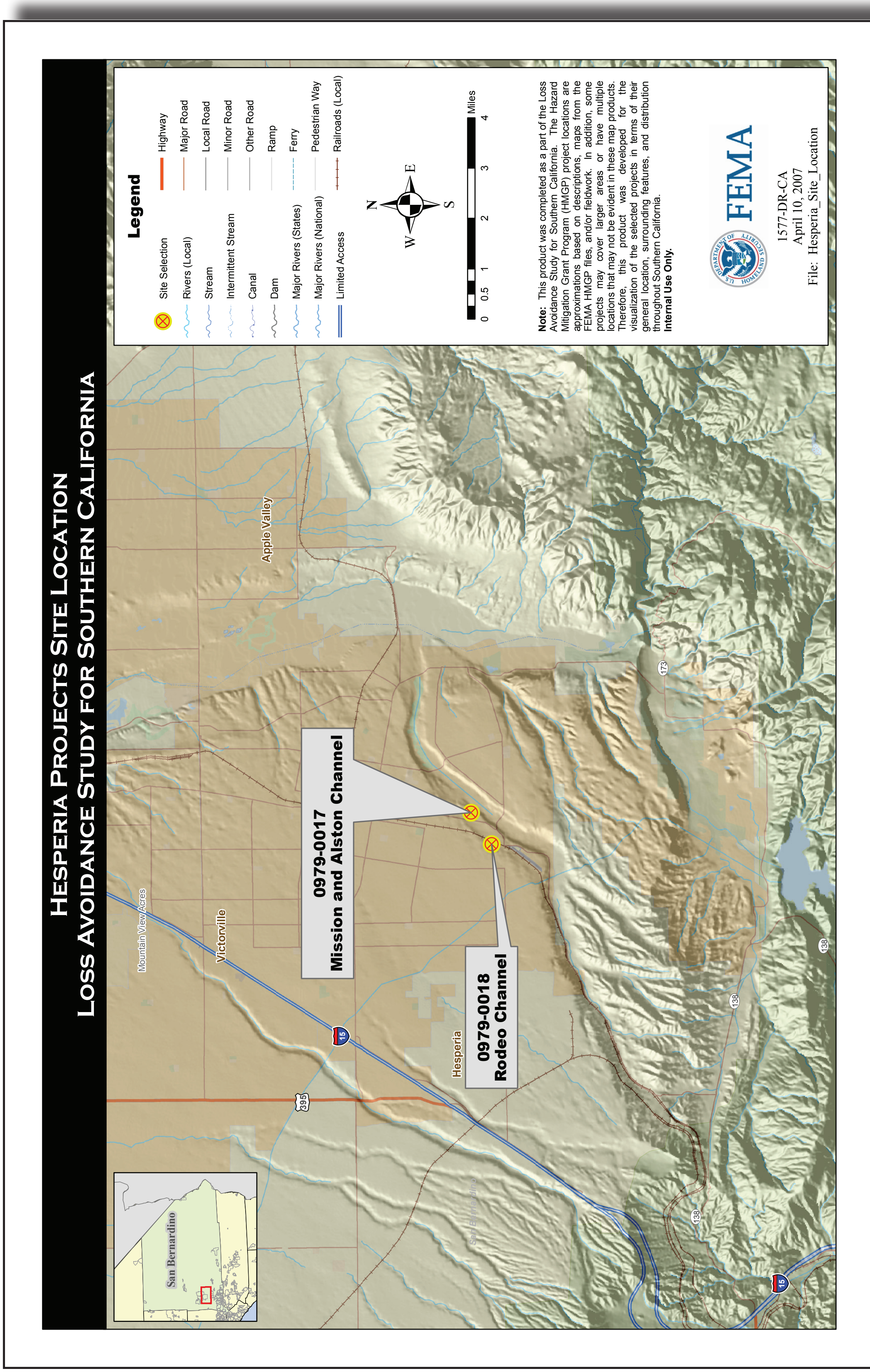
As illustrated in Figure B.1, the Rodeo Channel and the Mission and Alston Channel projects are located in the City of Hesperia, San Bernardino County, California. Figure B.2 illustrates that the Rodeo Channel project site is specifically located between the intersection of Seventh Avenue and Ranchero Road and the Antelope Valley Wash. It additionally shows that the Mission and Alston Channel project is specifically located between the intersection of E Avenue and Mission Street and the Antelope Valley Wash. Both projects drain into the Antelope Valley Wash, which conveys flow out of the city to the northeast, eventually discharging into the Mojave River.

Both project areas are located in the same watershed. Prior to construction of the projects, the existing natural channels were hydraulically connected; Rodeo Channel flowed into Mission-Alston Channel before discharging into the Antelope Valley Wash, as is shown on Figure B.2. Therefore, the projects were modeled and analyzed for losses avoided as one system.

B.1.2 Project Description

The City of Hesperia has repeatedly experienced flood-related losses in the residential neighborhoods lying north and west of the Antelope Valley Wash. This area was originally subdivided in the mid-1950s. However, at that time, San Bernardino County did not require the installation of stormwater management facilities. Over time the there was an increase in residential development which, subsequently, increased stormwater runoff. Still, sufficient drainage improvements were not constructed, and stormwater runoff flowed overland into existing natural water courses.

In addition to localized flooding, these residential neighborhoods received stormwater runoff from west of the Atchison, Topeka & Santa Fe (AT&SF) railroad through two existing culverts under the railroad and the adjacent Santa Fe Avenue roadway which exacerbated the localized flooding problems in the residential areas. To contain the overland flows, the city deployed concrete K-rail barriers along the east side of Santa Fe Avenue to direct the floodwaters away from nearby structures. In some years, use of the barriers was necessary two or three times in a season to avoid flooding of the area.


Hesperia Projects Site Location
Loss Avoidance Study for Southern California
0979-0017
Mission and Alston Channel
0979-0018
Rodeo Channel
Apple Valley
Victorville
Hesperia
Mountain View Acres
San Bernardino
Legend
Site Selection
Rivers (Local)
Stream
Intermittent Stream
Canal
Dam
Major Rivers (States)
Major Rivers (National)
Limited Access
Highway
Major Road
Local Road
Minor Road
Other Road
Ramp
Ferry
Pedestrian Way
Railroads (Local)
N
E
S
W
0 0.5 1 2 3 4
Miles
Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California.
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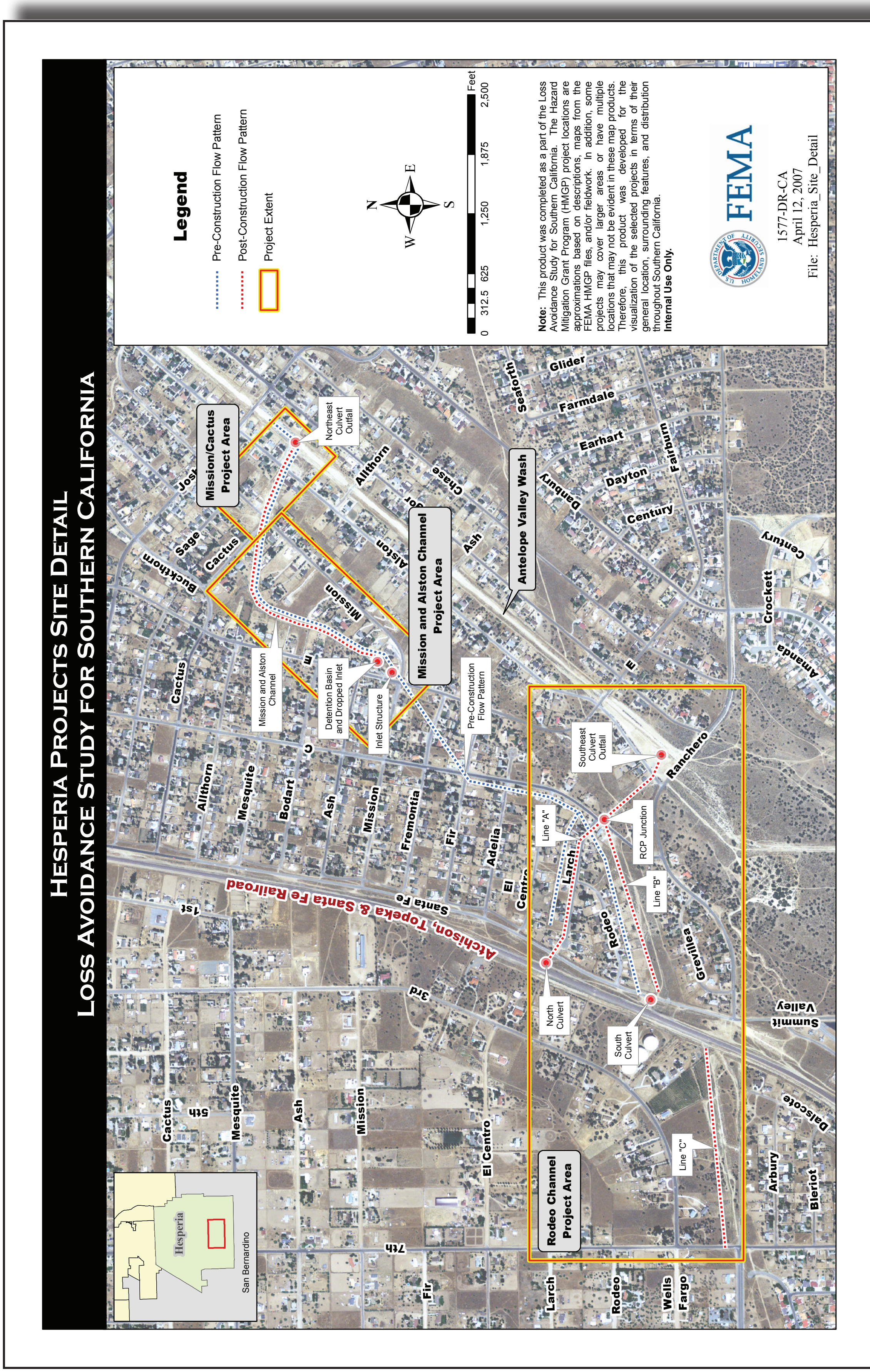
April 10, 2007
File: Hesperia_Site_Location

Figure B.1


Hesperia Projects Site Detail
Loss Avoidance Study for Southern California
Legend
Pre-Construction Flow Pattern
Post-Construction Flow Pattern
Project Extent
N
S
E
W
Feet
0 312.5 625 1,250 1,875 2,500
Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California.
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1577-DR-CA
April 12, 2007
File: Hesperia_Site_Detail
Hesperia
San Bernardino
Mission/Cactus Project Area
Northeast Culvert Outfall
Mission and Alston Channel Project Area
Mission and Alston Channel
Detention Basin and Dropped Inlet
Inlet Structure
Pre-Construction Flow Pattern
Antelope Valley Wash
Southeast Culvert Outfall
RCP Junction
Line "A"
Line "B"
Line "C"
North Culvert
South Culvert
Rodeo Channel Project Area
Atchison, Topeka & Santa Fe Railroad
Santa Fe
Cactus
Mesquite
Ash
Mission
El Centro
Fir
Larch
Rodeo
Wells
Fargo
Allthorn
Bodart
Fremontia
Adelia
Buckthorn
Sage
Chase
Alston
Danbury
Dayton
Century
Earhart
Farmdale
Glider
Seaforth
Fairburn
Crockett
Amanda
Ranchero
Grevillea
Summit Valley
Dalscote
Arbury
Bleriot
1st
3rd
5th
7th

Figure B.2

According to a report prepared by FEMA Region IX (1997), the winter storms of 1993 were particularly severe, causing over $1.5 million in damages to private property in the City of Hesperia. Approximately 100 homes were impacted in the area between Santa Fe Avenue and the Antelope Valley Wash during this event, which was declared a presidential disaster (0979-DR-CA).

The Rodeo Channel and Mission and Alston Channel projects were constructed to improve stormwater conveyance throughout the project areas and to alleviate the localized flooding conditions described above. The major features of each of the projects are described below.

Rodeo Channel Project

The Rodeo Channel project extends from the intersection of Seventh Avenue and Ranchero Road under the AT&SF railroad to the Antelope Valley Wash near Ranchero Road. As shown in Figure B.2, the project elements were built within the Southern California Edison right-of-way and Larch Street, and include:

- Line C – approximately 1,800 feet of 48-inch RCP west of the AT&SF railroad tracks
- Existing 30-inch South Culvert, under Santa Fe Avenue
- Existing 36-inch North Culvert, under Santa Fe Avenue (see Figure B.3)
- Line A – approximately 1,700 feet of RCP varying in diameter from 36 to 66 inches under Larch Street
- Line B – approximately 1,500 feet of 30-inch RCP and a 25-foot wide concrete-lined trapezoidal channel (see Figure B.4)
- A 42-inch, 700-foot long RCP at the junction of Lines A and B, through which water flows southeast to the Antelope Valley Wash

Figure B.3

Figure B.4

Mission and Alston Channel Project

The Mission and Alston Channel project extends from the intersection of E Avenue and Mission Street to the intersection of Cactus and Mission Streets before discharging into the Antelope Valley Wash southeast of Joshua Street. The project elements along the flowpath, shown in Figure B.2, include:

- An inlet structure at the northwest corner of the intersection of E Avenue and Mission Street to route flow into the system (see Figure B.5), where the culvert crosses under E Avenue and into the debris/detention basin
- A debris/detention basin, with a dropped inlet and trash guard outfall northeast of the intersection, discharging into an 80-inch RCP (see Figure B.6)

Figure B.5

Figure B.6

- An 80-inch RCP generally aligned along the rear property lines of the residential properties, with a V-shaped overflow channel, with manholes and check dams to intercept flow and direct it back into the RCP (see Figure B.7)
- A 5-foot by 5-foot RCB culvert outfall into Antelope Valley Wash

B.1.3 Project Funding and Construction Time Line

The total cost of the Rodeo Channel project was $2,140,942. Fifty percent of the project investment was provided by FEMA under HMGP Project Number 0979-0018. The remainder of the project was funded with local government funds as a match (FEMA, 2006b).

The City of Hesperia designed and constructed the Mission and Alston Channel project in conjunction with the Mission/Cactus drainage project. The total cost for both projects was $4,111,011. FEMA provided a grant for 50% of the cost for the Mission and Alston Channel project under HMGP Project Number 0979-0017, while the FEMA Public Assistance Program provided a grant for 50% of the cost for the Mission/Cactus drainage project[1].

The construction drawings for the project indicate that construction of the Rodeo Channel project was initiated in 1994 and was completed in December 1995. Construction plans indicate that construction Mission and Alston Channel project began in 1996. However, there is no "as-built" completion date on the plan set but local government officials stated that the project's construction was complete in January 1998. The subsequent closeout of both projects was May 29, 1998.

[1] Information for this project, which was funded under the presidential disaster declaration for the 1993 storms (FEMA-0979-DR-CA), is documented in Damage Survey Report #49906.

Figure B.7

B.2 Data Collection

The LAT completed a detailed review of the project file and noted the additional data that was needed in order to prepare for the analysis of the Rodeo Channel and Mission and Alston Channel projects. Additionally, the LAT conducted an initial site visit with City of Hesperia personnel to gather site-specific information related to past flooding, discuss the projects with city personnel, assess the site conditions (topography, drainage features, and structure types), and obtain photo documentation of the site. City personnel provided supplemental design information. Post-construction topographic data, developed in 2005 with a three meter contour interval, was purchased from Intermap Technologies. Aerial photography from 2005 was obtained from the State of California.

B.3 Physical Parameter Analysis

B.3.1 Storm Event Analysis

To identify candidate storm events, weather data were obtained from two sources: the NWS and the San Bernardino County ALERT system. San Bernardino ALERT data for the project sites were obtained from ALERT station 4002 at Hesperia Pump Plant #22, located at latitude 34.3900, longitude -117.3100, which is approximately 0.25 miles from the Rodeo Channel and 0.65 miles from the Mission and Alston Channel project site.

The pre-construction capacity of the natural drainage channels in the Rodeo Channel and Mission and Alston Channel project areas are unknown. However, based on the damage information provided in their HMGP applications, the City of Hesperia officials expected that damages would have occurred for the MP_A scenario for storm events with recurrence intervals of five and 10 years. Using NOAA's 1973 *Precipitation Frequency Atlas of the Western United States,* the LAT estimated that the 24-hour rainfall amounts for these recurrence intervals are approximately 2.0 inches and 2.5 inches, respectively (Miller et al., 1973).

A review of the ALERT rainfall data indicated that the storm of February 23, 1998, was the only event to occur since project completion that delivered a 24-hour rainfall total near the estimated rainfall amount for the 10-year storm (2.5 inches). This storm delivered 2.29 inches of rainfall in a 24-hour period. While city officials did not observe any actual MP_C damages for this event, it is likely that there would have been MP_A damage from this event.

B.3.2 Hydrologic Analysis

For the MP_A scenario analysis, to develop peak flows for both the Rodeo Channel and Mission and Alston Channel projects, the San Bernardino County Rational Method CIVIL-D hydrologic computer model was modified to reflect pre-construction watershed conditions. The model was then executed for the 10-year return frequency event to determine discharges at the desired design points. The calculated discharges were then scaled by the ratio of the actual 1998 rainfall amount to the 10-year rainfall amount in order to compute the design point discharges for the 1998 storm. This use of this method was necessary as it is not possible to input rainfall data from actual storm events into the CIVIL-D model.

As a result of the initial analysis of MP_A conditions in the Rodeo Channel project area, it was determined that the discharges from Rodeo Channel flow into the Mission and Alston Project area, and combine with the discharges of the Mission and Alston project in that area (see Figure B.2). Therefore, the peak discharges for the two projects were combined beginning at the upstream end of the Mission and Alston project area. It was assumed that peak flow timing coincided; therefore, the peak flows were combined without routing. The combined estimated peak discharge for the MP_A scenario at the outlet to the Antelope Valley Wash for the February 23, 1998, event was 555 cfs.

B.3.3 Hydraulic Analysis

As discussed above, the hydrologic analysis indicated that, for the MP_A scenario, flows from the Rodeo Channel project area contribute to flows in the Mission and Alston Channel project area. Therefore, the hydrologic and the hydraulic models for both project areas were combined to simulate the MP_A scenario. Topography representing the MP_A scenario was not available for either of the project areas. Therefore, information from the project files was used to modify the post-construction digital topography purchased from Intermap Technologies to represent MP_A conditions to the extent possible. It was assumed that MP_C topography in the Rodeo Channel project area provides a reasonable approximation of the MP_A topography, because the pre-construction topography shown on the construction drawings was similar to the post-construction topography available. The Mission and Alston channel in the MP_A scenario was estimated from one pre-construction channel cross-section that could be measured from the construction drawings. That cross-section was replicated along the channel at the same slope as the post-project channel.

Based on a review of the information provided in the Rodeo Channel project file, a branched flowpath was delineated in HEC-GeoRAS using the Intermap Technologies 3-meter contour data, and extended to the upstream limit of the Mission and Alston project site at E Avenue and Mission Street. This branched flowpath incorporates the tributary flooding along the flowpath from a low area at Rodeo Street and Santa Fe Avenue, as well as the tributary flooding from the North Culvert at Larch Street (see Figure B.2). Cross-section lines were then laid out along the flowpaths. HEC-GeoRAS was used to perform takeoffs of the topographic data along the flowpath and cross-sections for use in HEC-RAS version 3.1.3, which was used to conduct the hydraulic analysis. For purposes of this analysis, no hydraulic structures (such as bridges or culverts) were analyzed; and all conveyance was assumed to be overland. Manning's roughness coefficients were estimated from the aerial photography, using engineering judgment. A value of 0.4 was used to represent areas with houses and obstructed yards.

The hydraulic analysis indicated that, if the Rodeo Channel project had not been constructed, there would have been out-of-bank flooding in the Rodeo Channel study area and downstream as far as E Avenue. Therefore, loss avoidance would be expected for this project. However, the analysis indicated that, even considering the combined flows from the Rodeo Channel project area, the February 1998 event would not have resulted in out-of-bank channel flooding in the Mission and Alston project area. This is because the capacity of the channel before construction would have been sufficient to contain stormwater runoff during this event.

B.3.4 Flood Boundary Analysis

There were no flood boundary analyses in the project files for either the MP_A or the MP_C scenarios. Map Number 06071C6495G of the FIRM for San Bernardino County and Incorporated Areas, California, dated January 17, 1997, shows detailed flood hazard information for Antelope Valley Wash. The FIRM shows the Rodeo Channel and

Mission and Alston Channel project areas to be in Zone X, an area determined to be outside the 500-year floodplain. Consequently, the information shown on the FIRM was not used for the flood boundary analysis.

Because no other flood boundary information was available for either study area, a flood boundary analysis was prepared using the hydraulic analysis for the MP_A scenario. The model results from the simulation of the 1998 event were mapped using 2-foot contour interval topography derived from the 3-meter contour interval topography that was purchased from Intermap Technologies and the aerial photographs obtained from the State of California. Figure B.8 shows the flood inundation boundaries resulting from this analysis. The mapping indicates that 48 residences would have been impacted by flooding and 10 streets flooded by the February 23, 1998, storm event if the projects had not been constructed. The residences would have been inundated with 0.5 feet to 2.0 feet of floodwater, with the average flood depth being approximately nine inches. Based on this flood boundary and the corresponding flood depths, it was determined that losses avoided could be calculated for the project.

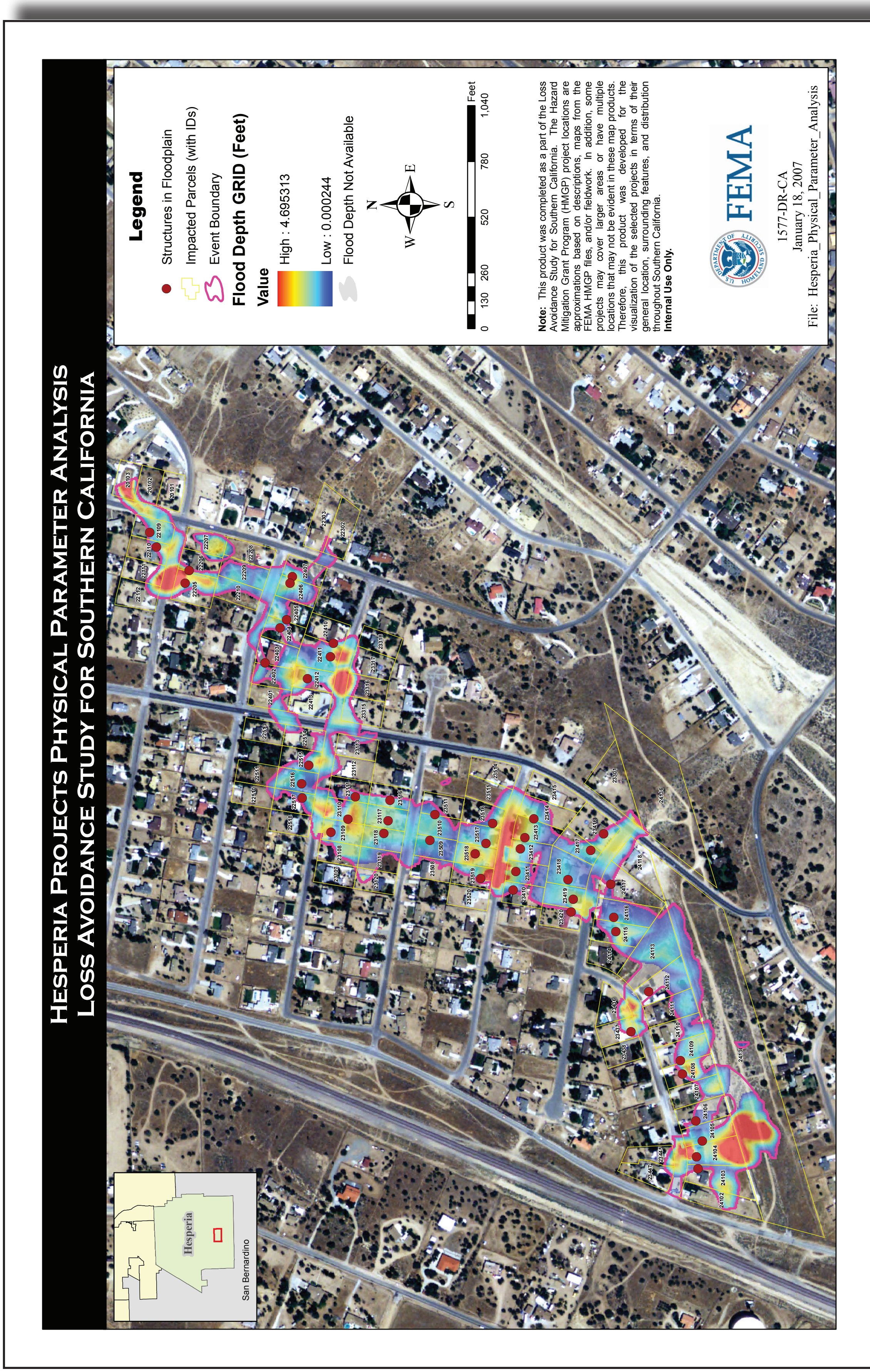
B.4 Loss Estimation Analysis

Table B.1 displays the results of the loss estimation analysis for the MP_A and MP_C scenarios by loss category and loss type. The various methods that were utilized to determine MP_A damages are detailed below. However, there was no cause to determine MP_C damages as the projects were found to be completely effective in the February 23, 1998, storm event. Details on the figures summarized in Table B.1 are discussed in the following sections, with calculation details being provided in the Attachment B.1 through B.6.

B.4.1 Physical Damage

As discussed in previous sections, the flood boundary analysis indicated that damage would have occurred under the MP_A scenario, and that losses avoided could be calculated for the Hesperia study areas. The LAT conducted a second site visit to field check and confirm the analysis results, evaluate potentially flooded structures to determine structure type, and approximate floor elevations in relation to adjacent grades. The second site visit indicated that all the residences impacted in the study area are one story, average construction quality, stud-framed, stucco structures, with slab-on-grade foundations (see Attachment B.2). If property photographs were unavailable, aerial photographs were used to estimate the area, in square feet, of the residences inundated, and to assess roof type and the presence of a garage. Marshall & Swift data for residential

Figure B.8


Hesperia Projects Physical Parameter Analysis
Loss Avoidance Study for Southern California
Legend
Structures in Floodplain
Impacted Parcels (with IDs)
Event Boundary
Flood Depth GRID (Feet)
Value
High : 4.695313
Low : 0.000244
Flood Depth Not Available
N
E
S
W
0 130 260 520 780 1,040
Feet
Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California.
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FEMA
1577-DR-CA
January 18, 2007
File: Hesperia_Physical_Parameter_Analysis
Hesperia
San Bernardino

Table B.1

Loss Estimation Analysis Results
Hesperia Projects

Loss Type	MP_A Scenario Losses[1]	MP_C Scenario Losses[1]	Losses Avoided[1]	Comments
Physical Damage				
Structure	$1,545,108	$0	**$1,545,108**	• Estimated with RES1[2], one floor, no basement depth-damage curve from HAZUS-MH • Replacement value based on Marshall & Swift (2006)
Contents	$463,532	$0	**$463,532**	• Contents estimated at 30% of the structure replacement value based on FEMA BCA defaults (FEMA, 2006c) • Damage assumed to be 1.5 times structure damage
Roads and Bridges	$2,113,232	$0	**$2,113,232**	• Damages scaled from historical damages in project file
Infrastructure	$145,513	$0	**$145,513**	• Damages scaled from historical damages in project file
Landscaping	$185,399	$0	**$185,399**	• Damages scaled from historical damages in project file
Environmental Impacts	$0	$0	**$0**	• Not predicted, not indicated in project file
Vehicles/Equipment	$0	$0	**$0**	• No significant vehicles/equipment damage predicted
Subtotal	***$4,452,784***	***$0***	***$4,452,784***	
Loss of Function				
Displacement Expense	$120,809	$0	**$120,809**	• Based on HAZUS-MH methods
Loss of Rental Income	$0	$0	**$0**	• No residential rental properties impacted
Loss of Business Income	$0	$0	**$0**	• No businesses impacted
Lost Wages	$0	$0	**$0**	• Not predicted, not indicated in project file
Disruption Time for Residents	$83,457	$0	**$83,457**	• Based on HAZUS-MH methods
Loss of Public Services	$0	$0	**$0**	• Not predicted, not indicated in project file
Economic Impact of Utility Loss	$0	$0	**$0**	• Not predicted, not indicated in project file
Economic Impact of Road/Bridge Closure	$39,867	$0	**$39,867**	• FEMA BCA traffic delay method based on delay time, number of vehicles, and lost income per vehicle • Assumed event duration was 2 days, 48 residences isolated for 2 days, 118 residences delayed by 5 minutes • Assumed 2 vehicles per residence
Subtotal	***$244,133***	***$0***	***$244,133***	
Emergency Management				
Debris Cleanup	$354,436	$0	**$354,436**	• Costs scaled from historical damages in project file
Governmental Expense	$371,560	$0	**$371,560**	• Costs scaled from historical damages in project file
Subtotal	***$725,996***	***$0***	***$725,996***	
Total	***$5,422,913***	***$0***	***$5,422,913***	

[1] All amounts rounded to the nearest dollar
[2] Residential Type 1 (Single Family Dwelling)

structures were used to estimate the replacement costs of each impacted residence.

The replacement values for stud-framed, stucco residences were assumed for all properties based on the photographs obtained during the second field visit. Adjustments to the replacement value were incorporated for the roof type, presence of a garage(s), a cost multiplier for frame construction in the west, and a local multiplier for the Hesperia area (see Attachment B.3). Estimates for content values were based on the FEMA BCA Module default for residential structures; under this option, the value of contents is 30% of the structure replacement value (FEMA, 2006c).

The Residential Type 1 (Single Family Dwelling) depth-damage curve (RES1) for a one floor, no basement residential structure from HAZUS-MH MR2 was used to estimate the percent damage associated with flood depth (see Attachment B.4). Content damages were assumed to be 1.5 times the structural damage for this analysis, which is the FEMA BCA Module default value for content damage.

Roads, bridges, infrastructure, and landscaping costs were estimated using the Damage Survey Reports that FEMA prepared for the PA grants following the 1993 flood. These reports provided cost information for debris removal, emergency work, repair of damaged roads and bridges, repair of damaged public buildings and utilities, and repair of other features, such as landscaping. This information was included in the HMGP project files. Based on maps that were included in the project files of an area impacted in a post-1993 flood that is similar to the flooded area shown by this analysis, it was assumed that the February 1998 event simulated for this analysis was comparable to the 1993 event. The landscaping costs were scaled to the number of estimated residences impacted by the February 23, 1998, event. The costs for repairs to damaged infrastructure, utilities, and landscaping were converted to 2006 dollars and included in the loss estimation for this analysis.

No physical MP_C damages were observed for the actual February 23, 1998, event. Therefore, the total physical losses avoided were estimated to be $4,452,784 (see Table B.1).

B.4.2 Loss of Function

Loss of function costs for the Rodeo Channel and Mission and Alston Channel study areas include displacement and disruption cost for residents, and the cost of traffic delays. Displacement costs relates to the time period during which occupants are displaced from a building in order for repairs to be made (FEMA, 2006c). For this analysis, the method from the FEMA BCA Module that relates percent structure damage to structure repair time was used to estimate days of displacement. For RES1 residences, the amount of days for repair time is between 30 days and one year, depending upon the depth of flooding. As a result, displacement costs equated to $120,809 (see Attachment B.1).

Disruption time for residents is the economic value of a person's time spent conducting activities associated with the event, such as evacuating from, cleaning, and repairing property (FEMA, 2006c). For this analysis, the disruption costs from HAZUS-MH MR2 for RES1 residences were used. The disruption costs for this event would have been approximately $0.82 per square foot for a total disruption cost of $83,457 (see Attachment B.1).

It was assumed that flooding in the study area would be expected to cause isolation for the residences without alternative routes for two days (approximately 48 residences); one day while the flooding occurs and one day for debris cleanup. Residences with alternative routes would only be delayed approximately five minutes (approximately 118 residences). For this analysis, it was also assumed that there would be two cars per residence impacted. The cost per vehicle hour used is approximately $37.29 (FEMA, 2006c) (see Attachment B.5). The total estimated cost for impact of road/bridge closure is $39,867 (see Attachment B.1).

No loss of function was observed for the actual MP_C event. Therefore, losses avoided for loss of function costs were determined to be $244,133 (see Attachment B.1).

B.4.3 Emergency Management

For these two projects, the Damage Survey Reports prepared for the Public Assistance Program indicated that emergency management costs were estimated for debris clean-up from various roadways, and emergency protective measures (see Attachment B.6). Examples of emergency protective measures include: placing of sandbags, road barriers, K-rail barriers, and emergency warning beacons on flooded roadways; firefighter assistance to the public; and emergency operations supplies and personnel. These costs were converted to 2006 dollars. There were no emergency management costs directly related to the Hesperia project areas for the actual MP_C event. Therefore, the total losses avoided for emergency management costs were determined to be $725,996 (see Table B.1).

B.4.4 Results Summary

Table B.1 shows the total losses avoided for these projects are $5,422,913. This can be compared to the original project cost to estimate the ROI. When the total project costs of $6,251,953 for the both the Rodeo Channel and the Mission and Alston Channel projects are compared with the losses avoided, the ROI for the February 1998 storm event is 87% which is significantly higher than the average ROI of 37%. It is expected that the ROI for these projects will continue to increase as additional storm events, of the same or greater magnitude, test the projects' effectiveness.

Losses in Project File and Loss Calculations, Part 1
Hesperia Projects

Event	Physical Damage: Structure	Contents	Roads and Bridges	Infrastructure	Landscaping	Environmental Impacts	Vehicles/ Equipment	Comments
January 1993 (MP_A)	$1,545,108	$463,532	$2,839,228 ($2,113,232)	$145,513	$185,339	$0	$0	***Structure*** • See *Study Area Parcel Information* attachment ***Contents*** • See *Study Area Parcel Information* attachment ***Roads and Bridges*** • Includes debris cleanup and governmental expenses, see *0979-DR-CA Damage Survey Reports Summary* attachment ***Infrastructure*** • See *0979-DR-CA Damage Survey Reports Summary* attachment ***Landscaping*** • See *0979-DR-CA Damage Survey Reports Summary* attachment
February 1998 (MP_C)	$0	$0	$0	$0	$0	$0	$0	

Event	Loss of Function: Displacement Expense	Loss of Rental Income	Loss of Business Income	Lost Wages	Disruption Time for Residents	Loss of Public Services	Economic Impact of Utility Loss	Economic Impact of Road/Bridge Closure	Comments
January 1993 (MP_A)	$120,809	$0	$0	$0	$83,457	$0	$0	$39,867	***Displacement Expense*** • $0.020645161 per square foot per day, see *Study Area Parcel Information* attachment ***Disruption Time for Residents*** • $0.815483867 per square foot, see *Study Area Parcel Information* attachment ***Economic Impact of Road/Bridge Closure*** • See *Travel Delay Calculations* attachment
February 1998 (MP_C)	$0	$0	$0	$0	$0	$0	$0	$0	

Losses in Project File and Loss Calculations, Part 2
Hesperia Projects

Event	Loss Type		Comments
	Emergency Management		
	Debris Cleanup	*Governmental Expense*	
January 1993 (MP_A)	$354,436	$371,560	***Debris Cleanup*** • See *0979-DR-CA Damage Survey Reports Summary* attachment, subtracted from road and bridge repair costs ***Governmental Expense*** • See *0979-DR-CA Damage Survey Reports Summary* attachment, subtracted from road and bridge repair costs
February 1998 (MP_C)	$0	$0	

All amounts are adjusted for 2006 dollars and rounded to the nearest dollar.

Attachment B.2

Study Area Parcel Information, Part 1
Hesperia Projects

Parcel ID	Address	Shape Area (sq ft)	Land Value	Improvement Value	Assessed Value	Structure Footprint[3] (sq ft)	House Footprint[8] (sq ft)	House Unit Cost ($/sq ft)	House Base Cost	Roof Type[5]	Roof Type Adjustment[6] ($/sq ft)	Roof Cost	Garage[1]	Garage Unit Cost	Garage Cost	Total House and Garage Costs
22109	16620 Mission	18882.23	$11,333	$70,623	$59,290	2982.73	2182.7	$61.83	$134,961.50	T	$6.16	$13,445.61	800.00	$17.12	$13,696.00	$162,103.12
22110	16610 Mission	18992.82	$11,247	$101,891	$90,644	1956.92	1156.9	$69.51	$80,421.98	S	$0.00	$0.00	800.00	$17.12	$13,696.00	$94,117.98
22205	16585 Mission	27347.65	$26,010	$110,000	$83,990	2151.26	2151.3	$62.00	$133,374.26	T	$6.16	$13,251.73	000.00	$0.00	$0.00	$146,625.99
22206	16605 Mission[2]	18991.14	$12,393	$60,513	$48,120	2539.93	2539.9	$60.14	$152,762.45	T[4]	$6.16	$15,645.98	000.00	$0.00	$0.00	$168,408.43
22403	16545 Fremontia[2]	21537.67	$11,919	$147,289	$135,370	4442.73	3642.7	$56.19	$204,689.09	T[4]	$6.16	$22,439.31	800.00	$17.12	$13,696.00	$240,824.30
22404	16555 Fremontia	19080.54	$24,312	$93,329	$69,017	3207.82	2407.8	$60.73	$146,216.18	S[4]	$0.00	$0.00	800.00	$17.12	$13,696.00	$159,912.18
22405	16565 Fremontia[2]	18988.31	$21,144	$91,305	$70,161	2995.03	2195.0	$61.77	$135,578.93	S[4]	$0.00	$0.00	800.00	$17.12	$13,696.00	$149,274.93
22406	16575 Fremontia[2]	18988.19	$31,095	$99,502	$68,407	2201.68	1401.7	$67.07	$94,005.18	S[4]	$0.00	$0.00	800.00	$17.12	$13,696.00	$107,701.18
22407	16595 Fremontia[2]	18986.35	$14,862	$94,427	$79,565	2676.46	2676.5	$59.57	$159,437.70	T[4]	$6.16	$16,487.00	000.00	$0.00	$0.00	$175,924.70
22410	16550 Fir	20886.26	$29,103	$87,497	$58,394	3043.00	2243.0	$61.53	$138,010.17	S	$0.00	$0.00	800.00	$17.12	$13,696.00	$151,706.17
22411	16530 Fir[2]	25803.43	$11,100	$82,958	$71,858	3008.56	2208.6	$61.70	$136,263.82	T[4]	$6.16	$13,604.72	800.00	$17.12	$13,696.00	$163,564.54
22412	16520 Fir	18652.63	$11,472	$122,462	$110,990	3389.86	3389.9	$56.98	$193,165.55	S	$0.00	$0.00	000.00	$0.00	$0.00	$193,165.55
22415	16476 Fir[2]	18988.78	$13,676	$57,570	$43,894	2809.06	2809.1	$59.04	$165,836.88	T[4]	$6.16	$17,303.79	000.00	$0.00	$0.00	$183,140.67
22416	16456 Fir[2]	18988.73	$18,932	$92,434	$73,502	4113.09	3313.1	$57.25	$189,670.79	S[4]	$0.00	$0.00	800.00	$17.12	$13,696.00	$203,366.79
22417	16436 Fir[2]	18988.65	$20,540	$73,401	$52,861	2565.76	2565.8	$60.03	$154,024.36	T[4]	$6.16	$15,805.10	000.00	$0.00	$0.00	$169,829.46
23109	16415 Fir[2]	18988.75	$19,668	$57,769	$38,101	1736.90	0936.9	$72.29	$67,728.56	S[4]	$0.00	$0.00	800.00	$17.12	$13,696.00	$81,424.56
23110	16435 Fir	18988.72	$84,750	$254,250	$169,500	3079.52	2279.5	$61.35	$139,849.26	T	$6.16	$14,041.83	800.00	$17.12	$13,696.00	$167,587.09
23111	16449 Fir	18988.72	$8,282	$61,333	$53,051	3152.15	3152.1	$57.81	$182,210.21	S	$0.00	$0.00	000.00	$0.00	$0.00	$182,210.21
23116	16438 Adelia	18989.78	$11,759	$75,348	$63,589	2198.96	1399.0	$67.09	$93,855.84	S	$0.00	$0.00	800.00	$17.12	$13,696.00	$107,551.84
23117	16424 Adelia	18989.78	$27,464	$68,657	$41,193	1970.01	1170.0	$69.36	$81,152.72	S	$0.00	$0.00	800.00	$17.12	$13,696.00	$94,848.72
23118	16410 Adelia	18989.79	$18,111	$54,329	$36,218	2144.32	1344.3	$67.59	$90,865.54	S[4]	$0.00	$0.00	800.00	$17.12	$13,696.00	$104,561.54
23410	16375 El Centro[2]	18988.83	$16,539	$80,752	$64,213	2681.78	1881.8	$63.54	$119,577.39	T[4]	$6.16	$11,591.77	800.00	$17.12	$13,696.00	$144,865.17
23411	16391 El Centro	18988.80	$23,104	$92,417	$69,313	2320.71	1520.7	$66.08	$100,485.96	S	$0.00	$0.00	800.00	$17.12	$13,696.00	$114,181.96
23412	16403 El Centro	18988.71	$81,600	$268,260	$186,660	3556.80	2756.8	$59.24	$163,326.60	T	$6.16	$16,981.90	800.00	$17.12	$13,696.00	$194,004.50
23413	16415 El Centro[2]	20758.44	$23,001	$68,765	$45,764	3378.34	2578.3	$59.98	$154,636.69	T[4]	$6.16	$15,882.57	800.00	$17.12	$13,696.00	$184,215.26
23414	16425 El Centro[2]	24576.96	$65,000	$195,000	$130,000	2160.23	2160.2	$61.95	$133,827.84	T[4]	$6.16	$13,307.00	000.00	$0.00	$0.00	$147,134.84
23416	16406 Larch[2]	29141.89	$12,128	$89,450	$77,322	2072.38	1272.4	$68.28	$86,876.79	S[4]	$0.00	$0.00	800.00	$17.12	$13,696.00	$100,572.79
23417	16396 Larch[2]	18712.92	$19,666	$29,606	$9,940	2497.79	2497.8	$60.33	$150,690.75	S[4]	$0.00	$0.00	000.00	$0.00	$0.00	$150,690.75
23418	16382 Larch[2]	28065.70	$11,472	$64,243	$52,771	2386.42	1586.4	$65.57	$104,015.04	S[4]	$0.00	$0.00	800.00	$17.12	$13,696.00	$117,711.04
23419	16370 Larch	18989.48	$21,196	$116,475	$95,279	1987.99	1188.0	$69.15	$82,150.17	S	$0.00	$0.00	800.00	$17.12	$13,696.00	$95,846.17
23420	16358 Larch	18989.40	$12,859	$142,544	$129,685	2939.79	2139.8	$62.06	$132,793.55	S	$0.00	$0.00	800.00	$17.12	$13,696.00	$146,489.55
23437	16280 Rodeo[2]	17990.48	$30,151	$120,603	$90,452	3523.84	2723.8	$59.38	$161,737.20	S[4]	$0.00	$0.00	800.00	$17.12	$13,696.00	$175,433.20
23509	16407 Adelia	18988.47	$10,616	$74,292	$63,676	2280.59	1480.6	$66.40	$98,315.50	S	$0.00	$0.00	800.00	$17.12	$13,696.00	$112,011.50
23511	16433 Adelia	18988.21	$38,495	$153,979	$115,484	2872.00	2072.0	$62.43	$129,348.50	C	$0.86	$1,781.92	800.00	$17.12	$13,696.00	$144,826.43
23516	16424 El Centro[2]	20506.64	$2,901	$54,311	$51,410	3263.51	2463.5	$60.48	$148,994.68	T[4]	$6.16	$15,175.25	800.00	$17.12	$13,696.00	$177,865.93
23517	16410 El Centro[2]	18039.91	$22,907	$68,770	$45,800	2234.93	1434.9	$66.79	$95,834.26	T[4]	$6.16	$8,839.19	800.00	$17.12	$13,696.00	$118,369.45
23518	16398 El Centro	18039.96	$81,600	$182,580	$100,980	1855.87	1055.9	$70.70	$74,636.31	T	$6.16	$6,504.18	800.00	$17.12	$13,696.00	$94,846.49
23519	16384 El Centro	18989.36	$19,756	$96,454	$76,698	2800.54	2000.5	$62.83	$125,688.03	S	$0.00	$0.00	800.00	$17.12	$13,696.00	$139,384.03
24103	16175 Rodeo	35666.54	$54,060	$162,180	$108,120	1749.46	0949.5	$72.10	$68,459.16	T	$6.16	$5,848.70	800.00	$17.12	$13,696.00	$88,003.86
24104	16189 Rodeo	29360.75	$31,794	$93,159	$61,365	1733.12	1733.1	$64.51	$111,800.11	S	$0.00	$0.00	000.00	$0.00	$0.00	$111,800.11
24105	16201 Rodeo[2]	21993.85	$71,000	$213,000	$142,000	1941.73	1141.7	$69.69	$79,569.14	S[4]	$0.00	$0.00	800.00	$17.12	$13,696.00	$93,265.14
24106	16215 Rodeo	24285.00	$28,403	$113,613	$85,210	2188.48	1388.5	$67.19	$93,286.59	S	$0.00	$0.00	800.00	$17.12	$13,696.00	$106,982.59
24108	16243 Rodeo	24284.90	$31,212	$123,287	$92,075	2459.15	1659.1	$65.03	$107,891.33	T	$6.16	$10,220.34	800.00	$17.12	$13,696.00	$131,807.67
24109	16255 Rodeo	24284.74	$12,717	$132,479	$119,762	2779.82	1979.8	$62.95	$124,632.01	T	$6.16	$12,195.72	800.00	$17.12	$13,696.00	$150,523.73
24115	16351 Larch	23625.77	$33,657	$100,969	$67,312	2391.95	1592.0	$65.52	$104,309.15	S	$0.00	$0.00	800.00	$17.12	$13,696.00	$118,005.15
24116	16361 Larch	28228.74	$11,472	$75,140	$63,668	2388.49	1588.5	$65.55	$104,125.39	S	$0.00	$0.00	800.00	$17.12	$13,696.00	$117,821.39
24117	16381 Larch	33297.99	$18,292	$65,843	$47,551	2678.32	1878.3	$63.57	$119,398.54	S	$0.00	$0.00	800.00	$17.12	$13,696.00	$133,094.54

Assumptions:

[1] All garages are two car and approximately 800 sq ft each
[2] No photo available - used Google map to identify presence of garage
[3] Measured from aerial photo in GIS
[4] Roof type unknown - assume same type as neighboring houses - if random, then choose randomly
[5] T = Tile; S = Shingle; C = Composition
[6] Roof adjustments based on average quality, one story residences
[7] Current cost multiplier for Western U.S. for frame construction - 1.03; local multiplier for Hesperia for frame construction = 1.09; total = 1.03 x 1.09 = 1.12
[8] House area estimated from total footprint area excluding garage area

Study Area Parcel Information, Part 2
Hesperia Projects

Parcel ID	Address	Replacement Value[7]	Contents Value	Flood Depth (ft)	Structure Damage Ratio	Contents Damage Ratio	Structure Damage	Contents Damage	Displacement Time (days)	Displacement Costs	Disruption Costs
22109	16620 Mission	$181,555.49	$54,466.65	0.3	0.19	0.29	$35,174.60	$10,552.38	48.3	**$2,371.16**	**$1,940.18**
22110	16610 Mission	$105,412.14	$31,623.64	0.7	0.21	0.31	$21,730.96	$6,519.29	55.5	**$1,444.15**	**$1,028.36**
22205	16585 Mission	$164,221.11	$49,266.33	1.4	0.23	0.35	$38,345.39	$11,503.62	73.9	**$3,579.23**	**$1,912.20**
22206	16605 Mission[2]	$188,617.45	$56,585.23	0.8	0.21	0.32	$39,668.61	$11,900.58	57.9	**$3,308.41**	**$2,257.69**
22403	16545 Fremontia[2]	$269,723.22	$80,916.96	0.1	0.18	0.27	$49,437.84	$14,831.35	42.2	**$3,460.57**	**$3,237.94**
22404	16555 Fremontia	$179,101.65	$53,730.49	0.5	0.20	0.30	$35,703.14	$10,710.94	51.5	**$2,791.79**	**$2,140.25**
22405	16565 Fremontia[2]	$167,187.93	$50,156.38	0.2	0.19	0.28	$31,101.20	$9,330.36	43.8	**$2,163.57**	**$1,951.11**
22406	16575 Fremontia[2]	$120,625.32	$36,187.60	1.6	0.24	0.36	$28,814.31	$8,644.29	78.1	**$2,463.19**	**$1,245.93**
22407	16595 Fremontia[2]	$197,035.66	$59,110.70	1.4	0.23	0.35	$45,672.73	$13,701.82	72.6	**$4,373.94**	**$2,379.05**
22410	16550 Fir	$169,910.91	$50,973.27	0.2	0.19	0.28	$31,896.46	$9,568.94	44.8	**$2,260.58**	**$1,993.75**
22411	16530 Fir[2]	$183,192.28	$54,957.69	1.0	0.22	0.33	$40,218.22	$12,065.47	63.2	**$3,142.71**	**$1,963.14**
22412	16520 Fir	$216,345.42	$64,903.62	0.8	0.21	0.32	$45,884.67	$13,765.40	58.9	**$4,494.09**	**$3,013.17**
22415	16476 Fir[2]	$205,117.55	$61,535.27	0.6	0.20	0.30	$41,688.54	$12,506.56	53.8	**$3,399.82**	**$2,496.91**
22416	16456 Fir[2]	$227,770.81	$68,331.24	0.4	0.20	0.30	$44,849.05	$13,454.72	50.1	**$3,735.88**	**$2,944.93**
22417	16436 Fir[2]	$190,208.99	$57,062.70	0.3	0.19	0.29	$36,561.36	$10,968.41	47.4	**$2,736.26**	**$2,280.65**
23109	16415 Fir[2]	$91,195.51	$27,358.65	0.8	0.21	0.32	$19,217.85	$5,765.36	58.1	**$1,225.50**	**$832.79**
23110	16435 Fir	$187,697.54	$56,309.26	1.6	0.24	0.36	$44,885.65	$13,465.69	78.3	**$4,016.28**	**$2,026.21**
23111	16449 Fir	$204,075.44	$61,222.63	0.9	0.22	0.33	$44,416.30	$13,324.89	62.1	**$4,407.48**	**$2,801.87**
23116	16438 Adelia	$120,458.07	$36,137.42	0.9	0.22	0.32	$25,931.42	$7,779.43	60.8	**$1,912.78**	**$1,243.51**
23117	16424 Adelia	$160,230.56	$31,869.17	0.9	0.22	0.33	$23,099.96	$6,929.99	62.0	**$1,632.98**	**$1,039.99**
23118	16410 Adelia	$117,108.93	$35,132.68	1.0	0.22	0.33	$25,638.16	$7,691.45	62.9	**$1,902.13**	**$1,194.93**
23410	16375 El Centro[2]	$162,248.99	$48,674.70	0.2	0.19	0.28	$30,619.74	$9,185.92	45.4	**$1,920.99**	**$1,672.67**
23411	16391 El Centro	$127,883.80	$38,365.14	1.1	0.22	0.34	$28,690.81	$8,607.24	66.9	**$2,288.12**	**$1,351.72**
23412	16403 El Centro	$217,285.04	$65,185.51	1.0	0.22	0.33	$47,622.35	$14,286.70	63.0	**$3,909.49**	**$2,450.46**
23413	16415 El Centro[2]	$206,321.09	$61,896.33	1.2	0.23	0.34	$46,513.42	$13,954.03	67.7	**$3,928.42**	**$2,291.83**
23414	16425 El Centro[2]	$164,791.02	$49,437.31	1.0	0.22	0.33	$36,291.44	$10,887.43	63.7	**$3,095.40**	**$1,920.18**
23416	16406 Larch[2]	$112,641.53	$33,792.46	0.3	0.19	0.29	$21,409.59	$6,422.88	46.1	**$1,321.27**	**$1,130.99**
23417	16396 Larch[2]	$168,773.64	$50,632.09	0.9	0.22	0.33	$36,767.60	$11,030.28	62.3	**$3,499.20**	**$2,220.22**
23418	16382 Larch[2]	$131,836.37	$39,550.91	0.6	0.21	0.31	$27,061.22	$8,118.37	55.0	**$1,961.90**	**$1,410.13**
23419	16370 Larch	$107,347.71	$32,204.31	1.1	0.22	0.34	$24,041.06	$7,212.32	66.6	**$1,779.33**	**$1,055.98**
23420	16358 Larch	$164,068.30	$49,220.49	0.0	0.18	0.27	$29,676.49	$8,902.95	40.8	**$1,965.44**	**$1,902.01**
23437	16280 Rodeo[2]	$196,485.18	$58,945.55	0.9	0.21	0.32	$42,086.97	$12,626.09	60.1	**$3,686.08**	**$2,421.16**
23509	16407 Adelia	$125,452.88	$37,635.86	0.7	0.21	0.31	$26,004.52	$7,801.36	56.1	**$1,870.07**	**$1,316.06**
23511	16433 Adelia	$162,205.60	$48,661.68	0.7	0.21	0.31	$33,705.18	$10,111.55	56.4	**$2,630.79**	**$1,841.76**
23516	16424 El Centro[2]	$199,209.84	$59,762.95	0.8	0.21	0.32	$42,143.39	$12,643.02	58.6	**$3,248.73**	**$2,189.76**
23517	16410 El Centro[2]	$132,573.78	$39,772.13	0.8	0.21	0.32	$27,883.22	$8,364.97	57.9	**$1,869.26**	**$1,275.48**
23518	16398 El Centro	$106,228.06	$31,868.42	1.9	0.25	0.37	$26,080.08	$7,824.02	83.2	**$1,977.39**	**$938.54**
23519	16384 El Centro	$156,110.11	$46,833.03	1.0	0.22	0.33	$34,400.25	$10,320.08	63.8	**$2,871.18**	**$1,778.24**
24103	16175 Rodeo	$98,564.32	$29,569.30	0.0	0.18	0.27	$17,775.27	$5,332.58	40.5	**$865.45**	**$843.96**
24104	16189 Rodeo	$125,216.13	$37,564.84	1.0	0.22	0.33	$27,612.66	$8,283.80	63.9	**$2,492.22**	**$1,540.53**
24105	16201 Rodeo[2]	$104,456.95	$31,337.09	0.8	0.21	0.32	$22,230.77	$6,669.23	59.3	**$1,524.55**	**$1,014.86**
24106	16215 Rodeo	$119,820.50	$35,946.15	0.0	0.18	0.27	$21,743.21	$6,522.96	41.2	**$1,285.97**	**$1,234.19**
24108	16243 Rodeo	$147,624.59	$44,287.38	0.0	0.18	0.27	$26,748.31	$8,024.49	41.0	**$1,530.72**	**$1,474.78**
24109	16255 Rodeo	$168,586.57	$50,575.97	0.7	0.21	0.31	$35,044.28	$10,513.28	56.5	**$2,515.77**	**$1,759.82**
24115	16351 Larch	$132,165.77	$39,649.73	1.0	0.22	0.33	$29,041.62	$8,712.49	63.3	**$2,269.35**	**$1,415.05**
24116	16361 Larch	$131,959.96	$39,587.99	0.6	0.20	0.31	$26,906.17	$8,071.85	54.2	**$1,936.13**	**$1,411.98**
24117	16381 Larch	$149,065.89	$44,719.77	0.0	0.18	0.27	$27,072.05	$8,121.62	41.2	**$1,743.23**	**$1,669.60**
TOTAL		***$156,696.08 (avg)***	***$47,308.82 (avg)***				***$1,545,108.09***	***$463,532.43***		***$120,808.94***	***$83,456.51***

Assumptions:

[1] All garages are two car and approximately 800 sq ft each
[2] No photo available - used Google map to identify presence of garage
[3] Measured from aerial photo in GIS
[4] Roof type unknown - assume same type as neighboring houses - if random, then choose randomly
[5] T = Tile; S = Shingle; C = Composition
[6] Roof adjustments based on average quality, one story residences
[7] Current cost multiplier for Western U.S. for frame construction - 1.03; local multiplier for Hesperia for frame construction = 1.09; total = 1.03 x 1.09 = 1.12
[8] House area estimated from total footprint area excluding garage area

Average Structure Value Calculations
Hesperia Projects

House: Stud-Framed, Stucco on Wood		Garage: Stud-Framed, Stucco on Wood	
Total Area (sq ft)	*Value (per sq ft)*	*Total Area (sq ft)*	*Value (per sq ft)*
600	***$78.36***	200	***$24.99***
800	***$74.33***	400	***$20.46***
1,000	***$71.35***	600	***$18.12***
1,200	***$69.01***	800	***$17.12***
1,300	***$68.00***	1,000	***$16.24***
1,400	***$67.08***		
1,500	***$66.24***		
1,600	***$65.26***		
1,700	***$64.73***		
1,800	***$64.06***		
1,900	***$63.43***		
2,000	***$62.83***		
2,100	***$62.27***		
2,200	***$61.74***		
2,400	***$60.76***		
2,600	***$59.88***		
2,800	***$59.07***		
3,000	***$58.33***		
3,200	***$57.64***		
3,400	***$56.95***		
3,600	***$56.31***		
3,800	***$55.74***		

HAZUS-MH Damage - RES1
Hesperia Projects

Depth–Damage Curve		Interpolation	
Flood Depth	Damage Ratio	Flood Depth	Damage Ratio
0 ft	***0.18***	0.0 ft	***0.180***
1 ft	***0.22***	0.1 ft	***0.184***
2 ft	***0.25***	0.2 ft	***0.188***
3 ft	***0.28***	0.3 ft	***0.192***
4 ft	***0.30***	0.4 ft	***0.196***
5 ft	***0.31***	0.5 ft	***0.200***
		0.6 ft	***0.204***
		0.7 ft	***0.208***
		0.8 ft	***0.212***
		0.9 ft	***0.216***
		1.0 ft	***0.222***
		1.1 ft	***0.223***
		1.2 ft	***0.226***
		1.3 ft	***0.229***
		1.4 ft	***0.232***
		1.5 ft	***0.235***
		1.6 ft	***0.238***
		1.7 ft	***0.241***
		1.8 ft	***0.244***
		1.9 ft	***0.247***
		2.0 ft	***0.250***

Travel Delay Calculations[1]
Hesperia Projects

1. Daily Volume of Traffic Flow[2]

Detour: 236 VPD (assumed, no traffic data available)

2. Average Delay or Detour Time per Vehicle

Detour and Isolated Residences

Segment	*VPD*	*Time*	*Distance*	**3. Economic Impact of Delay**
Alternate routes for: Mission, E, C, West Fremontia, West Fir				
Adelia to Santa Fe		2 minutes	0.7 miles	
Santa Fe to Cactus and Mission		2 minutes	0.7 miles	***$37.2907627118 per vehicle hour***
Cactus and Mission to Mission and E		1 minute	0.4 miles	
Normal Travel Time	**236**	**5 minutes**	**1.8 miles**	
Delay Duration: 1 day flooding, 1 day debris cleanup = *2 days*				***Delay Cost:*** ***$1466.77***
Isolated Residences				
48 residences isolated for 2 days				***$200.00 per vehicle per day***
Assumed: 2 vehicles per residence				
Delay Duration: 1 day flooding, 1 day debris cleanup = *2 days*				***Cost:*** ***$38,400.00***
Total Cost (2006 $)				***$39,866.77***

[1] General Methodology from "What is a Benefit?" document in FEMA BCA Toolkit, Version 3.0
[2] Vehicles per day

0979-DR-CA Damage Survey Reports Summary
Hesperia Projects

Public Assistance							Private Property		
Category A	Category B	Category C	Category D	Category E	Category F	Category G	Total Residential	Yard	Road
$253,306	$24,7799	$399,691			$3,360		$150,000	$2,000	$5,000
	$8,805	$177,165			$100,634		$150,000	$4,000	$5,000
	$8,940	$58,478						$2,000	$5,000
		$422,478						$5,000	$2,500
		$139,847						$5,000	$5,000
		$312,612						$7,500	$22,400
								$5,000	$5,000
								$5,000	$5,000
								$5,000	$5,000
								$200	$5,000
								$500	$5,000
								$2,000	
								$10,000	
								$2,000	
								$500	
								$1,500	
								$2,000	
								$3,500	
								$1,000	
								$2,000	
								$6,000	
								$1,000	
								$1,000	
								$500	
								$500	
								$1,000	
								$500	
								$1,000	
								$500	
								$400	
								$400	
								$300	
								$2,000	
								$3000	
								$10,000	
								$500	
								$10,000	
								$500	
								$500	
								$500	
								$750	
								$1,000	
								$750	
								$500	
								$700	
								$15,000	
								$1,000	
								$500	
								$5,000	
								$1,500	
$253,306 (2003 $)	*$265,544 (2003 $)*	*$1,510,271 (2003 $)*	*$0 (2003 $)*	*$0 (2003 $)*	*$103,994 (2003 $)*	*$0 (2003 $)*	*$300,000 (2003 $)*	*$132,500 (2003 $)*	*$69,900 (2003 $)*
$354,436 (2006 $)	***$371,560 (2006 $)***	***$2,113,232 (2006 $)***	***$0 (2006 $)***	***$0 (2006 $)***	***$145,513 (2006 $)***	***$0 (2006 $)***	***$419,772 (2006 $)***	***$185,399 (2006 $)***	***$97,807 (2006 $)***

Public Assistance Categories

Category A - Debris Removal
Category B - Emergency Protective Measures
Category C - Roads and Bridges
Category D - Water Control Facilities
Category E - Buildings and Contents
Category F - Utilities
Category G - Parks, Recreational, and Other

Appendix C:

Nason Detention Basin and Drainage Improvement Project

Project: 0979-0032

Table of Contents:

List of Figures and Tables

Appendix C:

Project: 0979-0032

Nason Detention Basin And Drainage Improvement Project

C.1 General Project Information

C.1.1 Project Location

As illustrated in Figure C.1, the Nason Detention Basin and Drainage Improvement project is located in the City of Moreno Valley, Riverside County, California. More specifically, the project site is adjacent to a two-mile stretch of Nason Street. The northern extent of the project is just north of SR 60 (the Pomona Freeway) with the southern extent ending just south of Cactus Avenue (see Figure C.2).

C.1.2 Project Description

Prior to construction of this project, runoff from Urban drainage area approximately 3.5-square-miles drained into the Nason Street corridor, where it was moved by natural drainage channels and small roadside ditches. These features were inadequate to convey storm flows, resulting in frequent flooding of Nason Street especially during the 1992-1993 rainy season where flooding caused portions of Nason Street to be closed for more than three months.

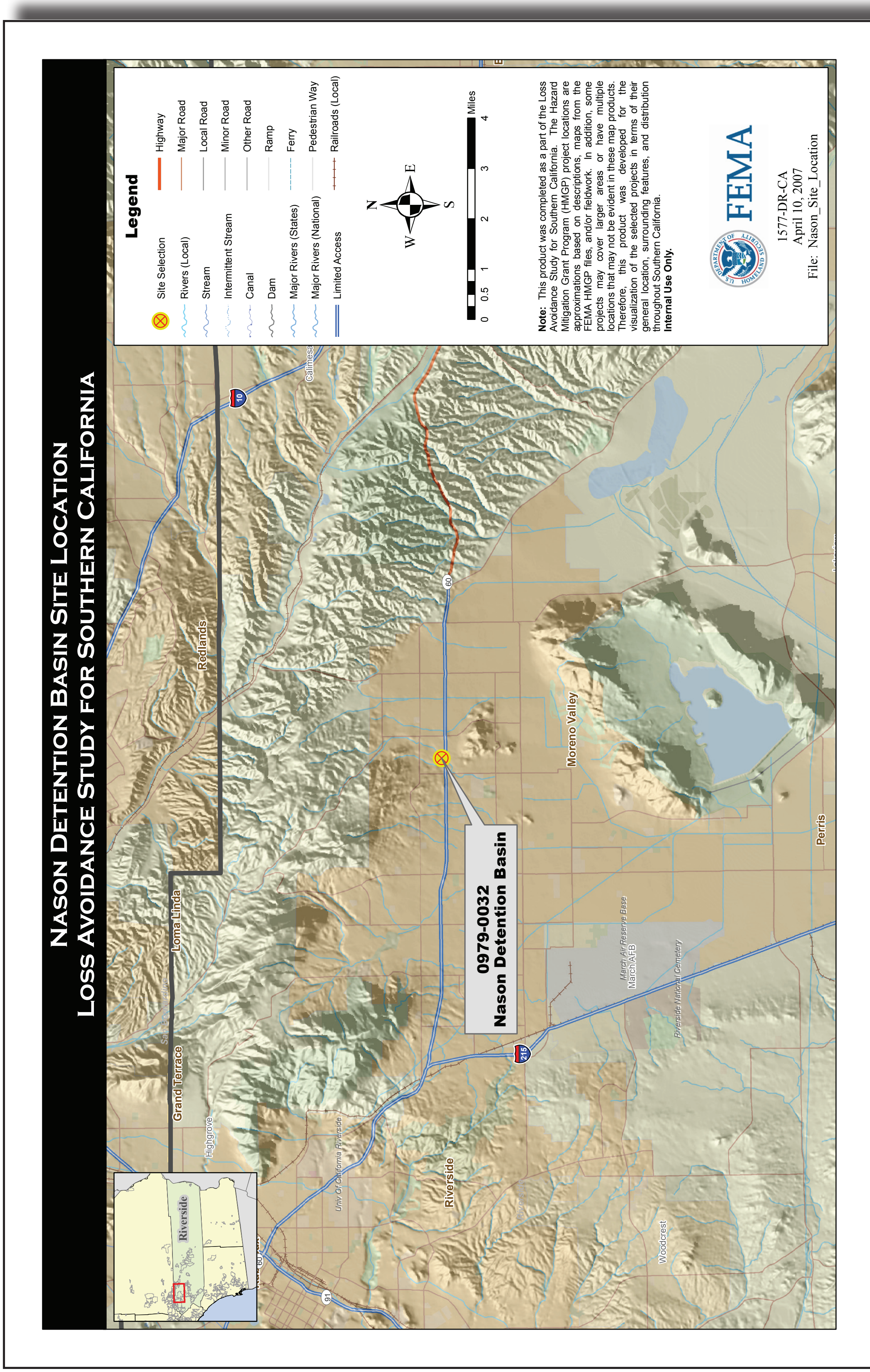
In an effort to reduce the risk of flooding and reduce the area's vulnerability to road closures, the Riverside County Flood Control and Water Conservation District developed a plan for drainage improvements along the Nason Street corridor. The project consists of construction of the Nason Detention Basin near SR 60 and installation of approximately 1.5 miles of 70-inch diameter RCP along Nason Street from Eucalyptus Avenue to Cactus Avenue (see Figure C.2, C.3, and C.4). The improved system discharges runoff to an existing natural drainage channel south of Cactus Avenue, which drains to Lake Perris (see Figure C.5).

C.1.3 Project Funding and Construction Time Line

The total project cost was $5,957,151. Fifty percent of the project investment was provided by FEMA under HMGP Project Number 0979-0032. The remainder of the project was funded with local government funds as a match (FEMA, 2006b).

The construction of the project was completed in four phases.

- Phase 1: Installation of the RCP from Cactus Avenue to Alessandro Boulevard



Nason Detention Basin Site Location
Loss Avoidance Study for Southern California
Legend
Site Selection
Rivers (Local)
Stream
Intermittent Stream
Canal
Dam
Major Rivers (States)
Major Rivers (National)
Limited Access
Highway
Major Road
Local Road
Minor Road
Other Road
Ramp
Ferry
Pedestrian Way
Railroads (Local)
N
E
S
W
0 0.5 1 2 3 4
Miles
Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California.
Internal Use Only.
FEMA
1577-DR-CA
April 10, 2007
File: Nason_Site_Location
0979-0032
Nason Detention Basin
Redlands
Loma Linda
Grand Terrace
Highgrove
Riverside
Univ Of California Riverside
Moreno Valley
March Air Reserve Base
March AFB
Riverside National Cemetery
Perris
Woodcrest
10
60
215
91

Figure C.1

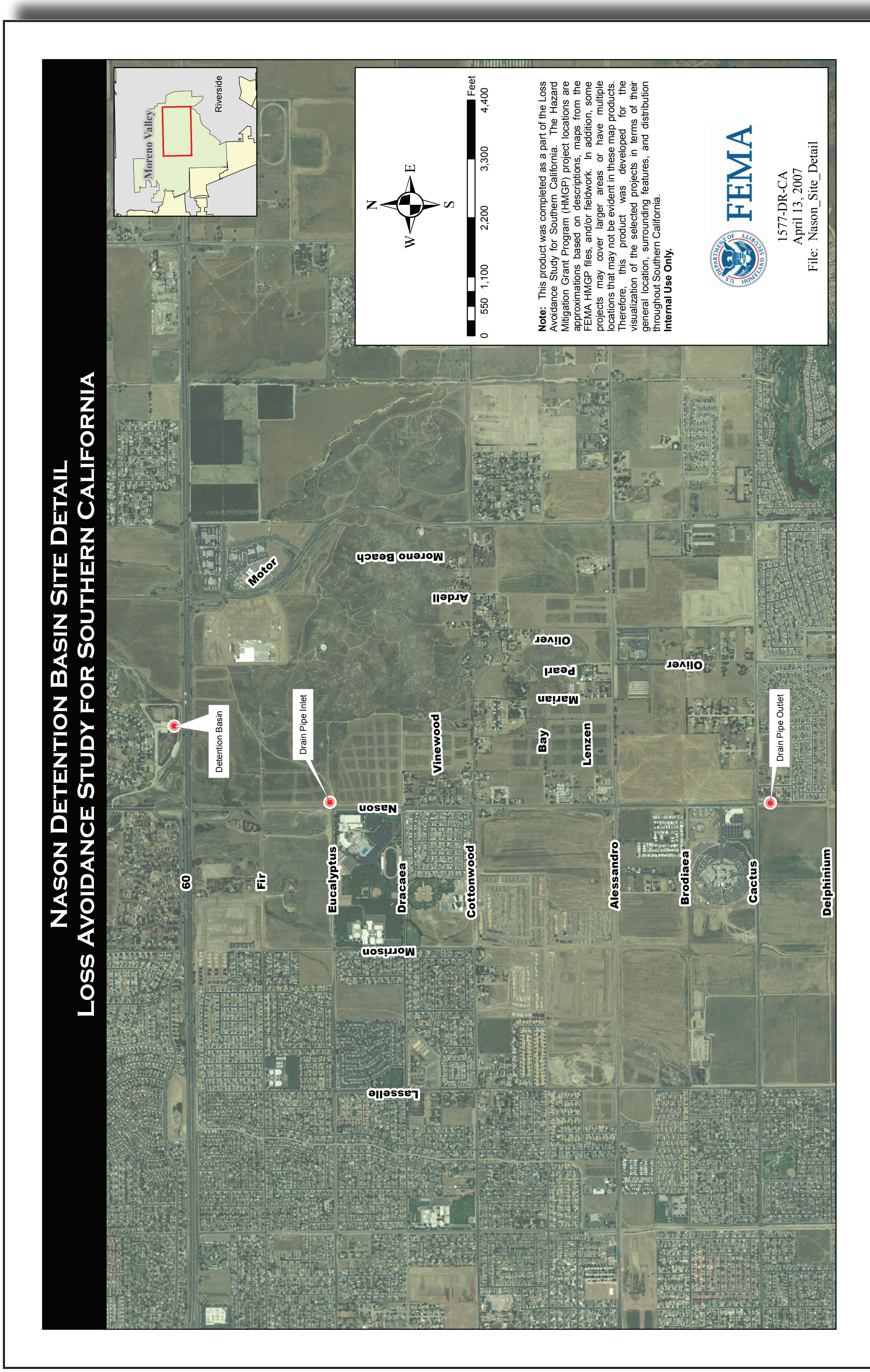

Nason Detention Basin Site Detail
Loss Avoidance Study for Southern California
Moreno Valley
Riverside
Detention Basin
Drain Pipe Inlet
Drain Pipe Outlet
60
Fir
Eucalyptus
Dracaea
Cottonwood
Alessandro
Brodiaea
Cactus
Delphinium
Nason
Morrison
Lasselle
Vinewood
Bay
Lenzen
Marian
Pearl
Oliver
Oliver
Ardell
Moreno Beach
Motor
N
S
E
W
0 550 1,100 2,200 3,300 4,400
Feet
Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California.
Internal Use Only.
FEMA
1577-DR-CA
April 13, 2007
File: Nason_Site_Detail

Figure C.2

- Phase 2: Extension of the RCP from Alessandro Boulevard to Dracaea Avenue
- Phase 3: Completion of the RCP from Dracaea Avenue to Eucalyptus Avenue
- Phase 4: Construction of the Nason Detention Basin

All phases of construction were complete before January 2003. The subsequent closeout of the project was completed on October 22, 2003.

Figure C.3

C.2 Data Collection

The LAT conducted a detailed review of the project file and noted the additional data that was needed in order to prepare for the analysis of the Nason Detention Basin project. In addition, an initial site visit with the Riverside County Flood Control and Water Conservation District was completed to gather site-specific information related to past flooding, discuss the project, assess the site condition (topography, drainage features, and structure types), and obtain photo documentation of the site. Local Officials provided various documents, including the *Moreno Master Drainage Plan*, to assist in completing the analysis of the projects effectiveness.

C.3 Physical Parameter Analysis

C.3.1 Storm Event Analysis

Weather data were obtained from the Riverside County ALERT system in order to identify candidate storm events for analysis. Riverside County ALERT data were obtained from ALERT station Moreno-Clark, located at latitude 33.9427, longitude -117.1826,

Figure C.4

approximately 0.2 miles from the project site. The maximum MP_C, 24-hour rainfall recorded at this gage was 2.81 inches on March 16, 2003. Using NOAA's 1973 *Precipitation Frequency Atlas of the Western United States,* the LAT estimated this event to have a recurrence interval of two to five years (Miller et al., 1973). However, local officials did not observe any actual damage during this event.

C.3.2 Hydrologic Analysis

Hydrologic data was obtained from the design information, as presented in the report *Preliminary Hydrology and Hydraulics for the Moreno Master Drainage Plan Nason Street Detention Basin, 2001* (FEMA, 2001). The original digital HEC-1 model that represented MP_A conditions was included with the design information. The HEC-1 data that were

Figure C.5

used in the original report reflected a theoretical 24-hour, 100-year storm event.

To reflect the actual rainfall that occurred during the March 16, 2003, event, the 24-hour total precipitation that was used in the original HEC-1 model was modified to reflect that actual event, including the actual 1-hour increments recorded by the ALERT gage. Results of the modified hydrologic analysis indicated a maximum peak flow rate of 307 cfs for the MP_A scenario. This flow rate, which represents the discharge for the watershed in the vicinity of Cactus Avenue, was used to represent the peak flow throughout the project site.

C.3.3 Hydraulic Analysis

A hydraulic model representing the MP_A scenario was not available. Therefore, a hydraulic model was developed using HEC-RAS to determine if the channel had sufficient capacity for the March 16, 2003, event, and to determine the extent and depth of out-of-bank flooding.

Topographic data for the MP_A scenario were available from the following sources:

- The Riverside County Flood Control and Water Conservation District provided 4-foot contour mapping prepared in 2001 for the entire project area in microstation format.
- Construction drawings, in microstation format, were available for Phases 2 and 3 of the project, including 1-foot contour mapping prepared in 1996 for the reach between Eucalyptus Avenue and Alessandro Boulevard.

The hydraulic analysis for the MP_A scenario showed that, for the March 16, 2003, storm:

- Drainage channels from Cottonwood Avenue to Alessandro Boulevard would have been insufficient to carry the peak runoff. All other reaches of the drainage channels for the project area would have had sufficient capacity for the event.
- Nason Street would have served as the main flow channel, with flooding outside of the road right-of-way near the Alessandro Boulevard intersection.
- Flood depths would have reached up to five feet.
- Flow velocities would have been between two and five feet per second.

C.3.4 Flood Boundary Analysis

There was no flood boundary analysis available in the project files for either the MP_A or MP_C scenarios. Existing flood boundary information is shown on FIRM Number 0650740025B, dated May 17, 1993 for the City of Moreno Valley. The FIRM shows the project area to be in Zone X, an area of minimal to non-existent flood hazard (FEMA, 1993). Consequently, a flood boundary analysis for the MP_A scenario was performed using the hydraulic model for the March 16, 2003, storm event from Cottonwood Avenue to Alessandro Boulevard. Flood elevations were mapped using the above-referenced 1- and 4-foot contour mapping.

Figure C.6 provides an illustration of the MP_A flood boundary analysis results. As illustrated, street flooding would have occurred from Cottonwood Avenue to Alessandro Boulevard, with structure flooding near Alessandro Boulevard. The analysis also indicates that street flooding would have occurred along Nason Street from Cottonwood Avenue to Alessandro Boulevard, with structure flooding near Alessandro Boulevard. Additionally, flooding could be expected in residential structures located at:

- 13920 Nason Street – approximately 1.0 feet
- 13940 Nason Street – approximately 0.1 feet

All other structures within the study area are located sufficiently above and away from the flooding and would not have been inundated.

C.4 Loss Estimation Analysis

Table C.1 displays the results of the loss estimation analysis for the MP_A and MP_C scenarios by loss category and loss type. Various methods were utilized and are detailed below to determine MP_A damages. However, there was no cause to determine MP_C damages as the project was found to be completely effective in the March 2003 storm event. Details on the figures summarized in Table C.1 are discussed in the following sections, with calculation details being provided in Attachments C.1 through C.4.

C.4.1 Physical Damage

As shown in the Flood Boundary Analysis two residences, 13920 Nason Street and 13940 Nason Street, and Nason Street itself would have been inundated in the MP_A scenario. As a result, physical damage costs were calculated for each structure and its contents and for road

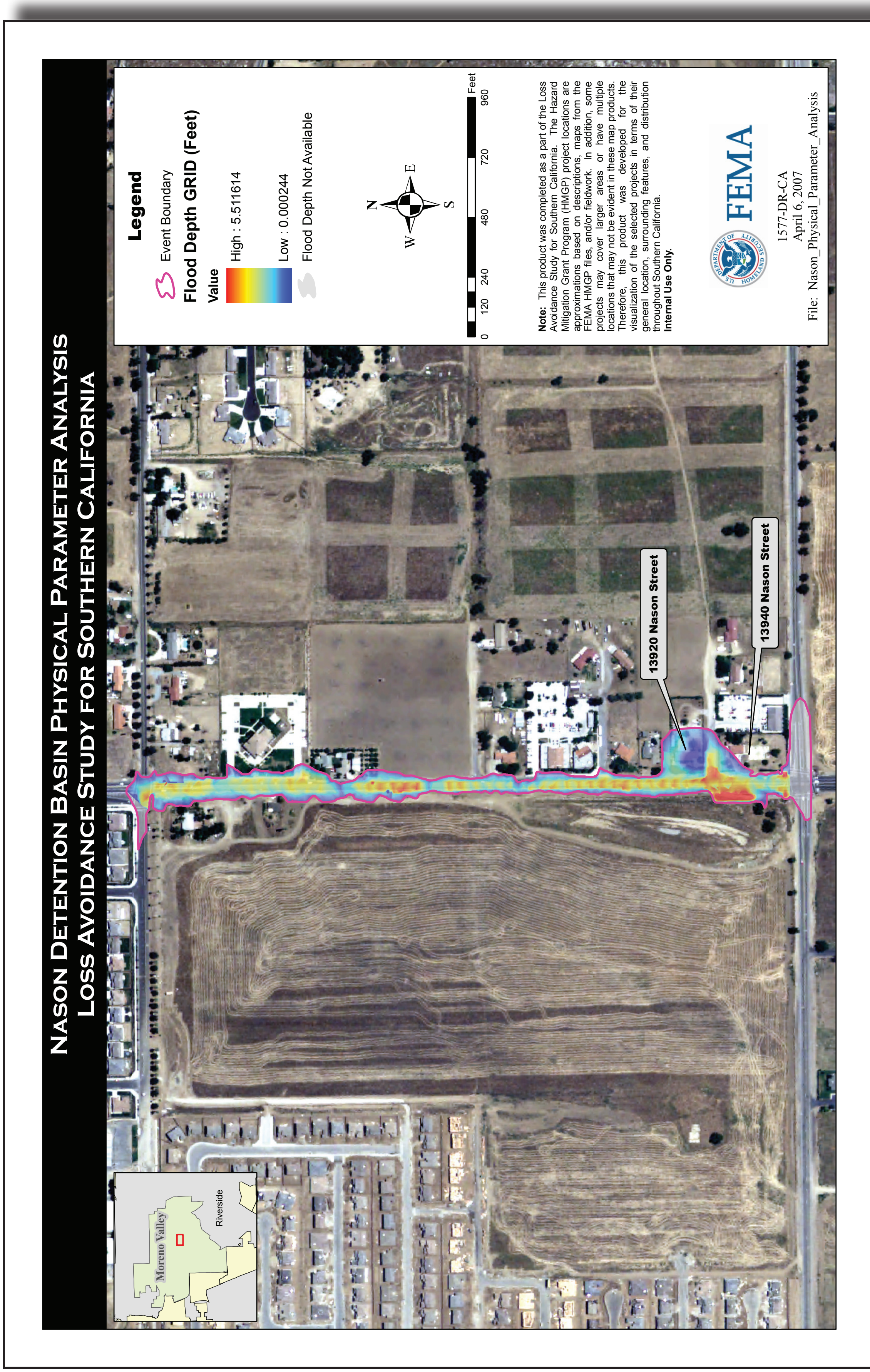

Nason Detention Basin Physical Parameter Analysis
Loss Avoidance Study for Southern California
Legend
Event Boundary
Flood Depth GRID (Feet)
Value
High : 5.511614
Low : 0.000244
Flood Depth Not Available
N
E
S
W
0 120 240 480 720 960
Feet
Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California.
Internal Use Only.
FEMA
1577-DR-CA
April 6, 2007
File: Nason_Physical_Parameter_Analysis
13920 Nason Street
13940 Nason Street
Moreno Valley
Riverside

Figure C.6

Table C.1

Loss Estimation Analysis Results
Nason Detention Basin

Loss Type	MP_A Scenario Losses[1]	MP_C Scenario Losses[1]	Losses Avoided[1]	Comments
Physical Damage				
Structure	$74,865	$0	**$74,865**	• 1.0 ft flooding at 13920 Nason Street • 0.1 ft flooding at 13940 Nason Street • Applied HAZUS-MH depth-damage curve for RES1[2] • Replacement value based on RSMeans (Mewis, 2006)
Contents	$82,441	$0	**$82,441**	• Contents value and damage based on FEMA BCA defaults (FEMA, 2006c)
Roads and Bridges	$20,794	$0	**$20,794**	• Damages scaled from historical damages in project file
Infrastructure	$0	$0	**$0**	• Not predicted, not indicated in project file
Landscaping	$0	$0	**$0**	• Not predicted, not indicated in project file
Environmental Impacts	$0	$0	**$0**	• Not predicted, not indicated in project file
Vehicles/Equipment	$0	$0	**$0**	• Not predicted, not indicated in project file
Subtotal	***$178,100***	***$0***	***$178,100***	
Loss of Function				
Displacement Expense	$5,505	$0	**$5,505**	• Based on HAZUS-MH methods
Loss of Rental Income	$0	$0	**$0**	• No residential rental properties impacted
Loss of Business Income	$1,210	$0	**$1,210**	• Based on HAZUS-MH methods
Lost Wages	$2,852	$0	**$2,852**	• Based on HAZUS-MH methods
Disruption Time for Residents	$3,411	$0	**$3,411**	• Based on HAZUS-MH methods
Loss of Public Services	$0	$0	**$0**	• Not predicted, not indicated in project file
Economic Impact of Utility Loss	$0	$0	**$0**	• Not predicted, not indicated in project file
Economic Impact of Road/Bridge Closure	$65,115	$0	**$65,115**	• FEMA BCA traffic delay method based on delay time, number of vehicles, and lost income per vehicle • Average delay estimated at 3.5 minutes
Subtotal	***$78,093***	***$0***	***$78,093***	
Emergency Management				
Debris Cleanup	$1,980	$0	**$1,980**	• Costs scaled from historical damages in project file
Governmental Expense	$2,531	$0	**$2,531**	• Costs scaled from historical damages in project file
Subtotal	***$4,511***	***$0***	***$4,511***	
Total	***$260,704***	***$0***	***$260,704***	

[1] All amounts rounded to the nearest dollar
[2] Residential Type 1 (Single Family Dwelling)

and bridge damage. The structure and contents damages for the MP_A scenario were estimated based on the flood depths at each structure (provided in Section C.3.4). Both structures can be classified as one-story residential structures; however, the structure at 13920 is used as a religious facility. Estimates for structure replacement values were based on RSMeans square footage values, Riverside County tax parcel data, and observations obtained during a site visit by the LAT (see Attachment C.2). For 13940 Nason Street, the estimate for contents values were based on the FEMA BCA Module default for residential structures; under this option, the value of contents is 30% of the structure replacement value. However, because 13920 Nason Street is used as a religious facility, the FEMA BCA Module business default was used. Under this option, the value of contents is 100% of the structure replacement value. The HAZUS-MH MR2 depth-damage function for damages to Residential Type 1 (Single Family Dwelling) was used to estimate the percent of damage associated with the flood depths at each structure (see Attachment C.3). These methods produced estimations of structure damages at $74,865 and content damages at $82,441 (see Attachment C.1).

Flood damage to the pavement on Nason Street was based on pavement damage information provided in the project files for a 1993 flood caused by a rainfall event of between 1.5 and 2.3 inches. This flood resulted in pavement washout and roadside channel damage. The costs from the 1993 event, which total $20,794, were assumed to be approximately the same as those that would have been incurred by the March 16, 2003, event under the MP_A scenario.

Total estimated physical losses for the MP_A scenario were determined to be $178,101 (see Table C.1). There was no observed physical damage for the MP_C event on March 2003 event, so estimated MP_C physical losses were determined to be $0. As a result, the avoided losses for physical damage were $178,101.

C.4.2 Loss of Function

Costs due to loss of function result from displacement of the occupants of flooded residences, disruption to the lives of those occupants, loss of business income, and costs associated with the closure of Nason Street. The estimation of losses for each of these elements is detailed below.

The flooding of residences, and the time necessary to repair the damage to the residences, would result in displacement of the occupants and costs to them as a result of this disruption. Using the

FEMA BCA Module, which relates percent of structure damage to structure repair time, the displacement at 13920 Nason Street was estimated to be 63.5 days and the displacement at 13940 Nason Street was estimated to be 42.6 days. Using HAZUS-MH MR2 methods, displacement costs for the two flooded structures were estimated to be $5,505 (see Attachment C.1).

Disruption costs to the residents at 13940 Nason Street were estimated to be $3,411. The religious establishment at 13920 Nason Street would also have functional downtime while a suitable alternative facility was located. Using FEMA BCA methods, this functional downtime was estimated to be 12 days. This disruption would result in lost income of $1,210 and lost wages of $2,852 (see Attachment C.1).

Flooding on Nason Street under the MP_A scenario would have produced road closures for two days – one day while the flooding occurred and one day for debris cleanup. Based on local traffic patterns and detailed traffic counts provided by local officials, it was estimated that 12,800 vehicles a day would encounter an average traffic delay of approximately 3.5 minutes (City of Moreno Valley, 2004) (see Attachment C.4). Using the FEMA BCA Module, which estimates lost wages to people in delayed vehicles, loss of function damages due to traffic delays were estimated to be $65,115 (see Attachment C.1).

No loss of function was observed for the actual MP_C event. Therefore, losses avoided for loss of function costs were determined to be $78,903 (see Table C.1).

C.4.3 Emergency Management

For this project, emergency management costs include debris cleanup and governmental costs. Flooding conditions and emergency management costs expected for the MP_A scenario were assumed to be similar to those experienced during the 1993 event. The project files indicated that, for the 1993 flood event, debris cleanup on Nason Street was completed at a cost of $1,980. A cost for the local government to provide police and public works personnel to close off and repair the road was assumed. This was estimated to be 10% of total local government costs for debris cleanup and road repair, or $2,530 (see Attachment C.1). There were no emergency management costs for the MP_C storm event on March 2003. Therefore, losses avoided for emergency management were $4,510 (see Table C.1).

C.4.4 Results Summary

For the March 2003 storm event, losses avoided due to the construction of the project total $260,704 (see Table C.1). When compared to the project cost of $5,957,151 this represents a ROI of 4%. However, it is expected that the ROI will increase as additional storm events, of this magnitude or greater, test the project's effectiveness.

Losses in Project File and Loss Calculations, Part 1
Nason Detention Basin

Event	Physical Damage: Structure	Contents	Roads and Bridges	Infrastructure	Landscaping	Environmental Impacts	Vehicles/ Equipment	Comments
January 1993 (MP_A)	$74,865	$82,441	$25,305 ($20,794)	$0	$0	$0	$0	***Structure*** • 13920 Nason 22.0% damaged, $42,687 • 13940 Nason 18.0% damaged, $32,178 ***Contents*** • 13920 Nason 34.0% damaged, $65,964 • 13940 Nason 31.0% damaged, $16,477 ***Roads and Bridges*** • Total cost of shoulder replacement, repaving, debris cleanup along Nason, and governmental expense
March 2003 (MP_C)	$0	$0	$0	$0	$0	$0	$0	

Event	Loss of Function: Displacement Expense	Loss of Rental Income	Loss of Business Income	Lost Wages	Disruption Time for Residents	Loss of Public Services	Economic Impact of Utility Loss	Economic Impact of Road/Bridge Closure	Comments
January 1993 (MP_A)	$5,505	$0	$1,210	$2,852	$3,411	$0	$0	$65,115	***Displacement Expense*** • 13920 Nason, $0.030967742 per square foot per day, 63.5 days, $3,810 • 13940 Nason, $0.020645161 per square foot per day, 42.6 days, $1,695 ***Disruption Time for Residents*** • 13920 Nason, $0.949677415 per square foot, $1,840 • 13940 Nason, $0.815483867 per square foot, $1,571 ***Loss of Business Income*** • $0.130064516 per square foot per day, 12 days ***Lost Wages*** • $0.306580644 per square foot per day, 12 days ***Economic Impact of Road/Bridge Closure*** • See *Travel Delay Calculations* attachment
March 2003 (MP_C)	$0	$0	$0	$0	$0	$0	$0	$0	

Losses in Project File and Loss Calculations, Part 2
Nason Detention Basin

Event	Loss Type		Comments
	Emergency Management		
	Debris Cleanup	*Governmental Expense*	
January 1993 (MP_A)	$1,980	$2,531	***Debris Cleanup*** • Scaled from project files and subtracted from road and bridge repair costs ***Governmental Expense*** • 10% of road and bridge repair costs and debris cleanup costs are assumed to be governmental expenses
March 2003 (MP_C)	$0	$0	

All amounts are adjusted for 2006 dollars and rounded to the nearest dollar.

Study Area Parcel Information, Part 1
Nason Detention Basin

Parcel ID	Address	Elevation	Year Built	Built sq ft	Structure Description	Floors	Garage	Basement	RSMeans Class	RSMeans Type	Exterior	Base Cost (per sq ft)	Garage Cost	Location Factor	Replacement Value	Contents Value
477-210-128-9	13920 Nason	1601/1601 ft	1979	1811	Stucco on wood, 4 bdrm/1.75 bath, 1 story, garage, tile roof, central heat and cooling	1	528 sq ft	No	Average	Average, 1-story	Stucco on Wood	$90.67	$17,135	1.07	$194,034	$194,034
477-210-035-5	13940 Nason	1594/1598 ft	1985	1800	Base year: 1985	1	No	No	Average	Average, 1-story	Stucco on Wood	$90.80	$0	1.07	$174,881	$52,464

Study Area Parcel Information, Part 2
Nason Detention Basin

Parcel ID	Address	Replacement Value	Contents Value	Flood Depth (ft)	Structure Damage Ratio	Contents Damage Ratio	Structure Damage	Contents Damage	Displacement Time (days)	Displacement Costs	Disruption Costs
477-210-128-9	13920 Nason	$194,034	$194,034	1.0	0.22	0.34	$42,687	$65,964	63.5	***$3,810***	***$1,840***
477-210-035-5	13940 Nason	$174,881	$52,464	0.1	0.18	0.31	$32,178	$16,477	42.6	***$1,695***	***$1,571***
TOTAL		***$184,458 (avg)***	***$123,249 (avg)***				***$74,865***	***$82,441***		***$5,505***	***$3,411***

HAZUS-MH Damage - RES1

Nason Detention Basin

Occupancy	Specific Occupancy ID	Source	Description	Stories	Comment	Default Function	Editable	Selected	-4 ft -4.00	-3 ft -3.00	-2 ft -2.00	-1 ft -1.00	0 ft 0.00	1 ft 1.00	2 ft 2.00	3 ft 3.00	4 ft 4.00	5 ft 5.00	6 ft 6.00	7 ft 7.00	8 ft 8.00	9 ft 9.00	10 ft 10.00	11 ft 11.00	12 ft 12.00	13 ft 13.00
RES1	R11N	FIA	one floor, no basement, structure, A-Zone	1 Story		1			0.00	0.00	0.00	0.00	18.00	22.00	25.00	28.00	30.00	31.00	40.00	43.00	43.00	45.00	46.00	47.00	47.00	49.00
RES1	R11B	FIA (Mod.)	one floor, with basement, structure, A-Zone	1 Story		1			7.00	7.00	7.00	11.00	17.00	21.00	29.00	34.00	38.00	43.00	50.00	50.00	54.00	55.00	55.00	57.00	58.00	60.00
RES1	R12N	FIA	two floor, no basement, structure, A-Zone	2 Story		1			0.00	0.00	0.00	0.00	11.00	12.00	14.00	18.00	20.00	22.00	24.00	26.00	30.00	34.00	38.00	39.00	40.00	42.00
RES1	R12B	FIA (Mod.)	two floor, with basement, structure, A-Zone	2 Story		1			4.00	4.00	8.00	14.00	19.00	21.00	26.00	29.00	34.00	39.00	44.00	50.00	55.00	57.00	59.00	61.00	63.00	65.00
RES1	R13N	FIA	three or more floors, no basement, structure, A-Zone	3 Story		1			0.00	0.00	0.00	0.00	5.00	8.00	12.00	17.00	19.00	22.00	24.00	25.00	30.00	35.00	38.00	39.00	40.00	42.00
RES1	R13B	FIA (Mod.)	three or more floors, with basement, structure, A-Zone	3 Story		1			3.00	3.00	6.00	10.00	12.00	14.00	20.00	25.00	31.00	36.00	38.00	41.00	44.00	48.00	50.00	52.00	54.00	56.00
RES1	R1SN	FIA	split level, no basement, structure, A-Zone	Split Level		1			0.00	0.00	0.00	0.00	3.00	9.00	13.00	25.00	27.00	28.00	33.00	34.00	41.00	43.00	45.00	46.00	47.00	48.00
RES1	R1SB	FIA (Mod.)	split level, with basement, structure, A-Zone	Split Level		1			6.00	6.00	9.00	14.00	15.00	24.00	27.00	30.00	35.00	400.00	43.00	44.00	52.00	56.00	58.00	60.00	62.00	64.00

Occupancy	Specific Occupancy ID	Source	Description	Stories	Comment	Default Function	Editable	Selected	14 ft 14.00	15 ft 15.00	16 ft 16.00	17 ft 17.00	18 ft 18.00	19 ft 19.00	20 ft 20.00	21 ft 21.00	22 ft 22.00	23 ft 23.00	24 ft 24.00	ID	Basement	Hazard Riverine	Hazard CV	Hazard CA
RES1	R11N	FIA	one floor, no basement, structure, A-Zone	1 Story		1			50.00	50.00	50.00	51.00	51.00	52.00	52.00	53.00	53.00	54.00	54.00	105		1		1
RES1	R11B	FIA (Mod.)	one floor, with basement, structure, A-Zone	1 Story		1			62.00	63.00	65.00	67.00	69.00	70.00	72.00	74.00	76.00	77.00	79.00	106	1	1		1
RES1	R12N	FIA	two floor, no basement, structure, A-Zone	2 Story		1			43.00	44.00	45.00	47.00	48.00	49.00	50.00	52.00	53.00	54.00	56.00	107		1		1
RES1	R12B	FIA (Mod.)	two floor, with basement, structure, A-Zone	2 Story		1			66.00	68.00	69.00	71.00	72.00	74.00	75.00	77.00	79.00	80.00	82.00	108	1	1		1
RES1	R13N	FIA	three or more floors, no basement, structure, A-Zone	3 Story		1			43.00	44.00	45.00	47.00	48.00	49.00	50.00	52.00	53.00	54.00	56.00	109		1		1
RES1	R13B	FIA (Mod.)	three or more floors, with basement, structure, A-Zone	3 Story		1			57.00	59.00	61.00	63.00	65.00	67.00	69.00	71.00	73.00	75.00	77.00	110	1	1		1
RES1	R1SN	FIA	split level, no basement, structure, A-Zone	Split Level		1			49.00	50.00	51.00	52.00	53.00	54.00	55.00	56.00	57.00	58.00	59.00	111		1		1
RES1	R1SB	FIA (Mod.)	split level, with basement, structure, A-Zone	Split Level		1			66.00	68.00	70.00	72.00	74.00	76.00	78.00	81.00	83.00	85.00	87.00	12	1	1		1

Travel Delay Calculations[1]
Nason Detention Basin

1. Daily Volume of Traffic Flow[2]

Detour: Nason Street - **12,800 VPD**

2. Average Delay or Detour Time per Vehicle

Nason Street Delay

Segment	*VPD*	*Delay (Min)*	*Hours/day*
North Nason to East Cottonwood	*810.3*	2.7000	36.463
North Nason to East Alessandro	*1253.7*	2.8000	58.525
North Nason to South Nason	*99.7*	4.4833	7.447
North Nason to West Alessandro	*1636.4*	2.8166	76.818
East Cottonwood to North Nason	*1439.7*	2.7000	64.787
East Cottonwood to East Alessandro	*4.3*	0.1000	0.007
East Cottonwood to South Nason	*0.3*	2.9000	0.017
East Cottonwood to West Alessandro	*5.6*	4.5667	0.429
East Cottonwood to West Cottonwood	*600*	5.4333	54.333
West Cottonwood to East Cottonwood	*600*	5.4333	54.333
East Alessandro to North Nason	*1095.2*	2.8000	51.108
East Alessandro to East Cottonwood	*296.8*	0.1000	0.495
East Alessandro West Alessandro	*1608.0*	4.4667	119.707
South Nason to North Nason	*78.7*	4.4833	5.879
South Nason to East Cottonwood	*21.3*	2.9000	1.031
West Alessandro to North Nason	*1186.4*	2.8167	55.697
West Alessandro to East Cottonwood	*321.6*	4.5667	24.474
West Alessandro to East Alessandro	*1742.0*	4.4667	129.682
Normal	**12800**	**3.5**	**742.21**
Congestion factor: Allowed for additional congestion			10%
Delay Duration: 1 day flooding, 1 day debris cleanup = *2 days*		***Vehicle hours per day***	***815.33***

3. Economic Impact of Delay

$39.9314704227
per vehicle hour

Total Delay Cost (2006 $) ***$65,114.88***

[1] General Methodology from "What is a Benefit?" document in FEMA BCA Toolkit, Version 3.0
[2] Vehicles per day

Appendix D:

Federal Boulevard Drainage Improvements

Project: 1008-6063

TABLE OF CONTENTS:

LIST OF FIGURES AND TABLES

Appendix D:

Project: 1008-6063

Federal Boulevard Drainage Improvements

D.1 General Project Information

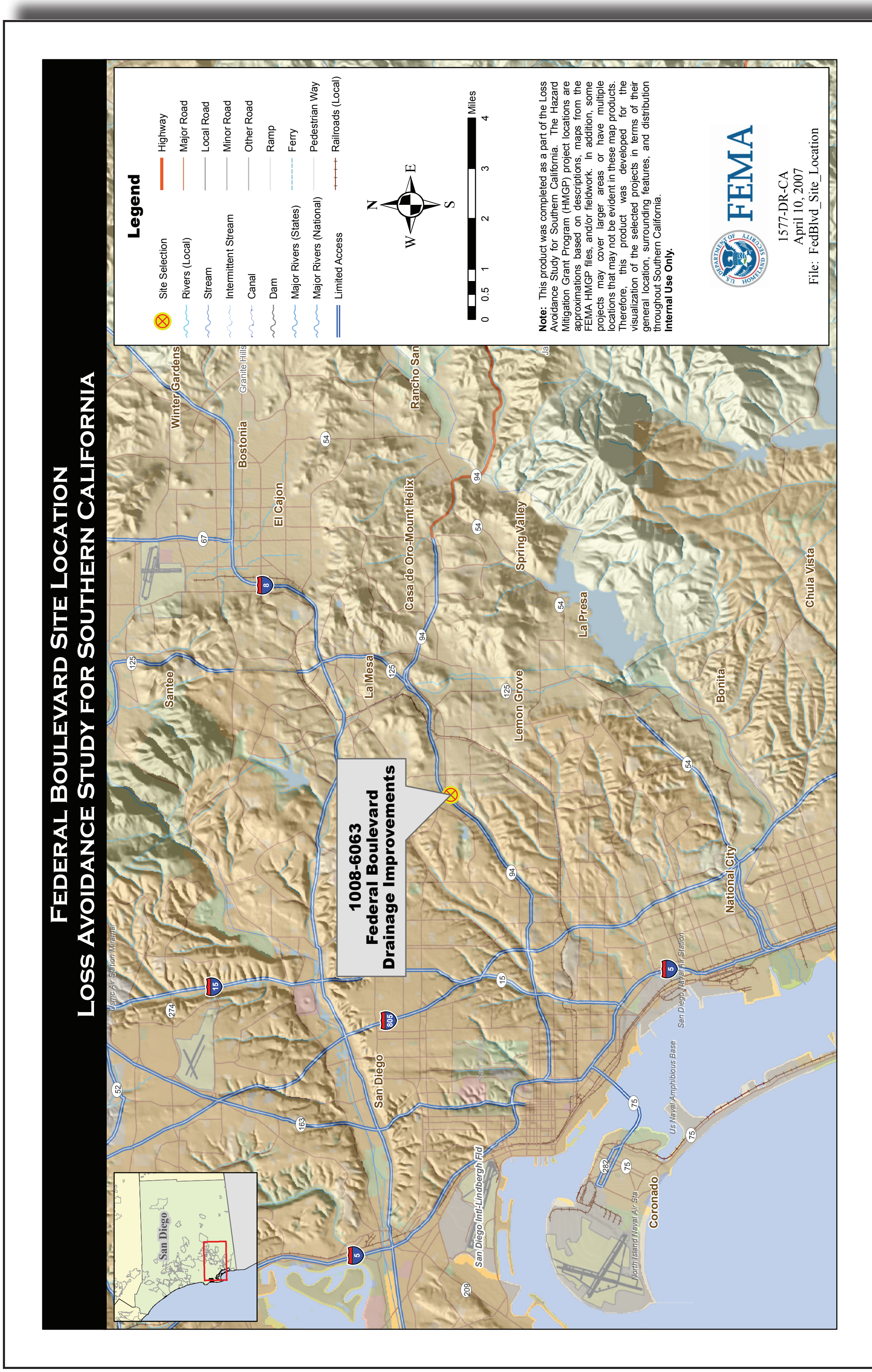
D.1.1 Project Location

As illustrated in Figure D.1, the Federal Boulevard Drainage Improvement project is located in the City of Lemon Grove, San Diego County, California. The site is specifically located immediately southeast of SR 94 along Federal Boulevard. The northern upstream extent of the project is located near College Avenue with the southern, downstream extent ending at Central Avenue (see Figure D.2).

D.1.2 Project Description

Federal Boulevard is an arterial highway lined with commercial and light industrial properties. It was originally constructed in the 1940s with a minimal storm drainage system, consisting of roadside drainage ditches with roadway culvert crossings. The area north and west of SR 94 has seen substantial development. Runoff from north of SR 94, which previously discharged directly onto Federal Boulevard, is conveyed under the highway by three storm drain pipes constructed prior to this mitigation project. The watershed north of SR 94 contributes approximately 75% of the total runoff along Federal Boulevard within the project limits. The discharge of this runoff onto the west side of Federal Boulevard caused roadway flooding during moderate to heavy rainfall events due to limited roadway drainage capacity and the fact that the roadside drainage ditch was located on the opposite side of the road. According to city officials, the road typically experienced four to 18 inches of flooding during heavy rains. The Federal Boulevard drainage system had a pre-project capacity sufficient to convey a storm event with a 2-year return period. In 1995, flood-related losses along Federal Boulevard included property damage to abutting businesses, periodic road closures, road repairs, costs associated with emergency protective measures, and economic losses.

Due to the frequency of flooding along Federal Boulevard, the City of Lemon Grove initiated mitigation activities to reduce or eliminate the risk associated with flooding in the area. The mitigation project consisted of the construction of approximately 1,700 feet of 60- to 66-inch diameter RCP along the east side of Federal Boulevard, with three lateral pipes that cross Federal Boulevard to the west and connect to existing storm drain pipes draining the area west of SR


Federal Boulevard Site Location
Loss Avoidance Study for Southern California
1008-6063
Federal Boulevard
Drainage Improvements
Legend
Site Selection
Rivers (Local)
Stream
Intermittent Stream
Canal
Dam
Major Rivers (States)
Major Rivers (National)
Limited Access
Highway
Major Road
Local Road
Minor Road
Other Road
Ramp
Ferry
Pedestrian Way
Railroads (Local)
N
E
S
W
0 0.5 1 2 3 4 Miles
Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California.
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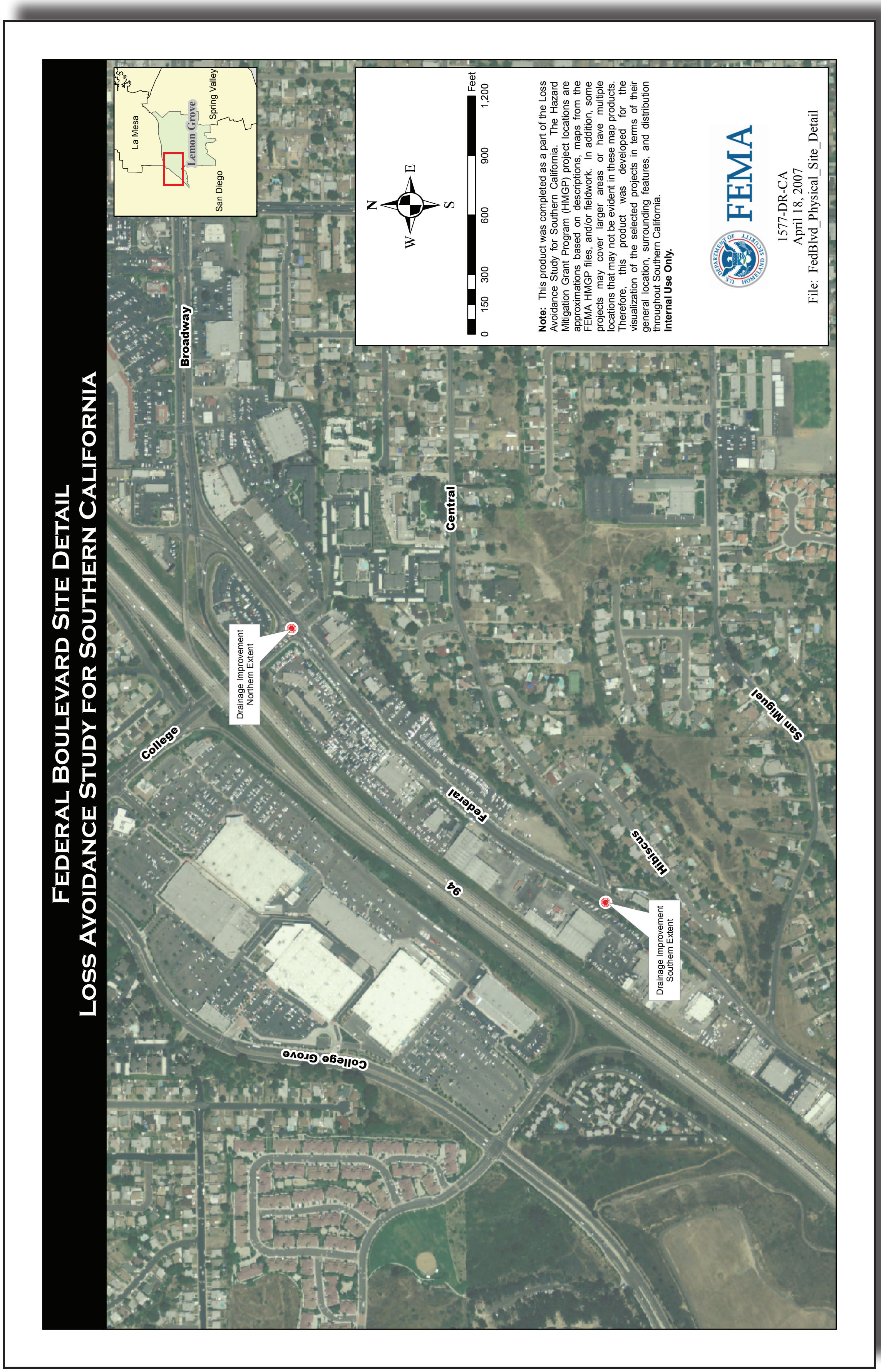
April 10, 2007
File: FedBlvd_Site_Location
San Diego
Santee
Winter Gardens
Bostonia
Granite Hills
El Cajon
Rancho San
La Mesa
Casa de Oro-Mount Helix
Spring Valley
Lemon Grove
La Presa
Bonita
Chula Vista
National City
Coronado
San Diego Intl-Lindbergh Fld
North Island Naval Air Sta
Us Naval Amphibious Base
San Diego Naval Air Station

Figure D.1


Federal Boulevard Site Detail
Loss Avoidance Study for Southern California
La Mesa
Lemon Grove
Spring Valley
San Diego
Broadway
Central
College
Federal
94
Hibiscus
San Miguel
College Grove
Drainage Improvement Northern Extent
Drainage Improvement Southern Extent
N
E
S
W
0 150 300 600 900 1,200 Feet
Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California. Internal Use Only.
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1577-DR-CA
April 18, 2007
File: FedBlvd_Physical_Site_Detail

Figure D.2

94 (see Figure D.3). The project was designed to collect runoff from the SR 94 cross culverts and local runoff from the properties and roadway along Federal Boulevard. The project, which is designed with the capacity to contain runoff from a 100-year rainfall event, conveys runoff through the underground storm drain system to the open channel south of Central Avenue; the open channel then drains into Los Chollas Creek. Since the time of project completion, Federal Boulevard has not been subject to any road closures, and the businesses fronting the road have not been flooded.

Figure D.3

D.1.3 Project Funding and Construction Time Line

The total project cost was $621,619. Seventy-five percent of the investment was provided by FEMA under HMGP Project Number 1008-6063 with the remainder of the project being funded with local funds. Project construction began in September 2001 and was completed in August 2002. Subsequent closeout of the project was on December 31, 2002.

D.2 Data Collection

In order to prepare for the analysis of the Federal Boulevard Drainage Improvements project, the LAT completed a review of the HMGP project files, noting the data that was available and the data that required further research. In addition, the LAT conducted an initial site visit with City of Lemon Grove to gather site-specific information related to past flooding, discuss the project with city personnel, assess the site condition (including topography, drainage features, and structure types), determine whether additional project information was available, and obtain photo documentation of the site. In an effort to assist with the data collection process, Lemon Grove officials provided supplemental design information, along with contact information for GIS data from San Diego County.

D.3 Physical Parameter Analysis

D.3.1 Storm Event Analysis

Two sources were utilized in identifying candidate storm events for the project, weather data were obtained from NWS and the County of San Diego ALERT system. San Diego County ALERT data were obtained from ALERT station 1560 at the La Mesa Fire Department, located at latitude 33.94275, longitude -117.1826, approximately 2.5 miles from the project site.

Based on the damage information provided in the HMGP application, damage to the Federal Boulevard area would have occurred for the MP_A scenario for storm events equal to, or greater than, a 3-year return event rainfall. According to the 2003 *San Diego County Hydrology Manual*, a 3-year return event rainfall is equal to approximately 2.2 inches of rainfall in 24 hours. Review of the rainfall data from the La Mesa ALERT station indicated that the storm of February 23, 2004 produced 2.32 inches of rainfall in a 24-hour period and was the only MP_C event to deliver a 24-hour rainfall total exceeding 2.2 inches. Lemon Grove city officials did not observe any MP_C damages for this event. However, because this rainfall exceeded the damage threshold of the original Federal Boulevard drainage system, there would have been MP_A damages from this event had the project not been in place.

D.3.2 Hydrologic Analysis

The hydrologic data used for the original project design consisted of hardcopy MRM spreadsheet calculations for the 100-year storm event for the area of Federal Boulevard between College Avenue and Central Avenue. The MRM calculations were based on the 1992 *County of San Diego Storm Drain Design Manual and Hydrology Manual,* which was used to size the project storm drains for Federal Boulevard.

A new hydrologic analysis was conducted to determine peak runoff generated by the February 23, 2004, storm event. The MRM analysis used for the project design was modified to reflect MP_A conditions, and the runoff was recalculated with the actual storm event rainfall values. Results of the hydrologic analysis indicated that a maximum peak flow rate in Federal Boulevard of 160 cfs would have occurred for the MP_A scenario. This peak flow rate is approximately half of the post-project, 100-year design flow rate of 320 cfs.

D.3.3 Hydraulic Analysis

The hydraulic data used for the original project design consisted of a hardcopy StormCAD v3.0[1] output. The analysis was used to determine the hydraulic grade line in the storm drain pipe for the 100-year storm event. No hydraulic modeling was performed for out-of-pipe flooding.

Topographic data for this project consisted of the following:

- Pre-project, 1-foot contour interval topography with spot elevations from "as-built" construction drawings for the mitigation project in hard copy format only
- Pre-project, 2-foot digital contour interval topography from 1992 and 1999, obtained from the San Diego Geographic Information Source (SanGIS)

To define the floodplain for the February 23, 2004, storm under the MP_A scenario, a HEC-RAS model was created using the pre-project, 1-foot contour interval topography from the record drawings. The modeling was performed along Federal Boulevard within the project limits only. Downstream of Central Avenue, project runoff combines with much heavier regional runoff from the Los Chollas Creek watershed, and the mitigating effects of the project are minimal.

Results of the hydraulic analysis for the February 23, 2004, storm indicate MP_A flow depths between approximately six and 24 inches, and flow velocities between one and 10 feet per second. Slight out-of-bank flooding was shown at many cross sections, so a flood boundary analysis was needed to determine if there would have been any MP_A damage.

D.3.4 Flood Boundary Analysis

The project files did not contain pre-project inundation modeling and the City of Lemon Grove did not prepare post-project inundation modeling. However, according to the drainage report included the HMGP project file, the City assumed the100-year flood would

[1] Developed by Haestad Methods, Inc.

be contained in the street and the underground storm drain pipe. In addition, flood boundary information was available from the countywide FIRM for San Diego County, which shows the City of Lemon Grove. Because the area in question is designated Zone A and was studied using approximate methods, it was assumed that detailed flood boundary information was not available.

A new flood boundary analysis was performed based on the results of the HEC-RAS hydraulic model for the February 23, 2004, storm event using the 1-foot contour interval record drawing topography and available aerial photographs. This analysis was limited to the area where improvements were constructed as the project was designed to alter flooding conditions in that area with little upstream or downstream effect. As illustrated in Figure D.4, the flood boundary indicates partial street flooding upstream of 6826 Federal Boulevard, and full street flooding downstream of 6826 Federal Boulevard to Central Avenue. The only structure that would have been impacted during the February 23, 2004, storm for the MP_A scenario was 6826 Federal Boulevard, which would have experienced a flood depth of approximately 0.5 feet. All other structures along Federal Boulevard within the project limits are located sufficiently above street level such that they would not have been impacted by this storm event. Based on this flood boundary and corresponding flood depth, it was determined that losses avoided could be calculated for the project.

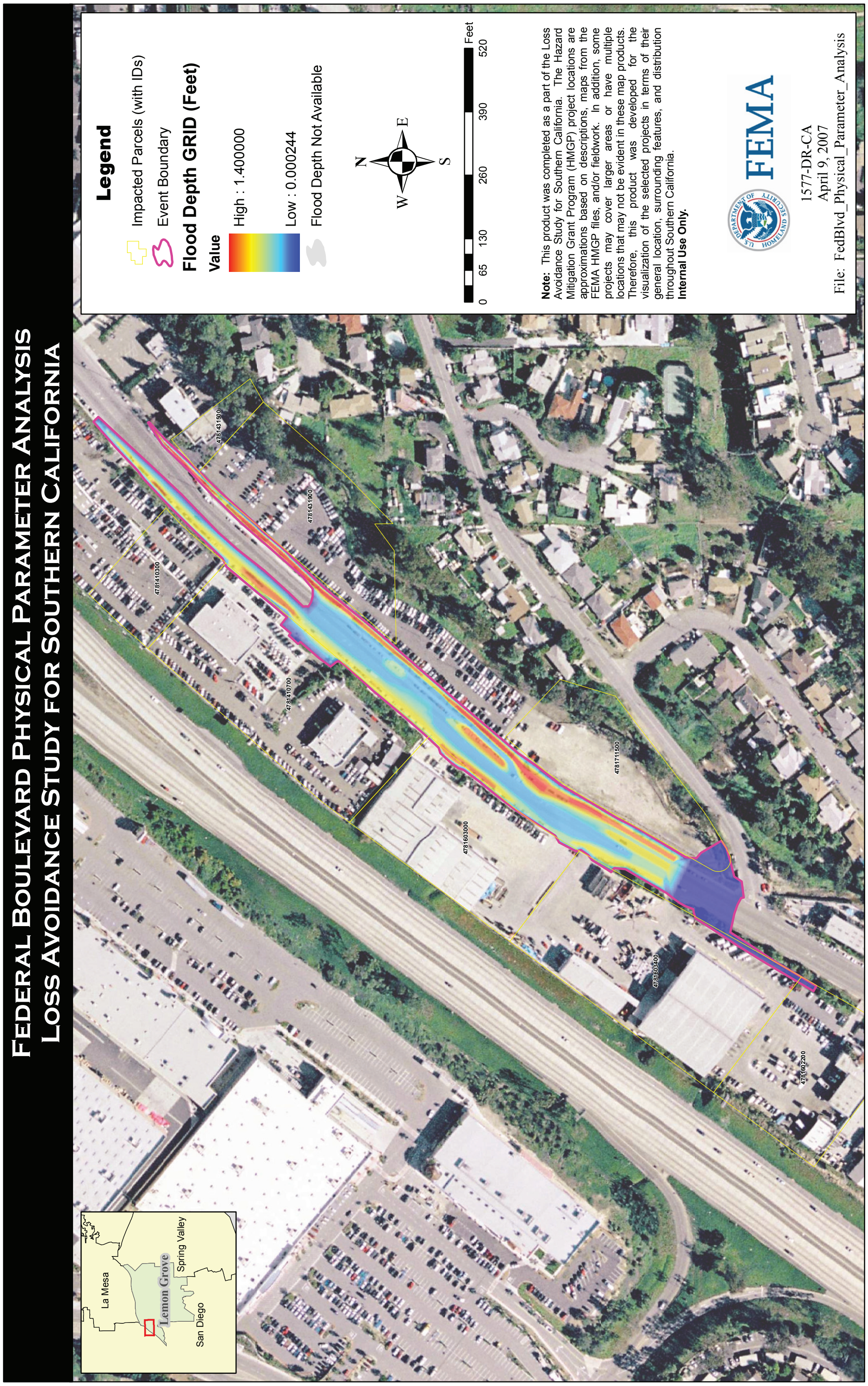
D.4 Loss Estimation Analysis

Table D.1 displays the results of the loss estimation analysis for both MP_A and MP_C scenarios by loss category and loss type. Various methods were utilized and are detailed below to determine MP_A damages. However, since the project was found to be completely effective in the February 2004 storm, there were no MP_C damages. Details on figures provided in Table D.1 are discussed in the following sections, with calculation details being provided in Attachments D.1 through D.5.

D.4.1 Physical Damage

As stated above, the flood boundary analysis indicated that damage would have occurred under the MP_A scenario and that losses avoided could be calculated for the Federal Boulevard project. The LAT conducted a second site visit to field check and confirm the analysis results, evaluate potentially flooded structures in terms of business and structure type, and document structure floor elevations in relation to adjacent grades.

The flood boundary analysis indicated the only structure that would have been damaged by flooding was the retail parts store and automotive repair facility for the Bob Baker Toyota Dealership


Federal Boulevard Physical Parameter Analysis
Loss Avoidance Study for Southern California
Legend
Impacted Parcels (with IDs)
Event Boundary
Flood Depth GRID (Feet)
Value
High : 1.400000
Low : 0.000244
Flood Depth Not Available
N
E
S
W
0 65 130 260 390 520
Feet
Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California.
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1577-DR-CA
April 9, 2007
File: FedBlvd_Physical_Parameter_Analysis
La Mesa
Lemon Grove
Spring Valley
San Diego

Figure D.4

Table D.1

Loss Estimation Analysis Results
Federal Boulevard

Loss Type	MP_A Scenario Losses[1]	MP_C Scenario Losses[1]	Losses Avoided[1]	Comments
Physical Damage				
Structure	$195,631	$0	**$195,631**	• 0.5 ft flooding in car dealership • Applied HAZUS-MH MR2 depth-damage curve • Replacement value based on RSMeans (Mewis, 2006)
Contents	$293,447	$0	**$293,447**	• Contents estimated at 100% of the structure replacement value based on HAZUS-MH MR2 defaults • Damage assumed to be 1.5 times structure damage
Roads and Bridges	$18,405	$0	**$18,405**	• Damages scaled from historical damages in project file
Infrastructure	$0	$0	**$0**	• Not predicted, not indicated in project file
Landscaping	$0	$0	**$0**	• Not predicted, not indicated in project file
Environmental Impacts	$0	$0	**$0**	• Not predicted, not indicated in project file
Vehicles/Equipment	$0	$0	**$0**	• Not predicted, not indicated in project file
Subtotal	***$507,483***	***$0***	***$507,483***	
Loss of Function				
Displacement Expense	$0	$0	**$0**	• No displacement expense due to limited structural damages
Loss of Rental Income	$0	$0	**$0**	• No residential rental properties impacted
Loss of Business Income	$18,963	$0	**$18,963**	• 5 days lost of business at car dealership • lost revenue based on annual revenue in project file
Lost Wages	$113,739	$0	**$113,739**	• 5 days of lost wages at car dealership • 1 day of lost wages at other businesses • Lost wages based on regional data and the project file
Disruption Time for Residents	$0	$0	**$0**	• No residential structures impacted
Loss of Public Services	$0	$0	**$0**	• Not predicted, not indicated in project file
Economic Impact of Utility Loss	$0	$0	**$0**	• Not predicted, not indicated in project file
Economic Impact of Road/Bridge Closure	$87,866	$0	**$87,866**	• FEMA BCA traffic delay method based on delay time, number of vehicles, and lost income per vehicle • Average delay estimated at 5 minutes
Subtotal	***$220,568***	***$0***	***$220,568***	
Emergency Management				
Debris Cleanup	$751	$0	**$751**	• Costs scaled from historical damages in project file
Governmental Expense	$2,342	$0	**$2,342**	• Costs scaled from historical damages in project file
Subtotal	***$3,093***	***$0***	***$3,093***	
Total	***$731,144***	***$0***	***$731,144***	

[1] All amounts rounded to the nearest dollar

(see Figure D.5). The structure is located at 6826 Federal Boulevard (shown as 6800-6830 Federal Boulevard on the building), Assessor's Parcel Number 4781410700. The structure is two stories, has a footprint of approximately 50,000 square feet, and is constructed of concrete blocks with concrete flooring. The roof of the structure is used as a parking facility for the car dealership. The finished floor of the parts store is approximately 1.5 feet above the adjacent grade, and the lowest floor elevation of the auto repair facility is at the same grade as the sidewalk. The interior of the repair facility portion of the structure slopes up several feet above sidewalk level. An electric room and pump rooms for the building are located at approximately the same grade as the sidewalk. According to the SanGIS parcel data, the assessed land value is $1,895,357, and the structure value is $2,971,631. The estimated 2006 replacement value is approximately $4,347,367, based on data from RSMeans.

Under the MP_A scenario, portions of the repair facility would have been inundated by approximately 0.5 feet of flooding, with minor flooding of the electrical room and pump equipment rooms. The interior of the auto repair facility would have been slightly flooded, but because the floor slopes upward away from the street, inundation of the working area of the garage would not have occurred. The retail parts store would not have been inundated, because the finished floor is approximately one foot above the modeled water surface elevation. The second site visit confirmed that all other structures along Federal Boulevard within the project limits were located sufficiently above street level such that they would not have been impacted under the MP_A scenario.

Given these conditions, physical damages were calculated only for the structure and contents of 6826 Federal Boulevard and the pavement on Federal Boulevard. The structure and content damages for the MP_A scenario were estimated based on the 0.5-foot flood depth. A depth-damage function for "Personal and Repair Services"

Figure D.5

commercial properties from HAZUS-MH MR2 was used to estimate the percent damage associated with this depth (see Attachment D.2). RSMeans estimates for replacement values of commercial structures in the San Diego area were used to convert this percentage into a dollar amount of $195,631 (see Attachment D.1). Content damages were estimated based on the assumptions from FEMA BCA and HAZUS methodologies that content of commercial structures are approximately equal to the structure's replacement value and that content damages are 1.5 times the structural damage. The estimate of the content damage was $293,447. It was assumed that the car dealership would have had enough advance notice to move any cars from the areas with potential flooding, so no vehicle damage was estimated.

Damage to the pavement on Federal Boulevard due to flooding was based on pavement damage information provided in the project files for a 3.8-inch rainfall from the 1995 flood event (see Attachment D.3). The damage estimated for the 1995 event was reduced proportionally to reflect the fact that the 2004 event was a smaller storm; these damages were estimated at $18,405. Total physical damages for the MP_A scenario were estimated to be $507,483. There were no actual observed physical damages for the 2004 event, that is, for the MP_C scenario. Therefore, the losses avoided, in terms of physical damages, were estimated to be $507,483 (see Table D.1).

D.4.2 Loss of Function

Loss of function damages were calculated for business losses, wages losses, and traffic delays. Under the MP_A scenario, flooded businesses along Federal Boulevard would have closed during flooding, and during subsequent cleanup and repair activities. FEMA BCA methods indicate that the number of days a business is closed for repairs is equal to the structural percent damage when that damage is under 10% (FEMA, 2006c). Since the structural percent damage was 4.5%, it was estimated that 6826 Federal Boulevard would be closed for five days. Based on annual revenue provided in the project files, lost business was estimated to be $18,963.

Lost wages would have been more significant. Besides the car dealership, it was assumed that the other businesses along Federal Boulevard would be closed for one day due to flooding, repairs, and cleanup. This assumption was supported by information in the project files demonstrating that Federal Boulevard was closed for one day during several MP_A storm events similar to the 2004 event. Using regional wage values and employment estimates from the impacted businesses along Federal Boulevard, the lost wages were estimated to be $113,739 (see Attachment D.4).

The cost of traffic delays resulting from the re-routing of vehicles due to closure of Federal Boulevard was also estimated. Based on local traffic patterns, the detour around the flooded section of Federal Boulevard was estimated to take five minutes. Local traffic count data indicate that there are 26,000 vehicles per day on this section of Federal Boulevard. Using FEMA BCA methods, based on the lost wages to people in delayed vehicles, the costs due to traffic delay were estimated at $87,866 (see Attachment D.5). No loss of function costs were observed for the actual MP_C event. Therefore, the total losses avoided due to loss of function were determined to be $220,568 (see Table D.1).

D.4.3 Emergency Management

For this project, emergency management costs were estimated for debris cleanup and governmental expense. As a result of the 1995 flood event, the project files indicated there was debris cleanup required on this portion of Federal Boulevard. When this estimate was adjusted based on the relative severity of the 2004 event, the debris cleanup cost was estimated to be $751 (see Attachment D.1).

The project files also indicated local government expense to provide police personnel to close off the road for debris cleanup and road repairs. When this estimate was adjusted based on the relative severity of the 2004 event, the cost for providing police personnel was estimated to be $297. However, 10% of the road and bridge repair is also considered to be governmental expense for public works labor. As a result, the total governmental expense was estimated to be $2,342 (see Attachment D.1).

There were no MP_C emergency management costs directly related to the actual event for the Federal Boulevard project area. Therefore, the total losses avoided for emergency management costs were determined to be $3,093 (see Table D.1).

D.4.4 Results Summary

For the February 2004 MP_C storm event, losses avoided due to the construction of the project total $731,144. When compared to the original project cost of $621,619 this represents a ROI of 118%. Therefore, the losses avoided from the February 2004 event would be more than sufficient to justify the original project costs. It is expected that the ROI will increase as additional storm events, of the same or larger magnitude, test the project's effectiveness.

Losses in Project File and Loss Calculations, Part 1
Federal Boulevard

Event	Loss Type: Physical Damage							Comments
	Structure	*Contents*	*Roads and Bridges*	*Infrastructure*	*Landscaping*	*Environmental Impacts*	*Vehicles/ Equipment*	
1995[1] (MP_A)	$195,631	$293,447	$20,450 ($18,405)	$0	$0	$0	$0	***Structure*** • Car dealership, 50,000 sq ft, $81.47 (2004 dollars) per sq ft, $4,347,367 (structure value) 4.5% damaged ***Contents*** • $4,347,367 (contents value) 6.75% damaged ***Roads and Bridges*** • Damages scaled from project files, includes governmental expense • See *Historical Damage to Roads and Bridges* attachment
February 2004 (MP_C)	$0	$0	$0	$0	$0	$0	$0	

Event	Loss Type: Loss of Function								Comments
	Displacement Expense	*Loss of Rental Income*	*Loss of Business Income*	*Lost Wages*	*Disruption Time for Residents*	*Loss of Public Services*	*Economic Impact of Utility Loss*	*Economic Impact of Road/Bridge Closure*	
1995[1] (MP_A)	$0	$0	$18,963	$113,739	$0	$0	$0	$87,866	***Loss of Business Income*** • 5 days lost business, scaled from annual sales of $1,100,000 (1997) ***Lost Wages*** • See *Lost Wages Calculation* attachment ***Economic Impact of Road/Bridge Closure*** • See *Traffic Delay Calculations* attachment
February 2004 (MP_C)	$0	$0	$0	$0	$0	$0	$0	$0	

Losses in Project File and Loss Calculations, Part 2
Federal Boulevard

Event	Loss Type		Comments
	Emergency Management		
	Debris Cleanup	*Governmental Expense*	
1995[1] (MP_A)	$751	$2,342	***Debris Cleanup*** • Scaled from project files ***Governmental Expense*** • $297, costs identified from project worksheets • 10% of road and bridge repair costs are assumed to be governmental expenses
February 2004 (MP_C)	$0	$0	

All amounts are adjusted for 2006 dollars and rounded to the nearest dollar.
[1] 1995 event frequency was 15-year. MP_A scenario scaled to match February 2004 event which was determined to be approximately 61% of 1995 event.

HAZUS-MH MR2 Damage - COM3
Federal Boulevard

Occupancy	Specific Occupancy ID	Source	Description	Stories	Comment	Default Function	Editable	Selected	-4 ft -4.00	-3 ft -3.00	-2 ft -2.00	-1 ft -1.00	0 ft 0.00	1 ft 1.00	2 ft 2.00	3 ft 3.00	4 ft 4.00	5 ft 5.00	6 ft 6.00	7 ft 7.00	8 ft 8.00	9 ft 9.00	10 ft 10.00	11 ft 11.00	12 ft 12.00	13 ft 13.00
COM3	C3LN	USACE Galveston	average personal and repair services, structure	Low Rise		1			0.00	0.00	0.00	0.00	0.00	9.00	12.00	13.00	16.00	19.00	22.00	25.00	28.00	32.00	35.00	39.00	43.00	47.00
COM3	C3LB	USACE Galveston	average personal and repair services, structure	Low Rise		1			0.00	0.00	0.00	0.00	0.00	9.00	12.00	13.00	16.00	19.00	22.00	25.00	28.00	32.00	35.00	39.00	43.00	47.00
COM3	C3MN	USACE Galveston	average personal and repair services, structure	Mid Rise		1			0.00	0.00	0.00	0.00	0.00	9.00	12.00	13.00	16.00	19.00	22.00	25.00	28.00	32.00	35.00	39.00	43.00	47.00
COM3	C3MB	USACE Galveston	average personal and repair services, structure	Mid Rise		1			0.00	0.00	0.00	0.00	0.00	9.00	12.00	13.00	16.00	19.00	22.00	25.00	28.00	32.00	35.00	39.00	43.00	47.00
COM3	C3HN	USACE Galveston	average personal and repair services, structure	High Rise		1			0.00	0.00	0.00	0.00	0.00	9.00	12.00	13.00	16.00	19.00	22.00	25.00	28.00	32.00	35.00	39.00	43.00	47.00
COM3	C3HB	USACE Galveston	average personal and repair services, structure	High Rise		1			0.00	0.00	0.00	0.00	0.00	9.00	12.00	13.00	16.00	19.00	22.00	25.00	28.00	32.00	35.00	39.00	43.00	47.00

Occupancy	Specific Occupancy ID	Source	Description	Stories	Comment	Default Function	Editable	Selected	14 ft 14.00	15 ft 15.00	16 ft 16.00	17 ft 17.00	18 ft 18.00	19 ft 19.00	20 ft 20.00	21 ft 21.00	22 ft 22.00	23 ft 23.00	24 ft 24.00	ID	Basement	Hazard Riverine	Hazard CV	Hazard CA
COM3	C3LN	USACE Galveston	average personal and repair services, structure	Low Rise		1			50.00	54.00	57.00	61.00	64.00	68.00	71.00	75.00	78.00	82.00	85.00	375		1	1	1
COM3	C3LB	USACE Galveston	average personal and repair services, structure	Low Rise		1			50.00	54.00	57.00	61.00	64.00	68.00	71.00	75.00	78.00	82.00	85.00	375	1	1	1	1
COM3	C3MN	USACE Galveston	average personal and repair services, structure	Mid Rise		1			50.00	54.00	57.00	61.00	64.00	68.00	71.00	75.00	78.00	82.00	85.00	375		1	1	1
COM3	C3MB	USACE Galveston	average personal and repair services, structure	Mid Rise		1			50.00	54.00	57.00	61.00	64.00	68.00	71.00	75.00	78.00	82.00	85.00	375	1	1	1	1
COM3	C3HN	USACE Galveston	average personal and repair services, structure	High Rise		1			50.00	54.00	57.00	61.00	64.00	68.00	71.00	75.00	78.00	82.00	85.00	375		1	1	1
COM3	C3HB	USACE Galveston	average personal and repair services, structure	High Rise		1			50.00	54.00	57.00	61.00	64.00	68.00	71.00	75.00	78.00	82.00	85.00	375	1	1	1	1

Historical Damage to Roads and Bridges
Federal Boulevard

Year	Event Frequency	Damage	Annual Repair Cost
1978	*5-year*	Road	***$44,501***
1979	*3-year*	Road	***$38,910***
1980	*5-year*	Road	***$44,562***
1981	*3-year*	Road	***$37,491***
1982	*5-year*	Road	***$72,565***
1983	*15-year*	Road	***$81,502***
1984	*3-year*	Road	***$42,871***
1985	*3-year*	Road	***$39,902***
1986	*5-year*	Road	***$58,760***
1987	*3-year*	Road	***$40,651***
1988	*3-year*	Road	***$42,585***
1989	*3-year*	Road	***$41,870***
1990	*3-year*	Road	***$60,052***
1991	*5-year*	Road	***$39,475***
1992	*5-year*	Road	***$85,580***
1993	*10-year*	Road/Riprap	***$92,510***
1994	*3-year*	Road	***$44,249***
1995	*15-year*	Road	***$94,097***
1996	*3-year*	Road	***$57,888***
1997	*3-year*	Road/Riprap	***$81,966***
		Average	***$57,099***

Note: It is not known whether the road repair costs are specifically for Federal Boulevard or whether they include nearby roads. 1995 Damage Survey Report amounts were used to calculate asphalt/roadway repair (15-year event scaled for other frequencies).

Lost Wages Calculation
Federal Boulevard

Address	Name of Business	Employees	Type of Business	Wages Lost per Day[1, 2]
6750 Federal Blvd	*Edco Recycling*	220	Recycling center	**$16,896**
6826 Federal Blvd	*Bob Baker Toyota*	100	Car dealership and repair center	**$7,680**
6849 Federal Blvd	*Farmer's Insurance*	10	Insurance broker	**$768**
6867 Federal Blvd	*VFW Post*	10	Veterans of Foreign Wars	**$768**
6880 Federal Blvd	*GMC Vehicle Sales Department*	100	Car dealership and repair center	**$7,680**
6883 Federal Blvd	*Southern California Discount Tire*	25	Retail auto tire center	**$1,920**
Total Wages Lost per Day: $35,712			***Total Wages Lost (5-day total)***	***$113,739 (2006 dollars)***

Wages in San Diego, Full–Time Workers[3]

Occupation	Hourly Wage[1]	Occupation	Hourly Wage[1]
All	$19.07	***Machine operators, assemblers, and inspectors***	***$10.97***
Professional specialty	$32.52	***Transportation and material moving***	***$14.34***
Technical	$19.47	***Handlers, equipment cleaners, helpers, and laborers***	***$11.95***
Executives, administrators, and managers	$39.91	Protective service	$17.45
Management related	$24.54	Food service	$8.25
Sales	***$15.86***	Health service	$10.18
Administrative support, including clerical	***$13.63***	***Cleaning and building service***	***$8.27***
Precision production, craft, and repair	$17.55	***Personal service***	***$8.33***

Average Hourly Wage for Selected Occupations: $11.91

[1] All amounts reflect 2000 dollars unless otherwise noted
[2] Assumptions:
- $12.00 average hourly wage
- 8-hour workday
- 20% of employees are salaried (no lost wages)

[3] Source: Bureau of Labor Statistics, National Compensation Survey, 2000

Travel Delay Calculations[1]
Federal Boulevard

1. Daily Volume of Traffic Flow[2]

Detour: Federal Boulevard - **26,000 VPD**

2. Average Delay or Detour Time per Vehicle

Federal Boulevard Delay

Segment	*Time*	*Distance*	*Speed*	**3. Economic Impact of Delay**
Reroute	*5 minutes*	1.7 Miles	20 mph	***$40.5535634020 per vehicle hour***
Delay Duration: 1 day minor flooding and cleanup = ***1 day*** **Delay Time per Day**	***5 minutes***			***Delay Cost: $87,866.05***
Total Delay Cost (2006 $)				***$87,866.05***

[1] General Methodology from "What is a Benefit?" document in FEMA BCA Toolkit, Version 3.0
[2] Vehicles per day

Appendix E:

Flood Protection for Todd Road Jail Facility

Project: 1008-6077

Table of Contents:

List of Figures and Tables

Appendix E:

Project: 1008-6077

Flood Protection for Todd Road Jail Facility

E.1 General Project Information

E.1.1 Project Location

As illustrated in Figure E.1, the Flood Protection for the Todd road Jail Facility project is located approximately one mile west of the City of Santa Paula, Ventura County, California. More specifically the project is located in the Todd Barranca Channel which, as shown in Figure E.2, runs parallel to Todd Road along the west side of the Todd Road Jail facility. The northern extent of the project is just north of SR 126 with the southern extent ending at the south end of Todd Road Jail.

E.1.2 Project Description

Flooding in February 1998 caused severe damage to the Todd Barranca Channel and threatened to erode portions of Todd Road. Under a presidential disaster declaration for that storm (1203-DR-CA), FEMA provided funding through the Public Assistance Program to restore the channel to pre-disaster condition, including installation of grouted riprap. The total cost to repair the channel was approximately $280,000. However, Ventura County, which operates the jail facility and is responsible for maintaining the channel, expressed concern that future flooding could potentially affect operations at the jail facility. While County officials were not afraid that the structures themselves would be flooded, they were concerned that flooding of the road and damage to channel banks would limit access to the facility or divert floodwaters to the jail site. This disruption could result in the evacuation of the 860 inmates housed at the jail, which would be disruptive and costly.

Taking into account the potential disruption and cost, Ventura County requested that FEMA provide funding under the HMGP to mitigate the area by improving the channel armoring in the vicinity of the jail (see Figures E.3, E.4, and E.5). This improvement would reduce future channel and road erosion thereby reducing the risk to the jail facility. The flood protection project consists of approximately 400 linear feet of Armorflex concrete block mat protection for the channel embankments along the east bank of the Todd Barranca Channel where the channel and includes expanding the grouted riprap near the entrance of the jail so that it ties into the Armorflex.

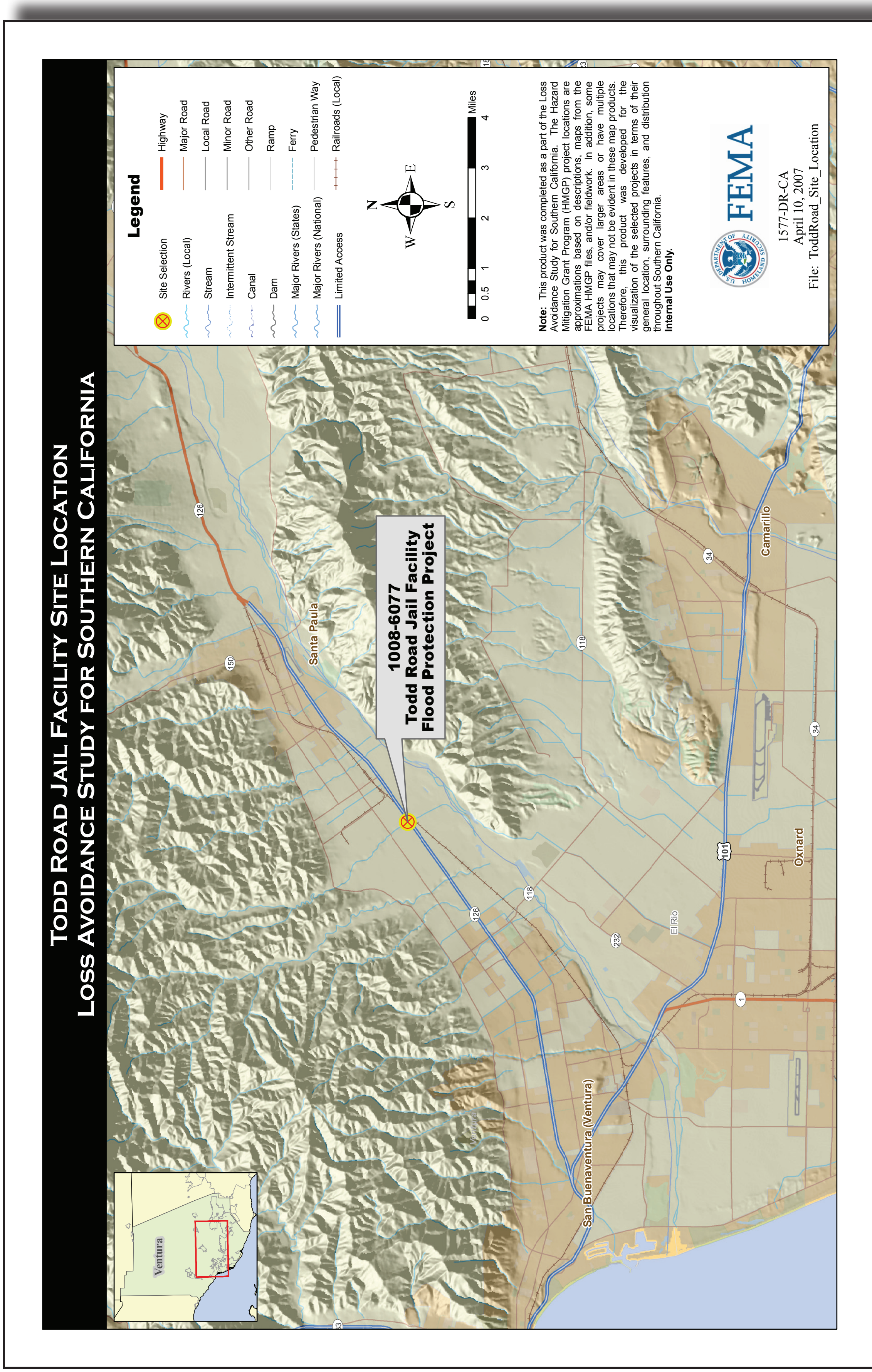
Todd Road Jail Facility Site Location
Loss Avoidance Study for Southern California
1008-6077
Todd Road Jail Facility
Flood Protection Project
Legend
Site Selection
Rivers (Local)
Stream
Intermittent Stream
Canal
Dam
Major Rivers (States)
Major Rivers (National)
Limited Access
Highway
Major Road
Local Road
Minor Road
Other Road
Ramp
Ferry
Pedestrian Way
Railroads (Local)
N
E
S
W
0 0.5 1 2 3 4 Miles
Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California.
Internal Use Only.
FEMA
1577-DR-CA
April 10, 2007
File: ToddRoad_Site_Location
Santa Paula
Camarillo
Oxnard
El Rio
San Buenaventura (Ventura)
Ventura
126
150
118
34
232
101
1

Figure D.1

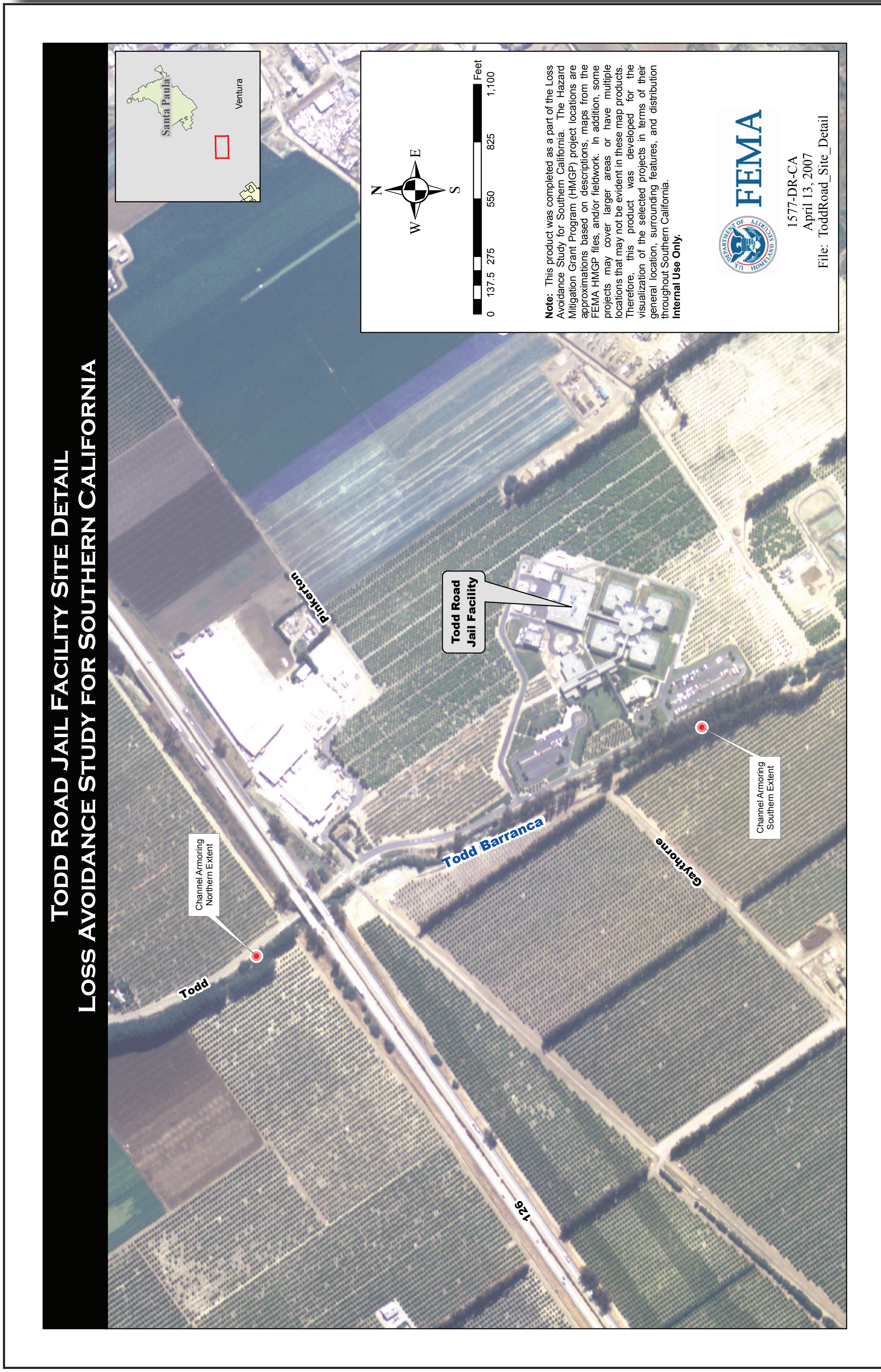
Todd Road Jail Facility Site Detail
Loss Avoidance Study for Southern California
Santa Paula
Ventura
Channel Armoring Northern Extent
Todd
Pinkerton
Todd Road Jail Facility
Todd Barranca
Gaythorne
Channel Armoring Southern Extent
126
N
W
E
S
0 137.5 275 550 825 1,100 Feet
Note: This product was completed as a part of the Loss Avoidance Study for Southern California. The Hazard Mitigation Grant Program (HMGP) project locations are approximations based on descriptions, maps from the FEMA HMGP files, and/or fieldwork. In addition, some projects may cover larger areas or have multiple locations that may not be evident in these map products. Therefore, this product was developed for the visualization of the selected projects in terms of their general location, surrounding features, and distribution throughout Southern California. Internal Use Only.
FEMA
1577-DR-CA
April 13, 2007
File: ToddRoad_Site_Detail

Figure D.2

Figure E.3

E.1.3 Project Funding and Construction Time Line

The total investment in the mitigation project was $308,699. Seventy-five percent of the investment was provided by FEMA under HMGP Project Number 1008-6007 with the remaining 25% being a match from the local government (FEMA, 2006b). Project construction began in October 2001 and was completed by mid-December 2001. Subsequent closeout of the project was completed on October 18, 2002.

E.2 Data Collection

The LAT completed a detailed review of the project file and noted the additional data that was needed in order to prepare the loss avoidance study for the Flood Protection for the Todd road Jail Facility project. Additionally, the LAT conducted an initial site visit with Ventura County personnel for the purpose of gathering site-specific

Figure E.4

information related to past flooding, discuss the project with city personnel, assess the site condition (including topography, drainage features, and structure types), determine whether additional project information was available, and obtain photo documentation of the site. Ventura County officials also provided supplemental design information and photographs of the flooding from the 2005 event.

Figure E.5

E.3 Physical Parameter Analysis

E.3.1 Storm Event Analysis

Two sources were utilized in identifying candidate storm events for the project, weather data were obtained from the NWS as well as the Ventura County ALERT system. Ventura County ALERT data were obtained from station 175 at the Saticoy Fire Station, located at latitude 34.2856, longitude -119.1550, approximately 2.9 miles from the project site. The maximum MP_C 24-hour rainfall recorded at this gage was 5.31 inches on January 10, 2005. Using NOAA's 1973 *Precipitation Frequency Atlas of the Western United States*, the LAT estimated this event to have a recurrence interval between 10 and 25 years (Miller et al., 1973) (see Figure E.6).

According to Ventura County officials, the 2005 event resulted in damage to the Todd Barranca channel. More specifically, 60 to 70 feet of the Armorflex was damaged but the grouted riprap remained in tact (see Figure E.7). The cost to repair the Armorflex damage was approximately $54,000. In addition to the Armorflex damage, the event caused minor out-of-bank flooding along the channel, and Todd Road was closed for approximately three hours to allow for debris cleanup. However, there was no erosion of the channel that would have otherwise threatened the road.

Figure E.6

E.3.2 Hydrologic Analysis

The hydrologic analysis available for the Todd Road Jail project was a pre-construction MRM model originally run for the 100-year design storm of 9.0 inches. To predict the runoff from the 2005 event, the information contained in the MRM output was used to develop a HEC-1 model (USACE, 1998). This information included a unit hydrograph, temporal rainfall distribution, and watershed response factors. The temporal rainfall distribution from the original MRM analysis was scaled to represent the 5.31-inch rainfall that occurred during the 2005 event.

The HEC-1 model was first run for the original 100-year storm event. The results of that run matched the original MRM analysis within 1% indicating the different model runs would be comparable to one another. The HEC-1 model was run a second time using the 2005 event rainfall of 5.31 inches which produced a peak runoff of 2,325 cfs. Because the project did not change the topography or watershed conditions, this peak runoff is applicable to both the MP_A and MP_C conditions.

E.3.3 Hydraulic Analysis

Typically, hydraulic modeling is conducted to determine flood depths, which are used to determine the flood inundation area. For the MP_A scenario, hydraulic modeling was necessary to determine if there would have been excessive erosion that could have threatened Todd Road, had the channel armoring not been installed. However, hydraulic modeling was not performed as part of the original project design for this project. A review of channel erosion models determined that the Bridge Stream Tube Model for Alluvial River Simulation (Bri-Stars) from the Federal Highway Administration

(FHWA) would provide an appropriate simulation of channel erosion (FHWA, 1998). The primary inputs for this model were channel cross-sections and flood depths at set time intervals for the event of interest. A HEC-RAS model (USACE, 2002) was run with the peak flow rate described above to determine the flood depths. Channel cross-sections were derived from 1-foot elevation contour data prepared in 2005 and provided by Ventura County.

The HEC-RAS model showed minor out-of-bank flooding, matching conditions observed during the 2005 event. Local officials were concern that without the armoring, floodwaters might erode the channel banks enough to collapse portions of Todd Road. However, for the actual MP_C event erosion was minor and was not of a level to have caused road failure. For the MP_A scenario, the Bri-Stars model was used to determine whether channel bank erosion would have threatened Todd Road. Utilizing the data from the 2005 event, the model results showed that in-channel erosion would have occurred for the MP_A scenario. However, this erosion would have been confined to the channel bottom and the lower portions of the channel banks. The erosion damage produced in the model was similar to, but less severe than, what local officials observed from the February 1998 event and would not have threatened Todd Road.

E.3.4 Flood Boundary Analysis

There was no flood boundary analysis conducted for this project because the channel armoring project had no appreciable impact on flood levels for the 2005 event.

Figure E.7

E.4 Loss Estimation Analysis

Table E.1 displays the results of the loss estimation analysis for the MP_A and MP_C scenarios by loss category and loss type. The damages and costs recorded during the February 1998 event were chosen as most representative of the MP_A scenario. The January 2005 event represents the MP_C scenario. Details on the figures provided in Table E.1 are discussed in the following sections, with calculation details being provided in Attachment E.1.

E.4.1 Physical Damage

The modeled 2005 storm event showed that the only physical damage from the storm would have been infrastructure damage. As a result, the MP_A and MP_C physical damage costs were figured for damage to infrastructure only. The HMGP project files provided information about the costs to repair the Todd Barranca Channel following both the February 1998 and January 2005 events. For the February 1998 event, the Project Worksheets prepared by FEMA for PA indicate that the total, adjusted, cost to repair the channel was $279,689. Ten percent of the reported costs were assumed to be local government costs incurred while administering channel repairs. Therefore, the channel repair costs were estimated to be $251,720 for the MP_A scenario (see Attachment E.1).

The January 2005 event (MP_C) resulted in damage to the Armorflex. The project files indicate that the total costs for repair was $76,903. Again, it was assumed that 10% of those costs were local government costs incurred while administering channel repairs. Therefore, the channel repair costs were assumed to be $69,213 for the MP_C scenario (see Attachment E.1).

Based on MP_A and MP_C estimates, the losses avoided for physical damage to infrastructure was $182,507 (see Table E.1).

E.4.2 Loss of Function

The jail facility would not have closed as a result of either the MP_A or MP_C scenarios. Further, the minor out-of-bank flooding that would have occurred during either scenario would not have resulted in road closures of sufficient duration to disrupt the operation of the facility. As a result, there were no loss of function costs estimated for this project.

E.4.3 Emergency Management

Governmental expense for administering channel repairs was the only emergency management costs calculated for this project. As previously stated, those costs were assumed to be 10% of the total physical damage repair costs. For the MP_A scenario, the cost was

Table E.1

Loss Estimation Analysis Results
Todd Road Jail Facility

Loss Type	MP_A Scenario Losses[1]	MP_C Scenario Losses[1]	Losses Avoided[1]	Comments
Physical Damage				
Structure	$0	$0	**$0**	• Not predicted, not indicated in project file
Contents	$0	$0	**$0**	• Not predicted, not indicated in project file
Roads and Bridges	$0	$0	**$0**	• Not predicted, not indicated in project file
Infrastructure	$251,720	$69,213	**$182,507**	• Channel repair costs, estimated from February 1998 and January 2005 events
Landscaping	$0	$0	**$0**	• Not predicted, not indicated in project file
Environmental Impacts	$0	$0	**$0**	• Not predicted, not indicated in project file
Vehicles/Equipment	$0	$0	**$0**	• Not predicted, not indicated in project file
Subtotal	***$251,720***	***$69,213***	***$182,507***	
Loss of Function				
Displacement Expense	$0	$0	**$0**	• Not predicted, not indicated in project file
Loss of Rental Income	$0	$0	**$0**	• No residential rental properties impacted
Loss of Business Income	$0	$0	**$0**	• No businesses impacted
Lost Wages	$0	$0	**$0**	• Not predicted, not indicated in project file
Disruption Time for Residents	$0	$0	**$0**	• No residential structures impacted
Loss of Public Services	$0	$0	**$0**	• Not predicted, not indicated in project file
Economic Impact of Utility Loss	$0	$0	**$0**	• Not predicted, not indicated in project file
Economic Impact of Road/Bridge Closure	$0	$0	**$0**	• Not predicted, not indicated in project file
Subtotal	***$0***	***$0***	***$0***	
Emergency Management				
Debris Cleanup	$0	$0	**$0**	• Not predicted, not indicated in project file
Governmental Expense	$27,969	$7,690	**$20,279**	• Costs scaled from historical damages in project file
Subtotal	***$27,969***	***$7,690***	***$20,279***	
Total	***$279,689***	***$76,903***	***$202,786***	

[1] All amounts rounded to the nearest dollar

estimated to be $27,969 (see Attachment E.1). The cost for the MP_C scenario was estimated to be $7,690 (see Attachment E.1). Therefore, the losses avoided for governmental costs were estimated to be $20,279 (see Table E.1).

E.4.4 Results Summary

For the January 2005 storm, the project was found to reduce losses from $279,689 to $76,903. As a result, losses avoided due to project construction are $202,786. When compared to the project cost of $308,699, this represents a 66% ROI which is significantly higher than the 37% average. The ROI is expected to increase as additional storm events, of the same or higher magnitude, test the project's effectiveness.

Losses in Project File and Loss Calculations
Todd Road Jail Facility

Event	Loss Type: Physical Damage							Comments
	Structure	*Contents*	*Roads and Bridges*	*Infrastructure*	*Landscaping*	*Environmental Impacts*	*Vehicles/ Equipment*	
February 1998 (MP_A)	$0	$0	$0	$279,689 ($251,720)	$0	$0	$0	***Infrastructure*** · Channel repair costs (rip rap and grout), design costs, governmental expense
January 2005 (MP_C)	$0	$0	$0	$76,903 ($69,213)	$0	$0	$0	***Infrastructure*** · Design: $5,161 · Repair: grading, $18,065; channel Armorflex, $53,677 · Governmental expense: $7,690

Event	Loss Type: Loss of Function								Comments
	Displacement Expense	*Loss of Rental Income*	*Loss of Business Income*	*Lost Wages*	*Disruption Time for Residents*	*Loss of Public Services*	*Economic Impact of Utility Loss*	*Economic Impact of Road/Bridge Closure*	
February 1998 (MP_A)	$0	$0	$0	$0	$0	$0	$0	$0	
January 2005 (MP_C)	$0	$0	$0	$0	$0	$0	$0	$0	

Event	Loss Type: Emergency Management		Comments
	Debris Cleanup	*Governmental Expense*	
February 1998 (MP_A)	$0	$27,969	***Governmental Expense*** · 10% of channel repair costs are assumed to be governmental expenses
January 2005 (MP_C)	$0	$7,690	***Governmental Expense*** · 10% of channel repair costs are assumed to be governmental expenses

All amounts are adjusted for 2006 dollars and rounded to the nearest dollar.
Debris cleanup and fence removal expenses are assumed to be the same for both scenarios.

Acronyms:

ADAMS
Automated Disaster Assistance Management System

ALERT
Automated Local Evaluation in Real Time

AT&SF
Atchison, Topeka & Santa Fe Railroad

BCA
Benefit-Cost Analysis

BRI-STARS
Bridge Stream Tube Model for Alluvial River Simulation

CADD
Computer-Assisted Drafting and Design

CFS
Cubic Feet per Second

CLOMR
Conditional Letter of Map Revision

CN
Curve Number

DEM
Digital Elevation Model

DFIRM
Digital Flood Insurance Rate Map

EPA
United States Environmental Protection Agency

FEMA
Federal Emergency Management Agency

FFE
First Floor Elevation

FHWA
Federal Highway Administration

FIRM
Flood Insurance Rate Map

FIS
Flood Insurance Study

FIT
Flood Information Tool

GIS
Geographic Information System

GPS
Global Positioning System

HAZUS-MH
Hazards U.S. – Multihazard

HAZUS-MH MR2
Hazards U.S. – Multihazard Maintenance Release 2

HEC-1
Hydrologic Engineering Centers – "Flood Hydrograph Package"

HEC-GeoRAS
Hydrologic Engineering Centers – Georeferenced River Analysis System

HEC-RAS
Hydrologic Engineering Centers – River Analysis System

HMGP
Hazard Mitigation Grant Program

IfSAR
Interferometric Synthetic Aperture Radar

LA
Losses Avoided

LAS
Loss Avoidance Study

LAT
Loss Avoidance Team

LIDAR
Light Detection and Ranging (system)

LOMR
Letter of Map Revision

MMC
Multihazard Mitigation Council

MP_A
Mitigation Project Absent

MP_C
Mitigation Project Complete

MRM
Modified Rational Method

NEMIS
National Emergency Management Information System

NFIP
National Flood Insurance Program

NGVD
National Geodetic Vertical Datum

NOAA
National Oceanic and Atmospheric Administration

NRCS
National Resources Conservation Service

NWS
National Weather Service

OES
Governor's Office of Emergency Services

PA
Public Assistance Program

PI
Project Investment

PW
Project Worksheet

RCB
Reinforced Concrete Box

RCP
Reinforced Concrete Pipe

RES1
Residential Type 1

ROI
Return on Investment

SanGIS
San Diego Geographic Information Source

SFHA
Special Flood Hazard Area

SR
State Road

TIN
Triangulated Irregular Network

USACE
United States Army Corps of Engineers

USDA
United States Department of Agriculture

USFS
United States Forest Service

USGS
United States Geological Survey

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FEMA Hazard Mitigation Grant Program: http://www.fema.gov/government/grant/hmgp/

FEMA Public Assistance Program: http://www.fema.gov/government/grant/pa/index.shtm

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