Loss Avoidance Study

Northern California Flood Control Mitigation
Part Two: Detailed Methodology

July 2008

FEMA

Federal Emergency Management Agency
U.S. Department of Homeland Security
500 C Street, Southwest
Washington, DC 20472

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U.S. DEPARTMENT OF HOMELAND SECURITY

FEMA

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Flood disasters have impacted and continue to impact many regions of the United States at a significant frequency and often with devastating results to the built environment. As the nation's population continues to grow and migrate to flood-prone regions, flood related losses continue to escalate. In response, mitigation actions to reduce or eliminate long-term risk to life, property, and infrastructure posed by flooding are being taken in communities around the country.

In Northern 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 1994 and 1998. 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. Rebecca Wagoner and David Kennard envisioned the need for this study following the 2006 disaster declarations in Northern California. 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 Robert Patten provided technical expertise and were instrumental in collecting data for the analysis. Robert Patten also provided report writing, GIS, graphics design, and photography throughout the process. Shabbar Saifee provided technical support and review of the analysis. 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 support throughout the study. Special thanks is extended to the local governments in Butte, Contra Costa, Napa, Sonoma, and Yuba counties who spent many hours assisting the Loss Avoidance Team in data collection and whose participation in the study was tireless.

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Executive Summary:

Each year federal, state, and local agencies, as well as private entities contribute funds towards mitigation in order to reduce the risk posed to people, the built environment, and the economy by hazards. In California alone, various entities have invested more than $1.4 billion dollars in reducing or eliminating the 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 used 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. With such significant investment in mitigation being made, policy makers have taken great interest in the effectiveness of mitigation during actual hazard events. In response, FEMA developed methodology using 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 used this quantitative approach to complete the two loss avoidance studies in Northern California. By conducting this type of study, FEMA can identify the benefits of the mitigation projects in terms of economic performance using actual storm events. The results demonstrate the effectiveness of the projects and can be used to promote the value of investing in mitigation measures.

These two independent studies are described below:

- ***Loss Avoidance Study: Northern California Flood Control Mitigation***
  Referred to as the Northern California flood control study, this study provides analysis of flood control mitigation projects designed to reduce the losses from flooding by altering the flood hazard through structural measures.

- ***Loss Avoidance Study: Sonoma County, California Elevated Structures***
  Referred to as the Sonoma County elevation study, this study provides analysis of structures that were elevated above flood levels. By definition, an elevated structure is a building that has no basement and has its lowest elevated floor raised above the ground level by foundation walls, shear walls, posts, piers, pilings, or columns.

This report provides detailed documentation of the methodology implemented during the Northern California flood control study and can be used as guidance for the preparation of future loss avoidance studies specific to flood control mitigation projects. Additionally, it describes considerations and recommended practices that were identified during the completion of the study. The appendices to this report describe the specific application of the methodology to the six projects that proceeded through all phases of the analysis.

While the results of the Northern California flood control study demonstrate the nominal effectiveness of the selected projects for the events analyzed, a comparison of the results with the original project investment demonstrates the return on investment. For the projects assessed in the Northern California flood control study, the aggregate project investment was $48.0 million[ES.1] and aggregated losses avoided were $46.9 million. This equated to a 98% return on investment.

[ES.1] All figures in this document are adjusted and reported in 2008 dollars.

Section One:
Introduction

Following the winter storms and flooding that impacted parts of Northern California in 2006, FEMA completed a loss avoidance study to quantitatively assess the performance of flood control mitigation projects and structure elevation projects within the area.

The focus of this report is on flood control mitigation projects that were implemented within the areas impacted by these storms. The projects were analyzed to determine the amount of losses that were avoided. The losses avoided were then compared to the original project investment to determine the return on mitigation investment (ROI).

1.1 Background

FEMA's Mitigation Directorate defines mitigation as any sustained action taken to reduce or eliminate long-term risk to people and their property from hazards and their effects. Effective mitigation reduces loss of life and property, allows communities and individuals to recover more quickly from disasters, and lessens the financial impact of disasters to individuals and all levels of government. Through a variety of programs, including the Hazard Mitigation Grant Program (HMGP), Pre-Disaster Mitigation (PDM), Flood Mitigation Assistance (FMA), Severe Repetitive Loss (SRL), and Repetitive Flood Claims (RFC), FEMA provides state and local entities financial assistance to reduce or eliminate the risks posed by natural hazards.

With significant investment being made in mitigation, demonstrating cost-effectiveness is crucial for continued support. In order to evaluate the effectiveness of mitigation projects, FEMA has developed loss avoidance study methodology. This methodology is based on the analysis of actual events that have occurred in the project study area since project completion. Using this methodology, a project sponsor can assess the benefits of a mitigation project in terms of its actual performance. The methodology used in this report was first used in California for the Loss Avoidance Study for Southern California Flood Control Mitigation (Southern California study). The study is documented in *Loss Avoidance Study: Southern California Flood Control Mitigation — Part Two: Detailed Methodology*. In the Southern California study, it was concluded that implementation of the 7 flood control mitigation projects that were studied saved $7,309,402 in losses. Each project was evaluated for only 1 flood event in a 10-year period, so this value is expected to increase as

Southern California Study
The total losses avoided for the projects analyzed were $7.3 million which yielded an average return on investment of 37%.

storms continue to test the projects' effectiveness over their useful lives (FEMA, 2007).

The methodology has now been applied in Northern California to study the effectiveness of flood control mitigation projects. In addition, the methodology was adapted and used to evaluate structure elevations in Sonoma County. That study was detailed in a separate report.

1.2 Purpose

The purpose of this study is to verify the effectiveness and document the economic performance of structural flood control mitigation projects in Northern California. Flood control projects, such as stormwater drainage system modifications, channel modifications, or flood walls, reduce the severity of flood damages. This study includes a quantification of the losses avoided (damage prevented or benefits) due to the implementation of the projects through analysis of storm events that occurred after the projects were completed. Losses avoided are determined by comparing damage that would likely have been caused by the same storms without the project (Mitigation Project Absent, or MP_A) with damages that actually occurred with the project in place (Mitigation Project Complete, or MP_C).

1.3 Methodology Overview

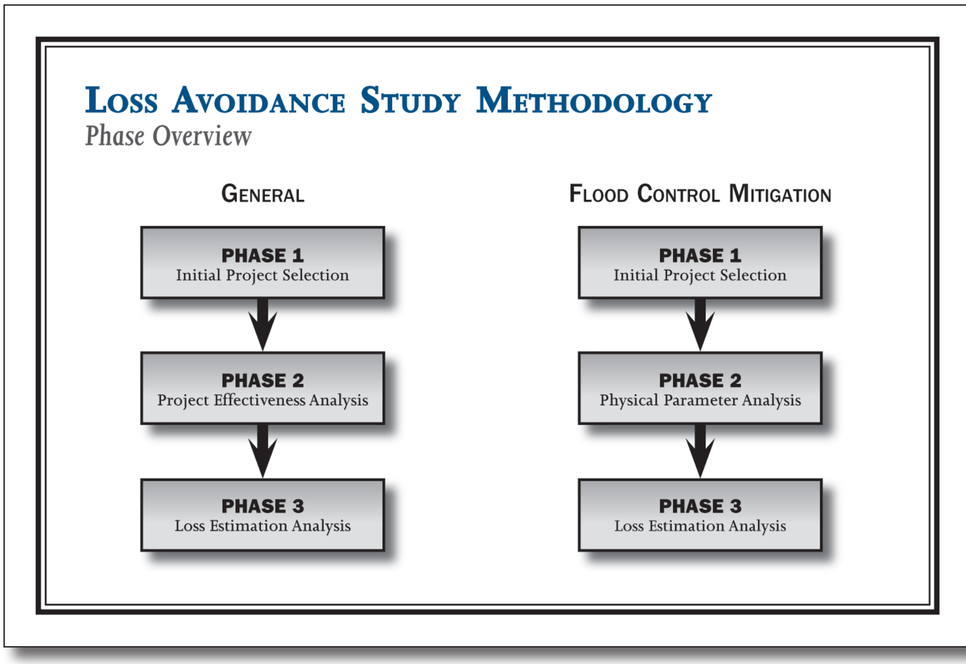
The Northern California flood control study uses the methodology that was introduced in the Southern California study. Figure 1.1 illustrates the phases of the general methodology for loss avoidance studies and the methodology specific to flood control projects. While Phase 1 and Phase 3 would be the 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 focuses on the methodology utilized when assessing flood control mitigation projects (FEMA, 2007).

Figure 1.2 provides a detailed illustration of the flood control mitigation project loss avoidance study methodology.

Phase 1 includes site selection and development of the initial project list. Projects are selected based on criteria determined by the sponsoring agency. The initial list of projects is screened, and projects are prioritized based on the availability of data required for completion of all phases of the analysis. Projects with adequate data advance to Phase 2 of the study.

Two distinct analyses comprise Phase 2: Storm Event Analysis and Flow Parameter Analysis. A storm event analysis is performed to

Figure 1.1



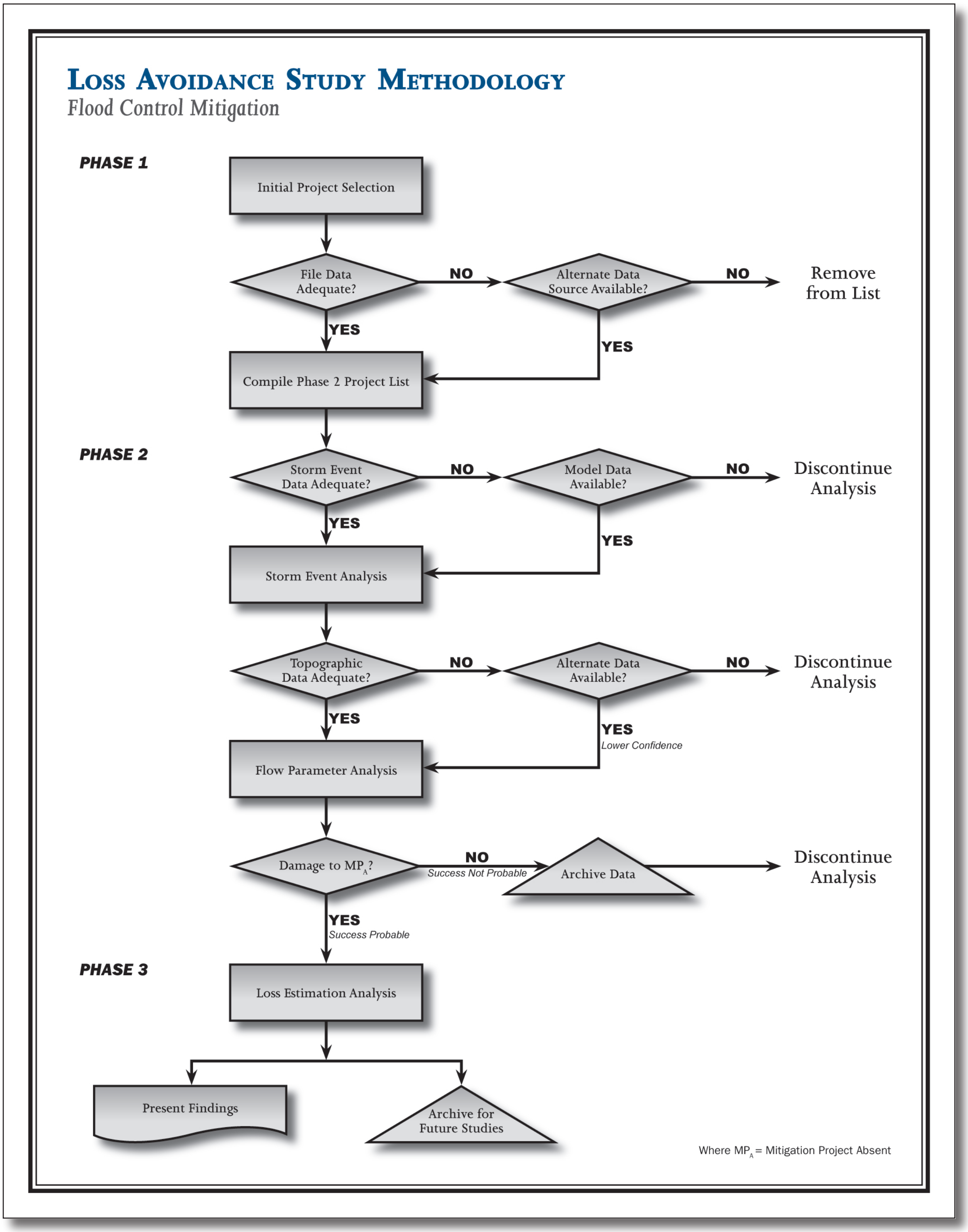
Source: FEMA, 2007

determine if a post-construction precipitation event severe enough to have the potential to cause damage if the project had not been constructed (the MP_A condition) has occurred. A flow parameter analysis is performed to determine the extent, depth, and duration of flooding. Based on hydrologic, hydraulic, and topographic data, a flood boundary analysis is performed to delineate the limits of inundation that would have occurred. If the limits of inundation determined for the MP_A scenario indicate damage would have occurred if the project had not been implemented, the project advances to Phase 3 for a Loss Estimation Analysis.

Two steps comprise Phase 3. First, damages are calculated for the MP_A and MP_C conditions. Once the MP_A and MP_C damages are estimated, the difference between the two scenarios is calculated to determine the losses avoided. Second, the ROI is calculated by comparing the losses avoided to the project investment.

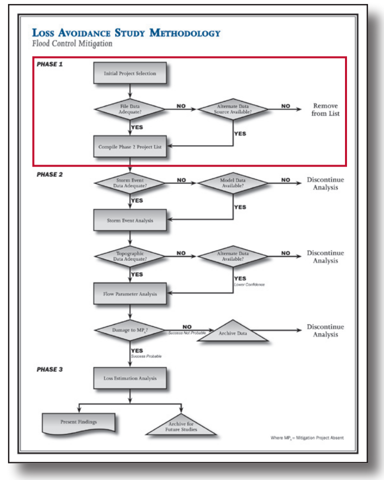
The three phases of the loss avoidance study and the results of the Northern California flood control study are discussed in greater detail in Sections Two, Three, and Four and the appendices to this report.

Figure 1.2



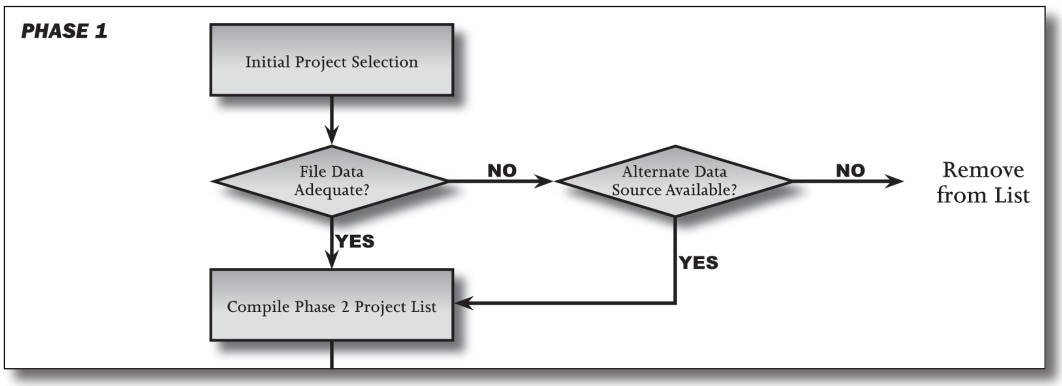
Source: FEMA, 2007

Section Two:
Phase 1 - Initial Project Selection



This section contains a discussion of Phase 1 - Initial Project Selection for any loss avoidance study, as well as details about the selection of projects for the Northern California flood control study. Figure 2.1 illustrates the process for Phase 1. As shown in Figure 2.1, an initial list of candidate mitigation projects is selected, data are collected for analysis of the projects. The projects are then screened based on the availability of the data that is required for Phase 2, and a list of projects advancing to Phase 2 is compiled.

Figure 2.1



Source: FEMA, 2007

2.1 Initial Project Selection

The Initial Project Selection is based on specific criteria defined for a particular loss avoidance study; as discussed in the Southern California study, these criteria may include but are not limited to:

- **Area of Interest** - The area of interest is the geographic boundary of a study. It can be a reach of a particular river or channel, a single community or watershed, a region such as Northern or Southern California, any jurisdictional boundary (city, county, state, special district, etc.), or any other area, but it must be defined by the agency sponsoring the loss avoidance study.
- **Hazard Type** - Projects in a loss avoidance study can be selected based on the type of hazard they are mitigating (riverine or coastal flood, seismic, wildfire, etc.).
- **Project Type** - The type of project (flood control projects, seismic retrofit of a building, vegetation maintenance for wildfire mitigation, etc.) is a parameter for a loss avoidance study.
- **Project Baseline** - Projects may be selected based on the date of completion. This may be selected as a parameter in order to include a particular storm event in the study. Older projects

have likely experienced a greater number of events and may have prevented more losses.

2.2 Project Screening And Prioritization

The manner in which projects are screened and prioritized varies based on the selection parameters for the loss avoidance study but is heavily influenced by the availability of data required for completion of the study. For the Southern California study, the availability of the data needed to implement the loss avoidance study methodology was a primary determining factor for project selection and ranking (FEMA, 2007). Projects can also be prioritized based on the quality of the available data.

In loss avoidance studies, projects should be removed from the initial project list if specific, necessary data are not available, cannot be easily replicated, or if flood conditions cannot be easily modeled using acceptable methods. Each project on the initial project list should be evaluated for the data requirements of that particular study and the availability of that data. As in the Southern California study, criteria for screening and prioritizing the initial project list may include:

- **Data Availability** - There may be limitations of the availability of data. A project with critical data readily available from the local community would be given a higher priority for analysis, whereas a project without critical data, or no source for obtaining critical data, would be eliminated from the list. The process for collecting specific data components, such as topographic data, typically occurs during Phase 2 and is discussed in more detail in Section Three. For project screening and prioritization, however, it is advisable to determine whether critical data are available early in the process. Based on data availability, a determination can be made as to whether a project should be eliminated from the initial project list. Sources of initial project data may include site visits, project files, local governments and their consulting engineers, and third-party vendors:
  - **Site Visits** - An initial site visit should be completed to conduct a preliminary assessment of the project, meet local and state officials, and initiate the more detailed data collection efforts for Phases 2 and 3. The site visit may reveal a lack of data or resources. Further, the site visit may reveal a project complexity that may hinder the completion of Phases 2 and 3.
  - **Project Files** - Agencies have different record archiving systems for project data. FEMA maintains basic information in project files, such as the original project grant application and financial reports. However, FEMA project files rarely contain

engineering drawings and electronic files, particularly if the project is more than a few years old.

- **Local Governments and Consulting Engineers** - Most detailed engineering information must be obtained from the local government that implemented the mitigation project or its consulting engineer. Different agencies may have different record keeping or long-term data storage procedures for mitigation projects, so this data may or may not be available.
- **Third-Party Vendors** - Some project data may be available from third-party vendors. Agencies conducting loss avoidance studies should be familiar with third-party vendors for various data needs.

- **Local Preferences** - Projects may be screened or prioritized based on the preferences of the agency sponsoring the loss avoidance study or the local mitigation project sponsor.
- **Occurrence of a Potentially Damaging Event** - An event of sufficient magnitude to have potentially caused damage must have occurred after the completion of the mitigation project for losses to be avoided. If no events that could have caused damage have occurred since project completion, the project should be eliminated from the list.
- **Analysis Potential** - Initial data collection efforts and general project knowledge should provide sufficient information for the loss avoidance analyst to determine the potential for a project to advance to Phase 2. If data are not readily available or are difficult to create for a project, analysis should be discontinued for that project. In a similar way, the required data might be readily available, but the Phase 2 analysis might be unfeasible to complete due to the project's size, complexity, location, etc.

2.3 Northern California Flood Control Study - Phase 1 Summary

FEMA Region IX and the (California) Governor's Office of Emergency Services (OES) initiated the Northern California flood control study after the severe storm events that occurred in Northern California during December 2005, January 2006, and April 2006. Presidential Disaster Declarations 1628-DR-CA and 1646-DR-CA resulted from these storms. Northern California was previously impacted by severe storms and flooding in 1995 (1044-DR-CA and 1046-DR-CA), 1997 (1155-DR-CA), and 1998 (1203-DR-CA). Officials noticed a dramatic decrease in damages during the 2005 and 2006 events when compared with the events that occurred during the late 1990s. They believed the decrease in damages in

Northern California during the later events was the result of the implementation of flood control mitigation projects following the flood events of the 1990s.

FEMA Region IX and OES worked together to develop a project list for the loss avoidance study based on the following parameters:

- **Area of Interest** - The area of interest was the Northern California counties included in disaster declarations 1628-DR-CA and 1646-DR-CA.
- **Hazard Type** - The hazard type was flood or multi-hazard (including flood).
- **Project Type** - The type of project was structural flood control.
- **Project Baseline** - Projects selected must have been completed by April 2006, the most recent flood-related Presidential Disaster Declaration.

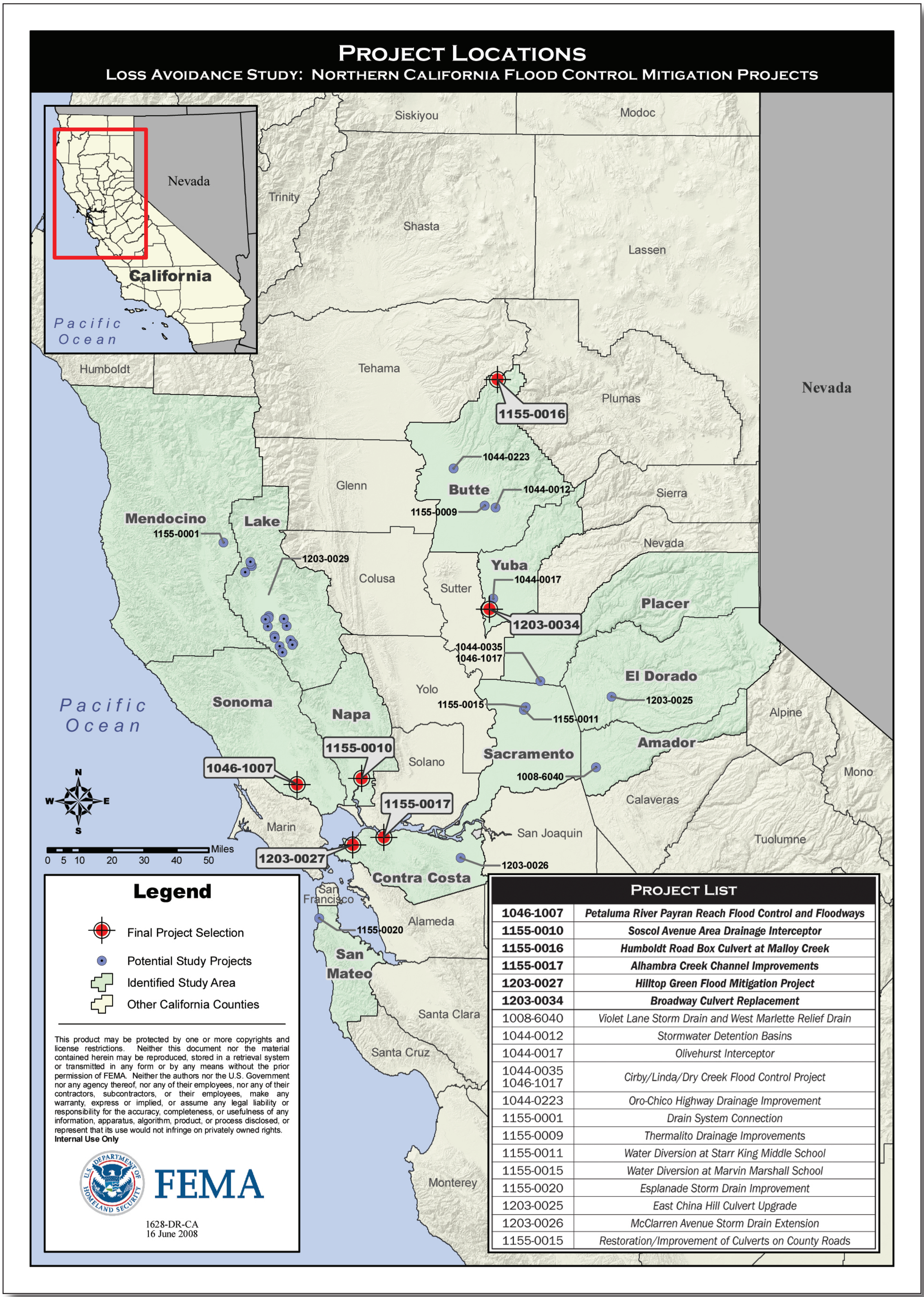
Table 2.1 lists the projects included on the initial project list, and Figure 2.2 illustrates the project locations. The initial project list included 20 projects; 2 of these projects (1044-0035 and 1046-1017) were constructed at the same location and were analyzed as 1 project in the study. The projects were located in Amador, Butte, Contra Costa, El Dorado, Lake, Mendocino, Napa, Placer, Sacramento,

Table 2.1

Initial Project List

County	Disaster and Project Number	Project Name
Amador	1008-6040	Violet Lane Storm Drain and West Marlette Relief Drain
Butte	1044-0012	Stormwater Detention Basins
	1044-0223	Oro-Chico Highway Drainage Improvement
	1155-0009	Thermalito Drainage Improvements
	1155-0016	Humboldt Road Box Culvert at Malloy Creek
Contra Costa	1155-0017	Alhambra Creek Channel Improvements
	1203-0026	McClarren Avenue Storm Drain Extension
	1203-0027	Hilltop Green Flood Mitigation Project
El Dorado	1203-0025	East China Hill Culvert Upgrade
Lake	1203-0029	Restoration/Improvement of Culverts on County Roads
Mendocino	1155-0001	Drain System Connection
Napa	1155-0010	Soscol Avenue Drainage Interceptor
Placer	1044-0035 1046-1017	Cirby/Linda/Dry Creek Flood Control Project
Sacramento	1155-0011	Water Diversion at Starr King Middle School
	1155-0015	Water Diversion at Marvin Marshall School
San Mateo	1155-0020	Esplanade Storm Drain Improvement
Sonoma	1046-1007	Petaluma River Payran Reach Flood Control and Floodways
Yuba	1044-0017	Olivehurst Interceptor
	1203-0034	Broadway Culvert Replacement

Figure 2.2



Project	Description
1046-1007	***Petaluma River Payran Reach Flood Control and Floodways***
1155-0010	***Soscol Avenue Area Drainage Interceptor***
1155-0016	***Humboldt Road Box Culvert at Malloy Creek***
1155-0017	***Alhambra Creek Channel Improvements***
1203-0027	***Hilltop Green Flood Mitigation Project***
1203-0034	***Broadway Culvert Replacement***
1008-6040	*Violet Lane Storm Drain and West Marlette Relief Drain*
1044-0012	*Stormwater Detention Basins*
1044-0017	*Olivehurst Interceptor*
1044-0035 1046-1017	*Cirby/Linda/Dry Creek Flood Control Project*
1044-0223	*Oro-Chico Highway Drainage Improvement*
1155-0001	*Drain System Connection*
1155-0009	*Thermalito Drainage Improvements*
1155-0011	*Water Diversion at Starr King Middle School*
1155-0015	*Water Diversion at Marvin Marshall School*
1155-0020	*Esplanade Storm Drain Improvement*
1203-0025	*East China Hill Culvert Upgrade*
1203-0026	*McClarren Avenue Storm Drain Extension*
1155-0015	*Restoration/Improvement of Culverts on County Roads*

San Mateo, Sonoma, and Yuba Counties. The projects included in the initial project list received funding through HMGP under disasters 1008-DR-CA, 1044-DR-CA, 1046-DR-CA, 1155-DR-CA, and 1203-DR-CA. For clarification, disaster declaration 1008-DR-CA was not a flood-related disaster declaration, but a disaster declaration for the Northridge Earthquake that occurred in 1994. Project 1008-6040 was funded by HMGP funds from this disaster but was unrelated to the earthquake.

Following the initial project list development, the Loss Avoidance Team (LAT) reviewed the HMGP project files and compiled the data. All of the data necessary for the completion of the loss avoidance study were not included in the HMGP project files. In early 2007, the LAT initiated a data collection process by contacting all selected county and city governments and lead agencies for the selected projects, and conducted initial site visits. The LAT used these sources to collect hydrologic, hydraulic, and topographic data and engineering drawings, to the extent these data were available. Data collected by the LAT were organized with the loss avoidance project files for all 20 projects.

The scope of work for this loss avoidance study required the identification of six to eight projects in Northern California that could proceed through all three phases of the loss avoidance study methodology. After the initial project list and loss avoidance project files were developed, the projects were prioritized and screened based on the parameters discussed in Section 2.2. Projects were ranked and prioritized based on the availability of data from HMGP project files, site visits, local governments and their consulting engineers, and third-party vendors.

The projects received an initial project rank of high, medium, and low based on the availability of necessary data for Phase 2. The ranking methodology was consistent with that of the Southern California study.

- **High** - Projects ranked as high appeared to have all necessary hydrologic, hydraulic, and topographic data for Phase 2 analysis of the MP_A and MP_C scenarios.
- **Medium** - Projects ranked as medium may have been missing some of the necessary data, but the data could be obtained through additional measures. A project may have been given a low ranking if there was a low likelihood of damage occurring in the MP_A scenario.
- **Low** - A project was ranked low if no data were available, or a key piece of data was unavailable and could not be replicated.

Consistent with the Southern California study, obtaining the necessary data for Phase 2 analysis proved difficult. Local officials and their engineering consultants did not maintain the digital files for the project or were unable to retrieve them from project archives. In most cases this was due to changes in the staff that managed the project. In addition, many of the projects are in rural areas or special districts, and the data management procedures are not as rigorous.

Table 2.2 summarizes the initial project ranking.

Table 2.2

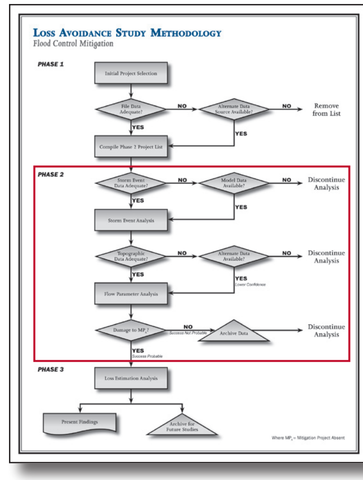
Initial Project List and Priority Rank

General Project Information				Project Priority
Project Number	Project Name	County	Project Type	Initial Rank[1]
1046-1007	*Petaluma River Payran Reach Flood Control and Floodways*	Sonoma	Flood Control and Floodways	**H**
1155-0010	*Soscol Avenue Area Drainage Interceptor*	Napa	Stormwater Management	**M**
1155-0016	*Humboldt Road Box Culvert at Malloy Creek*	Butte	Culvert Replacement	**M/H**
1155-0017	*Alhambra Creek Channel Improvements*	Contra Costa	Stormwater Management and Wetland Restoration	**M/H**
1203-0027	*Hilltop Green Flood Mitigation Project*	Contra Costa	Stormwater Management	**H**
1203-0034	*Broadway Culvert Replacement*	Yuba	Culvert Replacement	**H**
1008-6040	*Violet Lane Storm Drain and West Marlette Relief Drain*	Amador	Stormwater Management	**M/L**
1044-0012	*Stormwater Detention Basins*	Butte	Stormwater Management	**M/H**
1044-0017	*Olivehurst Interceptor*	Yuba	Flood Control	**M/H**
1044-0035 1046-1017	*Cirby/Linda/Dry Creek Flood Control Project*	Placer	Flood Control - Floodwall	**H**
1044-0223	*Oro-Chico Highway Drainage Improvement*	Butte	Stormwater Management	**M/L**
1155-0001	*Drain System Connection*	Mendocino	Water and Sanitary Sewer System Protective Measures	**L**
1155-0009	*Thermalito Drainage Improvements*	Butte	Stormwater Management	**M/L**
1155-0011	*Water Diversion at Starr King Middle School*	Sacramento	Stormwater Management	**L**
1155-0015	*Water Diversion at Marvin Marshall School*	Sacramento	Stormwater Management	**L**
1155-0020	*Esplanade Storm Drain Improvement*	San Mateo	Stormwater Management	**L**
1203-0025	*East China Hill Culvert Upgrade*	El Dorado	Stormwater Management	**L**
1203-0026	*McClarren Avenue Storm Drain Extension*	Contra Costa	Stormwater Management	**M/L**
1203-0029	*Restoration/Improvement of Culverts on County Roads*	Lake	Stormwater Management	**M**

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

Section Three

Phase 2 - Physical Parameter Analysis



This section contains a discussion of Phase 2 of the loss avoidance study methodology-the Physical Parameter Analysis. As with Phase 1, projects with inadequate data may be eliminated from the study during Phase 2. The Phase 2 analysis conducted for the Northern California flood control study followed the methodology first presented in the Southern California study (FEMA, 2007), which is illustrated in Figure 3.1. During Phase 2, the following analyses are conducted:

1. **Storm Event Analysis** - This analysis is conducted to identify storm events that could have caused damage in the MP_A scenario.

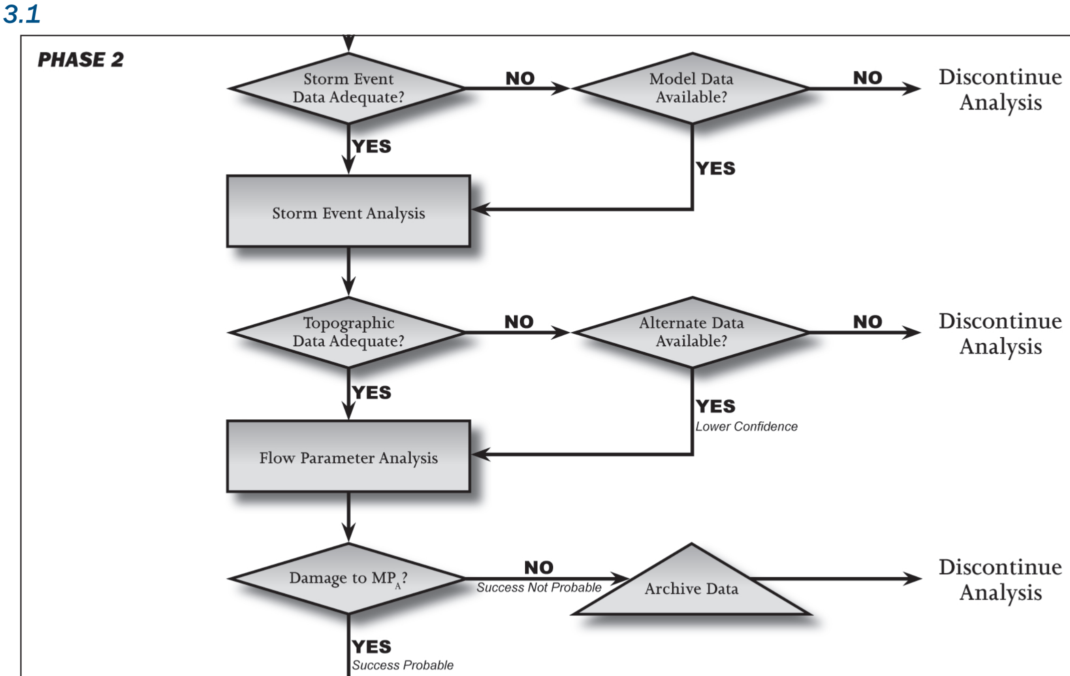
2. **Flow Parameter Analysis** - This analysis includes:

   - **Hydrologic Analysis** to determine the storm event runoff/ flow.

   - **Hydraulic Analysis** to determine how runoff moved through the project area, and what water surface elevations (WSEs) resulted from the storm event.

   - **Flood Boundary Analysis** to determine the flood inundation area, which is used to determine the flood depth at the project location.

Figure 3.1



Source: FEMA, 2007

3.1 Storm Event Analysis

A loss avoidance study for any flood-related project is dependent upon the occurrence of a storm event severe enough to have caused damage in the MP_A scenario (FEMA, 2007). For some projects, more than one storm event may have occurred during the project's lifetime that could have caused damages, or did cause damages, in the project area. The storm event analysis is conducted using existing gage data. There are three types of gage data that can be used in the storm event analysis: stream gage stage data, stream gage discharge data, and precipitation gage data. The method used for the analysis varies depending upon the type of gage data. To determine if damage would have occurred in the MP_A scenario, the project completion date and the MP_A capacity of the project area must be known. This helps to determine what storm size could be conveyed by the original structure/channel with no resulting damages (FEMA, 2008).

3.1.1 Data Collection

Storm event data may be available in the form of stream gage data, precipitation gage data, or both. Stream gages provide flow or stage for a particular channel, whereas precipitation gages provide rainfall at a particular point. When collecting gage data, it is important to reference:

- **Identification Number or Code** - This may be an alphanumeric code used for identification and recordkeeping purposes by the agency responsible for maintaining the gage.
- **Location** - The latitude and longitude of the gage to determine proximity of the gage to the project location.
- **Type** - The data may be stream gage data or precipitation gage data.
- **Recording Period** - How long the gage has been operating. The recording period must be relevant to the period of interest for the loss avoidance study.
- **Recording Interval** - The frequency of data readings (e.g., hourly, daily, event-based [FEMA, 2008]).

Gage data are typically recorded by various agencies, which may include local or regional water agencies or flood control districts, state departments of water resources, the National Weather Service (NWS), U.S. Geological Survey (USGS), U.S. Army Corps of Engineers (USACE), and U.S. Department of Agriculture Forest Service (FEMA, 2008).

The best data for storm event analysis is stream gage data for the

Storm Event Analysis Data Sources

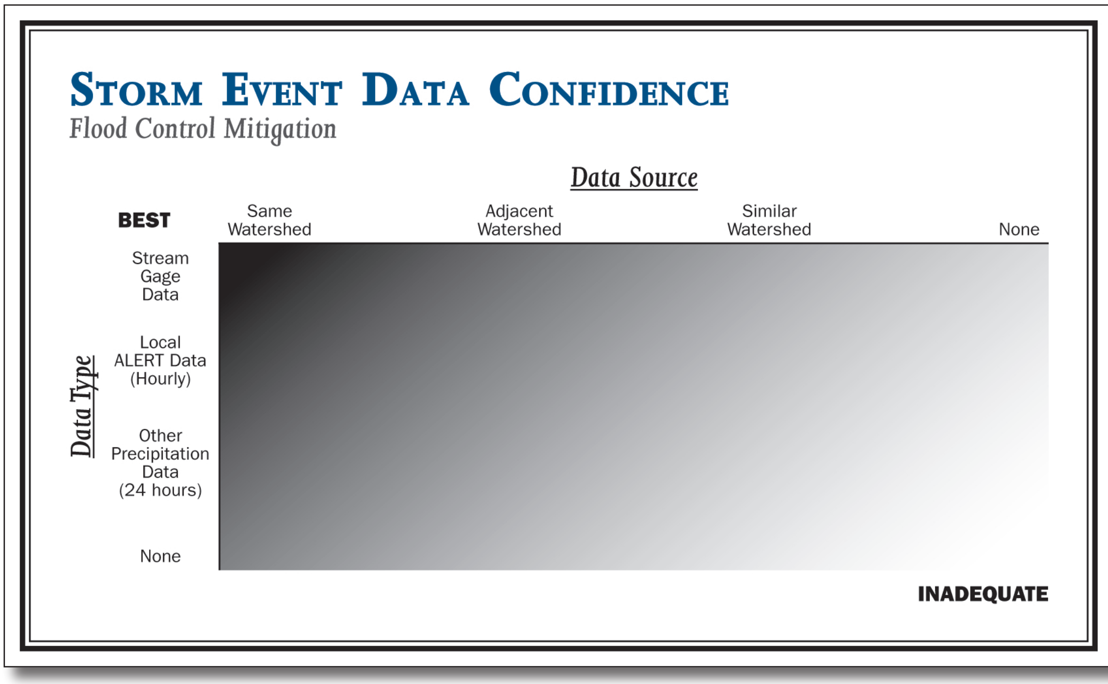
For loss avoidance studies, local, regional, state, and federal weather and conservation agencies are the primary source for data.

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)

specific channel being studied. If a stream gage is not located on the studied channel, then a precipitation gage must be used. A precipitation gage within the watershed of the project area would be preferable; precipitation gages in adjacent watersheds can be used in a loss avoidance study but would not provide the most accurate results. This concept is illustrated in Figure 3.2.

Figure 3.2



Source: FEMA, 2007

3.1.2 Stream Gage Event Analysis

Stream gage data are typically available for larger channels or rivers, but not for localized drainage projects or smaller watersheds. The availability of sufficient stream gage data should be determined for each mitigation project. If a stream gage is available in or near (upstream or downstream of) the project area and has a period of record covering the period of interest, a stream gage event analysis can be conducted.

Stream gages may provide information about flow, channel stage (depth), or both. In most cases, flow or stage data can be downloaded and ranked from highest to lowest flow/stage. The highest flows/stages and the dates of the events should be recorded. Based on information provided in the mitigation project file (initial MP_A capacity or level of protection), a determination can be made as to whether MP_A damages could have occurred. Projects are eliminated if MP_A damages do not appear to have been possible. For example, a peak flow event may be determined to be 3,000 cubic feet per second (cfs), but the MP_A capacity was 10,000 cfs. It is unlikely MP_A damages would have occurred, and the analysis would be discontinued for this project.

If gage data provide stage information only, the data must be converted to obtain the actual flow of the storm. This conversion is completed as a part of the hydrologic analysis.

3.1.3 Precipitation Gage Event Analysis

When stream gage data are not available, precipitation gage data should be analyzed. Similar to the stream gage event analysis, the selected gage should have a sufficient period of record and must be applicable to the project area watershed. Precipitation gages may provide hourly, daily, or event-based rainfall totals. Precipitation gage data may require screening for peak rainfall rates for multiple-duration storm events (e.g., 6-, 12-, 24-hour).

The precipitation gage event analysis methodology is:

1. The precipitation data is collected for the period of interest.
2. Rainfall totals are calculated for applicable storm durations (6-, 12-, or 24-hour).
3. Storm duration interval totals are ranked from highest to lowest.
4. The dates of the maximum precipitation event(s) are determined.
5. Precipitation gage data are used to complete a hydrologic analysis.
6. Gage data are compared to MP_A capacity to determine the likelihood of damage.

If it is determined that MP_A damages are unlikely, the loss avoidance analysis is discontinued for the project.

3.1.4 Northern California Flood Control Study - Storm Event Analysis

One project was removed from the Phase 2 project list due to the size and complexity of the project area.

- 1203-0029 Restoration/ Improvement of Culverts on County Roads

This project involved many culverts and a project area of many square miles in Lake County. Continued analysis was not feasible.

In the case of the Northern California flood control study, recent storm events at the project sites were analyzed to determine whether damage would have occurred in the study area had the project not been implemented. Projects were removed from the list if it was determined that no event was found to have been severe enough to cause damage in the MP_A scenario.

The following sources were used to collect storm event data:

- California Data Exchange Center (CDEC), maintained by the California Department of Water Resources (DWR) and the National Weather Service (NWS)

- USGS, and
- Hydrology studies performed by county or city engineers.

For this study, precipitation data were reviewed for the most severe 24-hour storm event since project completion. A 24-hour storm event was used for the following reasons:

1. Drainage system designs are often based on a 24-hour storm duration.
2. Flood Insurance Rate Maps (FIRMs) published by FEMA for the National Flood Insurance Program (NFIP) are often based on hydrologic models with 24-hour storm durations when stream gage data are not available.
3. Many precipitation databases only have daily (24-hour) totals available.

If the project information indicates that a different design storm duration was used for the project design analysis, then that storm duration should be used.

The most severe 24-hour storm event was compared to the severity of the storm events that caused flooding before the project was built. The storm event data were used to estimate the peak runoff along the stream or river reach of interest. The most direct way to estimate the peak runoff was from a stream gage located on the reach being studied. If applicable and available, stream gage data were collected for each project.

Detailed results of the storm event analysis for the Northern California flood control study are provided in Table 3.1. Although several gages may have been considered for a project, one gage was identified as the most applicable gage; this gage is identified for each project in Table 3.1. This table also provides the MP_A capacity, as estimated by the applicant, and an estimate of the likelihood of damages based on the most severe MP_C storm to have impacted the project area. The estimate of the likelihood of damage is noted as low, medium, or high based on a comparison of estimated MP_A capacity with the estimated recurrence interval of a storm event. This was only a qualitative estimate that was used to help guide the project screening process.

In the case of the Northern California flood control study, only a few of the projects had stream gage data for the reach of interest. The runoff for all the other project sites was estimated from precipitation data during the hydrologic analysis.

Unlike the Southern California study, during the Northern California flood control study, the storm event analysis was completed almost concurrently with Phase 1. This was due to the quality and

Five projects were removed from the Phase 2 project list due to the very low likelihood of MP_C storm events causing damage in the MP_A scenario.

- 1008-6040 Violet Lane Storm Drain and West Marlette Relief Drain
- 1044-0012 Stormwater Detention Basins
- 1044-0017 Olivehurst Interceptor
- 1155-0009 Thermalito Drainage Improvements
- 1203-0025 East China Hill Culvert Upgrade

Table 3.1 Part 1 of 2

Storm Event Analysis Results

Project Number	Project Name	Estimated MP_A Capacity	Estimated MP_C Capacity	Gage Type / Recording Interval / Recording Period	Greatest Post-Construction Event	Event Duration	Likelihood of MP_A Damage Return Frequency
1046-1007	Petaluma River Payran Reach Flood Control and Floodways	5-year	100-year	USGS Stream Gage River Stage and Discharge 11/29/1998 to present	December 31, 2005 (River stage 8.97 feet) (9,620 cfs discharge)	N/A	**High** Frequency not determined
1155-0010	Soscol Avenue Area Drainage Interceptor	Less than 1-year	10-year	Precipitation Gage Event Unknown	December 31, 2005 (5.64 inches)	24-hour	**High** Exceeding a 10-year event
1155-0016	Humboldt Road Box Culvert at Malloy Creek	5-year	50-year	Precipitation Gage Hourly 06/07/2000 to present	February 26, 2006 (6.83 inches)	24-hour	**Medium/High** Between a 10- and 25-year event
1155-0017	Alhambra Creek Channel Improvements	2-year	10- to 15-year	Precipitation Gage Event 02/25/2004 to present	December 31, 2005 (3.21 inches)	12-hour	**High** Estimated by Contra Costa County to be a 39-year event
1203-0027	Hilltop Green Flood Mitigation Project	Less than 10-year	100-year	Precipitation Gage Event 01/22/2005 to present	December 31, 2005 (3.16 inches)	12-hour	**High** Estimated by Contra Costa County to be a 14-year event
1203-0034	Broadway Culvert Replacement	3-year	100-year	Precipitation Gage Hourly 01/22/2005 to present	December 31, 2005 (3.4 inches)	24-hour	**High** Approximately a 25-year event
1008-6040	Violet Lane Storm Drain and West Marlette Relief Drain	10-year	50- to 100-year	Precipitation Gage Daily 01/23/1989 to present	April 4, 2006 (3.4 inches)	Daily	**Low** Between a 2- and 5-year event
1044-0012	Stormwater Detention Basins	15-year	100-year	Precipitation Gage Hourly 01/01/1987 to present	December 7, 2004 (3.56 inches)	24-hour	**Low** Approximately a 5-year event
1044-0017	Olivhurst Interceptor	10-year	100-year	Precipitation Gage Hourly 09/16/2005 to present	December 31, 2005 (3.4 inches)	24-hour	**Medium/Low** Approximately a 10-year event
1044-0035 1046-1017	Cirby/Linda/Dry Creek Flood Control Project	Unknown	100-year	Precipitation Gage Event 10/01/1995 to present	December 31, 2005 (3.78 inches)	24-hour	**Medium** Approximately a 25-year event
				Linda Creek ALERT River Stage 01/24/2000 to present	December 31, 2005 (River stage 153.78 feet)	N/A	**Medium** Frequency not determined
				Dry Creek ALERT River Stage 10/01/1995 to present	December 31, 2005 (River stage 121.91 feet)	N/A	**Medium** Frequency not determined

Continued

Table 3.1 Part 2 of 2

Storm Event Analysis Results

Project Number	Project Name	Estimated MP_A Capacity	Estimated MP_C Capacity	Gage Type Recording Interval Recording Period	Greatest Post-Construction Event	Event Duration	Likelihood of MP_A Damage Return Frequency
1044-0223	***Oro-Chico Highway Drainage Improvement***	*15-year*	*100-year*	Precipitation Gage Hourly *09/01/1998 to present*	**February 26, 2006 (3.59 inches)**	*24-hour*	**Medium** ***Between a 10- and 25-year event***
1155-0001	***Drain System Connection***	*Less than 10-year*	*Unknown*	Precipitation Gage Hourly *01/01/1997 to present*	**December 13, 2002 (5.2 inches)**	*24-hour*	**Medium** ***Approximately a 10-year event***
1155-0009	***Thermalito Drainage Improvements***	*8- to 10-year*	*25-year*	Precipitation Gage Hourly *01/01/1987 to present*	**December 7, 2004 (3.56 inches)**	*24-hour*	**Low** ***Approximately a 5-year event***
1155-0011	***Water Diversion at Starr King Middle School***	*Less than 5-year*	*10-year*	Precipitation Gage Event *10/01/1995 to present*	**December 31, 2005 (3.11 inches)**	*24-hour*	**High** ***Between a 10- and 25-year event***
1155-0015	***Water Diversion at Marvin Marshall School***	*Less than 5-year*	*10-year*	Precipitation Gage Event *10/01/1995 to present*	**December 31, 2005 (3.34 inches)**	*24-hour*	**High** ***Between a 10- and 25-year event***
1155-0020	***Esplanade Storm Drain Improvement***	*10-year*	*25-year*	Precipitation Gage Hourly *04/19/1999 to present*	**December 30, 2005 (4.53 inches)**	*24-hour*	**High** ***Approximately a 25-year event***
1203-0025	***East China Hill Culvert Upgrade***	*Less than 5-year*	*10-year*	Precipitation Gage Hourly *11/04/2003 to present*	**December 31, 2005 (4.06 inches)**	*24-hour*	**Medium/Low** ***Between a 2- and 5-year event***
1203-0026	***McClarren Avenue Storm Drain Extension***	*2-year*	*50-year*	County Precipitation Gage Unknown *Unknown*	**December 31, 2005 (1.76 inches)**	*12-hour*	**Medium/High** ***Estimated by Contra Costa County to be a 7.4-year event***
1203-0029	***Restoration/Improvement of Culverts on County Roads***	*5-year*	*25-year*	Not Determined	**Not Determined**	*Not Determined*	**Not Determined**

availability of gage data in Northern California. DWR maintains an extensive database for the State of California which includes precipitation gage data, river stage data, and flow data. Gage data were readily available and were collected from the DWR CDEC Web site. The quality and availability of gage data obtained for Northern California may not be found in other areas of the United States, so it is not expected that all projects on a loss avoidance study initial project list will undergo the storm event analysis. Rather, the storm event analysis is more likely to occur after the initial project list has been screened.

3.2 Flow Parameter Analysis

The flow parameter analysis consists of three separate analyses: a hydrologic analysis, a hydraulic analysis, and a flood boundary analysis. These three analyses help to determine how the project area was impacted by the storm events of interest identified during the storm event analysis.s

3.2.1 Hydrologic Analysis

A hydrologic analysis is required when only precipitation gages are available in the study area. It uses precipitation data to estimate the amount of runoff from a given storm event for different locations in a project area. Once the amounts of precipitation from the peak events are identified from the storm event analysis, a hydrologic analysis can be performed if all the other required data are available. The resulting runoff estimate can then be used in conjunction with a hydraulic analysis to determine flood depths (FEMA, 2008).

For studies confined to a limited reach of a single flooding source, a hydrologic analysis may only be needed for a single upstream watershed. For larger, multi-reach projects, hydrologic analyses of multiple watersheds may be required. If the required data and models are not available, or cannot be developed, for hydrologic analysis, then the project is removed from further consideration in the study (FEMA, 2008).

The scope of work for the loss avoidance study determines whether loss avoidance calculations are conducted for one particular MP_C storm event or for all MP_C storm events that could have caused damage in the MP_A scenario. For example, the study sponsor may only be interested in the most severe event that occurred since project construction was completed, and this one event is modeled for the MP_A scenario. Conversely, a study sponsor may want to model all large events that have occurred after project construction was completed.

3.2.1.1 Data Collection

The process of data collection is determined by the results of the storm event analysis, specifically by the type of gage data used. If stream gage data are available, they may be used to calculate peak runoff directly. If precipitation data are available, then some type of existing or new hydrologic model or method is needed to calculate the peak runoff. The following data may be required for hydrologic analysis:

- **Drainage Data** - Drainage data includes information about the watershed.
  - **Existing Hydrologic and Hydraulic Models** - Existing hydrologic and hydraulic (H&H) models should be collected during project selection and initial data collection. Sources of H&H models include locally developed flood studies; FEMA flood studies, including Flood Insurance Studies (FISs), Letters of Map Revision (LOMRs); and Conditional Letters of Map Revision (CLOMRs).
  - **Existing Floodplain Maps** - Existing floodplain maps should be collected during project selection and initial data collection. Sources of floodplain maps include locally developed flood studies, local hazard mitigation plans, and FEMA flood studies including the FIS and FIRM.
  - **Topographic Data** - Topographic data should be collected during project selection, because these data are required to conduct the flood boundary analysis. Sources of topographic information include USGS, site-specific surveys, construction drawings, existing flood studies, local agencies, and third-party vendors.
- **Infiltration Information** - The hydrologic method used will help to determine the infiltration information required. Infiltration information is used to determine whether rainfall will become runoff or infiltrate local soils. Data sources include drainage data and soils maps developed by the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS), and local agencies. Depending upon the hydrologic analysis method being used, the NRCS curve number (CN) may be required. The NRCS CN is developed to combine land use, soils, and antecedent moisture conditions.
- **Hydrologic Model-specific Data Requirements** - Different hydrologic analysis methods may have varying data requirements. Some may require regional regression equations to calculate flow rates, hydrologic design standards, or proprietary hydrologic model parameters.

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)

- **Sub-watershed Delineation and Model Parameters** - When analyzing larger watersheds, most models require that sub-watersheds be delineated and characterized. Sub-watersheds are typically delineated using topographic data. Characteristics (e.g., land use, soils, ground cover) of each sub-watershed are then determined and generalized parameters, typically area-weighted averages, are input into the hydrologic model.

3.2.1.2 Stream Gage Hydrologic Analysis

During the storm event analysis, applicable stream gage data are collected. If sufficient stream gage data are available for a particular project, they should be used. If a stream gage is available in or near the study area and has a period of record covering the period of interest, then a stream gage hydrologic analysis can be conducted.

Stage Data

If a gage that provides stage data is identified immediately adjacent to a project or structure within the project area, it is possible to compare the peak flood elevations directly to the design elevations of the project or the first floor elevation (FFE) of a structure without any further analysis. A gage that is not adjacent to the project but located in the vicinity of the study area may also be used. If a published rating curve, usually from USGS, exists for the site that compares flood stage to flow rates, the peak flood elevations determined from the gage can be used to estimate the peak flow rate. If a rating curve is not available, the stage information can be used in conjunction with hydraulic analysis to determine the peak WSE at the project site.

It should be noted that stage data may represent an average stage over an interval, such as an hour or a day. The method to calculate peak stage from average stage must be determined if required by the scope of work for the study. Otherwise, time-averaged values may be used.

Discharge Data

Similarly, if the stream gage identified in the study area provides only discharge data, and if sufficient data are available, the peak runoff can be identified for the event of interest. Similar to gages that provide stage data, the discharge data may represent an average runoff over an interval, such as an hour or a day. Statistical methods for analyzing data may be required to estimate an instantaneous peak, when only time-averaged peak data are available. Once the peak discharge is identified, it can be used in conjunction with a hydraulic analysis to determine the WSE of peak events (FEMA, 2008).

3.2.1.3 Modifying Existing Hydrologic Models for Analysis

If stream gage data are not available, then a hydrologic model may be used to determine peak runoff. For some projects, it may be possible to obtain existing hydrologic models. Models should represent both the MP_A and MP_C scenarios. When these models are available, they can be modified to simulate the event of interest. This may involve simply replacing the original input rainfall data with new rainfall data. The difficulty of modifying a model for a given project is highly dependent upon the model. Hydrologic modeling software tends to change over time, so it may be difficult to obtain the original model programs. It may be necessary to modify model inputs so that they are compatible with the latest software. Unfortunately, these modifications may not always provide results consistent with the original model output (FEMA, 2007).

3.2.1.4 Performing a New Hydrologic Analysis

Because of the difficulties associated with modifying existing hydrologic models, conducting a new hydrologic analysis may be less time consuming, even when existing models are available. If a new hydrologic analysis must be conducted, method selection should be matched to the available data and standard practices. FEMA has published acceptable methods for performing a hydrologic analysis. In addition to conducting a hydrologic analysis using gage station data; regional regression equations, rational method calculations, and numerical models may be used. Information about FEMA-acceptable hydrologic models can be found on FEMA's Web site, www.fema.gov, within the NFIP flood mapping guidance (FEMA, 2003).

Regional Regression Equations

Recurrence intervals for the peak events can be determined from precipitation data. FEMA guidelines and specifications for the preparation of FIRMs allow the use of regional regression equations to determine peak runoff for different recurrence intervals. Regional regression equations have been developed by the USGS. The most recently developed equations should be used. A relationship can be developed from the design rainfall amount at different recurrence intervals and the resulting runoff. Standard equations are available for specific recurrence intervals. If the recurrence interval of the actual peak event falls between the standard recurrence intervals, runoff can be estimated based on a line-fitting statistical process (FEMA, 2007).

The Rational Method

The Rational Method can be used to calculate the peak flow for small watersheds (generally less than 200 acres). The Rational Method is defined by the flowing equation:

$$Q = C \cdot I \cdot A$$

Where **Q** = Runoff in cubic feet per second (cfs)
Where **C** = Dimensionless runoff coefficient (an additional conversion factor is implicitly included since 1 acre-in/hr is approximately equal to 1 cfs)
Where **I** = Average rainfall intensity for a given duration in inches per hour (in/hr)
Where **A** = Contributing drainage area in acres

The runoff coefficient is usually determined from standard values based on land use, soil type, and land slope, and can vary from zero (no runoff) to 1.0 (100 percent runoff). The Rational Method provides the most accurate results as basins decrease in size, increase in imperviousness, and increase in homogeneity of basin characteristics. To estimate runoff with the Rational Method, the rainfall duration should be greater than the time of concentration calculated for the basin.

Numerical Models

In larger watersheds, or when the drainage network within the watershed contains reservoirs or other hydraulic structures that alter runoff response, more sophisticated hydrologic modeling is needed. There are numerous numerical models available; therefore, specific application of numerical models cannot be covered within this report. Guidance on numerical models, however, is available on FEMA's Web site, and a list of FEMA accepted models is located at www.fema.gov.

3.2.1.5 Northern California Flood Control Study - Hydrologic Analysis

Gage data for the storm event analysis was analyzed, and the LAT subsequently determined which projects had stream gages. The runoff for all the other project sites was estimated from rainfall data using one of the appropriate hydrologic analysis methods.

Most of the Northern California flood control study projects did not have adequate hydrologic data. Most hydrologic data provided in the project files were hardcopy reproductions of drainage master plans and other drainage studies. For the majority of the projects, hydrologic calculations or digital input and output files of hydrologic models were not provided; therefore, many projects were eliminated at this stage of the analysis. A hydrologic analysis was conducted only for those projects with sufficient data:

- **Cirby/Linda/Dry Creek Flood Control Project** - Hydrologic analysis used stream gage data.
- **Petaluma River Payran Reach Flood Control and Floodways** - Hydrologic analysis used stream gage data.
- **Soscol Avenue Area Drainage Interceptor** - Hydrologic analysis used precipitation gage data and a numerical model.
- **Humboldt Road Box Culvert at Malloy Creek** - Hydrologic analysis used precipitation gage data and regional regression equations.
- **Alhambra Creek Channel Improvements** - Hydrologic analysis used stream gage data and a hydrology report for the event of interest published by the local project sponsor.
- **Hilltop Green Flood Mitigation Project** - Hydrologic analysis used precipitation gage data and the Rational Method.
- **Broadway Culvert Replacement** - Hydrologic analysis used precipitation gage data and the regional regression equations.

The seven projects identified above proceeded to the hydraulic analysis. More detailed information on the hydrologic analysis conducted for the final project list can be found in the project-specific appendices.

Six projects were removed from the Phase 2 project list due to lack of the data required to perform a hydrologic analysis.

- 1044-0223 Oro-Chico Highway Drainage Improvement
- 1155-0001 Drain System Connection
- 1155-0011 Water Diversion at Starr King Middle School
- 1155-0015 Water Diversion at Marvin Marshall School
- 1155-0020 Esplanade Storm Drain Improvement
- 1203-0026 McClarren Avenue Storm Drain Extension

3.2.2 Hydraulic Analysis

Once the hydrologic analysis is completed, the WSE for the peak flow of the event(s) of interest can be determined through a hydraulic analysis. A hydraulic analysis is required for both the MP_A and MP_C scenarios because channel configurations and other conditions may have changed as a result of the mitigation project. Hydraulic analyses are used to estimate WSEs at a series of cross-sections to determine how a particular project performs during the peak flow of the event(s) of interest. A hydraulic analysis is required when data collected during the storm event and hydrologic analyses indicate:

- Stage data that are not directly adjacent to the project, but in the study area,
- Only discharge data are available for a stream gage in the study area,
- Only precipitation gages are available in the study area, and a hydrologic analysis is performed to determine the peak runoff for the event (FEMA, 2008).

3.2.2.1 Data Collection

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

As with other project analyses, the hydraulic analysis requires that certain data be collected, such as topographic data and other data required for the selected hydraulic model.

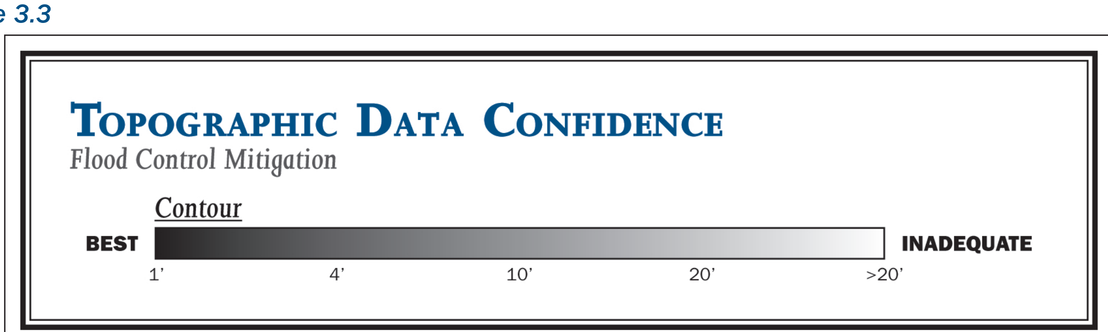
Topographic Data

Topographic data represent the elevation profile in the project area and should be available for the MP_A and MP_C scenarios if the project modified topographic conditions. Otherwise, data for the MP_A scenario are sufficient. The Southern California study provided substantial detail on the types of topographic data available and confidence intervals for the data. In summary, topographic data can be represented as:

- **Photogrammetric Data** - Digital topography produced from aerial photogrammetry with ground control and survey.
- **LIDAR Data** -Topography generated by airborne Light Detection and Ranging Systems (lidar).
- **Surveyed and Hardcopy Topographic Data** - Topographic data developed during a project-specific land survey and is generally provided by a local government or project sponsor in the design drawings. These data are generally provided in hardcopy and not a digital format and often require a significant amount of manual interpretation and adjustment.
- **USGS DEM Data** - Digital Elevation Models (DEMs) from the USGS typically available in 30- or 10-meter contours. These data are readily available across the United States.

Topographic data are available from a variety of sources, such as government agencies, engineering or surveying consultants, and third-party vendors. The best topographic data available should be used to improve the accuracy of the hydraulic analysis. Data with 1- to 4-foot contour intervals are considered the best data available for the hydraulic analysis. Confidence in the data drastically decreases if the contour intervals are greater than 10 feet, as illustrated in Figure 3.3.

Figure 3.3



Source: FEMA, 2007

Hydraulic Analysis Method Selection and Data Requirements

Based on the available data, a hydraulic analysis method must be selected and analysis-specific data must be collected. Most analysis methods require project cross-section elevation data, detailed parameters at each cross-section, information about hydraulic structures in the study area, and specific model configuration parameters, such as boundary conditions. There are numerous tools available, mostly Geographic Information System (GIS)-based, for cutting cross-sections from digital elevation data. Cross-sections are commonly placed at locations along a channel where flow conditions may change (e.g., before and after a bend in the channel, location of a hydraulic structure). If sufficient digital elevation data are not available, cross-sections can also be cut by hand using printed contour maps. This method can be very time-consuming when a large number of cross-sections are required.

Detailed cross-section information represents channel conditions, such as channel roughness. Many models use Manning's Roughness Coefficient to represent the resistance of the channel lining to flow. Particular cross-sections may also represent the upstream and downstream ends of hydraulic structure, such as bridges and culverts. Other data required for successful completion of the hydraulic analysis include peak flow, boundary conditions (at the upstream and downstream extents of the study area), and model runtime settings. Of course, data requirements change based on the hydraulic analysis method used, so an experienced professional should review the available data and conduct the hydraulic analysis.

3.2.2.2 Observed Data Analysis

The Southern California study contains information about conducting a hydraulic analysis based on the availability of observed flood elevations. This methodology was not used for the Northern California flood control study; however, if observed flood elevations were known for a particular project, these data would be used to validate the hydrologic and hydraulic analyses.

3.2.2.3 Modifying an Existing Hydraulic Model for Analysis

For some projects, it may be possible to obtain existing hydraulic models. Existing models may be obtained from the project files or during initial data collection. Models should represent MP_A and MP_C scenarios. When these models are available, they can be modified to simulate the event of interest. This may involve simply replacing the original input peak flow data with new peak flow data. In other cases, only portions of the original model may be applicable for use in the loss avoidance study. For example, it may be possible to use the channel cross-sections from an existing model in a new model. The difficulty of modifying a model for a given project is highly dependent upon the model. Hydraulic modeling software tends to change over time, so it may be difficult to obtain the original model programs. It may be necessary to modify model inputs so that they are compatible with the latest software. Unfortunately, these modifications may not always provide results consistent with the original model output.

3.2.2.4 Performing a New Hydraulic Analysis

For many projects, a new hydraulic analysis is required for the MP_A and MP_C scenarios, either because an existing model is not available, specific data are not available, or the difficulties associated with modifying an existing hydraulic model are too great. If a new hydraulic analysis must be conducted, the method selected should be matched to the data available and standard practices. Hydraulic analysis may be conducted through analysis of available gage data, analysis of an existing flood study, normal depth calculations, or numerical models. Additional information on FEMA acceptable hydraulic models can be found within the NFIP guidance on FEMA's Web site, www.fema.gov (FEMA, 2003).

Hydraulic Analysis Using Stream Gage Data

A hydraulic analysis can be conducted using stream gage stage or discharge data. A hydraulic analysis using stream gage data for most flood control mitigation projects would only be applicable to the MP_A scenario, because in most instances channel conditions have changed for the MP_C scenario.

Stage Data

If stage data are provided by a stream gage, and the gage is immediately adjacent to a project, the data can be compared directly to the design elevation of a project or FFE of a structure. However, if the project is not located directly adjacent to the gage, then it is necessary to use the gage data in combination with hydraulic analysis to determine the WSE at the project site. This can be accomplished if:

1. The channel was studied in detail for the FEMA FIRM. The location of the gage along the river can be found on an existing flood profile (found in the FIS), and the WSE at the gage can be compared to the WSEs of plotted profiles.
    a. If only hardcopies of flood profiles are available, the location of the project in question can also be found on the flood profile. Through interpolation between the plotted profiles, the WSE of the peak event at the project site can be determined.

b. If an electronic hydraulic model of the study area is available, the following method can be used. From the comparison of the WSEs, a recurrence interval for the event can be estimated. Based on the recurrence interval, the discharge of the event can be found through interpolation of the existing model's discharges found in the FIS. The discharge can then be entered into the model to estimate the WSE at the project site. If a hydraulic model does not exist, a new model may be created.

2. A published rating curve exists at the gage site. The rating curve can be used to estimate the flow rate of the peak event. The flow rate can then be used in conjunction with an existing hydraulic model, or a new model can be created to estimate the elevation of the peak event at the project site.

Discharge Data

If a flow rate is available from a stream gage that is adjacent to a project, and if a published rating curve that compares flow rate to flood stage is available for the site (such as from the USGS), then the rating curve can be used to estimate the WSE. If the gage is not adjacent to the project, hydraulic modeling is necessary to determine the flood elevation of the peak events.

Hydraulic Analysis Using an Existing Flood Study

The flood elevation at a project can be determined by using an existing flood study. If the flooding source was studied in detail for the FEMA FIRM, a table of discharges can be found in the FIS providing the various discharges used in the model (usually the 10-, 50-, 100-, and 500-year events). If only hardcopy of the FEMA model is available, the flow rate of the peak event can be compared to those used in the existing model to estimate the recurrence interval of the event. Based on the recurrence interval, the WSE of the event can be found through interpolation of the existing model's flood profiles at the site in question (published in the FEMA FIS). If a digital version of an existing hydraulic model of the study area is available, the WSE of the peak event can be determined by inputting the discharge data obtained from the stream gage or hydrologic analysis (FEMA, 2008).

Hydraulic Analysis Using Normal Depth Calculations

When there is no existing hydraulic model, normal depth calculations can be performed. These calculations require the peak flow for the event, the channel cross-section geometry, an estimation of the channel slope, and Manning's 'n' (roughness coefficient). The use of a computer software program for a limited reach, such as Hydrologic Engineering Center - River Analysis System (HEC-RAS), can aid in performing these calculations.

Hydraulic Analysis Using Numerical Models

There are numerous numerical models available; therefore, specific application of numerical models cannot be covered within this report. Guidance on numerical models and a list of acceptable models are available on FEMA's Web site, www.fema.gov.

3.2.2.5 Northern California Flood Control Study - Hydraulic Analysis

Hydraulic data collected for most of the Northern California flood control study projects included design drawings, as-built drawings, flood studies, and flood maps. Some projects had topographic data and numerical modeling files available for modification. Most hydraulic data provided in the project files were hardcopy reproductions of drawings, drainage master plans, and other drainage studies. Hydraulic calculations or digital input and output files of hydraulic models were not provided for most projects. The LAT obtained topographic data from local government Web sites, USGS, and third-party vendors, as appropriate. Hydraulic models were modified when available and appropriate; however, for most projects, a new hydraulic analysis was required.

The topographic data for many of the projects had limitations, including lack of appropriate geographic coverage, incompatible format, and insufficient level of detail. The ideal topographic data for the loss avoidance study would have contour intervals of four feet or less, be available in GIS, and cover the potential inundation areas in both the MP_A and MP_C scenarios. Unfortunately, data meeting all these criteria were not generally available.

Topographic data for the seven remaining projects were reviewed to determine if they would be sufficient for analysis during Phase 2. Table 3.2 summarizes the topographic data collected for these projects.

All seven projects had sufficient topographic data for the MP_A and MP_C scenarios and witnessed a storm event with the potential to have caused MP_A damages during the period of interest. For those seven projects, the following hydraulic analyses were conducted:

- **Cirby/Linda/Dry Creek Flood Control Project** - An existing hydraulic model was modified for the hydraulic analysis of this project. Stream gages in the project area were used to determine peak flows, and the new peak flow values were used as inputs to an existing HEC-RAS model.
- **Petaluma River Payran Reach Flood Control and Floodways** - An existing hydraulic model was modified for the hydraulic

Table 3.2

Topographic Data						
Project Number	**Project Name**	**Topographic Data Format**		**Contour Interval**		**Sufficient Data for Phase 2**
1046-1007	*Petaluma River Payran Reach Flood Control and Floodways*	Detailed cross-sections in HEC-RAS **Digital Copy**	CADD/GIS drawing **Hard Copy**	2-ft		**Yes**
1155-0010	*Soscol Avenue Area Drainage Interceptor*	Napa County GIS data **Digital Copy**		5-ft		**Yes**
1155-0016	*Humboldt Road Box Culvert at Malloy Creek*	Third-party vendor data **Digital Copy**		5-m		**Yes**
1155-0017	*Alhambra Creek Channel Improvements*	Third-party vendor data **Digital Copy**	CADD drawing **Hard Copy**	5-m	1-ft to 10-ft (digitized during study)	**Yes**
1203-0027	*Hilltop Green Flood Mitigation Project*	USGS DEM **Digital Copy**		10-m		**Yes**
1203-0034	*Broadway Culvert Replacement*	Third-party vendor data **Digital Copy**		5-m		**Yes**
1044-0035 1046-1017	*Cirby/Linda/Dry Creek Flood Control Project*	Detailed cross-sections in HEC-RAS **Digital Copy**	CADD drawing **Hard Copy**	5-ft, 2-ft, 1-ft (digitized during study)		**Yes**

analysis of this project. A stream gage in the project area was used to determine the peak flow for the event of interest, and the new peak flow value was used as an input to an existing HEC-RAS model.

- **Soscol Avenue Area Drainage Interceptor** - A new hydraulic analysis was completed for this project based on topographic data, as-built drawings, and simplified culvert calculations.
- **Humboldt Road Box Culvert at Malloy Creek** - A new hydraulic analysis was completed for this project based on available topographic data, design drawings, and the Federal Highway Administration's HY-8 culvert software.
- **Alhambra Creek Channel Improvements** - A new hydraulic analysis was completed for this project based on available topographic data, digitized topographic data taken from design drawings, as-built drawings, and HEC-RAS software. An existing HEC-RAS model was collected from the appropriate local agency, but significant modifications were made for the study.
- **Hilltop Green Flood Mitigation Project** - A new hydraulic analysis was completed for this project based on topographic data, design drawings, discussions with the local agency, and detention basin calculations that were representative of the project area.

One project was removed from the Phase 2 project list due to lack of a damaging event.

- 1044-0035 / 1046-1017 Cirby/Linda/Dry Creek Flood Control Project

- **Broadway Culvert Replacement** - A new hydraulic analysis was completed for this project based on topographic data, design drawings, and the Federal Highway Administration's HY-8 culvert software.

Six of the seven projects identified above advanced to the flood boundary analysis. The Cirby/Linda/Dry Creek Flood Control Project had sufficient data to conduct the flood boundary analysis, but the hydraulic analysis results indicated that the event of interest would not have caused damage in the MP_A scenario. The analysis showed that all flows would have been contained by the MP_A drainage system and would not have caused out-of-bank flooding in the project area. Therefore, this project was eliminated due to lack of a damaging event. More detailed information about the hydraulic analysis conducted for the final project list (those projects that were analyzed through Phase 3) can be found in the project-specific appendices.

3.2.3 Flood Boundary Analysis

The final step of Phase 2 is to delineate the floodplain and associated flood depth to determine whether there would have been impacted structures, facilities, and property during the event(s) of interest for both the MP_A and MP_C scenarios.

The methodology for performing a flood boundary analysis presented in the following subsections is discussed in greater detail in the Southern California study.

3.2.3.1 Data Collection

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)

Most of the data required for the flood boundary analysis are generated by the hydrologic and hydraulic analyses. The flood boundary analysis will likely require the hydraulic modeling results, existing floodplain modeling data (if available), supplemental topographic data inclusive of floodplain areas, and location and elevation data for assets within the floodplain. The data requirements for the flood boundary analysis are briefly summarized below:

- **Existing Floodplain Modeling Data** - Existing floodplain modeling data may include a FEMA FIRM. If the FIRM shows the project to be in the floodplain, then the FEMA Map Service Center should be checked for any LOMRs or CLOMRs that include data for the study area. If there is a LOMR or CLOMR prepared for the project area, then it will likely provide most of the data required for the flood boundary analysis, including hydrologic and hydraulic models and topography. FIRMs, LOMRs, and CLOMRs should be collected during the initial data collection efforts; as this data can be used in the H&H analyses, particularly if it can be collected in a digital format.

- **Supplemental Topographic Data** - The topographic data collected for the hydraulic modeling may only include the channel topography. When this is the case, supplemental topographic data (e.g., topographic data for the floodplain) is needed to produce the flood boundary and depth information for the entire floodplain. Topographic data can are available from a variety of sources, such as government agencies, engineering or surveying consultants, and third-party vendors.

- **Asset Data** - The location and elevation of an asset must be known to determine whether an asset would have been impacted by flooding. For structures, this is the FFE, for roads it is the top of the road, and for bridges it is the lowest horizontal structural member.

  Data sources may be:

  - **Surveyed** - Local site survey, elevation certificate, Global Positioning System (GPS) data points obtained in the field or

  - **Estimated** - Measuring the offset between the lowest adjacent grade and the first floor with a tape measure; taking site photographs; estimating FFE offset based on house characteristics (such as number of steps or bricks), offset from surveyed high-water marks.

  Collecting asset data can be time consuming, particularly when working with a large number of structures or with complex structures, such as commercial or industrial buildings, that have large square footages and varying uses. Asset data for a large number of structures can be estimated using one of the following methods:

  - **Location Methods** - For this method, the ground elevation is compared to the WSE to determine a flood depth. If a building footprint or center point of a building is known, the flood depth can be determined directly. If only a tax parcel boundary is available, then the WSE over the parcel is averaged before it is assigned to a structure on the parcel.

  - **Elevation Methods** - For this method, structures are grouped according to their relative ground elevation (e.g., structures with elevations 70 to 72 feet above mean sea level [msl]) and assigned a uniform flood depth (e.g., WSE in the area is 75 feet above msl; therefore, structures with ground elevations between 70 and 72 feet msl are assigned a 4-foot flood depth).

  - **Census Block/HAZUS Method** - For this method, FEMA's Hazards U.S. - Multihazard (HAZUS-MH) program is used. HAZUS uses approximate surface topography (such as a 10-

or 30-meter DEM) and WSE data to calculate the percentage of census block flooded. If 20 percent of a census block is flooded, then it is assumed that 20 percent of the structures within that census block are flooded. The difference between the WSE and the ground topography is used to assign various flood depths to the 20 percent of structures that are assumed flooded.

3.2.3.2 Using Existing Observed Flood Boundary Data

Some projects may have observed flood boundary data. These data may consist of aerial photographs and surveys taken during an actual flood event and may be used for the MP_C scenario to estimate losses during the actual event. These data may also be used to validate or verify the hydraulic analysis conducted in the previous step of the loss avoidance study. The observed flood boundary data, such as aerial photographs taken during the peak of flooding, can be digitized to develop a flood boundary in Computer-Assisted Drafting and Design (CADD) or GIS software. If acceptable topographic data are available, the WSE can be estimated and flood depths derived. For MP_A scenarios, there may be past events that closely approximate the event of interest for which flood boundaries are available. However, site conditions and drainage area land use could have changed greatly since that historical event.

3.2.3.3 Modifying an Existing Flood Boundary Analysis

Projects may have existing flood boundary data available from previous flood studies, such as FEMA FIRMs, LOMRs, or CLOMRs. Existing flood boundary models can be modified for an event of interest. For example, if the hydraulic model found that WSEs 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 Flood Information Tool in HAZUS-MH Maintenance Release 3 (MR3) can also make use of existing data to simplify the analysis of the flood boundary and depth (FEMA, 2007).

3.2.3.4 Creating a New Flood Boundary Analysis

Creating a new flood boundary analysis can be done in many ways, from a simple analysis conducted using stream gage data to a very detailed analysis using the H&H modeling data, acceptable topographic data, and specialized computer software.

Most new flood boundary analysis and mapping is conducted in GIS or CADD. Within these formats, WSE data can be represented in a number of different formats; the data are usually presented in either raster or TIN (Triangular Irregular Network) formats. In raster format, elevations are represented by 'cells' of certain predetermined resolutions, such as 10 meters x 10 meters. When using the raster format, the resolution must be sufficient to provide adequate detail to calculate an accurate flood depth. TIN based methods maintain the resolution of the source data better than raster-based methods. They are ideal for flood elevation modeling, but often require more specialized software and staff expertise.

A simplified flood boundary analysis can be conducted when stream gage data are available and a project/structure is adjacent to that gage. If stage data are used from a gage adjacent to a particular structure or project, the peak WSE can be compared to the structure elevation. Most often, the flood boundary analysis is conducted by digitizing the cross-sections from the hydraulic model in GIS and attributing the cross-sections with peak WSEs. The flood elevations from multiple cross-sections can then be interpolated and converted to a flood elevation surface (attributed layer in GIS) to account for flood elevations in all areas between cross-sections. From this surface, a peak WSE at each asset can be extracted.

When the elevation of an asset is known (e.g., FFE of a structure) the asset elevation can be subtracted from the peak WSE to determine the depth of flooding. When the asset elevation is unknown, detailed topographic information (collected previously) is used in conjunction with one of the methods-the Location Method, Elevation Method, or Census Block HAZUS Method-to determine the flood depth at a particular asset. A more accurate determination of flood depth would take into account a structure's elevation above grade (e.g., type of foundation). The flood depth at the structure is calculated by subtracting an assumed height above grade, based on the structure's foundation type or structure photographs, from the peak WSE.

3.2.3.5 Northern California Flood Control Study - Flood Boundary Analysis

The flood boundary analyses for the six remaining projects indicated that there would have been damages for the modeled scenarios. The analysis indicated that these projects would have sustained damage in the MP_A scenario. Table 3.3 summarizes the project analysis for all six remaining projects.

3.3 Northern California Flood Control Study - Phase 2 Summary

Table 3.4 provides a screening summary for all projects in the Northern California flood control study. The table illustrates at which phase a project was eliminated and lists the six projects that proceeded to Phase 3.

Table 3.3

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
Petaluma River Payran Reach Flood Control and Floodways	Petaluma	Sonoma	Flood Control and Floodways	***Storm Event Analysis:*** December 31, 2005, Event from California DWR and USGS data ***Hydrologic Analysis:*** Based on stream gage data within project reach ***Hydraulic Analysis:*** Modified using HEC-RAS model ***Flood Boundary Analysis:*** Mapping based on hydraulic model results and topographic data	***Primary Loss Categories:*** Residential Structure Damage, Displacement and Disruption for Residents
Soscol Avenue Area Drainage Interceptor	Napa	Napa	Stormwater Management	***Storm Event Analysis:*** December 31, 2005, Event from California DWR data ***Hydrologic Analysis:*** Based on precipitation gage data and Rational Method ***Hydraulic Analysis:*** New analysis based on topographic data and culvert calculations ***Flood Boundary Analysis:*** Mapping based on hydraulic model results and topographic data	***Primary Loss Categories:*** Business Structure Damage, Business Interruption
Humboldt Road Box Culvert at Malloy Creek	Butte Meadows	Butte	Culvert Replacement	***Storm Event Analysis:*** February 26, 2006, Event from California DWR data ***Hydrologic Analysis:*** Based on precipitation gage data and regional regression equation ***Hydraulic Analysis:*** New analysis based on topographic data and HY8 software ***Flood Boundary Analysis:*** Mapping based on hydraulic model results and topographic data	***Primary Loss Categories:*** Road Damage, Road Closure, Emergency Management
Alhambra Creek Channel Improvements	Martinez	Contra Costa	Stormwater Management and Wetland Restoration	***Storm Event Analysis:*** December 31, 2005, Event from California DWR and Contra Costa County data ***Hydrologic Analysis:*** Based on stream gage data within project reach ***Hydraulic Analysis:*** Modified using HEC-RAS model ***Flood Boundary Analysis:*** Mapping based on hydraulic model results and topographic data	***Primary Loss Categories:*** Business Structure Damage, Emergency Management
Hilltop Green Flood Mitigation Project	Richmond	Contra Costa	Stormwater Management	***Storm Event Analysis:*** December 31, 2005, Event from NOAA data ***Hydrologic Analysis:*** Based on precipitation gage data and Rational Method ***Hydraulic Analysis:*** New analysis based on topographic data ***Flood Boundary Analysis:*** Mapping based on hydraulic model results and topographic data	***Primary Loss Categories:*** Infrastructure Damage, Emergency Management
Broadway Culvert Replacement	Olivehurst	Yuba	Culvert Replacement	***Storm Event Analysis:*** December 31, 2005, Event from California DWR data ***Hydrologic Analysis:*** Based on precipitation gage data and regression equation ***Hydraulic Analysis:*** New analysis based on topographic data and HY8 software ***Flood Boundary Analysis:*** Mapping based on hydraulic model results and topographic data	***Primary Loss Categories:*** Residential Structure Damage, Displacement and Disruption for Residents

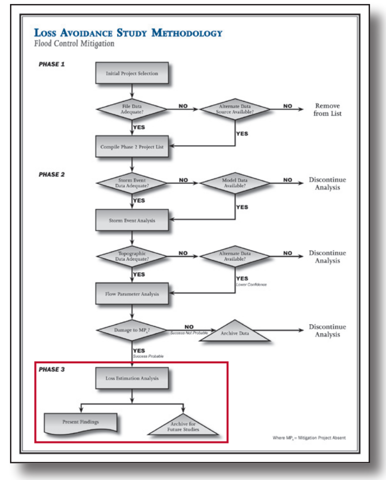
Table 3.4

Final Project Screening

County	Disaster and Project Number	Project Name	Phase 1	Phase 2				Phase 3
				Storm Event Analysis	Flow Parameter Analysis			
					Hydrologic Analysis	Hydraulic Analysis	Flood Boundary Analysis	
Amador	1008-6040	Violet Lane Storm Drain and West Marlette Relief Drain						
Butte	1044-0012	Stormwater Detention Basins						
	1044-0223	Oro-Chico Highway Drainage Improvement						
	1155-0009	Thermalito Drainage Improvements						
	1155-0016	Humboldt Road Box Culvert at Malloy Creek						
Contra Costa	1155-0017	Alhambra Creek Channel Improvements						
	1203-0026	McClarren Avenue Storm Drain Extension						
	1203-0027	Hilltop Green Flood Mitigation Project						
El Dorado	1203-0025	East China Hill Culvert Upgrade						
Lake	1203-0029	Restoration/Improvement of Culverts on County Roads						
Mendocino	1155-0001	Drain System Connection						
Napa	1155-0010	Soscol Avenue Drainage Interceptor						
Placer	1044-0035 1046-1017	Cirby/Linda/Dry Creek Flood Control Project						
Sacramento	1155-0011	Water Diversion at Starr King Middle School						
	1155-0015	Water Diversion at Marvin Marshall School						
San Mateo	1155-0020	Esplanade Storm Drain Improvement						
Sonoma	1046-1007	Petaluma River Payran Reach Flood Control and Floodways						
Yuba	1044-0017	Olivehurst Interceptor						
	1203-0034	Broadway Culvert Replacement						

Section Four:

Phase 3 - Loss Estimation Analysis



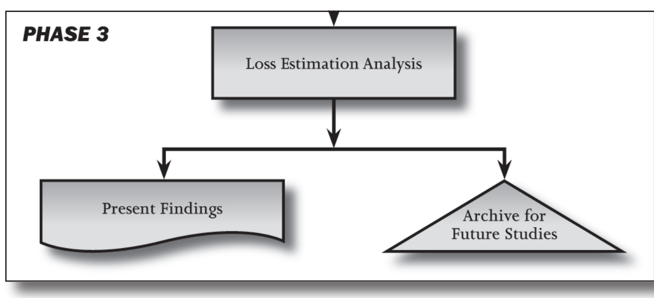
Phase 3 - Loss Estimation Analysis, the final phase of a loss avoidance study, is conducted to estimate the avoided losses based on the effectiveness of the mitigation project during the actual storm event(s) of interest. The Loss Estimation Analysis is accomplished by calculating the damage (in dollars) associated with the flood depths calculated in Phase 2. This section summarizes the process for Phase 3. It also provides details about the analysis specific to the Northern California flood control study.

Phase 3 includes two major tasks:

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

Phase 3 culminates in the presentation of the findings of the study. The data collected and analyses performed are also archived, so they can be used in future studies. This concept is illustrated in Figure 4.1.

Figure 4.1



Source: FEMA, 2007

4.1 Calculating Losses Avoided

For Phase 3, the dollar value estimate of the damage that would have occurred had the mitigation project not been built (MP_A) and the damages that did occur after construction of the project (MP_C) must be determined.

During Phase 2, the following information must be determined for each project advancing to the Loss Estimation Analysis:

- The post-construction storm event(s) that either caused damages or would have caused damage in either the MP_C and MP_A scenarios respectively.
- The number and type of assets impacted by the storm event(s) being analyzed in both the MP_A and MP_C scenarios.

- The flood depth at each impacted asset, estimated from the flood boundary analyses.

The result of Phase 2 is a list of impacted assets and the depth of the flooding at each asset. Based on these depths, the losses/damages can be calculated for both the MP_A and MP_C scenarios. The losses avoided (in dollars) are calculated by subtracting the MP_C scenario damages from the MP_A scenario damages. Figure 4.2 illustrates the formula used to calculate losses avoided.

Figure 4.2

Loss Estimation Analysis

$$MP_A - MP_C = LA$$

Where $\mathbf{MP_A}$ = Mitigation Project Absent
Where $\mathbf{MP_C}$ = Mitigation Project Completed
Where **LA** = Losses Avoided

Source: *FEMA*, 2007

When calculating losses, it is important to note that all of the losses should be calculated in present-day values. If historical losses are used as estimates, they should be adjusted to present-day values. Other values used in the calculations, such as the value of the structures and the project costs, should also be based on present-day values.

4.1.1 Loss Categories

After the flood boundary analysis has been completed and the impacted assets identified, the affected area must be evaluated for potential losses. Table 4.1 lists the loss categories for potential damages. Loss categories generally include physical damage, loss of function, and emergency management costs, each have multiple loss types.

For many of the loss types identified in Table 4.1, standard methodologies and values have been developed. Most commonly, established depth-damage relationships are used for determining losses caused by flooding. These relationships, which have been developed by FEMA, USACE, and other agencies using observed data from historical events, generally lead to a conclusion that increasing levels of loss are likely to occur at various intervals (e.g., greater flood depths). For example, FEMA and USACE have published depth-damage curves that relate depth of flooding to potential structure

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

Source: FEMA, 2007

damage, which is a value based on a percentage of the building replacement value (BRV). Flood depth-damage relationships can be either nationally published estimates or are estimated based on local damage information.

The FEMA Benefit-Cost Analysis (BCA) Modules were developed to standardize determinations of cost-effectiveness for mitigation projects and include damage curves for determining damage based on the severity of an event (FEMA, 2006b). These modules can be adapted for use during loss avoidance studies. For the flood module, these relationships are based on historical data taken from flood insurance claims under the NFIP. The modules include curves for building damage, content damage, displacement time, and loss of function time. No standardized curve currently exists within the FEMA BCA Modules for disruption time for residents; therefore, the time must be estimated.

In addition to the FEMA BCA Modules, depth-damage relationships are also used to estimate physical damage costs in the HAZUS-MH flood module. The *HAZUS-MH Technical Manual* (FEMA, 2006a) includes depth-damage curves for 28 general building stock categories (6 residential, 10 commercial, 6 industrial, and 6 other) from flood depths ranging from -4 to 24 feet. USACE has depth-damage and content-to-structural damage ratio tables that are used for preparing economic analyses for USACE flood control and floodplain management projects. Additionally, if the flow and resulting damages are known for particular flood events in the study area from another source, a depth-damage relationship can be constructed for the study area to estimate the total damages for any event (FEMA, 2007).

Damage curves or historical damage from events of similar size must be used to evaluate losses in the MP_A scenario because damage is theoretical. However, it may be possible to obtain values of actual losses in the MP_C scenario. Actual losses should be used in the loss avoidance study when available. If they are not available, the MP_C damages can also be estimated using depth-damage curves (FEMA, 2008).

4.1.1.1 Physical Damage

Physical Damage Data Sources

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

Physical damage includes impacts to structures (residential, commercial, industrial, and municipal); the contents and landscaping of those structures; roads, bridges, and infrastructure; the environment; and vehicles and equipment. The types of physical damage resulting from a given flood event will vary based on the land uses in the project area. When available, actual repair costs (or replacement costs if the structure was substantially damaged) should be used to estimate losses, if similar flood events have occurred in the past. If this information is not available, then the losses must be estimated. Historical damage data may be obtained from building owners, homeowners' insurance claims, flood insurance claims, the NFIP's BureauNet database, Small Business Administration loan application databases, local contractors, and homeowner interviews. The BCA that was performed for the funding application of the mitigation project may also contain historical damage data.

Additionally, for events in which there was a disaster declaration, FEMA may have provided grant funds under the Public Assistance (PA) Program for repairs to buildings owned by public entities and certain private non-profit organizations. Damage and repair information may be obtained from Project Worksheets (PWs) that FEMA prepared to document eligible costs under the PA Program (FEMA, 2008).

The calculation of physical damage is discussed in detail in the Southern California study (FEMA, 2007) and summarized in the following sub-sections.

Calculating Physical Damage to Structures

When actual losses are not available, the damage for each structure inundated can be estimated by following these steps:

1. Each structure is inventoried, and the building characteristics, such as type of structure (e.g., wood-frame residential), living area, number of floors, and FFE must be determined. Typically, structure characteristics and location are obtained during site visits or from community databases, such as tax assessment and parcel data.
2. The BRV of each structure is determined by using either local tax assessment values or cost guides, such as Marshall & Swift or RSMeans. Assessed or market value must be adjusted, however, to determine the BRV. When looking at flood impacts for larger areas; national databases, such as those within the FEMA *HAZUS-MH Technical Manual*, can be used to estimate BRVs.
3. The appropriate depth-damage curve is identified for each structure. For example, the depth-damage curves from the FEMA BCA Riverine Full Data Module for six building types are provided in Table 4.2.

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
Flood Depth (ft)	Percent Damaged (% of Structure Value)					
-2	0	0	0	4	3	0
-1	0	0	0	8	5	0
0	9	5	3	11	6	8
1	14	9	9	15	16	44
2	22	13	13	20	19	63
3	27	18	25	23	22	73
4	29	20	27	28	27	78
5	30	22	28	33	32	80
6	40	24	33	38	35	81
7	43	26	34	44	36	82
8	44	29	41	49	44	82
9	45	33	43	51	48	82
10	46	38	45	53	50	82
11	47	38	46	55	52	82
12	48	38	47	57	54	82
13	49	38	47	59	56	82
14	50	38	47	60	58	82
15	50	38	47	60	58	82
16	50	38	47	60	58	82
17	50	38	47	60	58	82
18	50	38	47	60	58	82

Source: FEMA BCA Full Data Flood Module

4. The percentage of damage to the structure is estimated by correlating the flood depth and duration with the appropriate damage ratio from the relevant depth-damage curve.
5. The damage (in dollars) from the flood event is calculated by multiplying the percent damage ratio by the BRV.

For example, a 2,000-square-foot, one-story, wood-frame residential structure without a basement is located within the project area. For the MP_A scenario, the flood boundary analysis indicates the structure witnessed two feet of flooding. According to a local cost estimating guide, the BRV is estimated to be $120 per square foot; therefore, the total BRV is $240,000. According to Table 4.2, the depth-damage curve indicates that the structure itself would have sustained damage totalling approximately 22 percent of the BRV, or $52,800 (0.22 x $240,000).

If the damage percentage determined from the depth-damage curve for a particular structure is greater than 50 percent, the building should be assumed to be substantially damaged and would be replaced rather than repaired. In those instances, 100 percent of the BRV should be used to calculate the losses. However, the threshold for substantial damage can vary, depending upon the quality of the building construction, or whether the building has historical significance. For example, if the building is extremely substandard, the threshold may be lower, or if the building is historic, the threshold may be higher.

Calculating Physical Damage to Contents

As with structure damage, actual repair or replacement costs should be used for contents damage, when available. Contents damage may be estimated by using the following steps:

1. The value of the contents is determined. The actual contents value may be obtained through owner interviews, insurance information, and tax records. The BCA that was performed for the funding application of the mitigation project may also contain actual contents data. If the actual contents value is known, the remaining parts of this step may be skipped.

   To estimate the contents value:

   - The BRV of the structure is determined (detailed in Calculating Structure Damage).
   - The BRV is multiplied by the appropriate content-to-structure ratio to determine the approximate contents value. The content-to-structure ratio may be FEMA's standard value of 30 percent of the building replacement value (or a minimum of $20,000) or based on USACE values.

2. The appropriate contents depth-damage curve is identified. For example, the depth-damage curves for the FEMA BCA Riverine Full Data Module for contents for six building types are provided in Table 4.3.

3. The contents value is multiplied by the damage ratio, as determined from the depth-damage curve and depth of flooding, to estimate damages to contents.

For example, there is a one-story, residential structure without a basement located within the project area. The BRV is $240,000; therefore, using the FEMA structure-to-contents ratio of 30 percent, the contents value is estimated to be $72,000 (0.30 x $240,000). For the MP_A scenario, the building witnessed two feet of flooding. According to Table 4.3, the depth-damage curve for contents indicates that the contents of this structure would have sustained damages totalling 33 percent of their value or $23,760 (0.33 x $72,000).

Table 4.3

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
Flood Depth (ft)	Percent Damaged (% of Contents Value)					
-2	0	0	0	6	4.5	0
-1	0	0	0	12	7.5	0
0	13.5	7.5	4.5	16.5	9	12
1	21	13.5	13.5	22.5	24	66
2	33	19.5	19.5	30	28.5	94.5
3	40.5	27	37.5	34.5	33	100
4	43.5	30	40.5	42	40.5	100
5	45	33	42	49.5	48	100
6	60	36	49.5	57	52.5	100
7	64.5	39	51	66	54	100
8	66	43.5	61.5	73.5	66	100
9	67.5	49.5	64.5	76.5	72	100
10	69	57	67.5	79.5	75	100
11	70.5	57	69	82.5	78	100
12	72	57	70.5	85.5	81	100
13	73.5	57	70.5	88.5	84	100
14	75	57	70.5	90	87	100
15	75	57	70.5	90	87	100
16	75	57	70.5	90	87	100
17	75	57	70.5	90	87	100
18	75	57	70.5	90	87	100

Source: FEMA BCA Full Data Flood Module

Calculating Physical Damage to Roads and Bridges

According to *What Is a Benefit?*, there are no typical or default damage functions available for estimating repairs to roads and bridges or damage costs (FEMA, 2001). There are no standard functions because roads and bridges vary greatly in construction materials, design, and level of maintenance. These damages can be identified if historical information is available, or subject matter experts can be consulted to estimate the amount.

Calculating Physical Damage to Infrastructure

Water, wastewater, electric transmission, gas transmission, and telecommunications systems are considered infrastructure. Damage to infrastructure is estimated using actual costs from past events, depth-damage relationships (if available), and evaluations written by subject matter experts.

When available, actual damage costs for previous events should be used to estimate infrastructure damages. Local officials and infrastructure owners, such as special districts and private utility companies, can provide information about damage from previous events. Further, repairs to disaster-related damage may have been funded under FEMA's PA Program, and PWs documenting damage to public infrastructure may be available. When actual damage information is not available, the *HAZUS-MH Technical Manual*, *What Is a Benefit?* or engineering cost estimating guides may be referenced (FEMA, 2007).

Calculating Physical Damage to Landscaping

According to *What Is a Benefit?*, there are no typical or default damage functions available for estimating landscaping repair or damage costs (FEMA, 2001). These damages can be identified separately if historical information is available, or subject matter experts can be consulted to estimate the amount (FEMA, 2007).

Calculating Environmental Impacts

Assessment of environmental impacts of flooding can be difficult. Impacts can vary greatly from site to site; therefore, assessments should be project-specific. Environmental impacts may include impacts to water quality, drinking water, recreation, and wetlands, as well as cultural and historical resources. For example, projects with potential environmental impacts may include flooding of a wastewater treatment plant or chemical manufacturer located within the impacted area.

According to *What Is a Benefit?*, there are no typical or default damage functions for estimating environmental impacts, and these impacts are typically not evaluated (FEMA, 2001). However, environmental impacts may be partially considered in the calculation of the loss of public services, such as wastewater treatment plants. *What Is a Benefit?* further suggests that the estimated regional economic impact (the loss of function for the wastewater treatment plant) may equal or exceed environmental damage (FEMA, 2001).

In general, the physical damage from environmental impacts should be based on the cost of remediation. Therefore, project-specific information about historical environmental cleanup costs and environmental fines due to flooding should be collected, when available. This information may be available through interviews with local and state environmental protection offices, as well as with the U.S. Environmental Protection Agency.

Calculating Physical Damage to Vehicles/Equipment

Physical damage to vehicles and equipment includes repair or replacement costs for damage incurred during a flood event. The types of vehicles and equipment in the affected area will vary by site. Information about vehicles and equipment may be obtained during site visits, from insurance information, and historical damages (PWs), or assumptions may be required as to the number and type of vehicles and equipment, based on the land use or building type (e.g., residential, commercial, industrial, agricultural, public, or academic). Specific costs for vehicles and equipment in the impacted structure should not be included in the building's contents value.

Physical damage to vehicles and equipment may not be applicable because 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).

4.1.1.2 Loss of Function

According to *What Is a Benefit?*, loss of function impacts are "the losses, costs and direct economic impacts that occur when physical damages are severe enough to interrupt the function of a building or other facility" (FEMA, 2001). Loss of function can vary significantly depending upon the building or facility damaged. For example, flooding of a residential structure would prompt the owners to move to (displace to) another residence while floodwaters recede and repairs are made (displacement time), as well as cause disruption to the lives of those affected (disruption time). Loss of function related to flooding of a business or commercial facility could include lost business income, temporary relocation to another structure, and lost wages. There are also economic impacts caused by the loss of public services and infrastructure.

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

Methods for estimating loss of function costs are summarized in the following sub-sections, but more information can be obtained from *What Is a Benefit?*, the *HAZUS-MH Technical Manual*, USACE, local agencies, and special districts. Typically, methods for estimating loss of function involve calculating a time delay based on the percentage of damage to an asset, then calculating costs for this delay of function.

Loss of function costs are summarized in the following subsections. Greater detail can be found in the Southern California study (FEMA, 2007).

Calculating Displacement Expense

Displacement time is "the time period during which occupants are displaced from a building in order for repairs to be made" (FEMA, 2006b). Therefore, the loss is associated with the cost of renting a temporary facility during the period of displacement. Displacement should be considered in the analysis only if a temporary alternate location is necessary to continue the function of the damaged building while it is being repaired (FEMA, 2008).

When available, actual displacement information is 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 under PA, PWs prepared for 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 the displacement of residents during previous flood events (FEMA, 2007).

Displacement expense can be calculated as follows:

1. The cost per day (or other unit of time, as appropriate) for displacement of occupants is determined. Within the BCA Toolkit (FEMA, 2006b), FEMA provides standard values that can be used to calculate costs for displacement, based on a national average. The costs include:
   - Rental costs for temporary quarters, which are assumed to be $1 per square foot per month,
   - Other monthly costs of displacement, which include furniture rental, additional bills and costs associated with renting an additional space, extra commuting costs, etc., and are assumed to be $500 per month, and
   - One-time costs, which include utility hookup fees, round-trip moving costs, etc., and are assumed to be $500.

If area-specific costs are available, they will produce a more accurate calculation of displacement costs and should be used. Area-specific values can be determined through historic information, information from real estate agents and rental companies, or information from emergency assistance organizations.

2. The number of days an occupant would be expected to be displaced must be determined. This can be accomplished by correlating the flood depth with the appropriate displacement time curve. For example, Table 4.4 provides the standard curves provided by the FEMA Full Data Flood Module for displacement time.

3. The number of displacement days is multiplied by the economic impact of each day.

For example, there is a 2,000-square-foot, one-story, residential structure without a basement within the project area. For the MP_A

Table 4.4

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
Flood Depth (ft)	Displacement Time (Days)					
-2	0	0	0	0	0	0
-1	0	0	0	0	0	0
0	0	0	0	38	0	0
1	62	0	0	70	78	302
2	126	54	54	110	102	365
3	166	94	150	134	126	365
4	182	110	166	174	166	365
5	190	126	174	214	206	365
6	270	142	214	254	230	365
7	294	158	222	302	238	365
8	302	182	278	342	302	365
9	310	214	294	365	334	365
10	310	214	294	365	334	365
11	310	214	294	365	334	365
12	310	214	294	365	334	365
13	310	214	294	365	334	365
14	310	214	294	365	334	365
15	310	214	294	365	334	365
16	310	214	294	365	334	365
17	310	214	294	365	334	365
18	310	214	294	365	334	365

Source: FEMA BCA Full Data Flood Module

scenario, the building witnessed two feet of flooding. Using the FEMA BCA standard costs for displacement of occupants-$1 per square foot per month, $500 per month, and a one-time cost of $500-displacement from this structure would cost $2,500 per month (2,000 square feet x $1 per square foot per month + $500 per month), plus the one-time cost of $500. According to Table 4.4, the depth-damage curve for displacement time indicates that for this structure, the displacement time would be 126 days. For ease of calculation, 30 days per a month is assumed; therefore, displacement time is 4.2 months. The total cost of displacement for this example is $11,000 (4.2 months x $2,500 per month + $500).

Calculating 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 damage resulting from flooding. Loss of rental income should be calculated on a site-by-site basis. Most often, the loss of rental income is not calculated; instead, displacement expense is estimated for all tenants of a property. Counting the displacement expense for the renter and the full loss of rental income for the owner is doubly-counting benefits and should be avoided.

To calculate the loss of rental income:

1. The rental income for the flooded units is determined.
2. The flood depth is correlated with the appropriate displacement time.
3. The number of displaced days is multiplied by the rental loss for each day (FEMA, 2007).

Calculating Loss of Business Income

A loss of business income may occur for commercial buildings when damage is severe enough to result in temporary loss of function of that building. To calculate loss of business income:

1. The economic impact of each lost day of operation is determined. This can be accomplished by dividing the annual net income by 365 days. According to *What Is a Benefit?* (FEMA, 2001), the proper measure of loss of business income is the net income, not the gross income, since expenses as well as receipts are lower when a business is closed.
2. The number of days a business would be closed due to flooding is calculated. The standard curves for loss of function time provided in the FEMA BCA Toolkit (FEMA, 2006b) are provided in Table 4.5. They can be used to calculate business

interruption. The *HAZUS-MH Technical Manual* (FEMA, 2006a) also provides guidance for determining functional downtime based on the percentage of structure damage.

3. The number of lost days is multiplied by the economic impact of each day.

Loss of business income calculations should be validated through site visits and discussions with local representatives and business owners (FEMA, 2008).

Calculating Lost Wages

Wages can be lost when there is a loss of function for any structure where people are employed. Similar to the loss of business income for the owner, employees can experience a loss of wages when a business closes. In accordance with *What Is a Benefit?* (FEMA, 2001), lost wages are counted only for short-term losses due to temporary business closures and only for hourly employees. Wages are not

Table 4.5

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
Flood Depth (ft)	**Loss of Function Time (Days)**					
-2	0	0	0	4	3	0
-1	0	0	0	8	5	0
0	9	5	3	11	6	8
1	14	9	9	15	16	30
2	22	13	13	20	19	30
3	27	18	25	23	22	30
4	29	20	27	28	27	30
5	30	22	28	30	30	30
6	30	24	30	30	30	30
7	30	26	30	30	30	30
8	30	29	30	30	30	30
9	30	30	30	30	30	30
10	30	30	30	30	30	30
11	30	30	30	30	30	30
12	30	30	30	30	30	30
13	30	30	30	30	30	30
14	30	30	30	30	30	30
15	30	30	30	30	30	30
16	30	30	30	30	30	30
17	30	30	30	30	30	30
18	30	30	30	30	30	30

Source: FEMA BCA Full Data Flood Module

counted for salaried employees, unless employees are laid off without pay, or public service employees (FEMA, 2008).

To compute total lost wages for employees of an affected business, various types of information are required.

1. The average employee per-hour wage and benefits amount is used. *What Is a Benefit?* provides a national average for wages and benefits at $21.16 per hour (FEMA, 2001). However, in place of the national average, regional or local averages can be used.
2. The number of places of employment in the affected area is determined (generally available from local officials).
3. The number of hourly employees for each affected employer is determined (generally available from local officials or from the employer directly).
4. The functional downtime for each business is determined using Table 4.5 for public and commercial buildings, Table 4.4 for residential buildings, guidance from the *HAZUS-MH Technical Manual,* or historic losses.
5. The total number of lost days for all employees is multiplied by the total value of the wages lost per day for each affected businesses (FEMA, 2007).

Calculating 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 evacuations and evacuating, cleaning and repairing property following the event, and making insurance claims. Disruption time for residents should only be counted if the structure being evaluated is a residential structure (FEMA, 2007).

As described in *What Is a Benefit?*, a person's time has value, whether or not that person is formally compensated by an employer (FEMA, 2001). Each hour of time is worth the same amount, whether such time is personal or business, compensated or not. The following methodology for calculating disruption time has been developed based on guidance in *What Is a Benefit?* (FEMA, 2001) and a training course provided at the Emergency Management Institute (EMI). Training slides are included in the 2005 BCA Toolkit (FEMA, 2005):

1. The average employee per-hour wage and benefits amount is used. *What Is a Benefit?* provides a national average for wages and benefits at $21.16 per hour (FEMA, 2001). However, in place of the national average, regional or local averages can be used.

2. The number of disrupted residents is determined. If the number of residential structures impacted is known, the average number of adults per household (from Census data or community demographic data) can be used to estimate the total number of residents disrupted.

3. The time of disruption is determined. Although the FEMA BCA modules do not provide a standardized curve, a training course provided at EMI estimated disruption time to be a standard of 40 hours for any amount of flooding, plus an additional 8 hours for every 1 percent of damage to the structure (Table 4.6 reflects this calculation). The calculated disruption time should be used for each adult in the household.

4. The number of lost hours due to disruption is multiplied by the value of average wages for all affected residents.

For example, for a one-story, residential structure without a basement that witnessed two feet of flooding, each adult resident

Table 4.6

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
Flood Depth (ft)	**Disruption Time (Hours)**					
-2	0	0	0	72	64	40
-1	0	0	0	104	80	40
0	112	80	64	128	88	104
1	152	112	112	160	168	392
2	216	144	144	200	192	544
3	256	184	240	224	216	624
4	272	200	256	264	256	664
5	280	216	264	304	296	680
6	360	232	304	344	320	688
7	384	248	312	392	328	696
8	392	272	368	432	392	696
9	400	304	384	448	424	696
10	408	344	400	464	440	696
11	416	344	408	480	456	696
12	424	344	416	496	472	696
13	432	344	416	512	488	696
14	440	344	416	520	504	696
15	440	344	416	520	504	696
16	440	344	416	520	504	696
17	440	344	416	520	504	696
18	440	344	416	520	504	696

Source: FEMA BCA Full Data Flood Module

would have experienced 216 hours of disruption time due to the flood event. Based on demographic data for the community, there is an average of 2 adults per household. Therefore, the total cost of disruption for this example is $9,141 (2 people x 216 hours per person x $21.16 per person per hour).

Calculating Loss of Public Services

If a public building temporarily closes due to a flooding event, there is a potential for a loss of public service. Public services include public works departments, police stations, libraries, courthouses, etc. Private non-profit organizations, such as schools and hospitals are classified as public services since they are essentially providing public services. To calculate the loss of public services:

1. The type of facility and public service is determined, as the loss of public service calculation varies by site.
2. The economic impact of each lost day of operation is determined. A public service is assigned an economic value that equals the costs necessary to provide that public service. Generally, the daily costs of providing service are estimated using the annual operating budget for the particular service. (If a building houses many public services, the annual operating budget of all the services is used). Local officials or the operators of private non-profit entities can provide information about the annual operating budget.
3. The number of lost days, or the total number of days the public service would be unavailable due to flooding is determined. Similar to the determination of loss of business income, this calculation uses the FEMA BCA Module functions provided in Table 4.5 to calculate loss of function time.
4. The economic impact of the loss of public service is multiplied by the number of lost days (FEMA, 2007).

If the public service is a critical service directly related to emergency response and recovery, a continuity premium can be included when estimating the economic value of the service. A continuity premium is a multiplier to the normal daily cost of service. *What Is a Benefit?* (FEMA, 2001) provides guidance for calculating the continuity premium for critical facilities such as fire, police, medical, emergency operation centers (EOCs), or emergency shelters. When a continuity premium is used, the functional downtimes for these services are expected to be significantly shorter than for ordinary (non-critical) public services; therefore, the functional downtimes found in the standard curves must also be adjusted. Table 4.7 provides guidance for using continuity premiums and adjusting functional downtime and the suggested values from *What Is a Benefit?* (FEMA, 2008).

Table 4.7

Economic Impact of Loss of Function of Critical Structures	
Condition	**Economic Impact**
Normal cost of service	• Annual operating budgets from local officials • EOCs: daily base cost of service is annual operating budget divided by average number of days of use, plus daily costs during operation • Shelters: $85 per day for temporary lodging and meals, in accordance with U.S. General Service Administration guidelines
Continuity Premiums police, fire, EOC, or shelter	• 10x cost of normal service
Continuity Premiums medical services	• None: typically during floods, the demand for services is not significantly greater than normal
Adjustment to Functional Downtime	• Police services: 1/3 of typical values • Fire services: 1/3 of typical values • Medical services: 1/2 of typical values • EOC or shelter: Maximum possible displacement times are limited by the typical duration of use of EOCs or shelters

Source: FEMA, 2008

Calculating the Economic Impact of Utility Loss

Utility services include electric power, potable water, wastewater services, gas transmission, and the like. The economic impact of utility loss is the economic value assigned when a utility service is unable to operate as a result of a flooding event. Due to the importance of these services, the economic impact of utility loss is generally much greater than the physical damage to the facility. To calculate the economic impact of utility loss:

1. The type of facility is determined. The loss of public service calculation varies slightly depending upon the type of utility.
2. The economic impact of each lost day of operation is determined. This value can be expressed as a dollar value per capita per day, or just a dollar value per day. *What Is a Benefit?* provides some values for economic impact per capita per day of lost service for electricity ($188 per person per day of lost service), potable water ($103 per person per day of lost service), and wastewater service ($33.50 per person per day of lost service [FEMA, 2001]). It should be noted that these values are for a complete loss of service only. If a FEMA standard value is not available for a utility, the utility is treated similarly to a public service and is assigned an economic value

that equals the cost to provide that utility service (i.e., the utility district operating budget).

3. The number of days of lost service, or the total number of days the utility would be unavailable due to flooding is determined. Similar to the determination of loss of business income, this calculation uses the FEMA BCA Module functions provided in Table 4.5 to calculate loss of function time.

4. The number of people serviced by the utility is determined when necessary. Interviews with utility providers can provide information on the number of people serviced by a particular utility (Note: in most instances, the entire utility service area should not be used, only that percentage of the area serviced within the study area).

5. The economic impact of the loss of public service is multiplied by the number of lost days (and the number of people serviced by the utility, when appropriate).

Calculating the Economic Impact of Road/Bridge Closure

The economic impact of road and bridge closure is analogous to estimating the impact of flooding to a utility or other public service. The impact is estimated by considering the number of vehicles using the route per day, the average delay or detour time, and the average value of a motorist's time. Roads and bridges are subject to physical damage during flooding, but they are also subject to loss of function when flooding makes them impassable. *What Is a Benefit?* considers loss of time to be the primary economic impact of road and bridge closures (FEMA, 2001).

The following steps provide guidance for calculating the economic impact of road and bridge closures. They are different from those described in the Southern California study (FEMA, 2007):

1. The roads and bridges impacted by flooding are determined. The flood boundary analysis indicates which roads and bridges would be inundated by floodwaters. When possible, the duration of flooding should be estimated using anecdotal information or information available based on the methodology used for the flood boundary analysis.

2. The closure time, or the time period during which the road or bridge is closed to normal traffic while repairs are made and floodwaters recede is estimated. Closure times may range from a few hours to several days, even several weeks in some cases. Estimates of closure times are generally based on historical events or experiences and should be made in coordination with local or state departments of transportation.

3. The number of one-way traffic trips per day for each impacted road is estimated. Traffic counts may be available from local or state departments of transportation.
4. The delay or detour time, which is the average amount of extra time that motorists spend taking an alternative route due to a road or bridge closure is determined. Delay or detour time may be only a few minutes if the flooding is in an urban area and the detour is only few blocks. In some instances, delay or detour times may be over an hour if the detour is a long distance or there is no alternative route (up to 24 hours). This can be estimated by discussing detours with local officials, reviewing local maps, or using online mapping tools.
5. The economic impact per vehicle per hour of delay is determined. This value can be based on local, state, or federal guidance. FEMA has developed a standard value for the average economic value of travel delay time as $32.23 per vehicle hour of delay due to road and bridge closures (FEMA, 2001).
6. The economic impact of road and bridge closures is calculated by multiplying all the values determined in the previous steps. The resulting value (in dollars) represents the economic impact of the road or bridge closure.

4.1.1.3 Emergency Management

Emergency management costs are those costs related to response and recovery activities conducted by government agencies as a result of a hazard event. These costs should be included in a loss avoidance study when they are known or can be estimated (FEMA, 2007).

If a flood control mitigation project under evaluation significantly reduces these emergency management costs, then the benefits of reduced emergency management costs should be counted. Many mitigation projects affect a small area, or are associated with single structures or a few scattered structures. There may be little difference between MP_A and MP_C emergency management costs.

When actual emergency management costs are known they should be used. These values are primarily obtained from historic damage records, such as PWs. They may also come from interviews with local emergency managers. As discussed in the Southern California study, the emergency management costs can be estimated by:

- Using 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 fighting the flood.
- Using the estimated flood recovery time and the appropriate

Emergency Management Data Sources

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

salary categories to estimate the impact to other municipal employees. This may include cleanup and costs associated with implementing repairs (FEMA, 2007).

4.1.2 Northern California Flood Control Study - Calculating Losses Avoided

Each of the six projects analyzed in Phase 3 exhibited MP_A damages. Damages varied by project, but most projects evaluated would have sustained physical damage to structures, contents, and roadways, loss of function impacts, and emergency management costs. Two projects also sustained damages in the MP_C scenario due to the event of interest exceeding the MP_C capacity, or level of protection of the project. As expected, the MP_C damages for these two projects were much less than the MP_A scenario damages. The remaining four project sites did not experience a storm event that exceeded the MP_C damage threshold and did not sustain MP_C damages. Table 4.8 displays the loss categories and types predicted by the analysis.

Table 4.9 displays the results of the Loss Estimation Analysis for all six projects. All damage estimates have been converted to 2008 dollars. Details regarding the methods used for each project are included in the project-specific appendices. At $44,170.317, the Petaluma River Payran Reach Flood Control and Floodways Project exhibited the greatest amount of losses avoided. The Humboldt Road Box Culvert at Malloy Creek Project exhibited the least amount of losses avoided at $67,924. The Petaluma River project exhibited such high losses avoided because the mitigation project protected nearly 600 flood-prone structures, whereas the Humboldt Road project did not protect any structures, it prevented the loss of function for 1 roadway. Physical damage was the most significant damage type for all projects in this study, representing over 80 percent of the total losses avoided.

The loss categories of landscaping, vehicles and equipment, loss of rental income, and economic impact of loss of utilities were not estimated for any of the final projects because either the loss category was not protected by the project (e.g., no assets in the project area) or the losses were accounted for elsewhere (e.g., calculating displacement for residents of a rental unit instead of loss of rental income).

Table 4.8

Loss Categories and Types for the Northern California Flood Control Study

Project	Physical Damage	Loss of Function	Emergency Management
Petaluma River Payran Reach Flood Control and Floodways	Structure Contents Roads and Bridges	Displacement Expense Loss of Business Income Lost Wages Disruption Time for Residents Economic Impact of Road/Bridge Closure	Debris Cleanup Governmental Expense
Soscol Avenue Area Drainage Interceptor	Structure Contents Roads and Bridges	Loss of Business Income Lost Wages Disruption Time for Residents Economic Impact of Road/Bridge Closure	Debris Cleanup Governmental Expense
Humboldt Road Box Culvert at Malloy Creek	Roads and Bridges	Economic Impact of Road/Bridge Closure	Debris Cleanup Governmental Expense
Alhambra Creek Channel Improvements	Structure Contents Roads and Bridges	Loss of Business Income Lost Wages Economic Impact of Road/Bridge Closure	Debris Cleanup Governmental Expense
Hilltop Green Flood Mitigation Project	Infrastructure Environmental Impacts	Economic Impact of Utility Loss	Debris Cleanup Governmental Expense
Broadway Culvert Replacement	Structure Contents Roads and Bridges	Displacement Expense Loss of Business Income Lost Wages Disruption Time for Residents	Debris Cleanup Governmental Expense

Table 4.9

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	
Petaluma River Payran Reach Flood Control and Floodways	Petaluma	Sonoma	Flood control and floodways	$38,171,451	$7,625,919	$175,261	$1,466,997	$306,111	$29,206	**$44,170,317**
Soscol Avenue Area Drainage Interceptor	Napa	Napa	Stormwater management	$1,060,411	$324,151	$13,570	$766,354	$230,060	$1,357	**$400,361**
Humboldt Road Box Culvert at Malloy Creek	Butte Meadows	Butte	Culvert replacement	$9,428	$50,762	$7,734	$0	$0	$0	**$67,924**
Alhambra Creek Channel Improvements	Martinez	Contra Costa	Stormwater management, wetland restoration	$280,104	$19,354	$170,586	$0	$0	$0	**$470,044**
Hilltop Green Flood Mitigation Project	Richmond	Contra Costa	Stormwater management	$132,891	$1,452	$58,366	$0	$0	$0	**$192,709**
Broadway Culvert Replacement	Olivehurst	Yuba	Culvert Replacement	$1,328,497	$233,289	$42,063	$0	$0	$0	**$1,603,849**
			Total	**$40,982,782**	**$8,254,927**	**$467,580**	**$2,233,351**	**$536,171**	**$30,563**	**$46,905,204**

All amounts rounded to the nearest dollar.

4.2 Calculating Return On Investment

The final task in a loss avoidance study is to calculate the ROI. The methodology and results may vary depending upon the number of events being analyzed for each mitigation project and the level of damage sustained during each event. Figure 4.3 illustrates the general formula utilized in calculating the ROI.

Figure 4.3

Return on Mitigation Investment

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

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

Source: FEMA, 2007

The numerator (LA) represents the total losses avoided for the mitigation project being evaluated. If the loss avoidance study is evaluating one event of interest, then the losses avoided and resulting ROI would represent one discrete event. If multiple events are being evaluated for each mitigation project, then the LA would represent the total losses avoided for all the storm events evaluated. Therefore, the ROI would represent the cumulative return on investment over several storm events.

The denominator (PI) represents the total project investment for the mitigation project being evaluated. The PI does not represent the federal investment alone, but rather the resource investment from all parties involved. The amount should represent the costs of the project components being evaluated in the loss avoidance study, and should not include work conducted outside of the mitigation project scope of work. Additionally, the PI should be converted to present-day values for the ROI calculations.

When evaluating ROI for multiple storms or multiple projects, averaging ROIs is never appropriate. The ROI calculation should be conducted by adding all the losses avoided and dividing by the total project investment.

4.2.1 Northern California Flood Control Study - Calculating Return on Investment

Table 4.10 displays a comparison of the losses avoided to the project investment for each project. The amount was determined using the project files. The actual project investment may have come from several sources. The amount displayed in Table 4.10 reflects the combined investment from all sources.

For the 6 projects, ROI ranged from 26 percent to 1,154 percent. The ROI for each project reflects the losses avoided for one event of interest; therefore, the ROIs presented are expected to increase as additional storm events test the projects' effectiveness over their useful lives. For this study, an ROI of 100 percent or greater would indicate the project investment was fully recovered during the 1 event of interest. The Broadway Culvert Replacement project yielded an ROI of 1,154 percent, recovering the project investment more than 10 times over, and the Petaluma River Payran Reach Flood Control and Floodways Project yielded an ROI of 98 percent, in a single event.

The ROIs for each project should not be compared relative to one another; a project with a greater ROI is not necessarily more effective than a project with a lesser ROI. The ROI is a function of the losses avoided and the project investment. Projects are designed to meet specific needs. A relatively inexpensive project that protected a large number of assets, such as the Broadway Culvert Replacement project, would be expected to yield a greater ROI. The Broadway Culvert Replacement project included the replacement of an undersized (i.e., low MP_A capacity) culvert designed to alleviate flooding of a residential neighborhood with 40 structures. Losses avoided for this project were over $1.6 million, whereas the project cost was approximately $139,000. The Humboldt Road Box Culvert at Malloy Creek project was intended to prevent the loss of function for only one road. The losses avoided were nearly $68,000, and the project investment was approximately $257,000. Even though the ROI for the latter project was significantly less than the ROI for the former project, it should be considered no less effective.

The aggregate ROI for the 6 projects analyzed for the Northern California flood control study was 98 percent, using the combined losses avoided of $46,905,204 and a combined project investment of $48,028,996. This ROI only reflects the losses avoided for one event of interest for each project and will increase as additional storm events test each project's effectiveness.

Table 4.10

Return on Mitigation Investment

General Project Information			Results by Loss Category			Losses Avoided Total	Project Investment (Adjusted for 2008 Dollars)	Current ROI
Project Name	County	Date of Project Completion	Physical Damage Subtotal	Loss of Function Subtotal	Emergency Management Subtotal			
Petaluma River Payran Reach Flood Control and Floodways	Sonoma	**2004**	$36,704,454	$7,319,808	$146,055	**$44,170,317**	**$44,907,802**	**98.36%**
Soscol Avenue Area Drainage Interceptor	Napa	**10/28/1998**	$294,057	$94,091	$12,213	**$400,361**	**$766,914**	**52.20%**
Humboldt Road Box Culvert at Malloy Creek	Butte	**10/14/1998**	$9,428	$50,762	$7,734	**$67,924**	**$257,106**	**26.42%**
Alhambra Creek Channel Improvements	Contra Costa	**07/06/2001**	$280,104	$19,354	$170,586	**$470,044**	**$1,709,693**	**27.49%**
Hilltop Green Flood Mitigation Project	Contra Costa	**07/03/1999**	$132,891	$1,452	$58,366	**$192,709**	**$248,520**	**77.54%**
Broadway Culvert Replacement	Yuba	**09/29/1998**	$1,328,497	$233,289	$42,063	**$1,603,849**	**$138,961**	**1,154.17%**
		Total	**$38,749,431**	**$7,718,756**	**$437,017**	**$46,905,204**	**$48,028,996**	**97.66%**

All amounts rounded to the nearest dollar.

Section Five

Considerations and Recommended Practices

This section contains a summary of the special considerations and recommended practices of this study. Many of the considerations and recommended practices of the Southern California study are also contained in this report. The intent of providing this information is so that it may be used in future loss avoidance studies. The information is divided into two categories: 1.) data collection and availability and 2.) analysis methodology.

5.1 Data Collection and Availability

Multiple types of data are collected throughout a loss avoidance study. The availability and quality of the data can affect the accuracy of the study significantly. Sections 5.1.1 and 5.1.2 describe the data-related challenges that were encountered in the Northern California flood control study and provide recommendations for data collection in future loss avoidance studies.

5.1.1 Availability of Topographic Data

Obtaining digital topographic data of sufficiently quality was a significant challenge in this study. Topographic data are required for both the MP_A and MP_C scenario conditions of the channel and floodplain. The best topographic data have 4-foot or less contour intervals and are digital. None of the data that were available for any of the projects in the Northern California flood control study satisfied both of these requirements. Most subgrantees (local project sponsors) were able to provide hardcopy design drawings of the project area only (e.g., channel but no floodplain). A significant amount of time was spent locating, interpreting, digitizing, and compiling the data. Generally, those data were combined with data purchased from a vendor or from USGS DEM using GIS to create a topographic surface that included the channel, project area, and floodplain.

Topographic data are improving in quality and availability. Many counties have produced or are currently producing countywide lidar topographic data, and as this trend continues, the availability and quality of topographic data will improve.

5.1.2 Recommendations for Data Collection

The data-collection process and the importance of having a clear data-collection plan and priority list for data are discussed in great detail in both this study and the Southern California study. Most of the data collection occurs very early in the loss avoidance study process. It is difficult to know at this early stage which assets will be impacted by MP_A flooding because the scenario is theoretical. Although historical flooding and those impacted assets can be used to guide initial data collection, the MP_A-impacted assets are unknown until the flood boundary analysis has been completed, which occurs near the end of Phase 2.

It is recommended that loss avoidance analysts allow additional time for data collection after the flood boundary analysis has been completed. The additional data-collection period would be used to obtain asset information that may not have been collected during Phase 1 or the initial data-collection phase.

5.2 Analysis Methodology

In Sections 5.2.1 through 5.2.6, the ways in which the analysis methodology was modified from previous loss avoidance studies are discussed, and the challenges that were encountered in the Northern California flood control study are described.

5.2.1 Storm Event Analysis Timing

Northern California has many reservoirs, rivers, and channels, and much of the water system is highly regulated. DWR maintains an extensive network of gages throughout California, and gage data are readily available in most cases. The type of data provided by these gages includes precipitation, stage, and discharge. Records for most locations are provided through the online CDEC.

A search of the CDEC at the beginning of this study revealed applicable gages for all projects on the initial project list. The CDEC database also included historical readings for the entire recording period of most gages. CDEC data were downloaded and formatted as a spreadsheet to make it easier to identify the most severe storm events for each project. Storm events were compared to a project's MP_A capacity to determine whether the storms were severe enough to cause damage. If a potentially damaging storm event occurred, the project advanced to the next step.

Because gage data were readily available for this study, the storm event analysis for each project was conducted concurrently with Phase 1. When gage data are readily available, the storm event analysis may be executed early in project screening. Doing so decreases the time spent collecting data for these projects, because some projects may be eliminated due to lack of a potentially damaging event.

5.2.2 Hydraulic Modeling and Analysis

Loss avoidance studies rely heavily on existing data, particularly hydraulic modeling and analysis data. Data are most useful when provided in a widely used format such as HEC-RAS, rather than in a proprietary or less used format. Using other formats can be expensive if the software must be purchased, and it may be difficult to interpret or modify the models. When data are in a proprietary or lesser-known format, it may be more efficient to recreate the hydraulic analysis than to spend a significant amount of time trying to organize and interpret an existing model or analysis.

5.2.3 Modification to Methodology for Calculating the Economic Impact of Road/Bridge Closure

The recommended methodology for calculating the economic impact of road and bridge closures in this study is different from the methodology that was used in the Southern California study. The Southern California study used the Federal mileage allowance, and although this may reflect the wear and tear and additional fuel costs for the vehicle, it does not account for the delay impacts to motorists. In this study, the FEMA standard value of $32.23 per vehicle per hour of delay was used. This methodology is also used for the development of BCAs for FEMA grant programs. The modified methodology strengthens the relationship between loss avoidance studies that are conducted following the completion of a mitigation project and the BCA that is completed while planning the project (FEMA, 2007).

5.2.4 Modification to Methodology for Determining Emergency Management Costs

In the case of the Southern California study, applying a continuity premium to emergency management costs was recommended (FEMA, 2007). This recommendation was removed from the current study to conform to standard BCA practices. Emergency management costs should represent actual or estimated emergency response and management costs during a flood event and should not be inflated with a continuity premium.

A continuity premium is used when calculating the loss of public service to a community and is added to services such as police, fire, medical, and emergency response. The continuity premium represents the extra importance that some public services have during disasters and is a measure of how much more a community would be willing to pay to continue these services during a disaster. It is not to be used to inflate actual response and recovery costs.

5.2.5 Modeling the MP_C Scenario

The MP_C scenario represents an event that actually occurred, and historical data are therefore likely to be available to help determine the actual MP_C damages. However, sufficient data for any stage of the loss avoidance analysis can be difficult to obtain for a variety of reasons. All of the data needed to calculate MP_C damages may not be available or obtained during data collection. For example, damage survey reports (DSRs) or PWs may be obtained, but these sources do not provide information about damages to private property or loss of function. For this study, when MP_C damages were known to have occurred, a model for the MP_C scenario was developed. The model results were used to 'fill in the blanks' and estimate damages for which historical data were unavailable. The MP_C scenario model results were modified based on information in the project file obtained during data collection to better represent the event that occurred. This methodology differs from the Southern California study and other loss avoidance studies but was used for this study to more accurately reflect losses avoided and provide the opportunity to analyze additional damage types.

5.2.6 Determination of a Threshold Event

For both this study and the Southern California study (FEMA, 2007), the most severe storm event that occurred since a project was completed was analyzed, i.e., losses avoided were calculated only for one event of interest. To determine the losses avoided over a project's useful life, a threshold event must be determined. A threshold event is different from the design capacity of a project. The threshold event represents the storm event that would have exceeded the project's MP_A capacity and would have caused the first dollar of damage. The threshold event is a theoretical event and can be determined by hydraulic and flood boundary analyses. Determining the threshold event is an iterative process in which various flows are modeled until the event that has the potential to cause initial damage is identified. When the magnitude of the threshold event has been determined, that magnitude is used to identify actual storm events that would have resulted in flows through the project area equal to or greater than flows caused by the threshold event. Damages in the MP_A and MP_C scenarios should be calculated for all these events. The total losses avoided for a project would be the sum of the losses avoided for all damaging storm events.

Determination of a threshold event and total losses avoided requires a significant amount of time and hydrologic, hydraulic, topographic, and asset data of the highest quality. A flow parameter analysis must be performed for each storm event equalling or exceeding the threshold event, so the time required to analyze a project will vary significantly, depending upon the number of potentially damaging storm events that occurred. This type of analysis provides a more accurate assessment of losses avoided and ROI for the project. In addition, as future storm events occur in the project area, this type of analysis could streamline the calculation of new losses avoided.

Appendix A:

Petaluma River Payran Reach Flood Control and Floodways

Project: 1046-1007

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Appendix A:

Project: 1046-1007

Petaluma River Payran Reach Flood Control and Floodways

A.1 General Project Information

A.1.1 Project Location

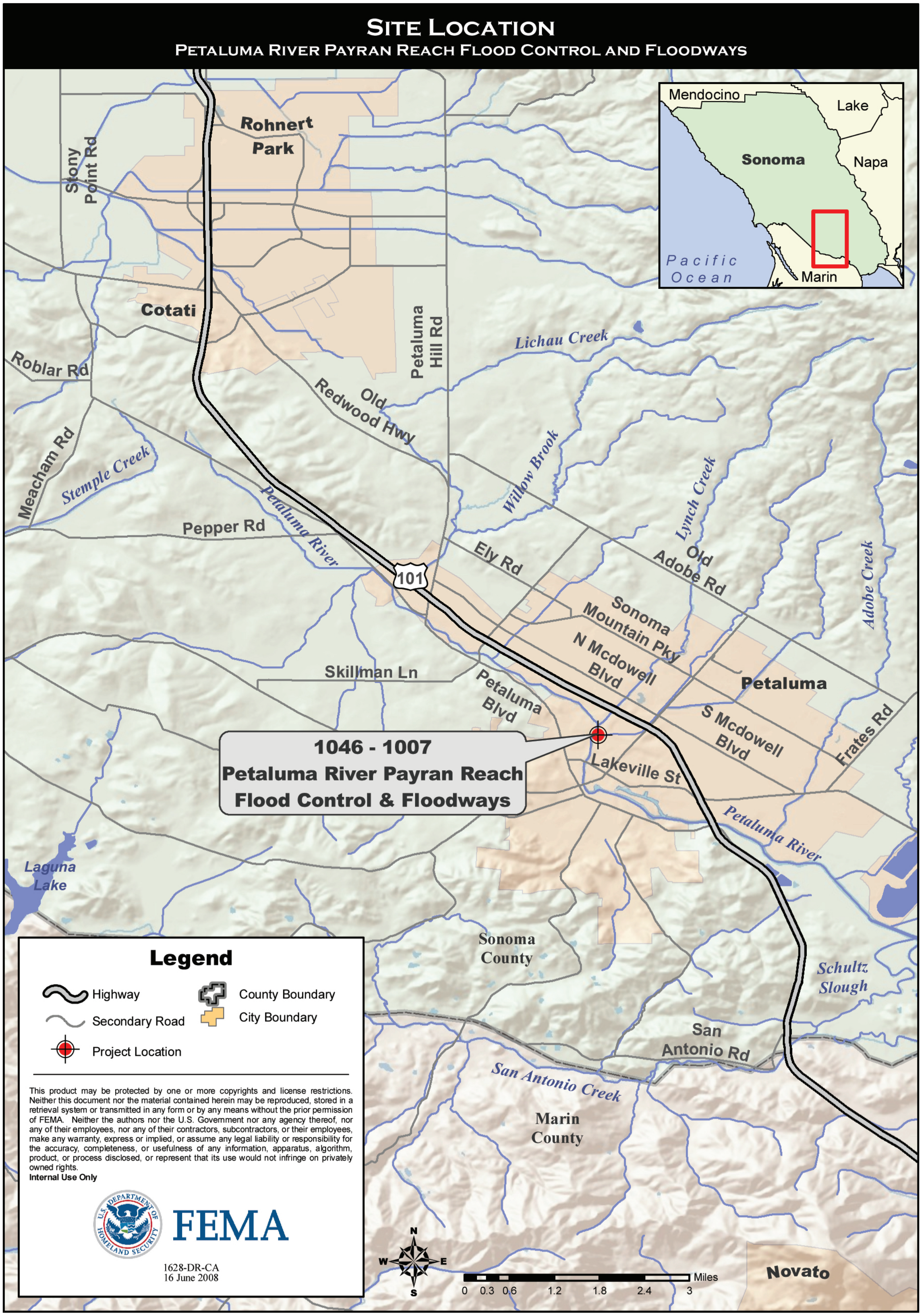
As illustrated in Figure A.1, the Petaluma River Payran Reach Flood Control and Floodways project is located in the City of Petaluma, Sonoma County, CA. More specifically, the project site is located on a 3,600-foot reach of the Petaluma River known as the Payran Reach. This reach extends from the North Coast Railroad Authority spur line bridge (formerly known as the North Western Pacific Rail Road spur line) to just beyond the confluence of the Petaluma River with Lynch Creek.

A.1.2 Project Description

Residential neighborhoods along the Payran Reach were prone to repetitive flooding which caused mild to severe damage. Flood events were recorded in 1982, 1983, 1986, 1993, and 1995. As a response, the Petaluma River Payran Reach Flood Control and Floodways project was implemented. The project included floodwall construction, channel excavation and widening, mitigation planting, bridge replacements and relocations, storm drainage facilities, and a channel constriction weir (Figure A.2) at the upstream extent of the Payran Reach. Prior to project implementation, the river channel reached full capacity at 3,100 cfs, a flood level associated with a 5-year storm event. Maximum peak flows on the Petaluma River were estimated to be between 8,500 and 9,900 cfs.

Flooding in 1982, which was determined to be a 150-year event, impacted approximately 500 homes and 100 businesses over 50 square blocks on both sides of the Petaluma River. During this event, flood depths ranged from 2 to 6 feet and resulted in $28.5 million in damages in 1982 dollars. Inflated to 2008 dollars, these damages equal $64.3 million. The 1983 storm event resulted in local evacuations. Flood depths ranging from 1 to 4 feet were recorded during the 1986 event; the flooding affected a 10-block area containing 100 residential properties. Monetary damages for that particular event totaled approximately $1.0 million (nearly $2 million in 2008 dollars). The 1986 event was estimated to be a 15- to 25-year event. Flooding occurred again in 1993 from a 5-year storm event. Although local evacuations were required, no significant damages were reported. The same area was evacuated

Figure A.1


Site Location
Petaluma River Payran Reach Flood Control and Floodways
Mendocino
Lake
Sonoma
Napa
Pacific Ocean
Marin
Rohnert Park
Stony Point Rd
Cotati
Petaluma Hill Rd
Lichau Creek
Roblar Rd
Old Redwood Hwy
Meacham Rd
Stemple Creek
Willow Brook
Lynch Creek
Petaluma River
Pepper Rd
Ely Rd
Old Adobe Rd
Adobe Creek
101
Sonoma Mountain Pky
N Mcdowell Blvd
Petaluma
Skillman Ln
Petaluma Blvd
S Mcdowell Blvd
Frates Rd
1046 - 1007
Petaluma River Payran Reach
Flood Control & Floodways
Lakeville St
Petaluma River
Laguna Lake
Sonoma County
Schultz Slough
San Antonio Rd
San Antonio Creek
Marin County
Novato
Legend
Highway
County Boundary
Secondary Road
City Boundary
Project Location
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twice more in 1995 as a result of 5-year storm event flood levels. Again, no significant damages were reported.

The greatest depths of flooding from these storm events (1982-1995) occurred in the residential sub-divisions near the Payran Street bridge crossing. Additional areas affected included the light industrial and business area from Washington Street to Edith Street and the residential area from Edith Street to Lynch Creek.

The mitigation project was designed to eliminate all expected flood damage in the project area and protect the city up to the 100-year flood event. Two bridges were replaced and elevated to accommodate increased channel capacity. Two other bridges were elevated, and one was relocated. To avoid bank erosion, a concrete channel constriction weir was constructed upstream of the project. A total of 3,300 feet of floodwalls were constructed, extending 1,650 feet on each side of the river. These floodwalls increased protection to a 100-year event under the City of Petaluma's 2005 General Plan build-out conditions. The entire channel length of the Payran Reach was excavated and widened as part of the project. Mitigation planting was conducted for a total area of 10.5 acres at locations along the riverbanks and areas within the channel to support riparian habitat and to achieve bank stabilization and erosion control (Figure A.3). Also, the existing storm drain system was modified to allow storm flows to pass through the floodwalls and discharge into the river. The pipes were constructed to prevent back flow and a new pump station was installed upstream of the Payran Street Bridge. Major project element locations are detailed in Figure A.4.

Figure A.2

A.1.3 Project Funding and Construction Time Line

The total cost of the project was $39,900,000 ($44,907,802 in 2008 dollars). Of the original $39,900,000 project costs, the USACE provided $5,000,000 and FEMA provided $2,896,000 under HMGP project number 1046-1007. The remaining amount was locally funded. The HMGP grant for the project was approved on March 3, 1998 and the project was completed in 2004.

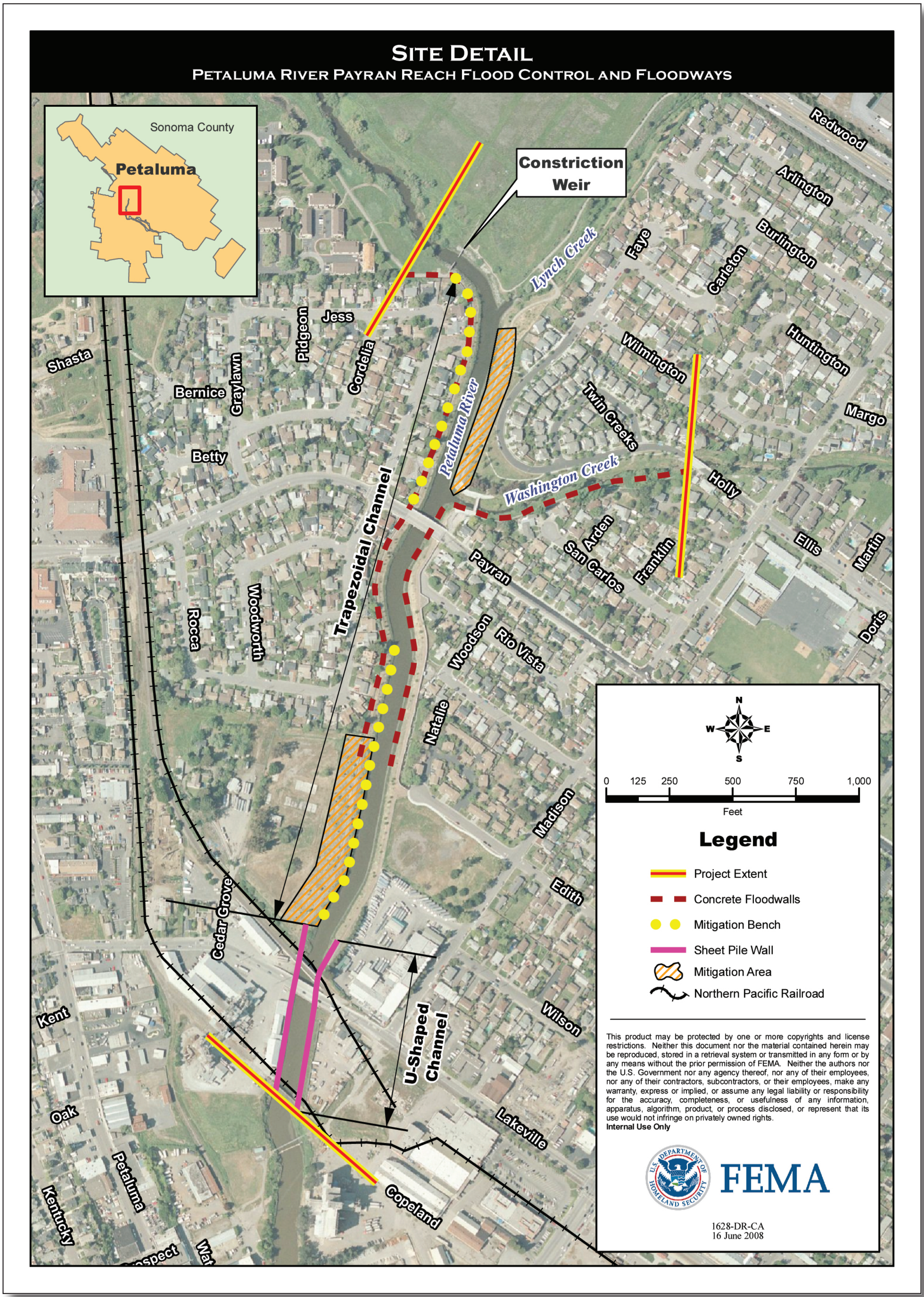
A.2 Data Collection

The LAT initiated data collection for this project in early 2007. Additionally, the LAT conducted a site visit in spring 2007 to obtain initial project information and meet with the local sponsoring agency. The LAT used the HMGP project file and several other sources to obtain hydrologic, hydraulic, and topographic data, to the extent these data were available.

Extensive data for the project, including hydrologic and hydraulic analyses, were available to the LAT from the previous work done by USACE. Although the City of Petaluma was initially contacted during the data collection phase of the project, correspondence was eventually channeled to USACE. USACE conducted most of the Petaluma River feasibility study, which eventually led to the implementation of the Payran Reach mitigation project. The analyses that USACE performed included hydrology for the Petaluma River and its tributaries in the vicinity and the hydraulic modeling of the MP_A and MP_C conditions.

Figure A.3

Figure A.4


SITE DETAIL
PETALUMA RIVER PAYRAN REACH FLOOD CONTROL AND FLOODWAYS
Sonoma County
Petaluma
Constriction Weir
Redwood
Arlington
Burlington
Lynch Creek
Faye
Carleton
Huntington
Wilmington
Margo
Twin Creeks
Jess
Pidgeon
Cordelia
Shasta
Bernice
Graylawn
Betty
Petaluma River
Washington Creek
Holly
Trapezoidal Channel
Arden
San Carlos
Franklin
Payran
Ellis
Martin
Rocca
Woodworth
Woodson
Rio Vista
Doris
Natalie
Madison
Edith
Cedar Grove
U-Shaped Channel
Wilson
Kent
Oak
Lakeville
Petaluma
Kentucky
Copeland
N
W
E
S
0
125
250
500
750
1,000
Feet
Legend
Project Extent
Concrete Floodwalls
Mitigation Bench
Sheet Pile Wall
Mitigation Area
Northern Pacific Railroad
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The project's MP_A condition was defined by a pre-mitigation hydraulic model that USACE developed in its HEC-RAS in 1989 as part of the feasibility study for the project. The MP_C condition was defined by a separate HEC-RAS model that USACE developed after project completion. The MP_C modeling includes topographic modifications that reflect the channel dredging and reshaping that were implemented as part of the project.

The hydraulic modeling that USACE provided included all the necessary input parameters, including: topography (cross-sections of the Petaluma River), flow data for the Petaluma River and its tributaries, roughness, contraction and expansion coefficients, obstructions and ineffective flow areas, and bridge parameters. The topographic data included in the hydraulic modeling were limited primarily to the river channel. Therefore, data for the overbank area were obtained by digitizing topographic data from design drawings provided by the City of Petaluma.

Several stream gages were available in the vicinity of the project to facilitate determination of the most severe event. Stream gage data were collected from the Web site of the DWR CDEC.

The final step in data collection was a second site visit after the MP_A and MP_C flood boundaries were developed to collect information about impacted structures (structures in the floodplain) for the Loss Estimation Analysis.

A.3 Physical Parameter Analysis

A.3.1 Storm Event Analysis

DWR maintains an extensive network of stream gages throughout California. These gages provide various types of data, including precipitation data, stage data, and flow data. A search of CDEC completed at the start of the Loss Avoidance Study revealed several stream gages in the vicinity of the project: Petaluma River at D Street Bridge (DWR gage PTB), Petaluma River near Corona Road (DWR gage CRD), and Petaluma River at Copeland Pumping Station (USGS gage 11459150). DWR gage PTB was selected for application to this analysis because of its location within the hydraulic model domain and because it provided stage data. The selection of this gage allowed a correlation to be made between the existing USACE hydraulic model and the event of interest. DWR gage PTB was used to determine the event of interest by establishing the highest river stage since project completion. The peak stage was 7.28 feet, which occurred December 31, 2005. This event was the most severe event recorded since project completion in 2004.

A.3.2 Flow Parameter Analysis

A.3.2.1 Hydrologic Analysis

To determine the flow rates for the event of interest at various locations throughout the hydraulic model, the LAT performed a hydrologic analysis. The method used involved iteratively running the model with several flow rates until the WSE at D Street Bridge matched the WSE recorded during the event of interest. An initial trial was based on an assumption of a 10-year return period for the event of interest. This 10-year event flow rate was given in the existing MP_A hydraulic model for the river and each tributary. However, when the model was analyzed, the WSE at the location of the gage was found to be too low to match the known WSE of the event of interest. Therefore, the flow rates of the 10-year event were increased at each flow change location by the same percentage until the set of flow rates that produced the known WSE at D Street Bridge were determined. The flow rates that produced a WSE of 7.28 feet at D Street Bridge are detailed in Table A.1.

Table A.1

Flows Modeled in the MP_A HEC-RAS

River Station	10-year (cfs)	50-year (cfs)	100-year (cfs)	500-year (cfs)	December 2005 (cfs)
79905	4,600	6,390	7,260	10,600	5,423
78440	5,700	7,230	8,500	12,500	6,404
77745	7,300	8,660	9,900	14,100	7,926
71450	7,300	8,660	9,900	14,100	7,926
66880	7,300	8,910	10,100	14,900	8,041

Because the MP_C model was completed much later than the MP_A model, the flows modeled, the cross-section locations, and the flow change locations were all different between the two models. To compare the performance of both scenarios for the event of interest, the same flows were used. New flow change locations were added to the MP_C model that were as close as practicable to the locations of those in the MP_A model. Table A.2 details the final flow rates at the flow change locations.

A.3.2.2 Hydraulic Analysis

Existing hydraulic models for the project were obtained during

Table A.2

Flows Modeled in the MP_C HEC-RAS					
River Station	10-year (cfs)	50-year (cfs)	100-year (cfs)	500-year (cfs)	December 2005 (cfs)
81100	4,600	6,390	7,260	10,600	5,423
79905	4,600	6,390	7,260	10,600	5,423
78400	5,700	7,230	8,500	12,500	6,404
77772	7,300	8,660	9,900	14,100	7,926
72670	7,300	8,660	9,900	14,100	7,926

data collection. USACE developed models for the MP_A and MP_C conditions. The MP_A condition was initially modeled using the HEC-2 model, but the files were later updated to HEC-RAS format. The MP_C condition was also modeled in HEC-RAS. The modeling that USACE provided included all the input parameters necessary to run the models once the appropriate flow rates for the event of interest were determined. The results of this modeling determined WSEs at each cross-section throughout the model domain. These WSEs were used in the flood boundary analysis.

A.3.2.3 Flood Boundary Analysis

The WSEs for the MP_A and MP_C scenarios that were determined during the hydraulic analysis were compared to the ground elevation surfaces obtained from the digitized topographic data. The boundary of the floodplain was delineated where the water surface intersected the ground surface for both event scenarios. The flood boundaries for the MP_A scenario and the MP_C scenario are illustrated in Figures A.5 and A.6, respectively.

The MP_C scenario exhibited a considerably smaller floodplain than did the MP_A scenario. This results illustrated the effectiveness of the implemented mitigation project and indicated that losses were avoided.

A.4 Loss Estimation Analysis

Table A.3 displays the results of the Loss Estimation Analysis for both the MP_A and MP_C scenarios by loss category and loss type. Although the project repairs greatly reduced the number of facilities impacted by flooding, a small number of homes were impacted in the MP_C scenario. The following sections describe the loss estimation calculations based on the December 31, 2005, event.

A.4.1 Physical Damage

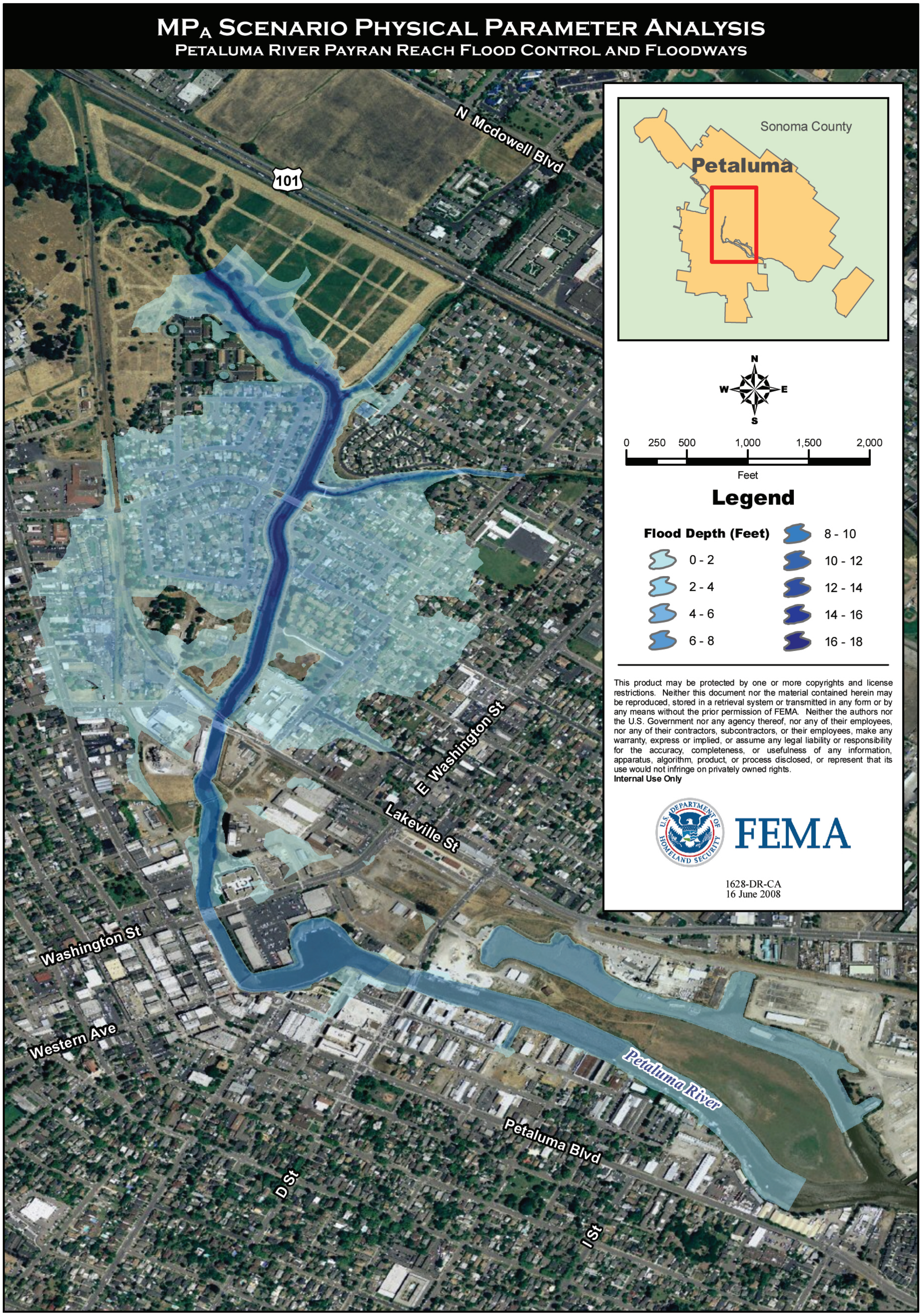
The model results for the December 31, 2005, storm event indicate that damage would occur in both the MP_A and MP_C scenarios. Physical damage for the MP_A scenario would be extremely high due to the heavy concentration of residential properties in areas with the greatest depths of projected flooding. This area included over 500 structures having greater than 500 square feet. Aerial photography and Petaluma City GIS information were used to identify structures as either residential or commercial/industrial.

The impacted residential properties were analyzed using aggregation to simplify the calculation and to mitigate for the lack of specific information readily available for each residence (see Attachments A.1 and A.2). Residential properties were grouped based on their scenario flood depth and FEMA building type. The BRV for the residential structures was $154 per square foot as determined by the Sonoma County elevation study using RSMeans and local official guidance (FEMA, 2008). Content values for residential structures were calculated as 30 percent of the BRV.

Information about the commercial and industrial properties impacted in the MP_A scenario can be found in Attachment A.3. No commercial or industrial properties were impacted in the MP_C scenario The BRVs for commercial and industrial properties were calculated using RSMeans and adjusted using a regional multiplier (RSMeans, 2006). Contents of each commercial and industrial structure were valued at either 100 percent or 150 percent of the BRV, depending upon the structure function and based on guidance within the *HAZUS-MH MR3 Technical Manual* for the flood model (FEMA, 2006a). The LAT performed a field visit to collect detailed information about each commercial and industrial structure. The structure function was identified in the field and then matched to a corresponding HAZUS label. HAZUS labels were taken from the HAZUS Building Occupancy Classes Table in the *HAZUS-MH MR3 Technical Manual* (FEMA, 2006a).

Based on the HAZUS assumption that all homes are elevated one foot above the ground elevation, 307 homes would have witnessed flooding of less than 0.5 feet of water in the MP_A scenario. Therefore, many of the homes in this group would experience lower levels of structure or content damage. The remaining 158 homes would have been inundated with 0.5 to 5.5 feet of water. The total physical damage to residential structures and contents was approximately $38.0 million in the MP_A scenario (Attachment A.4) and approximately $1.4 million in the MP_C scenario (Attachment A.5). The project improvements to the Petaluma River in this reach would yield avoided losses of approximately $36.6 million

Figure A.5


MPA SCENARIO PHYSICAL PARAMETER ANALYSIS
PETALUMA RIVER PAYRAN REACH FLOOD CONTROL AND FLOODWAYS
N Mcdowell Blvd
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Sonoma County
Petaluma
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Flood Depth (Feet)
0 - 2
2 - 4
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8 - 10
10 - 12
12 - 14
14 - 16
16 - 18
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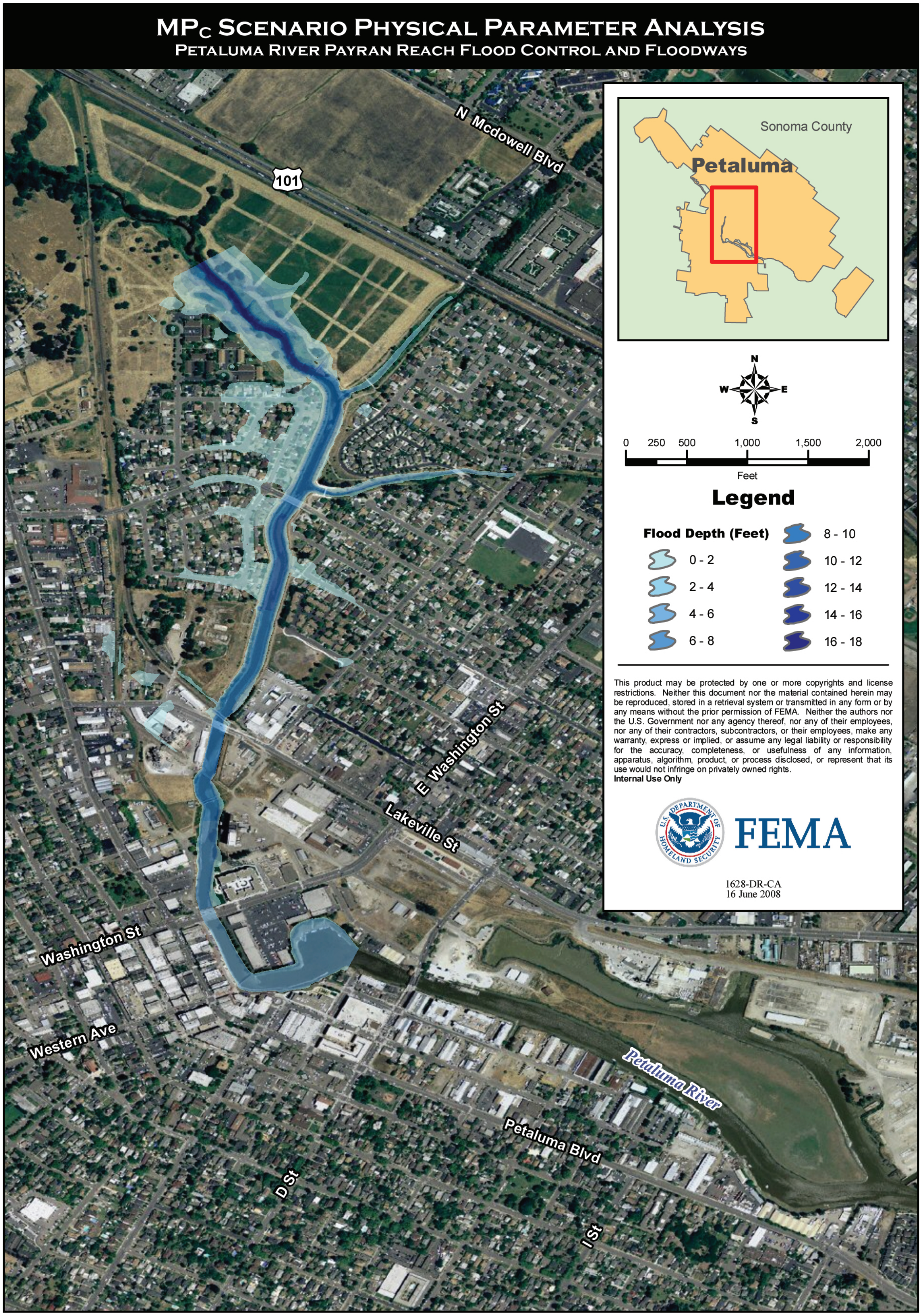
E Washington St
Lakeville St
Washington St
Western Ave
Petaluma River
Petaluma Blvd
D St
I St

Figure A.6


MPc Scenario Physical Parameter Analysis
Petaluma River Payran Reach Flood Control and Floodways
N Mcdowell Blvd
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Sonoma County
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Flood Depth (Feet)
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D St
I St

Table A.3 Part 1 of 2

Loss Estimation Analysis Results

Petaluma River Payran Reach Flood Control and Floodways

Loss Type	MP_A Scenario Losses[1]	MP_C Scenario Losses[1]	Losses Avoided[1]	Comments
Physical Damage				
Structure	$24,144,779	$988,205	**$23,156,574**	• 465 residential structures and 37 commercial and industrial structures were impacted in the MP_A scenario. • 48 residential structures and 0 commercial and industrial structures were impacted in the MP_C scenario. • Structure damages were estimated using depth-damage curves from the FEMA BCA Full Data Flood Module. • BRVs were based on local officials (residential) and RSMeans (commercial and industrial).
Contents	$13,857,072	$444,692	**$13,412,380**	• The contents of 502 structures were impacted. • Contents value for residential structures was estimated at 30% of the BRV based on the FEMA BCA. • Contents value for commercial and industrial structures was estimated based on HAZUS-MH. • Contents damages were estimated using depth-damage curves from the FEMA BCA Full Data Flood Module.
Roads and Bridges	$169,600	$34,100	**$135,500**	• Length of inundated roadway determined using GIS. • Damage values based on roadway damage functions developed for DWR flood projects (URS Group, Inc., 2007).
Infrastructure	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Landscaping	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Environmental Impacts	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Vehicles/Equipment	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Subtotal	***$38,171,451***	***$1,466,997***	***$36,704,454***	
Loss of Function				
Displacement Expense	$3,024,797	$65,479	**$2,959,318**	• Residents from 465 homes were displaced in the MP_A scenario. • Displacement from commercial and industrial facilities was not calculated based on the assumption that these businesses would not be displaced by short-term closure.
Loss of Rental Income	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Loss of Business Income	$608,002	$0	**$608,002**	• Daily business income was calculated based on HAZUS-MH guidance. • Functional downtime was estimated using depth-damage curves from the FEMA BCA Full Data Flood Module.
Lost Wages	$201,319	$0	**$201,319**	• Daily lost wages were calculated based on HAZUS-MH guidance. • Functional downtime was estimated using depth-damage curves from the FEMA BCA Full Data Flood Module.
Disruption Time for Residents	$3,461,121	$240,632	**$3,220,489**	• Over 900 residents were affected in the MP_A scenario. • Disruption costs were determined using the national average per-hour wage identified in *What Is a Benefit?* ($21.16 per hour). • Disruption time was calculated using EMI guidance.
Loss of Public Services	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.

Continued

Table A.3 Part 2 of 2

LOSS ESTIMATION ANALYSIS RESULTS PETALUMA RIVER PAYRAN REACH FLOOD CONTROL AND FLOODWAYS				
Loss Type	**MP_A Scenario Losses**[1]	**MP_C Scenario Losses**[1]	**Losses Avoided**[1]	**Comments**
Loss of Function (Continued)				
Economic Impact of Utility Loss	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Economic Impact of Road/Bridge Closure	$330,680	$0	**$330,680**	• Based on FEMA standard value of $32.23 per vehicle per hour of delay and information on road closures provided in the project file for previous events.
Subtotal	***$7,625,919***	***$306,111***	***$7,319,808***	
Emergency Management				
Debris Cleanup	$49,860	$2,721	**$47,139**	• Estimated using historical data provided in DSRs for events of similar magnitude.
Governmental Expense	$125,401	$26,485	**$98,916**	• Estimated using historical data provided in DSRs for events of similar magnitude.
Subtotal	***$175,261***	***$29,206***	***$146,055***	
Total	***$45,972,631***	***$1,802,314***	***$44,170,317***	

[1] All amounts rounded to the nearest dollar

in physical damage to residential structures and contents for the December 31, 2005, event alone.

Most of the impacted commercial and industrial facilities were located in areas with less flooding than the residential areas. Thirty-seven commercial and industrial structures were estimated to sustain damage in the MP_A scenario. These facilities included auto repair shops, business offices, restaurants, retail stores, and industrial facilities. Physical damage to the commercial and industrial facilities and their contents for the MP_A scenario was estimated to be approximately $6.4 million. As no commercial or industrial structures were impacted in the MP_C scenario, the total losses avoided for physical damage to commercial and industrial structures and their contents were approximately $6.4 million (Attachment A.6).

Physical damage for the flooded roadways was determined using damage functions developed for DWR. These damage functions estimated damage per mile of inundated roadway as $250,000 per mile for highways, $100,000 per mile for major roads, $30,000 per mile for minor roads, and $10,000 per mile for gravel roads (URS Group, Inc., 2007). In the MP_A scenario, 0.46 miles of major roadway and 4.12 miles of minor roadway were determined to be inundated, causing $169,600 in damage. For the MP_C scenario, 0.05 miles of major roadway and 0.97 miles of minor roadway were determined to be inundated, causing $34,100 in damage. The losses avoided for physical damage to roads and bridges totalled $135,500.

Total estimated physical losses for the MP_A and MP_C scenarios were $38,171,451 and $1,466,997, respectively. Therefore, the losses avoided for physical damage were $36,704,454. Details of the calculations can be found in Attachments A.1 through A.6.

A.4.2 Loss of Function

Loss of function was calculated for displacement expense, disruption time for residents, loss of business income, lost wages, and economic impact of road/bridge closure. The loss of function for the MP_A and MP_C scenarios was estimated based on the flood depths at each structure. The results of these calculations can be found in Attachments A.3 through A.7.

Using FEMA BCA Flood Depth-Damage Curves for Displacement Time (FEMA, 2006b) and EMI guidance for Disruption Time, loss of function costs were calculated for the MP_A and MP_C scenarios for residential structures and their occupants. FEMA standards were used for these calculations. Displacement was calculated using rental costs of $1 per square foot per month for temporary housing and $500 per month for utilities and other rental costs. A one-time cost of $500 was assumed for moving costs for each impacted structure.

For disruption, *What Is a Benefit?* provides a national average wage of $21.16 per hour per person (FEMA, 2001). The time of disruption was calculated using EMI guidance that each adult occupant is disrupted 40 hours plus an additional 8 hours for every 1 percent in building damage (FEMA, 2005). These standards were used to calculate the disruption to residents, assuming each home had two adult inhabitants (based on 2000 California Census data).

The calculations indicated that significant losses were avoided for loss of function to residents. Disruption expense and displacement costs totalled $6,485,918 in the MP_A scenario and $306,111 in the MP_C scenario. Total losses avoided in the loss of function category associated with residential structures were $6,179,807. Details of these calculations can be found in Attachments A.4 and A.5.

Loss of function for the commercial and industrial structures impacted in the MP_A scenario included loss of business income and lost wages. These losses were calculated using the FEMA BCA Flood Depth-Damage Curves for Functional Downtime and HAZUS guidance for determining business income and lost wages. The depth-damage curves relate the functional downtime to the type of structure and the depth of flooding. The functional downtime was then multiplied by the business income per day to determine the loss of business income and multiplied by the lost wages per day to determine the lost wages. The business incomes for each structure were determined using *HAZUS-MH MR3 Technical Manual* Tables 14.14 - Proprietor's Income and 14.16 - HAZUS99 Earthquake Table of Recapture Factors (FEMA, 2006a). The income per square foot per day was determined using the HAZUS code for each structure and was then multiplied by the structure's area and by the income recapture percentage for the appropriate HAZUS label to arrive at the daily lost business income. Lost wages were calculated in a similar manner, using the same HAZUS tables. Details of the calculations of loss of business income and lost wages are provided in Attachment A.7.

In the MP_A scenario, lost business income totalled $608,002, and lost wages totalled $201,319. No commercial or industrial facilities were within the MP_C flood boundary, so no losses were indicated in the MP_C scenario. Therefore, losses avoided for loss of function of commercial and industrial facilities totalled $809,321.

The economic impact of road/bridge closure was estimated using the number of vehicles per day that use the impacted route, the average delay or detour time, and the average value of a motorist's time. For this project, the economic impact for closures of Payran Street, Lakeville Street, and Petaluma Boulevard was considered. All other impacted roadways were excluded because the roads were in residential areas that typically evacuate or displace and were not through streets regularly used by non-residents. Because the residents of the excluded roads would be displaced, the economic impacts of these road closures would have to be determined for the location to which the residents are displaced. For example, if a resident was displaced to a location that increased his or her typical commute to work, this increase in commute could be included in the calculation of economic impacts of road closures. The commute may increase for some residents, but decrease for others, so this impact was not calculated.

The following data were used to calculate the economic impact of closures of Payran Street, Lakeville Street, and Petaluma Boulevard:

- The closure time was estimated to be one day based on historical closures for similar flood events.
- The number of one-way traffic trips per day was estimated to be 13,020 for Payran Street, 46,080 for Lakeville Street, and 45,120 for Petaluma Boulevard, based on traffic data provided by local officials.

- The detour time was determined using an online mapping tool and estimating the most probable detour route based on main roads in the project area. The detours were estimated to be 0.12 hours for Payran Street, 0.13 hours for Lakeview Street, and 0.06 hours for Petaluma Boulevard. These are relatively short detour times due to the urban project area.
- From *What Is a Benefit?*, FEMA's standard value of $32.23 per vehicle per hour of delay was used to determine the economic impact of the road closures (FEMA, 2001).

Based on this information, the estimated economic impact of Payran Street closure was $50,356, the estimated economic impact of Lakeville Street closure was $193,071, and the estimated economic impact of Petaluma Boulevard closure was $87,253. The total economic impact of road closures was $330,680. The project file indicated no road closures have occurred since the project was completed; therefore, no MP_C loss of function impacts occurred. The total losses avoided for economic impact of road/bridge closure was $330,680 (Attachment A.8).

Total losses avoided for loss of function for all structures and roadways impacted by the flooding were $7,319,808.

A.4.3 Emergency Management

Emergency management costs are those costs related to response and recovery activities. Expenses include debris cleanup and governmental costs. These costs were estimated using historical DSRs available for events of similar size. Debris cleanup costs were estimated to be $49,860 for the MP_A scenario and $2,721 for the MP_C scenario. Governmental expense was estimated to be $125,401 for the MP_A scenario and $26,485 for the MP_C scenario. Total losses avoided for emergency management costs were $146,055. This value is considered a lower bounds estimation, because it is based on DSRs and does not include costs for which the City of Petaluma did not request reimbursement from FEMA.

A.4.4 Results Summary

For the December 31, 2005, event of interest, losses avoided due to the completion of the mitigation project total $44,170,317. When compared to the project investment of $44,907,802, this project yields an ROI of 98 percent. This ROI only reflects the losses avoided for one event of interest; therefore, this ROI is expected to increase as additional storm events test the project's effectiveness over its useful life.

MP_A Scenario Impacted Residential Structure Information[1]

Petaluma River Payran Reach Flood Control and Floodways

Group	Aggregate Structure Information	FEMA BCA Building Type	Number of Buildings	Estimated Number of Occupants	Area (sf)	BRV ($/sf)	Total BRV	Contents Value Factor	Contents Value	Displacement Expense			Disruption Costs ($/person/hour)
										Rental ($/sf/mo)	Monthly ($/mo)	One-time ($/mo)	
1	1 story residential, 0 ft to 0.49 ft flood depth	1 story without basement	153	309	256,731	$154.00	$39,536,622.97	30%	$11,860,986.89	$1.00	$500.00	$500.00	$21.16
2	1 story residential, 0.5 ft to 1.49 ft flood depth	1 story without basement	123.3	273	221,673	$154.00	$34,137,642.92	30%	$10,241,292.88	$1.00	$500.00	$500.00	$21.16
3	1 story residential, 1.5 ft to 2.49 ft flood depth	1 story without basement	96.3	193	186,148	$154.00	$28,666,820.95	30%	$8,600,046.29	$1.00	$500.00	$500.00	$21.16
4	1 story residential, 2.5 ft to 3.49 ft flood depth	1 story without basement	27.9	56	58,808	$154.00	$9,056,387.34	30%	$2,716,916.20	$1.00	$500.00	$500.00	$21.16
5	1 story residential, 3.5 ft to 4.49 ft flood depth	1 story without basement	14.4	29	29,330	$154.00	$4,516,774.42	30%	$1,355,032.32	$1.00	$500.00	$500.00	$21.16
6	1 story residential, 4.5 ft to 5.49 ft flood depth	1 story without basement	3.6	7	8,019	$154.00	$1,234,870.56	30%	$370,461.17	$1.00	$500.00	$500.00	$21.16
7	2 story residential, 0 ft to 0.49 ft flood depth	2 story without basement	17	34	28,526	$154.00	$4,392,958.11	30%	$1,317,887.43	$1.00	$500.00	$500.00	$21.16
8	2 story residential, 0.5 ft to 1.49 ft flood depth	2 story without basement	13.7	30	24,630	$154.00	$3,793,071.44	30%	$1,137,921.43	$1.00	$500.00	$500.00	$21.16
9	2 story residential, 1.5 ft to 2.49 ft flood depth	2 story without basement	10.7	21	20,683	$154.00	$3,185,202.33	30%	$955,560.70	$1.00	$500.00	$500.00	$21.16
10	2 story residential, 2.5 ft to 3.49 ft flood depth	2 story without basement	3.1	6	6,534	$154.00	$1,006,265.26	30%	$301,879.58	$1.00	$500.00	$500.00	$21.16
11	2 story residential, 3.5 ft to 4.49 ft flood depth	2 story without basement	1.6	3	3,259	$154.00	$501,863.82	30%	$150,559.15	$1.00	$500.00	$500.00	$21.16
12	2 story residential, 4.5 ft to 5.49 ft flood depth	2 story without basement	0.4	1	891	$154.00	$137,207.84	30%	$41,162.35	$1.00	$500.00	$500.00	$21.16

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

MP_C Scenario Impacted Residential Structure Information[1]

Petaluma River Payran Reach Flood Control and Floodways

Group	Aggregate Structure Information	FEMA BCA Building Type	Number of Buildings	Estimated Number of Occupants	Area (sf)	BRV ($/sf)	Total BRV	Contents Value Factor	Contents Value	Displacement Expense			Disruption Costs ($/person/hour)
										Rental ($/sf/mo)	Monthly ($/mo)	One-time ($/mo)	
1	1 story residential, 0 ft to 0.49 ft flood depth	1 story without basement	43	86	58,781	$154.00	$9,052,274.00	30%	$2,715,682.20	$1.00	$500.00	$500.00	$21.16
2	2 story residential, 0 ft to 0.49 ft flood depth	2 story without basement	5	10	6,531	$154.00	$1,005,774.00	30%	$301,732.20	$1.00	$500.00	$500.00	$21.16

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

MP_A Scenario Impacted Commercial/Industrial Structure Information[1]
Petaluma River Payran Reach Flood Control and Floodways

Address	Structure Information	HAZUS Building Type	FEMA BCA Building Type	Area (sf)	BRV ($/sf)	Total BRV	Contents Value Factor	Contents Value	Business Income ($/day)	Lost Wages ($/day)
9 West Street	craft shop	IND2	1 story, without basement	2306.03	$42.22	$97,367.56	1.5	$146,051.35	$97.38	$20.06
814 Petaluma	motor (small and auto) repair shop, office in front, garage in rear.	COM3	1 story, without basement	2278.39	$89.20	$203,240.53	1.0	$203,240.53	$971.30	$367.20
30 Lakeview	hay and grain production and agricultural sales store.	IND3	1 story, without basement	69453	$76.12	$5,286,789.03	1.5	$7,930,183.54	$3,905.55	$810.59
601 Petaluma	toy shop	COM1	1 story, without basement	14556.33	$57.68	$839,681.58	1.0	$839,681.58	$1,023.95	$421.63
822 Petaluma	interior design and interior design sales, show room of high end fixtures and housing supplies, high value of stock, workshop in rear of store, sandblasting	COM1	1 story, without basement	16603.33	$78.50	$1,303,347.23	1.0	$1,303,347.23	$1,167.95	$480.92
610 Petaluma	auto garage and office	COM3	2 story, without basement	1643.71	$89.20	$146,624.81	1.0	$146,624.81	$700.73	$264.91
616 Petaluma	professional services office space	COM4	1 story, without basement	4206.37	$111.21	$467,778.31	1.0	$467,778.31	$905.98	$165.13
91 Lakeview	processing and distribution of Clover's Milk.	AGR1	1 story, without basement	2380.66	$60.66	$144,407.10	1.0	$144,407.10	$688.30	$56.83
91 Lakeview	processing and distribution of Clover's Milk.	IND3	2 story, without basement	71207	$117.15	$8,342,186.91	1.5	$12,513,280.36	$4,004.18	$831.06
6 C Street	office space	COM4	2 story, without basement	1500.08	$111.21	$166,819.58	1.0	$166,819.58	$323.09	$58.89
801 Petaluma	Mexican restaurant	COM8	1 story, without basement	3101.54	$170.08	$527,514.52	1.0	$527,514.52	$2,211.37	$631.82
619 Petaluma	glass workshop, home/auto/hobby.	COM3	1 story, without basement	5343.74	$95.15	$508,459.43	1.0	$508,459.43	$2,278.09	$861.23
810 Madison	nursery, child care provided in association with Petaluma City Schools.	EDU1	1 story, without basement	2297.28	$100.50	$230,882.83	1.0	$230,882.83	$3,402.63	$380.24
610 Petaluma	Thai restaurant	COM8	2 story, without basement	2336.62	$132.02	$308,483.59	1.0	$308,483.59	$1,665.99	$476.00
622 Petaluma	office space	COM4	1 story, without basement	3160.00	$111.21	$351,414.51	1.0	$351,414.51	$680.61	$124.05
37 Baylis	storage	IND2	1 story, without basement	3941.41	$42.22	$166,418.25	1.0	$166,418.25	$166.44	$34.29
699 Petaluma	massage and spa	COM4	2 story, without basement	1496.44	$111.21	$166,414.79	1.0	$166,414.79	$322.31	$58.75
620 Petaluma	multifunction shop space.	COM1	2 story, without basement	11224.37	$83.85	$941,178.70	1.0	$941,178.70	$789.57	$325.12
800 Petaluma	Mexican restaurant	COM8	1 story, without basement	736.79	$132.02	$97,271.97	1.0	$97,271.97	$525.33	$150.09
91 Lakeview	processing and distribution of Clover's Milk.	AGR1	1 story, without basement	1727.50	$60.66	$104,787.44	1.0	$104,787.44	$499.46	$41.24
1 C street	automotive body shop/paint. garage and office	COM3	1 story, without basement	9873.65	$95.15	$939,482.54	1.0	$939,482.54	$4,209.23	$1,591.30
91 Lakeview	processing and distribution of Clover's Milk.	AGR1	1 story, without basement	3383.34	$60.66	$205,228.10	1.0	$205,228.10	$978.20	$80.77
816 Petaluma	garage behind Norm's office	COM3	1 story, without basement	2326.57	$89.20	$207,538.36	1.0	$207,538.36	$991.84	$374.96
100 East D Street	industrial	IND1	1 story, without basement	10990.19	$76.12	$836,577.48	1.5	$1,254,866.22	$464.09	$95.62
714 Petaluma	sales, carpet, tile, hardwood, showroom, some minor furnishings (lamps, etc) .	COM1	1 story, without basement	5756.27	$78.50	$451,862.28	1.0	$451,862.28	$404.92	$166.73
704 Petaluma	office and garage area.	COM3	1 story, without basement	4806.28	$95.15	$457,319.85	1.0	$457,319.85	$2,048.96	$774.61
444 and 442 Petaluma	computer sales store and art and crafts store	COM1	2 story, without basement	3693.19	$57.68	$213,041.59	1.0	$213,041.59	$259.79	$106.97

Continued

MP_A Scenario Impacted Commercial/Industrial Structure Information[1]

Petaluma River Payran Reach Flood Control and Floodways

Address	Structure Information	HAZUS Building Type	FEMA BCA Building Type	Area (sf)	BRV ($/sf)	Total BRV	Contents Value Factor	Contents Value	Business Income ($/day)	Lost Wages ($/day)
696 Petaluma	insurance agency offices in old residence	COM4	1 story, without basement	1520.06	$111.21	$169,041.50	1.0	$169,041.50	$327.40	$59.67
51 Lakeview	truck maintenance associated bldg.	COM3	1 story, without basement	1116.34	$129.64	$144,725.14	1.0	$144,725.14	$475.91	$179.92
412 Madison	auto repair garage and office.	COM3	1 story, without basement	4042.10	$95.15	$384,607.76	1.0	$384,607.76	$1,723.19	$651.45
412 Madison	garage for auto repair	COM3	1 story, without basement	4155.07	$95.15	$395,356.90	1.0	$395,356.90	$1,771.35	$669.66
29 Lakeview	smog check	COM3	1 story, without basement	1626.48	$63.04	$102,528.73	1.0	$102,528.73	$693.38	$262.13
51 Lakeview	truck maintenance associated bldg.	COM3	1 story, without basement	429.28	$129.64	$55,652.94	1.0	$55,652.94	$183.01	$69.19
51 Lakeview	large garage for maintenance of Clover's Milk delivery trucks	COM3	1 story, without basement	10018.15	$129.64	$1,298,778.30	1.0	$1,298,778.30	$4,270.84	$1,614.58
A Lakeview	workshop	IND1	1 story, without basement	1158.13	$51.14	$59,230.69	1.0	$59,230.69	$48.91	$10.08
29 Lakeview	auto shop	COM3	1 story, without basement	2689.76	$63.04	$169,554.92	1.0	$169,554.92	$1,146.67	$433.50
704 Petaluma	auto body garage/main repairs	COM3	1 story, without basement	6783.75	$95.15	$645,477.07	1.0	$645,477.07	$2,891.98	$1,093.31

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

MP_A Scenario Loss Estimation Analysis for Residential Structures[1]
Petaluma River Payran Reach Flood Control and Floodways

Group	Structure Elevation (ft)	Water Surface Elevation (ft)	Depth of Flooding (ft)	Structure DDF (% of BRV)	Structure Damage	Contents DDF (% of contents value)	Contents Damage	Displacement Time (days)	Displacement Expense	Disruption Time (hours)	Disruption Costs
1	1.00	1.25	0.25	10%	$4,052,504	15%	$1,823,627	15.5	$248,670	82	$798,658
2	1.00	2.25	1.25	16%	$5,462,023	24%	$2,457,910	78.0	$798,290	128	$968,904
3	1.00	3.25	2.25	23%	$6,665,036	35%	$2,999,266	136.0	$1,110,302	186	$921,044
4	1.00	4.25	3.25	28%	$2,490,507	41%	$1,120,728	170.0	$426,244	220	$306,989
5	1.00	5.25	4.25	29%	$1,321,157	44%	$594,520	184.0	$231,249	234	$166,978
6	1.00	6.25	5.25	33%	$401,333	49%	$180,600	210.0	$70,530	260	$45,706
7	1.00	1.25	0.25	6%	$263,577	9%	$118,610	0.0	$8,500	48	$64,009
8	1.00	2.25	1.25	10%	$379,307	15%	$170,688	13.5	$21,016	80	$76,897
9	1.00	3.25	2.25	14%	$453,891	21%	$204,251	64.0	$60,887	114	$69,735
10	1.00	4.25	3.25	19%	$186,159	28%	$83,772	98.0	$27,958	148	$24,664
11	1.00	5.25	4.25	21%	$102,882	31%	$46,297	114.0	$16,224	164	$13,813
12	1.00	6.25	5.25	23%	$30,872	34%	$13,892	130.0	$4,927	180	$3,724

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

MP_C Scenario Loss Estimation Analysis for Residential Structures[1]

Petaluma River Payran Reach Flood Control and Floodways

Group	Structure Elevation (ft)	Water Surface Elevation (ft)	Depth of Flooding (ft)	Structure DDF (% of BRV)	Structure Damage	Contents DDF (% of contents value)	Contents Damage	Displacement Time (days)	Displacement Expense	Disruption Time (hours)	Disruption Costs
1	1.00	1.25	0.25	10%	$927,858	15%	$417,536	15.5	$62,979	82	$222,011
2	1.00	1.25	0.25	6%	$60,346	9%	$27,156	0.0	$2,500	48	$18,621

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

MP_A Scenario Loss Estimation Analysis for Commercial/Industrial Structures[1]

Petaluma River Payran Reach Flood Control and Floodways

Address	Structure Elevation (ft msl)	Water Surface Elevation (ft msl)	Depth of Flooding (ft)	Structure DDF (% of BRV)	Structure Damage	Contents DDF (% of contents value)	Contents Damage	Loss of Function (days)	Loss of Business Income	Lost Wages
9 West Street	17.32	17.39	0.07	9%	$9,107	14%	$20,490	9.4	$911	$188
814 Petaluma	18.50	18.08	-0.42	5%	$10,637	8%	$15,955	5.2	$5,083	$1,922
30 Lakeview	16.44	15.55	-0.89	1%	$51,500	1%	$115,875	1.0	$3,804	$790
601 Petaluma	17.16	16.85	-0.32	6%	$51,758	9%	$77,637	6.2	$6,312	$2,599
822 Petaluma	18.29	18.48	0.19	10%	$129,675	15%	$194,512	9.9	$11,620	$4,785
610 Petaluma	16.66	16.92	0.25	6%	$8,822	9%	$13,233	6.0	$4,216	$1,594
616 Petaluma	16.78	16.03	-0.74	2%	$10,807	3%	$16,211	2.3	$2,093	$382
91 Lakeview	16.00	16.34	0.34	11%	$15,424	16%	$23,136	10.7	$7,352	$607
91 Lakeview	16.00	16.34	0.34	6%	$529,302	10%	$1,190,930	6.3	$25,406	$5,273
6 C Street	10.73	10.08	-0.65	2%	$2,922	3%	$4,383	1.8	$566	$103
801 Petaluma	17.69	18.07	0.37	11%	$57,330	16%	$85,996	10.9	$24,033	$6,867
619 Petaluma	16.98	17.36	0.39	11%	$55,605	16%	$83,408	10.9	$24,913	$9,418
810 Madison	18.50	18.47	-0.03	9%	$20,157	13%	$30,236	8.7	$29,706	$3,320
610 Petaluma	16.33	15.95	-0.39	3%	$9,484	5%	$14,226	3.1	$5,122	$1,463
622 Petaluma	15.92	16.60	0.68	12%	$43,503	19%	$65,255	12.4	$8,426	$1,536
37 Baylis	12.01	12.71	0.70	13%	$20,816	19%	$31,224	12.5	$2,082	$429
699 Petaluma	16.61	16.82	0.21	6%	$9,726	9%	$14,589	5.8	$1,884	$343
620 Petaluma	15.65	16.45	0.80	8%	$77,364	12%	$116,046	8.2	$6,490	$2,672
800 Petaluma	17.07	17.96	0.89	13%	$13,075	20%	$19,612	13.4	$7,061	$2,017
91 Lakeview	16.00	16.95	0.95	14%	$14,399	21%	$21,599	13.7	$6,863	$567
1 C street	9.13	10.12	0.99	14%	$131,200	21%	$196,801	14.0	$58,783	$22,223
91 Lakeview	15.94	16.93	1.00	14%	$28,684	21%	$43,027	14.0	$13,672	$1,129
816 Petaluma	17.01	18.04	1.03	14%	$29,518	21%	$44,277	14.2	$14,107	$5,333
100 East D Street	9.66	10.84	1.19	15%	$129,576	23%	$291,546	15.5	$7,188	$1,481
714 Petaluma	17.50	17.79	0.29	10%	$47,176	16%	$70,764	10.4	$4,227	$1,741
704 Petaluma	15.86	17.21	1.35	17%	$76,876	25%	$115,314	16.8	$34,443	$13,021

Continued

MP_A Scenario Loss Estimation Analysis for Commercial/Industrial Structures[1]

Petaluma River Payran Reach Flood Control and Floodways

Address	Structure Elevation (ft msl)	Water Surface Elevation (ft msl)	Depth of Flooding (ft)	Structure DDF (% of BRV)	Structure Damage	Contents DDF (% of contents value)	Contents Damage	Loss of Function (days)	Loss of Business Income	Lost Wages
444 and 442 Petaluma	14.56	15.55	0.99	9%	$19,058	13%	$28,587	8.9	$2,324	$957
696 Petaluma	16.96	17.10	0.14	10%	$16,417	15%	$24,626	9.7	$3,180	$580
51 Lakeview	14.52	16.16	1.64	19%	$27,724	29%	$41,587	19.2	$9,117	$3,447
412 Madison	15.29	16.57	1.28	16%	$62,544	24%	$93,816	16.3	$28,022	$10,594
412 Madison	14.84	16.64	1.81	20%	$80,868	31%	$121,302	20.5	$36,232	$13,697
29 Lakeview	14.89	15.71	0.82	13%	$13,419	20%	$20,129	13.1	$9,075	$3,431
51 Lakeview	13.91	15.97	2.06	22%	$12,413	33%	$18,620	22.3	$4,082	$1,543
51 Lakeview	14.00	16.09	2.09	22%	$291,483	34%	$437,224	22.4	$95,850	$36,236
A Lakeview	15.34	17.50	2.16	23%	$13,502	34%	$20,254	22.8	$1,115	$230
29 Lakeview	14.52	16.00	1.48	18%	$30,292	27%	$45,438	17.9	$20,486	$7,745
704 Petaluma	13.99	17.69	3.70	28%	$183,365	43%	$275,048	28.4	$82,155	$31,058

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

MP_A Scenario Loss of Business Income and Lost Wages Calculations[1]

Petaluma River Payran Reach Flood Control and Floodways

Address	HAZUS Building Type	Area (sf)	Income, Output, and Wage Recapture Factor[2]	Owner Income per Day[3] ($/sf)	Output per Day[4] ($/sf)	Business Income[5] ($/day)	Wages per Day[6] ($/sf)	Lost Wages[7] ($/day)	Functional Downtime[8] (days)	Total Lost Business Income	Total Lost Wages
9 West Street	IND2	2306.03	98%	$0.27	$1.85	$97.38	$0.44	$20.06	9.4	$911	$188
814 Petaluma	COM3	2278.39	51%	$0.14	$0.73	$971.30	$0.33	$367.20	5.2	$5,083	$1,922
30 Lakeview	IND3	69453	98%	$0.35	$2.46	$3,905.55	$0.58	$810.59	1.0	$3,804	$790
601 Petaluma	COM1	14556.33	87%	$0.06	$0.48	$1,023.95	$0.22	$421.63	6.2	$6,312	$2,599
822 Petaluma	COM1	16603.33	87%	$0.06	$0.48	$1,167.95	$0.22	$480.92	9.9	$11,620	$4,785
610 Petaluma	COM3	1643.71	51%	$0.14	$0.73	$700.73	$0.33	$264.91	6.0	$4,216	$1,594
616 Petaluma	COM4	4206.37	90%	$1.09	$1.06	$905.98	$0.39	$165.13	2.3	$2,093	$382
91 Lakeview	AGR1	2380.66	75%	$0.24	$0.91	$688.30	$0.10	$56.83	10.7	$7,352	$607
91 Lakeview	IND3	71207	98%	$0.35	$2.46	$4,004.18	$0.58	$831.06	6.3	$25,406	$5,273
6 C Street	COM4	1500.08	90%	$1.09	$1.06	$323.09	$0.39	$58.89	1.8	$566	$103
801 Petaluma	COM8	3101.54	60%	$0.64	$1.15	$2,211.37	$0.51	$631.82	10.9	$24,033	$6,867
619 Petaluma	COM3	5343.74	51%	$0.14	$0.73	$2,278.09	$0.33	$861.23	10.9	$24,913	$9,418
810 Madison	EDU1	2297.28	60%	$0.17	$3.53	$3,402.63	$0.41	$380.24	8.7	$29,706	$3,320
610 Petaluma	COM8	2336.62	60%	$0.64	$1.15	$1,665.99	$0.51	$476.00	3.1	$5,122	$1,463
622 Petaluma	COM4	3160.00	90%	$1.09	$1.06	$680.61	$0.39	$124.05	12.4	$8,426	$1,536
37 Baylis	IND2	3941.41	98%	$0.27	$1.85	$166.44	$0.44	$34.29	12.5	$2,082	$429
699 Petaluma	COM4	1496.44	90%	$1.09	$1.06	$322.31	$0.39	$58.75	5.8	$1,884	$343
620 Petaluma	COM1	11224.37	87%	$0.06	$0.48	$789.57	$0.22	$325.12	8.2	$6,490	$2,672
800 Petaluma	COM8	736.79	60%	$0.64	$1.15	$525.33	$0.51	$150.09	13.4	$7,061	$2,017
91 Lakeview	AGR1	1727.50	75%	$0.24	$0.91	$499.46	$0.10	$41.24	13.7	$6,863	$567
1 C street	COM3	9873.65	51%	$0.14	$0.73	$4,209.23	$0.33	$1,591.30	14.0	$58,783	$22,223
91 Lakeview	AGR1	3383.34	75%	$0.24	$0.91	$978.20	$0.10	$80.77	14.0	$13,672	$1,129
816 Petaluma	COM3	2326.57	51%	$0.14	$0.73	$991.84	$0.33	$374.96	14.2	$14,107	$5,333
100 East D Street	IND1	10990.19	98%	$0.27	$1.85	$464.09	$0.44	$95.62	15.2	$7,188	$1,481
714 Petaluma	COM1	5756.27	87%	$0.06	$0.48	$404.92	$0.22	$166.73	10.4	$4,227	$1,741
704 Petaluma	COM3	4806.28	51%	$0.14	$0.73	$2,048.96	$0.33	$774.61	16.8	$34,443	$13,021
444 and 442 Petaluma	COM1	3693.19	87%	$0.06	$0.48	$259.79	$0.22	$106.97	8.9	$2,324	$957

Continued

MP_A Scenario Loss of Business Income and Lost Wages Calculations[1]

Petaluma River Payran Reach Flood Control and Floodways

Address	HAZUS Building Type	Area (sf)	Income, Output, and Wage Recapture Factor[2]	Owner Income per Day[3] ($/sf)	Output per Day[4] ($/sf)	Business Income[5] ($/day)	Wages per Day[6] ($/sf)	Lost Wages[7] ($/day)	Functional Downtime[8] (days)	Total Lost Business Income	Total Lost Wages
696 Petaluma	COM4	1520.06	90%	$1.09	$1.06	$327.40	$0.39	$59.67	9.7	$3,180	$580
51 Lakeview	COM3	1116.34	51%	$0.14	$0.73	$475.91	$0.33	$179.92	19.2	$9,117	$3,447
412 Madison	COM3	4042.10	51%	$0.14	$0.73	$1,723.19	$0.33	$651.45	16.3	$28,022	$10,594
412 Madison	COM3	4155.07	51%	$0.14	$0.73	$1,771.35	$0.33	$669.66	20.5	$36,232	$13,697
29 Lakeview	COM3	1626.48	51%	$0.14	$0.73	$693.38	$0.33	$262.13	13.1	$9,075	$3,431
51 Lakeview	COM3	429.28	51%	$0.14	$0.73	$183.01	$0.33	$69.19	22.3	$4,082	$1,543
51 Lakeview	COM3	10018.15	51%	$0.14	$0.73	$4,270.84	$0.33	$1,614.58	22.4	$95,850	$36,236
A Lakeview	IND1	1158.13	98%	$0.27	$1.85	$48.91	$0.44	$10.08	22.8	$1,115	$230
29 Lakeview	COM3	2689.76	51%	$0.14	$0.73	$1,146.67	$0.33	$433.50	17.9	$20,486	$7,745
704 Petaluma	COM3	6783.75	51%	$0.14	$0.73	$2,891.98	$0.33	$1,093.31	28.4	$82,155	$31,058

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.
[2] The Recapture Factors were taken from Table 14.16 HAZUS99 Earthquake Table of Recapture Factors in the HAZUS Flood Model Technical Manual.
[3] Owner Income per Day was taken from Table 14.14 Proprietor's Income in the HAZUS Flood Model Technical Manual. This value was inflated to 2008 dollars.
[4] Output per Day was taken from Table 14.14 Proprietor's Income in the HAZUS Flood Model Technical Manual. This value was inflated to 2008 dollars.
[5] Business Income was determined by adding the Owner Income and Output per Day and multiplying the sum by the square footage and 1 minus the Recapture Factor. For example, the Business Income for 704 Petaluma was ($0.14 per square foot + $0.73 per square foot) x 6,783.75 square feet x (1-0.51).
[6] Wages per Day was taken from Table 14.14 Proprietor's Income in the HAZUS Flood Model Technical Manual. This value was inflated to 2008 dollars.
[7] Lost Wages were determined by multiplying the Lost Wages per Day by the square footage and 1 minus the Recapture Factor. For example, the Lost Wages for 704 Petaluma was $0.33 per square foot x 6,783.75 square feet x (1-0.51).
[8] Functional Downtime was determined using the Depth Damage Functions from the FEMA BCA Riverine Full Data Module.

MP_A Scenario Economic Impact of Road/Bridge Closure[1]
Petaluma River Payran Reach Flood Control and Floodways

Road/Bridge Closure	Vehicles per Day	Cost per Vehicle Hour	Delay Time (hours)	Duration of Closure (days)	Total Cost of Delay
Payran Street Closure	13,020	$32.23	0.120	1.00	$50,356.15
Lakeville Street Closure	46,080	$32.23	0.130	1.00	$193,070.59
Petaluma Boulevard Closure	45,120	$32.23	0.060	1.00	$87,253.06

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

Appendix B:

Soscol Avenue Area Drainage Interceptor

Project: 1155-0010

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Appendix B:

Project: 1155-0010

Soscol Avenue Area Drainage Interceptor

B.1 General Project Information

B.1.1 Project Location

As illustrated in Figure B.1, the Soscol Avenue Area Drainage Interceptor is located in the City of Napa, Napa County, CA. More specifically, the project site is located between Shetler Avenue and Kansas Avenue. Affected areas surrounding Soscol Avenue include State Route 121 and local private businesses.

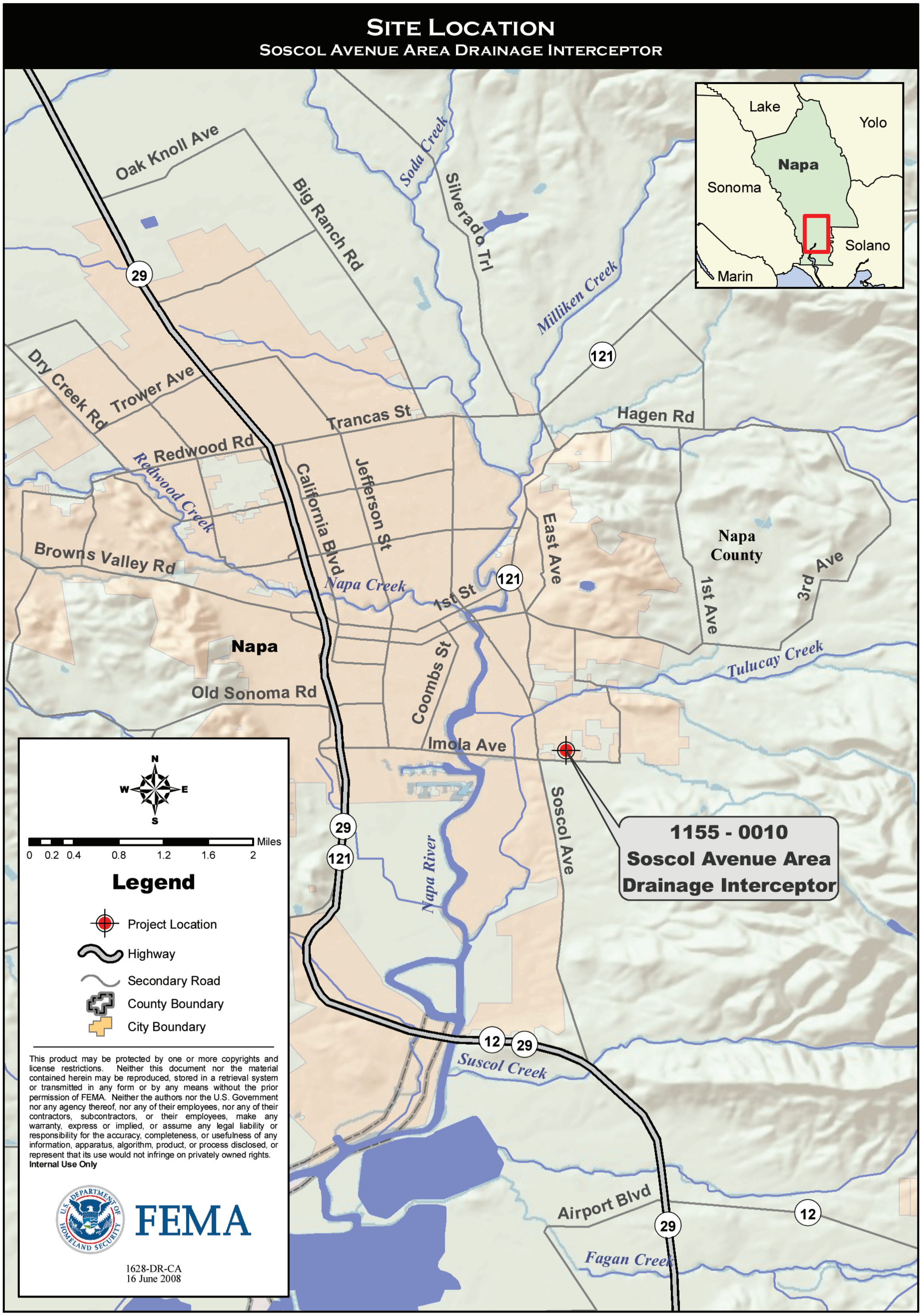
B.1.2 Project Description

The Soscol Avenue Area Drainage Interceptor was designed in response to 12 flood events between 1994 and 1997. These events caused mild to severe damage within the project area. Prior to project implementation, infrastructure provided flood-level protection for only a 1-year event. The purpose of the project was to collect and divert localized runoff from the Soscol Avenue area to a new outfall at the southwestern corner of the Soscol Avenue/Imola Avenue intersection (Figure B.2).

The most severe of the 12 flood events occurred in 1997. The flood impacted the local area for 12 hours, required evacuation of people, relocation of merchandise, temporary closure of businesses, and temporary closure of State Route 121. Flood depths varied from six inches to four feet. As indicated in the HMGP project file, 17 businesses on Soscol Avenue and 1 residential property have been historically impacted by flooding. Specific quantitative information regarding flood events prior to 1997 (including damage reports) was not available for this study.

The completed Soscol Avenue Drainage Interceptor Project involved drainage improvements to existing storm drains and underground pipes to increase the area's protection to a 10-year flood event. The Imola Avenue storm drain was redirected to Soscol Avenue and connected to a new drain inlet and 42-inch reinforced concrete pipe (RCP) (under roadway). The new RCP runs parallel to the existing detention basin storm drain (Figure B.3). Both drains discharge into the wetland on the western side of Soscol Avenue (Figure B.4).

Figure B.1


Site Location
Soscol Avenue Area Drainage Interceptor
Lake
Yolo
Napa
Sonoma
Solano
Marin
Oak Knoll Ave
Soda Creek
Silverado Trl
Big Ranch Rd
29
Milliken Creek
121
Hagen Rd
Dry Creek Rd
Trower Ave
Trancas St
Redwood Rd
Redwood Creek
California Blvd
Jefferson St
East Ave
Napa County
Browns Valley Rd
Napa Creek
1st St
121
1st Ave
3rd Ave
Napa
Coombs St
Tulucay Creek
Old Sonoma Rd
Imola Ave
Soscol Ave
1155 - 0010
Soscol Avenue Area
Drainage Interceptor
29
121
Napa River
12
29
Suscol Creek
Airport Blvd
29
12
Fagan Creek
N
W
E
S
Miles
0 0.2 0.4 0.8 1.2 1.6 2
Legend
Project Location
Highway
Secondary Road
County Boundary
City Boundary
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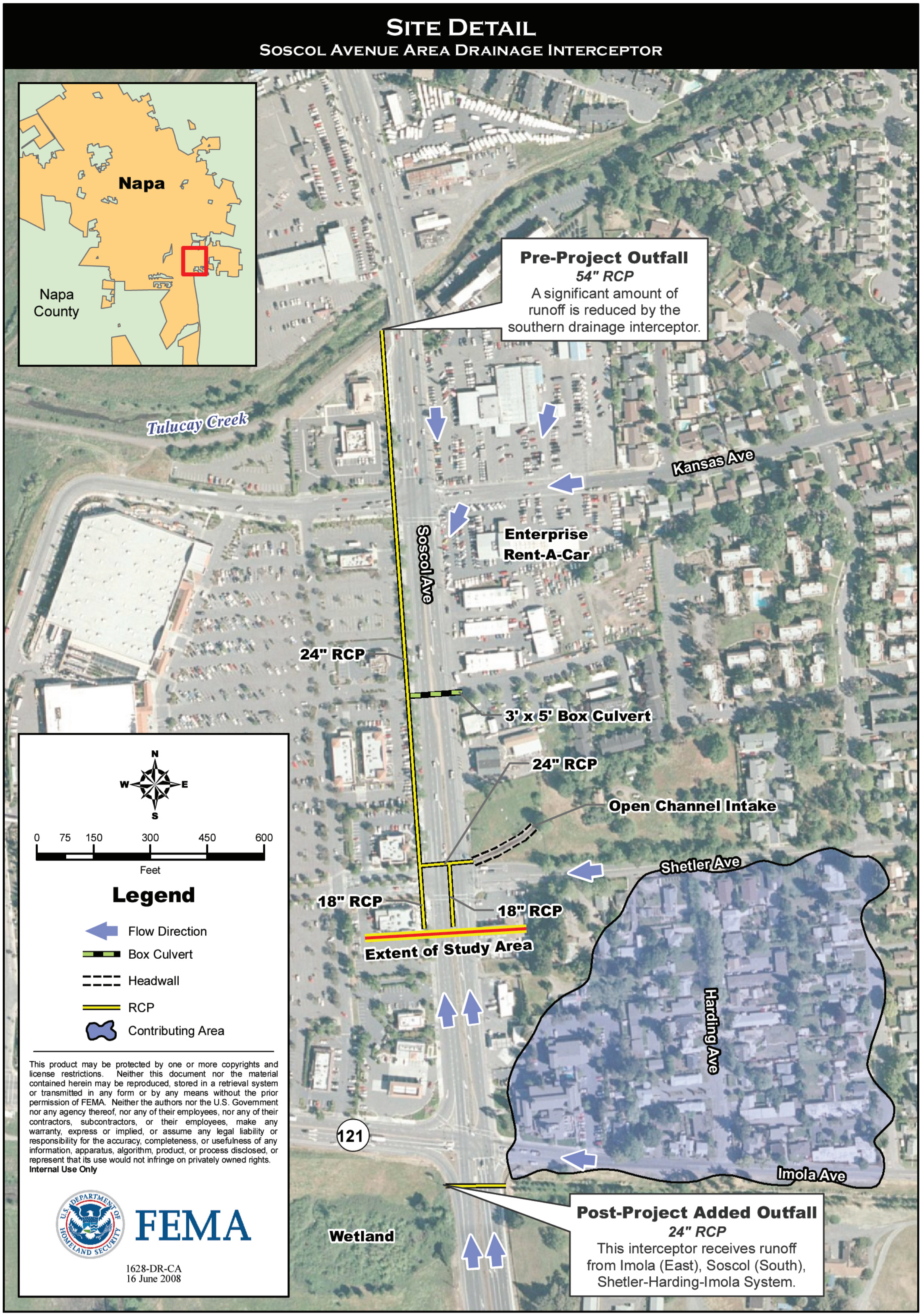
16 June 2008

Figure B.2


SITE DETAIL
SOSCOL AVENUE AREA DRAINAGE INTERCEPTOR
Napa
Napa County
Tulucay Creek
Pre-Project Outfall
54" RCP
A significant amount of runoff is reduced by the southern drainage interceptor.
Kansas Ave
Soscol Ave
Enterprise Rent-A-Car
24" RCP
3' x 5' Box Culvert
24" RCP
Open Channel Intake
Shetler Ave
18" RCP
18" RCP
Extent of Study Area
Harding Ave
121
Imola Ave
Wetland
Post-Project Added Outfall
24" RCP
This interceptor receives runoff from Imola (East), Soscol (South), Shetler-Harding-Imola System.
N
W
E
S
0 75 150 300 450 600
Feet
Legend
Flow Direction
Box Culvert
Headwall
RCP
Contributing Area
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16 June 2008

B.1.3 Project Funding and Construction Time Line

In 1997, the HMGP grant application was approved for a project cost of $536,288 (1997 dollars), with a Federal share of $402,216 (1997 dollars).The remaining costs were funded by local sources, including the City of Napa. The final project cost was $766,914 (2008 dollars). The grant for the project was approved on October 16, 1997, and the project was completed by October 27, 1998.

B.2 Data Collection

The LAT used the HMGP project file and several other sources to obtain hydrologic, hydraulic, and topographic data to the extent that these data were available. In addition, the LAT conducted a site visit in spring 2007 to gather initial project information and meet with staff from the City of Napa.

Both topographic data and hydraulic analyses from previous work completed by the City and County of Napa and project consultants were made available to the LAT. Topographic data for the project area were obtained from Napa County's Web site; the data were developed using lidar. The City of Napa was contacted initially during the data collection phase of the project; however, correspondence was eventually channeled to an engineering consultant, who provided the MP_C hydraulic analysis.

For the hydrologic analysis, gage information was collected from the DWR CDEC Web site. Because this was a localized storm drainage project, no stream gage data were collected, but data from

Figure B.3

several precipitation gages in the vicinity of the project facilitated a determination of the event of interest.

All of the structure information necessary for the Loss Estimation Analysis was provided in the project file.

B.3 Physical Parameter Analysis

B.3.1 Storm Event Analysis

DWR maintains an extensive network of gages throughout California and provides precipitation information through CDEC, an online interface. A search of CDEC at the beginning of the Loss Avoidance Study revealed several precipitation gages in the vicinity of the project. These included gages at Atlas Peak, Napa Corporation Yard (Corp Yard), Napa State Hospital, and Napa Airport. The gage at Corp Yard was determined to be the most applicable due to its proximity to the project site and because its period of record was sufficient. Review of this gage data indicated that the most severe storm event since project completion occurred on December 31, 2005. During this event, 5.64 inches of rain fell in 24 hours. This was the most severe event recorded between project completion, on October 27, 1998, and 2007.

B.3.2 Flow Parameter Analysis

B.3.2.1 Hydrologic Analysis

The Rational Method and Modified Rational Method were used

Figure B.4

to evaluate the peak runoff and the relevant runoff volume in the project area. The peak runoff was determined at the head of the northern 54-inch outlet pipe for both the MP_A and MP_C scenarios. To obtain the volume of runoff in the flooded region of Soscol Avenue, a trapezoidal hydrograph (Figure B.5) was developed based on the steepest portion of a cumulative rainfall hyetograph developed from data recorded at the Corp Yard rain gage. Other available rainfall data at the Atlas Peak, Napa State Hospital, and City of Napa gages were reviewed to obtain an applicable storm duration for use in the trapezoidal hydrograph. A time of concentration of 30 minutes at the head of the 54-inch outlet pipe was adapted from hydrologic calculations prepared by the City of Napa. The hydrograph rose linearly to the peak discharge computed by the Rational Method at the time of concentration and remained constant until the rainfall ceased and then receded linearly to zero discharge.

Figure B.5

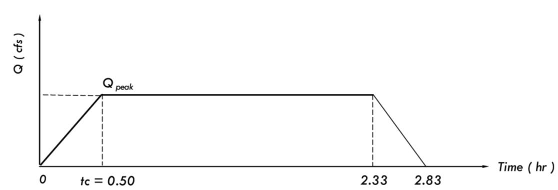
SOSCOL AVENUE AREA HYDROGRAPH

		Day	Time (hr)	Cum. Rainfall Depth (in)
FROM -	A	12/31/2005	2:50:00 AM	15.68
TO -->	B	12/31/2005	5:10:00 AM	17.38

Δt	2.33	hr
ΔP	1.70	in
i	0.73	in/hr

tc	0.50	hr

Since Δt > tc then Modified Rational Method is applicable to calculate runoff volume



cfs	ft³	ft
Q_{peak}	Runoff Volume	Pond Water Level
95	796860	17.4
54	452952	16.8

City of Napa Standard Specifications (City of Napa Department of Public Works, 2006) were used to specify design parameters, such as design event, rainfall intensity, and coefficient of runoff. Rainfall intensities were obtained by storm intensity-duration-frequency (IDF) curves identified in the *City of Napa Standard Specifications*. These curves are expressed by the following equations:

$$I_{10} = 5.529 / T^{0.46}, \text{ IF } T \leq 60 \text{ MIN}$$

$$I_{10} = 6.54 / T^{0.50}, \text{ IF } T > 60 \text{ MIN}$$

$$I_{25} = 1.20\, I_{10}$$

$$I_{50} = 1.35\, I_{10}$$

$$I_{100} = 1.50\, I_{10}$$

Current IDF curves (equations) rely on information that was developed by S.E. Rantz in 1971 based on precipitation gage data and a mean annual precipitation (MAP) of 26 inches. An explanatory note for the curves indicates that the intensities shall be modified as a direct ratio to the MAP of the drainage area. Because all of the drainage area in this project was located within the MAP of 24 inches, this modification needed to be considered in the evaluation of rainfall intensities. For example, the following relationship was used as a modified IDF equation for 10-year storms:

$$(I_{10})_{MAP24} = (24.0 / 26.0)\ (I_{10})_{MAP26}$$

B.3.2.2 Hydraulic Analysis

The total watershed in the project study area is drained by several storm drainage systems. Most of the storm drainage systems are connected to or terminated by roadside drainage facilities. A traditional hydraulic analysis of the storm drain system in the project study area was performed and included consideration of four concentration points: 1.) the 54-inch RCP outlet to Tulocay Creek, 2.) the manhole at the driveway into the Cadillac Flats Apartments, 3.) the drainage ditch at the northeastern corner of the Soscol-Shetler intersection, and 4.) the southeastern corner at the Soscol-Imola intersection. Investigation of the hydraulic performance of drainage facilities in the project study area showed that flooding at the commercial area of Soscol Avenue was strongly related to the discharge capacity of the 54-inch outlet pipe. Furthermore, the energy grade line through the storm drain system proved that the operation of the 54-inch outlet during a 10-year storm event would be affected by the high water level in Tulocay Creek, as well as the inadequacy of the storm drainage system. The relationship between the 54-inch outlet and flooding of Soscol Avenue was a fundamental assumption for generating the runoff hydrograph and storm runoff volume in the flooded zone of Soscol Avenue. These analyses verified the importance of comparing the discharge capacities of the northern 54-inch outlet in the MP_A and MP_C scenarios. Calculations showed that the total runoff inflow to the 54-inch RCP on the western side of Soscol Avenue due to a 10-year storm event was reduced from 95 to 54 cfs (Figure B.5). The Soscol Avenue Area Drainage Interceptor diminished the volume of runoff conveyed to the northern part of the watershed; therefore, losses avoided were expected at the flooded portions of Soscol Avenue area.

B.3.2.3 Flood Boundary Analysis

Given the results of the hydraulic modeling, flood boundary analyses were prepared to determine the level of damage for both the MP_A and MP_C scenarios. No existing flood boundary analyses were available for the MP_A or MP_C scenarios. Consequently, the flood boundary analyses were performed using the hydraulic model for the December 31, 2005, storm event and available topographic data. The flood boundary analyses for the MP_A and MP_C scenarios indicated flooding of several businesses along Soscol Avenue (Figures B.6 and B.7). The affected businesses and the depths of flooding for each scenario are listed in Table B.1. The impacted structures are located on the east side of Soscol Avenue. Due to the elevation profile of Soscol Avenue and the project area, there was no flooding on the west side of Soscol Avenue in either the MP_A or MP_C scenario.

Table B.1

Impacted Structures

Address	Structure Information	MP_A Flood Depth (ft)	MP_C Flood Depth (ft)
218 and 222 Soscol Avenue	Rental car company	2.7	1.8
230 Soscol Avenue	Take and bake pizza restaurant	2.0	1.1
238 Soscol Avenue	Automotive repair	2.1	1.2
250 Soscol Avenue	Automotive repair	1.0	0.1
266 Soscol Avenue	Automotive repair	0.9	0.0
234 Soscol Avenue	1 building of a 38-unit apartment complex	0.01	– 0.9

B.4 Loss Estimation Analysis

MP_A and MP_C damages were determined using the Physical Parameter Analysis results, standard FEMA depth-damage functions, and historical flood damage records. Loss estimation details provided in Table B.2 are discussed in the following subsections.

B.4.1 Physical Damage

Physical damage costs were calculated for the structure and contents of the affected businesses and an apartment complex. Historical damages for these structures were not available in the project file. The structure and contents damages, for both the MP_A and MP_C scenarios, were calculated by determining:

- **Structure Type** - Photographs were provided in the project file for each structure (five are one-story buildings without basements; the apartment complex is a two-story building without a basement).

- **Living Area** - The square footage for each structure was provided in the project file.
- **Structure Elevation** - Structure elevations were determined using topographic data and foundation height guidance in HAZUS.
- **Building Replacement Value** - BRVs for the structures were determined using RSMeans.
- **Contents Value** - The content values were determined using the FEMA BCA (FEMA, 2006b) standard value of 30 percent of the BRV for residential structures and guidance in the *HAZUS-MH MR3 Technical Manual* for commercial buildings (FEMA, 2006a). For the commercial buildings in this project, content values were assumed to be 100 percent of the BRV.
- Appropriate Depth-damage Functions - The depth-damage curves for the FEMA BCA Riverine Full Data Module were used.

The structure and contents damages for the MP_A and MP_C scenarios were estimated based on the flood depths at each structure. Total physical damage to structures and contents were $1,038,411 in the MP_A scenario and $746,354 in the MP_C scenario. Losses avoided were $292,057. Details of the calculations can be found in Attachments B.1 through B.3.

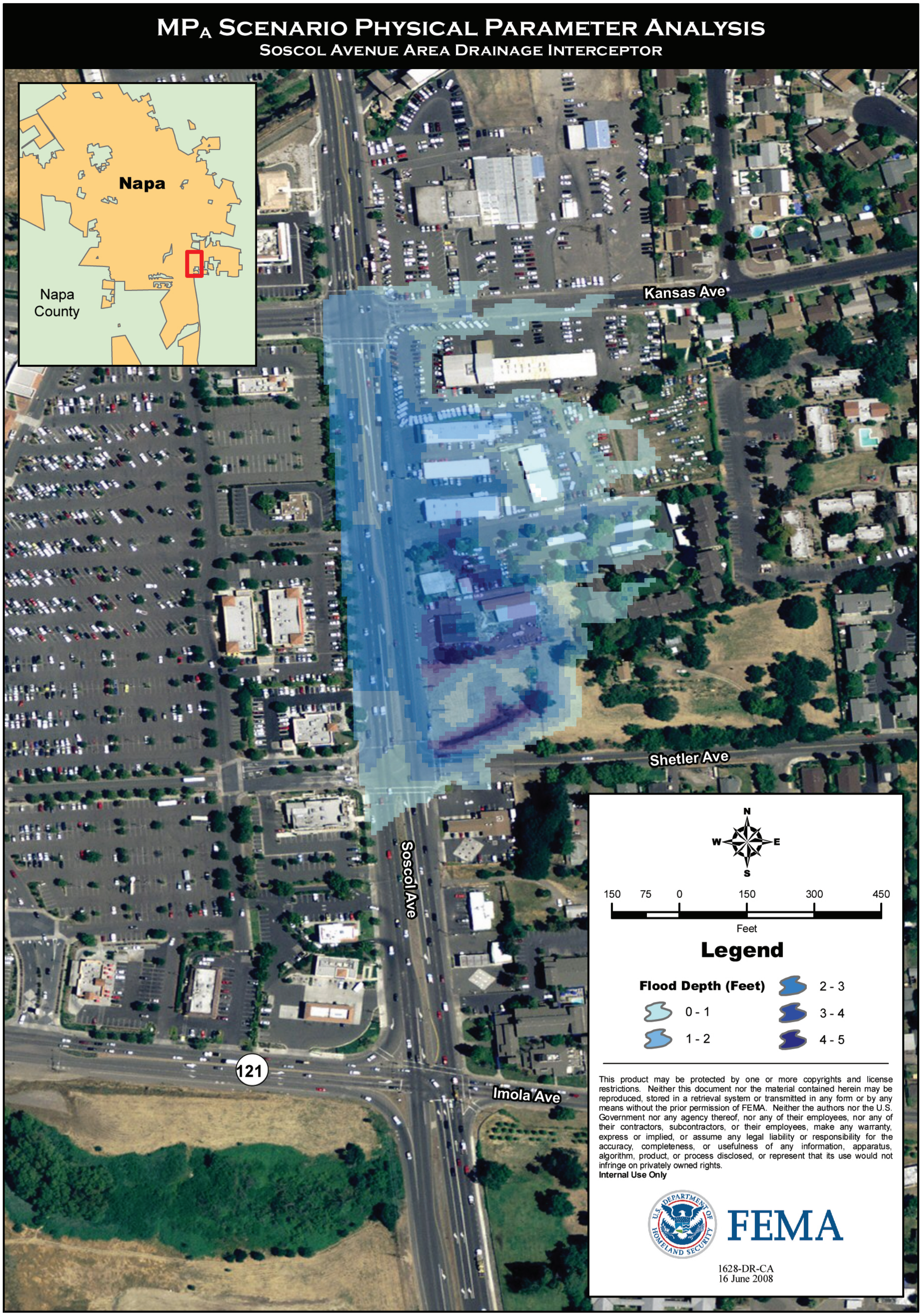
Physical damage for the flooded roadway was determined using damage functions developed for DWR. These DWR damage functions estimate damage for inundated major roadway to $100,000 per mile (URS Group, Inc., 2007). For the MP_A scenario 0.22 miles of major roadway (Soscol Avenue) were inundated and for the MP_C scenario 0.20 miles of Soscol Avenue were inundated. Damage for the MP_A scenario was $22,000 and $20,000 for the MP_C scenario. Therefore, the losses avoided for physical damages to roadways were $2,000.

Total estimated physical damage losses for the MP_A and MP_C scenarios were $1,060,411 and $766,354, respectively. Therefore, the losses avoided for physical damage were $294,057.

B.4.2 Loss of Function

Loss of function costs were considered for displacement of the occupants of flooded residences, disruption time for residents, loss of business income, lost wages for employees of the affected businesses and economic impact of road/bridge closure. The loss

Figure B.6



MP$_A$ Scenario Physical Parameter Analysis
Soscol Avenue Area Drainage Interceptor
Napa
Napa County
Kansas Ave
Shetler Ave
Soscol Ave
121
Imola Ave
N
W
E
S
150 75 0 150 300 450
Feet
Legend
Flood Depth (Feet)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
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Figure B.7

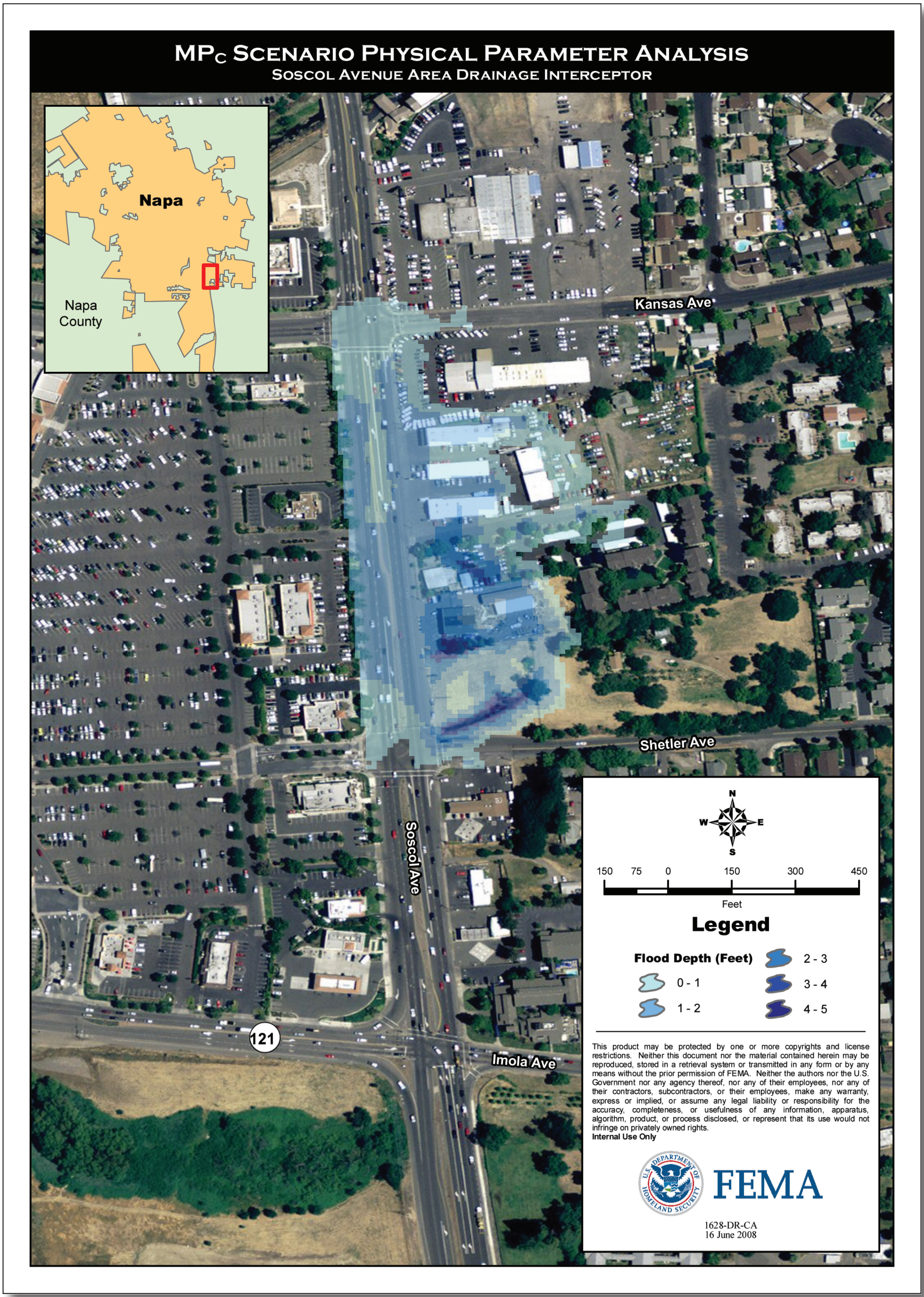
MPc Scenario Physical Parameter Analysis
Soscol Avenue Area Drainage Interceptor
Napa
Napa County
Kansas Ave
Shetler Ave
Soscol Ave
121
Imola Ave
N
W
E
S
150 75 0 150 300 450
Feet
Legend
Flood Depth (Feet)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
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Table B.2 Part 1 of 2

Loss Estimation Analysis Results
Soscol Avenue Area Drainage Interceptor

Loss Type	MP_A Scenario Losses[1]	MP_C Scenario Losses[1]	Losses Avoided[1]	Comments
Physical Damage				
Structure	$421,239	$299,156	**$122,083**	• Six structures were impacted; five were one-story buildings with no basements and one was a two-story building with no basement • Structure damages were estimated using depth-damage curves from the FEMA BCA Full Data Flood Module. • BRVs were based on RSMeans (2006).
Contents	$617,172	$447,198	**$169,974**	• The contents of six structures were impacted. • Contents value for residential structures was estimated at 30% of the BRV based on the FEMA BCA. • Contents damages were estimated using depth-damage curves from the FEMA BCA Full Data Flood Module.
Roads and Bridges	$22,000	$20,000	**$2,000**	• Length of inundated roadway determined using GIS. • Damage values based on roadway damage functions developed for DWR flood projects (URS Group, Inc., 2007).
Infrastructure	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Landscaping	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Environmental Impacts	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Vehicles/Equipment	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Subtotal	***$1,060,411***	***$766,354***	***$294,057***	
Loss of Function				
Displacement Expense	$0	$0	**$0**	• The flood depth for both scenarios was too shallow to cause displacement of apartment complex residents. • Displacement from commercial facilities was not calculated; the project file indicated that these businesses were not displaced during historical events.
Loss of Rental Income	$0	$0	**$0**	• Not predicted; displacement was considered for apartment complex residents.
Loss of Business Income	$215,332	$155,589	**$59,743**	• Five businesses were impacted by flooding. • Daily business income was calculated based on HAZUS-MH guidance. • Functional downtime was estimated using depth-damage curves from the FEMA BCA Full Data Flood Module.
Lost Wages	$78,846	$57,114	**$21,732**	• Five businesses were impacted by flooding. • Daily lost wages were calculated based on HAZUS-MH guidance. • Functional downtime was estimated using depth-damage curves from the FEMA BCA Full Data Flood Module.
Disruption Time for Residents	$12,891	$7,108	**$5,783**	• Disruption time was calculated for apartment complex residents • Disruption costs were determined using the national average per-hour wage identified in *What Is a Benefit?* ($21.16 per hour). • Disruption time was calculated using EMI guidance.
Loss of Public Services	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.

Continued

Table B.2 Part 2 of 2

Loss Estimation Analysis Results
Soscol Avenue Area Drainage Interceptor

Loss Type	MP_A Scenario Losses[1]	MP_C Scenario Losses[1]	Losses Avoided[1]	Comments
Loss of Function *(Continued)*				
Economic Impact of Utility Loss	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Economic Impact of Road/Bridge Closure	$17,082	$10,249	**$6,833**	• Based on FEMA standard value of $32.23 per vehicle per hour of delay and information on road closures provided in the project file for previous events.
Subtotal	***$324,151***	***$230,060***	***$94,091***	
Emergency Management				
Debris Cleanup	$13,570	$1,357	**$12,213**	• Estimated using BCA provided in project file.
Governmental Expense	$0	$0	**$0**	• Included in Debris Cleanup estimate.
Subtotal	***$13,570***	***$1,357***	***$12,213***	
Total	***$1,398,132***	***$997,771***	***$400,361***	

[1] All amounts rounded to the nearest dollar

of function impacts for the MP_A and MP_C scenarios were estimated based on the flood depths at each structure.

Displacement was considered only for the impacted residences of the apartment complex. Loss of rental income was not calculated to avoid doubly-counting losses. The project file indicated that the other affected businesses did not displace during previous flood events. Displacement expense was determined using:

- **FEMA BCA standard values for calculating costs for displacement.**
  - $1 per square foot per month rental costs for temporary quarters
  - $500 per month other monthly costs
  - $500 one-time costs
- **The standard depth-damage curve provided by the FEMA BCA Riverine Full Data Flood Module for displacement time.**

Due to minimal flood depths at the apartment complex for each scenario, no displacement resulted.

Disruption time for residents of the apartment complex was also calculated. Disruption time is applicable only for residential structures; therefore, disruption time was not calculated for the commercial businesses. Disruption was calculated by determining:

- **The per-hour wage of the disrupted residents** - The national average wage of $21.16 per hour from *What Is a Benefit?* (FEMA, 2001) was used.
- **The number of disrupted residents** - This was estimated by dividing the number of apartment units by the number of buildings to determine the number of impacted units. An average of two adults was assumed to occupy each unit, which was based on California Census data indicating an average of two adults per household. Based on this methodology, eight residents were estimated to be disrupted.
- **The time of disruption** - The time of disruption was estimated using EMI guidance. EMI estimates that disruption time is equal to 40 hours, plus 8 hours for every 1 percent in structure damage for each adult (Attachments B.2 and B.3).

The cost of disruption time for residents was estimated to be $12,891 for the MP_A scenario and $7,108 for the MP_C scenario. Therefore, losses avoided due to disruption time for residents were $5,783.

Loss of business income was estimated for all impacted commercial buildings. Guidance provided in the *HAZUS-MH MR3 Technical Manual* was used for this calculation. Attachment B.4 summarizes the calculation for loss of business income for each affected business for the MP_A and MP_C scenarios. Loss of business income was estimated by:

- **Determining the daily income for each business** - The daily income was determined by assigning each business a HAZUS building label and occupancy class and following the HAZUS guidance for determining loss of business income for each occupancy class.
- **Determining the functional downtime of the business** - The functional downtime was estimated using the standard curve for functional downtime provided in the FEMA BCA Riverine Full Data Flood Module.

Loss of business income for the 5 impacted commercial facilities was estimated to be $215,332 for the MP_A scenario and $155,589 for the MP_C scenario. Therefore, losses avoided were $59,743 for loss of business income.

Lost wages were estimated in a similar manner as loss of business income for all impacted commercial buildings. Guidance provided in the *HAZUS-MH MR3 Technical Manual* was also used for this calculation.

Attachment B.4 summarizes the calculation for lost wages for each affected business for the MP_A and MP_C scenarios. Lost wages were estimated by:

- **Determining the daily wages for each business** - Daily wages were determined using the same HAZUS building label and occupancy class (identified for the loss of business income calculation) and following the HAZUS guidance for determining lost wages for each occupancy class.
- **Determining the functional downtime of the business** - The functional downtime was estimated using the standard depth-damage curve for functional downtime provided in the FEMA BCA Riverine Full Data Flood Module.

Lost wages for the 5 impacted commercial facilities were estimated to be $78,846 for the MP_A scenario and $57,114 for the MP_C scenarios. Therefore, losses avoided were $21,732 for lost wages.

The economic impact of Soscol Avenue closure was estimated using the number of vehicles per day that use the route, the average delay or detour time, and the average value of a motorist's time. The following data were used to calculate the economic impact of Soscol Avenue closures:

- The closure time was estimated to be 0.5 days for the MP_A scenario and 0.3 days for the MP_C scenario based on data provided in the project file.
- The number of one-way traffic trips per day was 15,900 based on data provided by the California Department of Transportation.
- A detour time of 0.0667 hours was determined using an online mapping tool and estimating the most probable detour route based on main roads in the project area.
- From *What Is a Benefit?*, FEMA's standard value of $32.23 per vehicle per hour of delay was used to determine the economic impact of the road closure (FEMA, 2001).

Based on this information, the total estimated economic impact of Soscol Avenue closures was $17,082 for the MP_A scenario and $10,249 for the MP_C scenario. Therefore, the losses avoided for economic impact of road closures were $6,833. The calculations are detailed in Attachment B.5

Total estimated loss of function losses for the MP_A and MP_C scenarios were $324,151 and $230,060, respectively. Therefore, the losses avoided for loss of function were $94,091.

B.4.3 Emergency Management

Emergency management costs are costs related to response and recovery activities and include debris cleanup and governmental costs. The project files indicated that debris cleanup and governmental expenses for Soscol Avenue was approximately $13,570 for the MP_A scenario and $1,357 for the MP_C scenario. Therefore, losses avoided for emergency management costs were $12,213.

B.4.4 Results Summary

For the December 31, 2005, event of interest, losses avoided due to the completion of the mitigation project total $400,361. When compared to the project investment of $766,914, this project yields an ROI of 52 percent. This ROI reflects only the losses avoided for one event of interest; therefore, the ROI is expected to increase as additional storm events test the project's effectiveness over its useful life.

Impacted Structure Information[1]
Soscol Avenue Area Drainage Interceptor

Address	Structure Information	HAZUS Building Type	FEMA BCA Building Type	Area (sf)	BRV ($/sf)	Total BRV	Contents Value Factor	Contents Value	Business Income ($/day)	Lost Wages ($/day)	Displacement Expense			Disruption Costs ($/person/hour)
											Rental ($/sf/mo)	Monthly ($/mo)	One-time ($/mo)	
218 and 212 Soscol Ave.	Enterprise Rent-a-Car	COM3	1 story, without basement	7800	$95.14	$742,104	100%	$742,104	$3,325.22	$1,257.09	N/A	N/A	N/A	N/A
230 Soscol Ave.	Papa Murphy's	COM8	1 story, without basement	1800	$170.07	$306,118	100%	$306,118	$1,283.39	$366.68	N/A	N/A	N/A	N/A
238 Soscol Ave.	Williams Automotive	COM3	1 story, without basement	5000	$63.03	$315,156	100%	$315,156	$2,131.55	$805.83	N/A	N/A	N/A	N/A
250 Soscol Ave.	Williams Transmission	COM3	1 story, without basement	2400	$63.03	$151,275	100%	$151,275	$1,023.14	$386.80	N/A	N/A	N/A	N/A
266 Soscol Ave.	Blackhawk Body Shop	COM3	1 story, without basement	7200	$63.03	$453,825	100%	$453,825	$3,069.43	$1,160.39	N/A	N/A	N/A	N/A
234 Soscol Ave.	38 unit apartment complex	RES3F	2 story, without basement	3300	$84.44	$278,646	30%	$83,594	$0.00	$0.00	$1.00	$500.00	$500.00	$21.16

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

MP_A Scenario Loss Estimation Analysis[1]
Soscol Avenue Area Drainage Interceptor

Address	Structure Elevation (ft msl)	Water Surface Elevation (ft msl)	Depth of Flooding (ft)	Structure DDF (% of BRV)	Structure Damage	Contents DDF (% of contents value)	Contents Damage	Loss of Function (days)	Loss of Business Income	Lost Wages	Displacement Time (days)	Displacement Expense	Disruption Time (hours)	Disruption Costs
218 and 222 Soscol Ave.	16.2	18.9	2.7	25%	$188,865	38%	$283,298	25.5	$84,627	$31,993	N/A	N/A	N/A	N/A
230 Soscol Ave.	16.9	18.9	2.0	22%	$66,121	32%	$99,182	21.6	$27,721	$7,920	N/A	N/A	N/A	N/A
238 Soscol Ave.	16.8	18.9	2.1	22%	$70,122	33%	$105,183	22.3	$47,427	$17,930	N/A	N/A	N/A	N/A
250 Soscol Ave.	17.9	18.9	1.0	14%	$20,876	21%	$31,314	13.8	$14,119	$5,338	N/A	N/A	N/A	N/A
266 Soscol Ave.	17.9	18.9	0.9	14%	$61,266	20%	$91,900	13.5	$41,437	$15,665	N/A	N/A	N/A	N/A
234 Soscol Ave.	18.8	18.9	0.01	5%	$13,988	8%	$6,295	N/A	N/A	N/A	0	$0	80	$12,891

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

MP_C Scenario Loss Estimation Analysis[1]
Soscol Avenue Area Drainage Interceptor

Address	Structure Elevation (ft msl)	Water Surface Elevation (ft msl)	Depth of Flooding (ft)	Structure DDF (% of BRV)	Structure Damage	Contents DDF (% of contents value)	Contents Damage	Loss of Function (days)	Loss of Business Income	Lost Wages	Displacement Time (days)	Displacement Expense	Disruption Time (hours)	Disruption Costs
218 and 222 Soscol Ave.	16.2	18.0	1.8	20%	$150,795	30%	$226,193	20.3	$67,568	$25.544	N/A	N/A	N/A	N/A
230 Soscol Ave.	16.9	18.0	1.1	14%	$44,081	22%	$66,121	14.4	$18,481	$5,280	N/A	N/A	N/A	N/A
238 Soscol Ave.	16.8	18.0	1.1	15%	$47,904	23%	$71,856	15.2	$32,400	$12,249	N/A	N/A	N/A	N/A
250 Soscol Ave.	17.9	18.0	0.1	9%	$14,069	14%	$21,103	9.3	$9,515	$3,597	N/A	N/A	N/A	N/A
266 Soscol Ave.	17.9	18.0	0.1	9%	$40,844	14%	$61,266	9.0	$27,625	$10,444	N/A	N/A	N/A	N/A
234 Soscol Ave.	18.8	18.0	-0.8	1%	$1,463	1%	$658	N/A	N/A	N/A	0	$0	44	$7,108

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

Loss of Business Income and Lost Wages Calculations[1]
Soscol Avenue Area Drainage Interceptor

Address	HAZUS Building Type	Area (sf)	Income, Output, and Wage Recapture Factor[2]	Owner Income per Day[3] ($/sf)	Output per Day[4] ($/sf)	Business Income[5] ($/day)	Wages per Day[6] ($/sf)	Lost Wages[7] ($/day)	Functional Downtime[8] (days)	Total Lost Business Income	Total Lost Wages
MP_A Scenario											
218 and 222 Soscol Ave.	COM3	7800	51%	$0.14	$0.73	$3,325.22	$0.33	$1,257.09	25.5	$84,627	$31,993
230 Soscol Ave.	COM8	1800	60%	$0.64	$1.15	$1,283.39	$0.51	$366.68	21.6	$27,721	$7,920
238 Soscol Ave.	COM3	5000	51%	$0.14	$0.73	$2,131.55	$0.33	$805.83	22.3	$47,427	$17,930
250 Soscol Ave.	COM3	2400	51%	$0.14	$0.73	$1,023.14	$0.33	$386.80	13.8	$14,119	$5,338
266 Soscol Ave.	COM3	7200	51%	$0.14	$0.73	$3,069.43	$0.33	$1,160.39	13.5	$41,437	$15,665
MP_C Scenario											
218 and 222 Soscol Ave.	COM3	7800	51%	$0.14	$0.73	$3,325.22	$0.33	$1,257.09	20.3	$67,568	$25,544
230 Soscol Ave.	COM8	1800	60%	$0.64	$1.15	$1,283.39	$0.51	$366.68	14.4	$18,481	$5,280
238 Soscol Ave.	COM3	5000	51%	$0.14	$0.73	$2,131.55	$0.33	$805.83	15.2	$32,400	$12,249
250 Soscol Ave.	COM3	2400	51%	$0.14	$0.73	$1,023.14	$0.33	$386.80	9.3	$9,515	$3,597
266 Soscol Ave.	COM3	7200	51%	$0.14	$0.73	$3,069.43	$0.33	$1,160.39	9.0	$27,625	$10,444

Note

1 Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.
2 The Recapture Factors were taken from Table 14.16 HAZUS99 Earthquake Table of Recapture Factors in the HAZUS Flood Model Technical Manual.
3 Owner Income per Day was taken from Table 14.14 Proprietor's Income in the HAZUS Flood Model Technical Manual. This value was inflated to 2008 dollars.
4 Output per Day was taken from Table 14.14 Proprietor's Income in the HAZUS Flood Model Technical Manual. This value was inflated to 2008 dollars.
5 Business Income was determined by adding the Owner Income and Output per Day and multiplying the sum by the square footage and 1 minus the Recapture Factor. For example, the Business Income for 704 Petaluma was ($0.14 per square foot + $0.73 per square foot) x 6,783.75 square feet x (1-0.51).
6 Wages per Day was taken from Table 14.14 Proprietor's Income in the HAZUS Flood Model Technical Manual. This value was inflated to 2008 dollars.
7 Lost Wages were determined by multiplying the Lost Wages per Day by the square footage and 1 minus the Recapture Factor. For example, the Lost Wages for 704 Petaluma was $0.33 per square foot x 6,783.75 square feet x (1-0.51).
8 Functional Downtime was determined using the Depth Damage Functions from the FEMA BCA Riverine Full Data Module.

Economic Impact of Road/Bridge Closure[1]
Soscol Avenue Area Drainage Interceptor

Road/Bridge Closure	Vehicles per Day	Cost per Vehicle Hour	Delay Time (hours)	Duration of Closure (days)	Total Cost of Delay
MP_A Scenario					
Soscol Avenue Closure	15,900	$32.23	0.067	0.50	$17,081.90
MP_C Scenario					
Soscol Avenue Closure	15,900	$32.23	0.067	0.30	$10,249.14

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

Appendix C:

Humboldt Road Box Culvert at Malloy Creek

Project: 1155-0016

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Appendix C:

Project: 1155-0016

Humboldt Road Box Culvert at Malloy Creek

C.1 General Project Information

C.1.1 Project Location

The project location for project 1155-0016 is the section of Humboldt Road that intersects Malloy Creek near Butte Meadows, CA. Butte Meadows is located approximately 35 miles north of Chico, CA (Figure C.1). The affected area includes the local roadway, Humboldt Road, which conveys traffic between Butte Meadows and Jonesville.

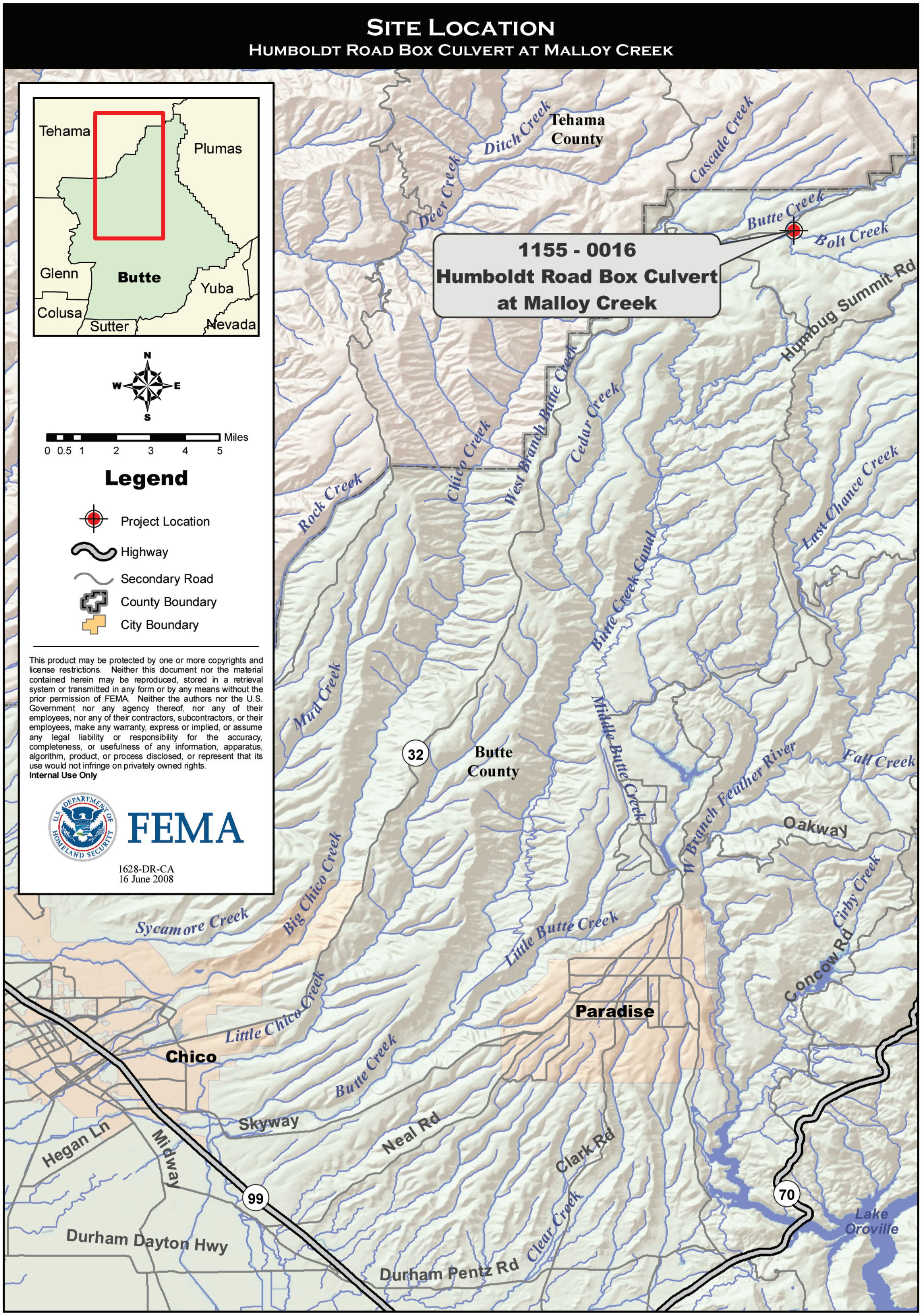
C.1.2 Project Description

The Humboldt Road Box Culvert at Malloy Creek project was designed in response to routine flooding events that occurred between 1983 and 1997. These events caused mild to severe damage to the Malloy Creek road crossing and affected the nearby communities of Butte Meadows and Jonesville. Prior to project completion, the tandem steel pipe culverts were insufficient to handle high water and debris flows associated with peak flood events. The purpose of the project was to replace the existing culverts with a single, larger culvert capable of handling a greater percentage of flood events (Figure C.2).

Flood history in the project area includes storm events in 1983, 1986, 1993, 1995, and 1997. The more severe events, including the 1986, 1995, and 1997 events, resulted in floodwaters exceeding culvert capacity due to heavy debris blockage. High-velocity flows overtopped the roadway to a depth of 1.5 feet. These events caused severe embankment erosion, scouring of roadside shoulders and ditching, and loss of asphalt surface and aggregate road base. These damages resulted in road closures and required emergency and non-emergency repair.

The project involved replacing the existing culverts with a 12-foot by 6-foot by 28.6-foot reinforced-concrete box culvert. This new culvert allows debris to flow through unobstructed (Figure C.3). In addition, the creek channel was slightly realigned and large rocks were placed along the channel walls to provide slope protection (Figure C.4). A total of 880 feet of roadway was also reconstructed using an aggregate base and asphalt road surface.

Figure C.1


Site Location
Humboldt Road Box Culvert at Malloy Creek
Tehama
Plumas
Glenn
Butte
Yuba
Colusa
Sutter
Nevada
N
W
E
S
Miles
0 0.5 1 2 3 4 5
Legend
Project Location
Highway
Secondary Road
County Boundary
City Boundary
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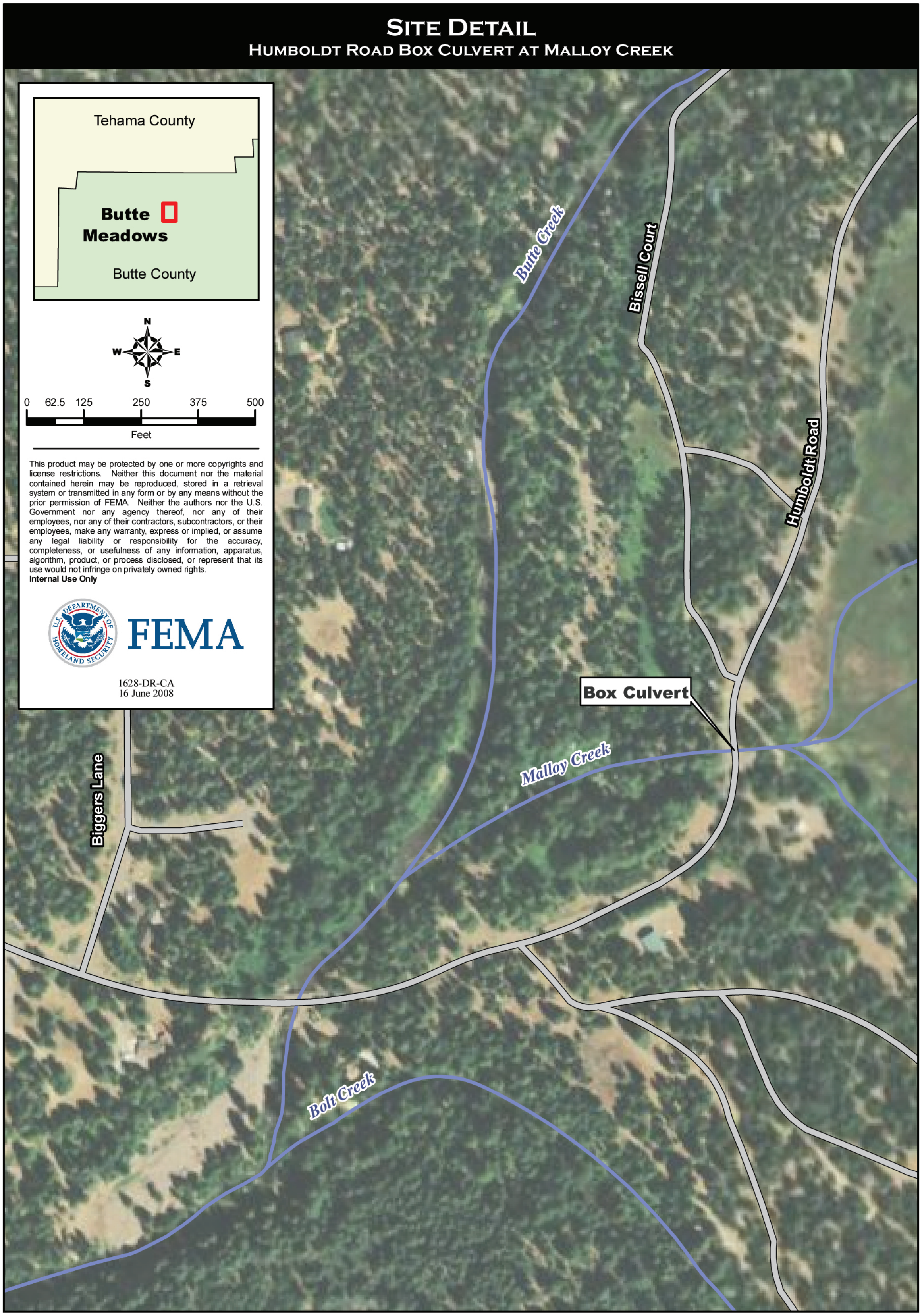
1628-DR-CA
16 June 2008
1155 - 0016
Humboldt Road Box Culvert
at Malloy Creek
Tehama County
Butte County
Ditch Creek
Deer Creek
Cascade Creek
Butte Creek
Bolt Creek
Humbug Summit Rd
West Branch Butte Creek
Cedar Creek
Chico Creek
Rock Creek
Last Chance Creek
Butte Creek Canal
Mud Creek
Middle Butte Creek
W Branch Feather River
Fall Creek
Oakway
Big Chico Creek
Sycamore Creek
Little Butte Creek
Cirby Creek
Concow Rd
Paradise
Little Chico Creek
Chico
Butte Creek
Skyway
Neal Rd
Hegan Ln
Midway
Clark Rd
Clear Creek
Durham Dayton Hwy
Durham Pentz Rd
Lake Oroville
32
99
70

Figure C.2


Site Detail
Humboldt Road Box Culvert at Malloy Creek
Tehama County
Butte Meadows
Butte County
N
W
E
S
0 62.5 125 250 375 500
Feet
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FEMA
1628-DR-CA
16 June 2008
Butte Creek
Bissell Court
Humboldt Road
Box Culvert
Malloy Creek
Biggers Lane
Bolt Creek

C.1.3 Project Funding and Construction Time Line

In 1997, the HMGP grant application was approved for a project cost of $94,272 (1997 dollars), with a Federal share of $70,704 (1997 dollars). The remaining costs were funded by local sources, including Butte County. The grant for this project (1155-0016) was approved on October 16, 1997, and the project was completed by October 14, 1998. The final project cost was $257,106 (2008 dollars).

C.2 Data Collection

The LAT conducted a site visit in spring 2007 to collect initial project information and meet with the local sponsoring agency. In addition to field work, the team used the HMGP project file and several other sources to obtain hydrologic, hydraulic, and topographic data, to the extent that the data were available.

Unfortunately, minimal information was available for this project in the HMGP project file. Topographic data and detailed design information, as well as hydrologic data, were obtained for the analysis through additional correspondence with Butte County staff and research conducted by the LAT.

Butte County provided design plans for the culvert replacement, including the size, slope, and alignment of the new box culvert and the two smaller barrel culverts that it replaced. In addition, roadway design information was provided. This information facilitated a determination of the roadway area that would be inundated should

Figure C.3

the culvert capacity be exceeded.

Topographic data available from Butte County were limited to those available with the culvert replacement plans, which covered only the area immediately adjacent to the project. A larger topography dataset was needed to describe the watershed. Therefore, digital terrain model data with 1-meter accuracy were purchased from a third-party vendor. The project's MP_A scenario was defined using these data.

C.3 Physical Parameter Analysis

C.3.1 Storm Event Analysis

A search of CDEC completed at the start of the loss avoidance study revealed two precipitation gages in the project vicinity: the Butte Meadows and Carpenter Ridge gages. Because of its proximity to the site, the Butte Meadows gage was preferable for this project. Unfortunately, the gage did not have a sufficient recording period. The most severe event recorded at the Butte Meadows gage between project completion and 2007 yielded six inches of rainfall in a 24-hour period on February 13, 2000. The period of record for this gage only included records through the year 2000, whereas the Carpenter Ridge gage had a period of record through the present. The Carpenter Ridge gage recorded a higher peak precipitation event on February 26, 2006, of 6.83 inches in 24 hours. Therefore, the Carpenter Ridge gage was used, and the February 26, 2006, event was modeled in the hydrologic analysis.

Figure C.4

C.3.2 Flow Parameter Analysis

C.3.2.1 Hydrologic Analysis

Hydrologic calculations were the most challenging portion of the analysis for the Humboldt Road Box Culvert at Malloy Creek project. Several methods were considered for estimating the peak runoff resulting from the event of interest. Among these were the Rational Method, the Snyder and Soil Conservation Service (SCS) Synthetic Unit Hydrograph Methods, and USGS regression equations. The method selection was based on the characteristics of the watershed and available data.

The Rational Method is commonly used to estimate design event peak runoff for areas as large as 200 acres. Although it involves a simplistic approach-which depends upon the rainfall intensity, area of the watershed, and watershed cover-no other drainage design method has received such widespread use. The watershed area that contributes to Malloy Creek at Humboldt Road is over 1,800 acres. Therefore, the resulting flow estimate of 129 cfs was rejected.

When a watershed lacks streamflow data, a synthetic unit hydrograph method is sometimes employed to represent the time distribution of one inch of surface runoff in a given timeframe for a given drainage area. The results of a synthetic unit hydrograph analysis may be scaled to any desired timeframe or drainage area. Thus, the result is primarily dependent upon a given storm event. The Snyder Unit Hydrograph is the most commonly used type of synthetic unit hydrograph. However, this method requires that the storm duration not exceed 20 percent of the time to peak. Values in excess of the 20 percent threshold are considered to result in overestimations of peak discharge. In the case of the Malloy Creek watershed, the time from the start of the event to peak runoff, as estimated by the Snyder Unit Hydrograph method was approximately 19 hours, considering the rainfall duration and the watershed characteristics. The rainfall duration of 24 hours is over 100 percent of the time to peak. The resulting flow of 625 cfs was rejected.

Another hydrologic analysis approach was conducted using the SCS synthetic Unit Hydrograph Method. The SCS dimensionless unit hydrograph is based on analyses of a large number of recorded flood hydrographs for a variety of basin types and areas up to 32,000 acres. The basin size suggested that this method was appropriate for application to the Malloy Creek watershed. A calculation of time to peak flow, based on watershed and event characteristics, resulted in a peak flow estimate of 235 cfs. This peak flow was used in the hydraulic analysis.

Finally, the USGS regression equations were applied to provide an estimate of the return period for the event of interest. The regression equations are regional in nature. For the Sierra Mountains, where Malloy Creek is located, the watershed area, average altitude, and average annual precipitation are required. The peak flow for the 2-year event is roughly 139 cfs and the peak flow for the 5-year event is roughly 345 cfs. The estimated 235 cfs flow on Malloy Creek from the 2006 event had between a 2- and 5- year return period.

C.3.2.2 Hydraulic Analysis

Hydraulic analysis for the Humboldt Road Box Culvert at Malloy Creek project involved the application of Federal Highway Administration's (2007) HY-8 culvert analysis software to the peak flow calculated from the hydrologic analysis. The physical characteristics of a road crossing can be defined in the HY-8 software, which uses either energy or momentum balance equations depending upon the water elevations that would naturally occur both upstream and downstream of the culvert during peak flow. The results indicated that Humboldt Road would be overtopped in the MP_A scenario. Butte County described debris removal from the culvert openings following past events; therefore, the theoretical conveyance estimated by HY-8 was considered conservative as the culverts would likely have been severely restricted during an actual storm event. Considering both depth and velocity, the flow over the roadway was expected to exceed the roadway design strength.

C.3.2.3 Flood Boundary Analysis

A flood boundary analysis was not conducted for this project. The objective of this loss avoidance study was to determine whether the roadway would have been overtopped by sufficient flow and result in road closure, which was confirmed by the hydraulic analysis. No structures were impacted by Malloy Creek flooding near the project area; therefore, a flood boundary analysis was considered unnecessary and was not developed.

C.4 Loss Estimation Analysis

MP_A damages were determined by using historical damage records for flooding events in 1986, 1995, and 1997, which were similar in magnitude to the event of interest in 2006. The project was completed on October 14, 1998, and since its completion, no damages have occurred in the project area (i.e., no MP_C damages). The loss estimation details are provided in Table C.1 and discussed in the following subsections.

Table C.1

Loss Estimation Analysis Results
Humboldt Road Box Culvert at Malloy Creek

Loss Type	MP_A Scenario Losses[1]	MP_C Scenario Losses[1]	Losses Avoided[1]	Comments
Physical Damage				
Structure	$0	$0	**$0**	• Not predicted, no structures at the project location.
Contents	$0	$0	**$0**	• Not predicted, no structures at the project location.
Roads and Bridges	$9,428	$0	**$9,428**	• Based on historical damages during 1986, 1995, and 1997 events detailed in the project file.
Infrastructure	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Landscaping	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Environmental Impacts	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Vehicles/Equipment	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Subtotal	***$9,428***	***$0***	***$9,428***	
Loss of Function				
Displacement Expense	$0	$0	**$0**	• Not predicted, no structures at the project location.
Loss of Rental Income	$0	$0	**$0**	• Not predicted, no structures at the project location.
Loss of Business Income	$0	$0	**$0**	• Not predicted, no structures at the project location.
Lost Wages	$0	$0	**$0**	• Not predicted, no structures at the project location.
Disruption Time for Residents	$0	$0	**$0**	• Not predicted, no structures at the project location.
Loss of Public Services	$0	$0	**$0**	• Not predicted, no structures at the project location.
Economic Impact of Utility Loss	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Economic Impact of Road/Bridge Closure	$50,762	$0	**$50,762**	• Based on FEMA standard value of $32.23 per vehicle per hour of delay and information on road closures provided in the project file for previous events.
Subtotal	***$50,762***	***$0***	***$50,762***	
Emergency Management				
Debris Cleanup	$950	$0	**$950**	• Estimated using BCA provided in project file.
Governmental Expense	$6,784	$0	**$6,784**	• Estimated using BCA provided in project file.
Subtotal	***$7,734***	***$0***	***$7,734***	
Total	***$67,924***	***$0***	***$67,924***	

[1] All amounts rounded to the nearest dollar

C.4.1 Physical Damage

Physical damage for this project included damage to the road surface, roadbed, culvert, and channel. Physical damage costs were calculated using historical damage data. These data were obtained from the HMGP project file and damage survey reports for flood events in 1986, 1995, and 1997.

Total physical damage for the MP_A scenario was estimated to be $9,428. Since the project was completed on October 14, 1998, no MP_C damages have occurred. Therefore, the total losses avoided for physical damage were $9,428.

C.4.2 Loss of Function

The loss of function for this project was calculated by estimating the impact of Humboldt Road closures. The economic impact of a road closure is estimated using the number of vehicles per day that use the route, the average delay or detour time, and the average value of a motorist's time. The following data were used to calculate the economic impact of the resulting Humboldt Road closure:

- Based on historical closures for similar flood events, the closure time was estimated to be three days.
- The number of one-way traffic trips per day was estimated to be 420 trips per day based on data provided in the HMGP project file.
- The detour time was determined using an online mapping tool and estimating the most probable detour route based on main roads in the project area. The detour was estimated to be 1 hour and 15 minutes for the rural project area. Some trails shown on the project area map were assumed to be unimproved, private, or forestry-owned roads and not usable by the general public.
- Based on *What Is a Benefit?*, FEMA's standard value of $32.23 per vehicle per hour of delay was used to determine the economic impact of the road closure (FEMA, 2001).

Based on these data, the total estimated economic impact of a Humboldt Road closure for the MP_A scenario was $50,762 (Attachment C.1). Since the project was completed on October 14, 1998, no road closures have occurred; therefore, no MP_C loss of function impacts occurred. Therefore the total losses avoided for loss of function damages were $50,762.

C.4.3 Emergency Management

Emergency management costs were identified in the HMGP project file. The Butte County Department of Public Works estimated its debris cleanup costs to be $950 and governmental expenses to be $6,784 for historical events of similar magnitude. These estimates were not itemized, so the costs included are unknown. For the MP_A scenario, emergency management costs were assumed to be $7,734. Since the project was completed on October 14, 1998, no MP_C damages have occurred. Therefore, the total losses avoided for emergency management costs were $7,734.

C.4.4 Results Summary

For the February 26, 2006, event of interest, losses avoided due to the completion of the mitigation project total $67,924. When compared to the project investment of $257,106, this project yields an ROI of 26 percent. This ROI only reflects the losses avoided for the one event of interest; therefore, the ROI is expected to increase as additional storm events test the project's effectiveness over its useful life.

Attachment C.1

MP_A Scenario Economic Impact of Road/Bridge Closure[1]

Humboldt Road Box Culvert at Malloy Creek

Road/Bridge Closure	Vehicles per Day	Cost per Vehicle Hour	Delay Time (hours)	Duration of Closure (days)	Total Cost of Delay
Humboldt Road Closure	420	$32.23	1.250	3.00	$50,762.25

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

Appendix D:

Alhambra Creek Channel Improvements

Project: 1155-0017

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Appendix D:

Project: 1155-0017
Alhambra Creek Channel Improvements

D.1 General Project Information

D.1.1 Project Location

As illustrated in Figure D.1, the Alhambra Creek Channel Improvements project is located in the City of Martinez, Contra Costa County, CA. More specifically the project site is located south of Union Pacific Rail Road. Marina Vista borders the project area to the north and Green Street borders the south end. Castro and Ferry Streets create the west and east perimeters. This project site encompasses a seven-block area.

D.1.2 Project Description

Prone to repetitive flooding, Alhambra Creek travels from the surrounding hills through the City of Martinez and out into the Carquinez Strait. In the downtown area of the City of Martinez, most of the flooding has been the result of insufficient capacity of the existing channel and culverts. During storm events, the creek's flooding inundated approximately 70 facilities in the downtown area, including commercial developments, parking lots, and offices, as well as downtown streets. Floods occurred on average every other year and impacted primarily Alhambra, Castro, Estudillo, and Ferry Streets. The flooding typically led to street closures, property damage, and silt deposits on streets and sidewalks.

Major flood events were recorded in 1907, 1916, 1922, 1937, 1940, 1958, 1969, 1973, 1975, 1983, 1986, 1995, and 1997. Flows of 2,600 cfs at the Union Pacific Rail Road were recorded for the 1958 flood. The average flood cleanup cost the City of Martinez approximately $100,000.

Under the Old City Hall building on the south side of Main Street, Alhambra Creek was characterized by a dogleg bend that entered a concrete pipe and flowed under Main Street and several properties. The capacity of the creek's reach at this section was insufficient to convey flows greater than the 5-year flood event. (A flow rate of 1,800 cfs was recorded for a 5-year flood event in 1997). During larger storm events, flood waters for this portion of the creek engulfed surrounding streets, deposited silt within buildings, and eroded the fill under the Old City Hall building. As a result, the concrete walkway on the east side collapsed and put the foundation of the building at risk.

The City of Martinez has undertaken several projects to alleviate flooding along Alhambra Creek. One of these projects was partially funded by HMGP. It included modifications to the 1,200-foot channel reach between Main and Ward Streets, where the bend in the creek significantly decreased the channel capacity. The project improvements consisted of bank stabilization, creek widening, straightening, and realignment of the section of Alhambra Creek between Main and Ward Streets, terracing creek banks, and restoration of riparian vegetation (Figure D.2).

Upstream of the project site, the creek flows through a residential development. Downstream of the project site, the creek flows through restored coastal wetlands (Figure D.3). The Alhambra Creek Channel Improvements project is considered Phase 3 of the city's flood mitigation plan.

The project improvements eliminated the dogleg bend underneath the Old City Hall building (Figure D.4). Along the western boundary of the project site downstream of Main Street, the creek's channel was widened, increasing channel capacity from 800 cfs to 2,400 cfs. These improvements increased channel capacity from what had been a 2- to 4-year peak flow to a 7- to 8.5-year peak flow (PWA, 2007a). A greenway system of pedestrian paths and outlooks was also incorporated to enhance the downtown community (Figure D.5).

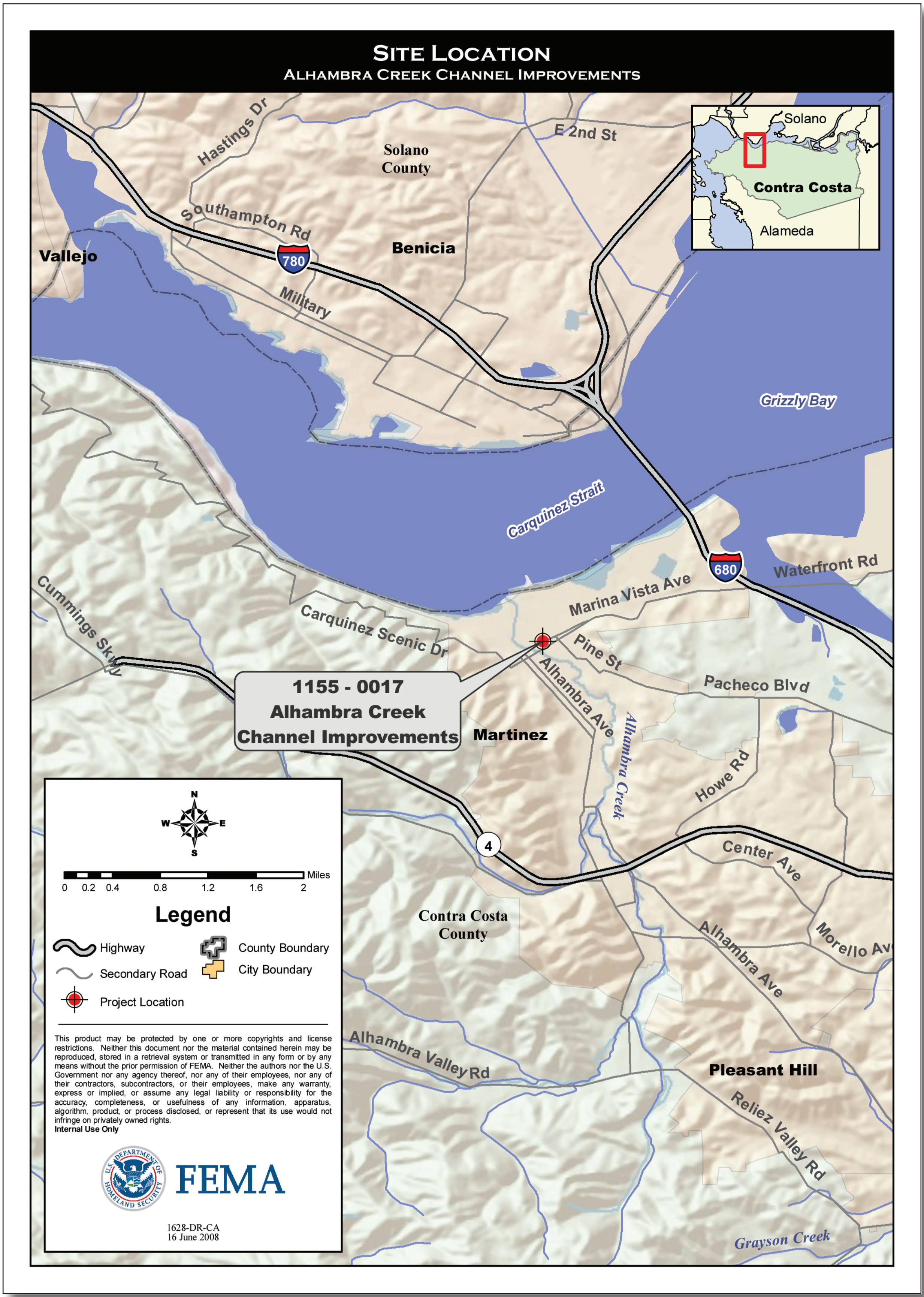
D.1.3 Project Funding and Construction Time Line

The total project cost for all phases of the Alhambra Creek Channel Improvement project was $3,972,052. The HMGP grant application was only submitted for Phase 3 of this project. In 1997, the project cost for Phase 3 was $1,260,000 ($1,709,693 in 2008 dollars), of which FEMA provided $945,000 (75 percent of the project cost. The grant was approved December 22, 1997, and the project was completed July 6, 2001.

D.2 Data Collection

The LAT conducted a detailed review of the project file for the Alhambra Creek Channel Improvements project, noting the data that were available and the data that required additional research. Additionally, the LAT conducted an initial site visit to gather site-specific information related to past flooding, discuss the project with city staff, and assess site conditions (topography, drainage features, and structure types). City engineers provided design information pertaining to the project, as well as information about the mitigation efforts completed downstream of the project. The

Figure D.1


SITE LOCATION
ALHAMBRA CREEK CHANNEL IMPROVEMENTS
Solano County
Hastings Dr
E 2nd St
Southampton Rd
780
Benicia
Vallejo
Military
Solano
Contra Costa
Alameda
Grizzly Bay
Carquinez Strait
680
Waterfront Rd
Marina Vista Ave
Cummings Skwy
Carquinez Scenic Dr
Pine St
Pacheco Blvd
1155 - 0017
Alhambra Creek
Channel Improvements
Martinez
Alhambra Ave
Alhambra Creek
Howe Rd
4
Center Ave
Contra Costa
County
Alhambra Ave
Morello Ave
Alhambra Valley Rd
Pleasant Hill
Reliez Valley Rd
Grayson Creek
N
W
E
S
Miles
0 0.2 0.4 0.8 1.2 1.6 2
Legend
Highway
County Boundary
Secondary Road
City Boundary
Project Location
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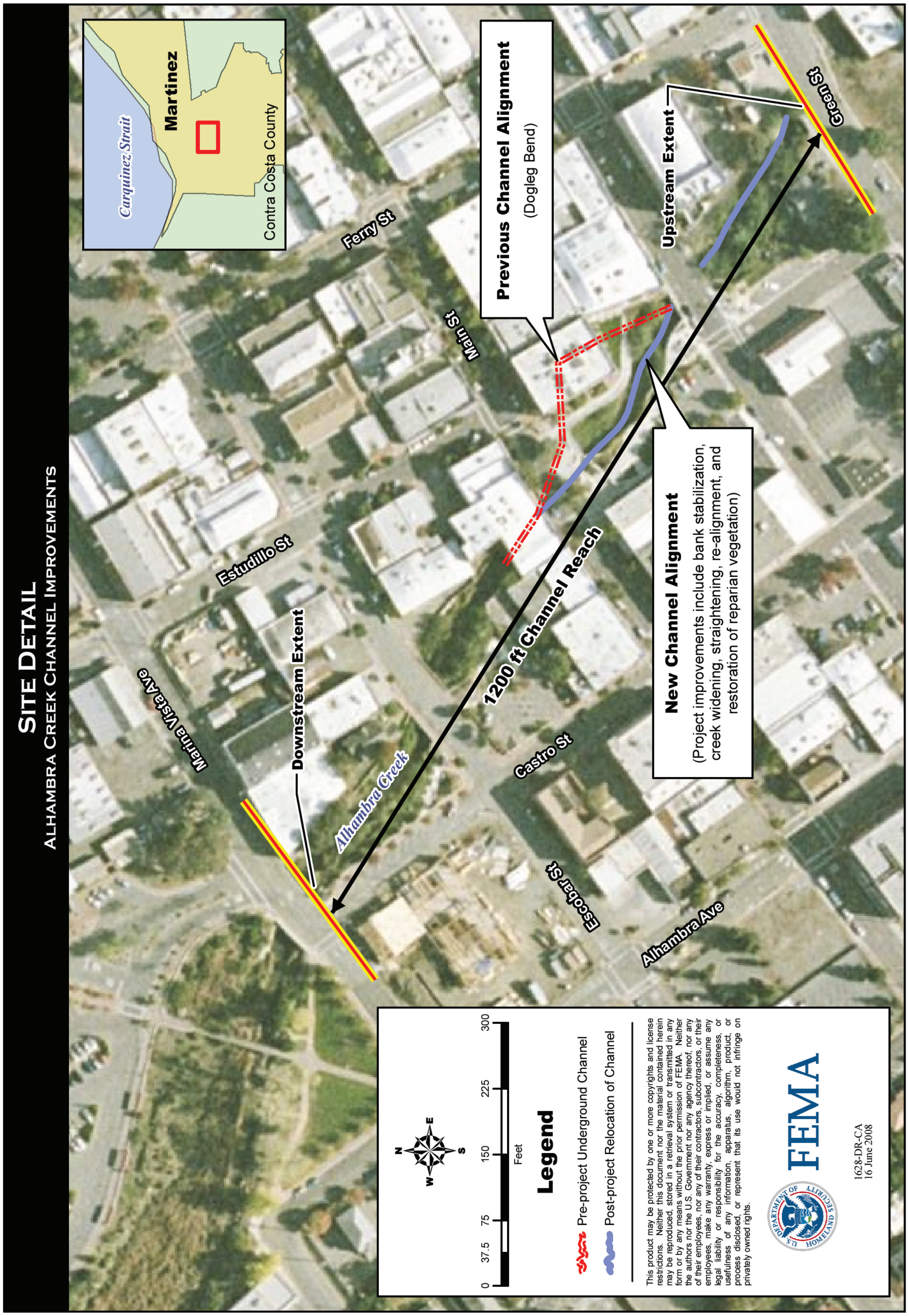
Site Detail
Alhambra Creek Channel Improvements
Carquinez Strait
Martinez
Contra Costa County
Ferry St
Main St
Estudillo St
Marina Vista Ave
Castro St
Escobar St
Alhambra Ave
Green St
Alhambra Creek
Downstream Extent
Upstream Extent
1200 ft Channel Reach
Previous Channel Alignment
(Dogleg Bend)
New Channel Alignment
(Project improvements include bank stabilization, creek widening, straightening, re-alignment, and restoration of reparian vegetation)
Legend
Pre-project Underground Channel
Post-project Relocation of Channel
0 37.5 75 150 225 300
Feet
N E S W
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16 June 2008

Figure D.2

downstream mitigation measures enhanced the Phase 3 repairs by preventing backwater effects at the railroad bridge. According to the project file and information obtained from the City of Martinez, various projects were completed in the Alhambra Creek watershed to mitigate flooding along Alhambra Creek. The Union Pacific Rail Road Bridge was expanded (the existing 40-foot railroad crossing was removed and replaced with a raised 150-foot span bridge) and the marsh area (downstream of Marina Vista) from the Carquinez Strait to the Union Pacific Rail Road bridge was widened and restored to coastal wetland elevation prior to the widening and straightening of the creek channel from Marina Vista to Green Street. The bridge expansion and wetland restoration were not funded by HMGP, but were part of the overall mitigation efforts for the Alhambra Creek watershed.

The City of Martinez provided the following reports, plans, and other project information related to the extensive modeling of Alhambra Creek:

- *Alhambra Creek Hydraulic Study: Marina Vista to Green Street*, prepared by Philip Williams & Associates (PWA). January 24, 2000.
- *1823/1535-04 - Martinez Flooding and Sedimentation December 2005 Flood and Sedimentation Assessment: Alhambra Creek, Martinez, CA*. Prepared by PWA. May 17, 2007a.
- *Martinez - Alhambra Creek Beaver Dam Assessment* (1823.02), prepared by PWA. October 16, 2007b.
- *Alhambra Creek Channel Improvements Project Marina Vista to Green Street, City*

Figure D.3

of Martinez, CA, December 20, 1999. File No. 10.16.4.19, prepared for the City of Martinez by multiple consultants (Gates and Associates, 1999).

- *Martinez Regional Shoreline: Marsh Restoration Project, City of Martinez,* prepared by PWA (1999).
- *Martinez Regional Shoreline: Marsh Restoration Project Phase 2 for the City of Martinez,* prepared by PWA (2001).
- HEC-RAS model provided by PWA in October 2007. Model provides MP_A and MP_C conditions. Both scenarios incorporate downstream mitigation measures.
- Topography for the region, 5-foot contour data for mountainous terrain with limited information pertaining to Alhambra Creek between Green Street and Marina Vista.

According to the City Engineer, the 1823/1535-04 - *Martinez Flooding and Sedimentation December 2005 Flood and Sedimentation Assessment* and local business owners in the downtown area, flooding occurred in December 2005, but not in the HMGP project area. The 2005 rainfall event produced landslides, erosion, and bank failures throughout the Alhambra Creek watershed. As a result, sediment was deposited in depths of one to three feet throughout the City of Martinez.

The 2005 damages were upstream of the project area and not related to the implemented HMGP project. According to the downtown business owners, the 2005 event was the first time the flow overbanked upstream, causing significant flows along Castro and Alhambra Streets. Portions of the downtown area were inundated

Figure D.4

with two to three feet of flooding. They also noted that the standing water drained fairly quickly, but left sediment deposits.

D.3 Physical Parameter Analysis

D.3.1 Storm Event Analysis

The DWR CDEC was used to identify candidate storm events. Two precipitation gage stations were used in the analysis of the peak flow for the 2005 storm event, Flood Control HQ - Contra Costa County (FCD) and Arroyo del Hambre (ADH), located on Ferndale Road (referred to as Alhambra Creek [ABA] by CDEC). The FCD gage is located at latitude 37.9880 N and longitude 122.0850 W, approximately four miles southeast of Green Street (the upstream project limit). The ADH gage is located at latitude 37.9970 N and longitude 122.1780 W, approximately 4.3 miles southwest of Green Street.

A report provided by the City of Martinez, 1823/1535-04 - *Martinez Flooding and Sedimentation December 2005 Flood and Sedimentation Assessment,* completed by PWA, used the 2 gage stations, ABA located at elevation 800 feet and FCD located at elevation 160 feet, to analyze the 2005 storm event. The ABA gage recorded 3.81 inches of precipitation in 12 hours and 4.19 inches of precipitation in 16 hours from December 30 to 31, 2005. The FCD gage recorded 3.21 inches of precipitation in 12 hours and 3.76 inches of precipitation in 16 hours from December 30 to 31, 2005. The precipitation-duration-frequency-depth curves produced by the Contra Costa County

Figure D.5

Public Works Department show that the precipitation recorded at the ABA station represents a 25-year rainfall event. The precipitation recorded at the FCD station represents a 50-year event for the 16-hour duration and a 25-year event for durations between 2 and 12 hours. According to the report, the maximum MP_C, 24-hour rainfall event recorded between December 30 and 31, 2005 was 4.47 inches at the ABA gage and 3.95 inches at the FCD gage (PWA, 2007a).

D.3.2 Flow Parameter Analysis

D.3.2.1 Hydrologic Analysis

For the MP_A conditions, the City of Martinez provided a hydrologic analysis: A Restudy of the December 2005 Flood and Sedimentation Assessment for Alhambra Creek. This analysis was made available digitally and was based on the return period results of a flood frequency analysis using the Hydrologic Engineering Center - Flood Frequency Analysis software. The report provides peak discharge and return periods at the D Street stream gage, which is located along Alhambra Creek, approximately 1.1 miles upstream from Green Street. This report shows that the maximum peak flow used for the Alhambra Creek Channel Improvements project was 2,400 cfs (PWA, 2007a).

D.3.2.2 Hydraulic Analysis

PWA provided a hydraulic model representing the MP_A and MP_C scenarios. The MP_A scenario was initially modeled using the same criteria established in the *Alhambra Creek Hydraulic Study: Marina Vista to Green Street*, with a downstream boundary condition of mean high-higher water (MHHW) of 3.08 feet National Geodetic Vertical Datum in the Carquinez Strait (PWA, 2000). The MP_C condition was modeled in HEC-RAS using the same boundary MHHW condition. The modeling provided by PWA included all the necessary input parameters to analyze the project once the appropriate flow rates for the event of interest were determined. This hydraulic analysis determined WSEs, which are used in the flood boundary analysis, at each cross-section throughout the model domain. The hydraulic analysis indicated that there would have been out-of-bank flooding at Escobar Street in the MP_A scenario. Therefore, losses avoided were expected for this project.

D.3.2.3 Flood Boundary Analysis

Given the results of the hydraulic modeling, the LAT conducted a flood boundary analysis to determine the level of damage for the MP_A and MP_C scenarios. No existing flood boundary analysis was available for either the MP_A or MP_C scenario. Consequently, the analysis was performed using the hydraulic model for the December 30-31, 2005, event and the available topographic data. The hydraulic model for the MP_A scenario indicated overbanking at Escobar Street. The hydraulic model for the MP_C scenario indicated the December 2005 event was contained in the project area (this was confirmed by interviews with the city engineers and local business owners).

Figure D.6 details the flood inundation boundaries resulting from this analysis for the MP_A scenario. The mapping indicates that five residences, three commercial buildings, and one local government building were within the flood boundary. The depth of flooding at these structures was determined using topographic data. The topographic data were modified slightly to include channel geometry. The .tiff design files were digitized and combined with the topographic data to determine the general topography for both the MP_A and MP_C scenarios.

A site visit was conducted to estimate the structure FFEs within the flood boundary for use in the flood boundary analysis. The government building FFE was approximately three feet above grade and the residential building FFEs were approximately four feet above grade. The FFEs of these structures were well above the projected flood depth for the MP_A scenario. However, based on the flood boundary analysis and data collected in the field, losses avoided could be calculated for three commercial properties within the project area.

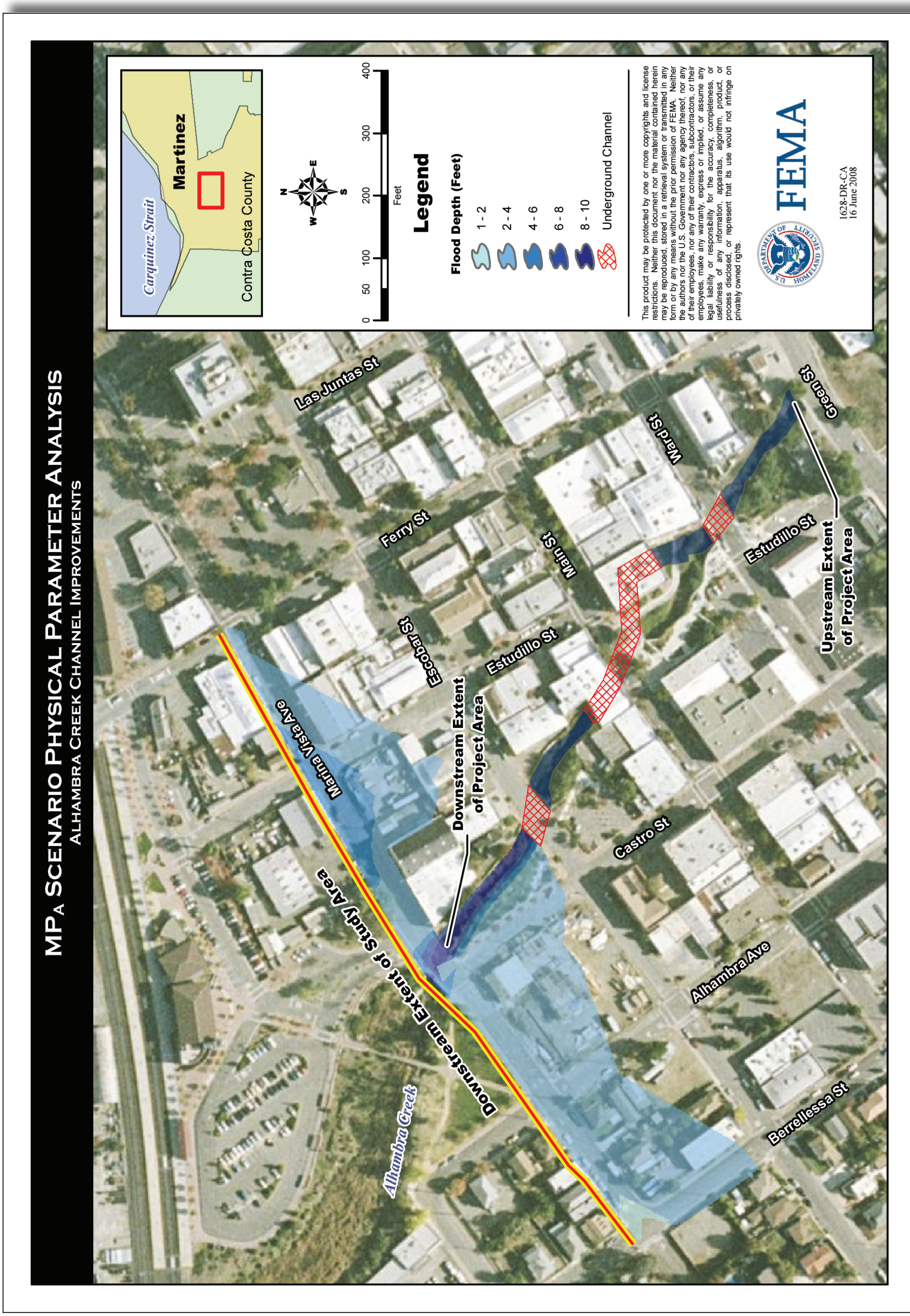
D.4 Loss Estimation Analysis

MP_A and MP_C damages were determined using the Physical Parameter Analysis results, standard FEMA depth-damage functions, and historical flood damage records. The Loss Estimation Analysis details for the December 30-31, 2005 storm event are provided in Table D.1 and discussed in the following subsections.

D.4.1 Physical Damage

Physical damage costs were calculated for the structure and contents of the affected businesses and the impacted roadways. Historical damages for impacted structures were not available in the project file. Information about the impacted structures can be found in Attachment D.1. The structure and contents damages for the MPA scenario were calculated by determining the following:

- **Structure Type** - Structure types were determined during a site visit. The structures were one-story buildings, without basements.


MPA Scenario Physical Parameter Analysis
Alhambra Creek Channel Improvements
Carquinez Strait
Martinez
Contra Costa County
N
E
S
W
0 50 100 200 300 400
Feet
Legend
Flood Depth (Feet)
1 - 2
2 - 4
4 - 6
6 - 8
8 - 10
Underground Channel
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16 June 2008
Las Juntas St
Ferry St
Escobar St
Estudillo St
Main St
Ward St
Green St
Estudillo St
Upstream Extent of Project Area
Downstream Extent of Project Area
Marina Vista Ave
Downstream Extent of Study Area
Castro St
Alhambra Ave
Berrellessa St
Alhambra Creek

Figure D.6

- **Square Footage** - The area of each structure was estimated in GIS using an aerial photograph and building footprint information.
- **Structure Elevation** - FFEs were determined using topographic data, data collected in the field, and foundation height guidance in HAZUS.
- **Building Replacement Value** - BRVs for each structure were determined using RSMeans.
- **Contents Value** - The contents values were determined using guidance in the *HAZUS-MH MR3 Technical Manual* for commercial buildings. For the commercial buildings in this project, content values were assumed to be 100 percent of the BRV (FEMA, 2006a).
- **Appropriate Depth-damage Functions** - The depth-damage curves from the FEMA BCA Riverine Full Data Module were used.

The structure and contents damage for the MP_A scenario was estimated based on the flood depths at each structure. The physical damage to structures and contents totalled $248,949 in the MP_A scenario. No damage occurred in the MP_C scenario. Details of the calculations can be found in Attachments D.1 and D.2. As indicated in the project file and verified by MP_C hydraulic modeling, no flooding or damages followed the project implementation.

Physical damage to the impacted roadways was determined based on the BCA submitted with the HMGP project application. The physical damage for the impacted roadways was estimated to be $30,155. As indicated in the project file and verified by MP_C hydraulic modeling, no flooding or damages followed the project implementation.

Total physical damages for the MP_A scenario were estimated to be $280,104. Since no damages have occurred since project completion, the losses avoided for physical damage were $280,104.

D.4.2 Loss of Function

Costs due to loss of function resulted from loss of business income, lost wages for employees of the affected businesses, and economic impact of road closures. The loss of function impacts for the MP_A scenario were estimated based on the flood depths at each structure. Details of the calculations can be found in Attachment D.3.

Loss of business income was estimated for all impacted commercial buildings. Guidance provided in the *HAZUS-MH MR3 Technical Manual* was used for this calculation. Loss of business income was estimated by:

Table D.1 Part 1 of 2

Loss Estimation Analysis Results
Alhambra Creek Channel Improvements

Loss Type	MP_A Scenario Losses[1]	MP_C Scenario Losses[1]	Losses Avoided[1]	Comments
Physical Damage				
Structure	$99,980	$0	**$99,980**	• Three commercial structures were impacted in the MP_A scenario, all were one-story buildings with no basements. • Structure damages were estimated using depth-damage curves from the FEMA BCA Full Data Flood Module. • BRVs were based on RSMeans.
Contents	$149,969	$0	**$149,969**	• The contents of three structures were impacted. • Contents value for commercial structures was estimated based on HAZUS-MH. • Contents damages were estimated using depth-damage curves from the FEMA BCA Full Data Flood Module.
Roads and Bridges	$30,155	$0	**$30,155**	• Estimated using BCA provided in project file.
Infrastructure	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Landscaping	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Environmental Impacts	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Vehicles/Equipment	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Subtotal	***$280,104***	***$0***	***$280,104***	
Loss of Function				
Displacement Expense	$0	$0	**$0**	• No displacement of residents was predicted by the analysis. • Displacement from commercial facilities was not calculated based on the assumption that these businesses would not be displaced by short-term closure.
Loss of Rental Income	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Loss of Business Income	$13,596	$0	**$13,596**	• Daily business income was calculated based on HAZUS-MH guidance. • Functional downtime was estimated using depth-damage curves from the FEMA BCA Full Data Flood Module.
Lost Wages	$4,869	$0	**$4,869**	• Daily lost wages were calculated based on HAZUS-MH guidance. • Functional downtime was estimated using depth-damage curves from the FEMA BCA Full Data Flood Module.
Disruption Time for Residents	$0	$0	**$0**	• No disruption of residents was calculated based on EMI guidance. • Disruption time was calculated using EMI guidance.
Loss of Public Services	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Economic Impact of Utility Loss	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Economic Impact of Road/Bridge Closure	$889	$0	**$889**	• Based on FEMA standard value of $32.23 per vehicle per hour of delay and information on road closures provided in the project file for previous events.
Subtotal	***$19,354***	***$0***	***$19,354***	

Continued

Table D.1 Part 2 of 2

Loss Estimation Analysis Results
Alhambra Creek Channel Improvements

Loss Type	MP_A Scenario Losses[1]	MP_C Scenario Losses[1]	Losses Avoided[1]	Comments
Emergency Management				
Debris Cleanup	$135,700	$0	**$135,700**	• Estimated using historical data provided in the project file.
Governmental Expense	$34,886	$0	**$34,886**	• Estimated using historical data provided in DSRs for events of similar magnitude.
Subtotal	***$170,586***	***$0***	***$170,586***	
Total	***$470,044***	***$0***	***$470,044***	

[1] All amounts rounded to the nearest dollar

- Determining the daily income for each business - The daily income was determined by assigning each business a HAZUS building label and occupancy class and following the HAZUS guidance for determining loss of business income for each occupancy class.
- Determining the functional downtime of the business - The functional downtime was estimated using the standard curve for functional downtime provided in the FEMA BCA Full Data Flood Module.

Loss of business income for the 3 impacted commercial facilities was estimated to be $13,596 for the MP_A scenario. No losses have occurred since project completion. Therefore, losses avoided were equal to $13,596 for loss of business income.

Lost wages were estimated in a similar manner for all impacted commercial buildings. The *HAZUS-MH MR3 Technical Manual* was also used for this calculation. Lost wages were estimated by:

- Determining the daily wages for each business - Daily wages were determined using the same HAZUS building label and occupancy class (identified for the loss of business income calculation) and following the HAZUS guidance for determining lost wages for each occupancy class.
- Determining the functional downtime for each business - The functional downtime was estimated using the standard curve for functional downtime provided in the FEMA BCA Full Data Flood Module.

Lost wages for the 3 impacted commercial facilities were estimated to be \$4,869 for the MP_A scenario. No losses have occurred since project completion. Therefore, losses avoided were equal to \$4,869 for lost wages.

The economic impact of Marina Vista Avenue closure was estimated using the number of vehicles per day that use the route, the average delay or detour time, and the average value of a motorist's time. The following data were used to calculate the economic impact of Marina Vista Avenue closures:

- The closure time was estimated to be two hours based on time of flooding for similar flood events.
- The number of one-way traffic trips per day was estimated to be 4,153 trips per day based on data provided in a local traffic study.
- The detour time was determined using an online mapping tool and estimating the most probable detour route based on main roads in the project area. The detour was estimated to be five minutes the downtown project area.
- From *What Is a Benefit?*, FEMA's standard value of \$32.23 per vehicle per hour of delay was used to determine the economic impact of the road closure (FEMA, 2001).

Based on this data, the total estimated economic impact of a Marina Vista Avenue closure for the MP_A scenario was \$889. Since the project was completed, no road closures have occurred. Therefore, the total losses avoided for loss of function damages were \$889 (Attachment D.4).

The total impact of loss-of-function, including loss of business income, lost wages, and economic impact of road closures, resulted in total losses avoided of \$19,354.

D.4.3 Emergency Management

Emergency management costs are those costs related to response and recovery activities and include debris cleanup and governmental costs. The project file indicated that typical debris cleanup costs are approximately \$135,700. For the MP_A scenario, the approximate cost for debris cleanup was assumed to be similar to historical records; therefore, typical debris cleanup costs of \$135,700 were used. DSRs for historical flood events were used to estimate the governmental costs, which were calculated to be approximately \$34,886. For the MP_C scenario, no flooding occurred in the project area. Therefore, losses avoided associated with emergency management costs were estimated to be \$170,586.

For other areas of the Alhambra Creek watershed in the City of

Martinez, the total sediment deposition for the December 2005, storm (based on the PWA 2007 report) was approximately 270 cubic yards. The Alhambra Creek Channel Improvements project was not designed to mitigate against this channel deposition; therefore, no costs were included for the MP_C scenario. The sediment deposition along Alhambra Creek occurs annually. Based on the reports provided by the City of Martinez the annual sediment deposition is covered under the City of Martinez maintenance efforts.

D.4.4 Results Summary

For the December 31, 2005, event of interest, losses avoided due to the completion of the mitigation project total $470,044. When compared to the project investment of $1,709,693, this project yields an ROI of 27 percent. The ROI only reflects the losses avoided for one event of interest; therefore, the ROI is expected to increase as additional storm events test the project's effectiveness over its useful life.

MP_A Scenario Impacted Commercial/Indurtrial Structure Information[1]
Alhambra Creek Channel Improvements

Address	Structure Information	HAZUS Building Type	FEMA BCA Building Type	Area (sf)	BRV ($/sf)	Total BRV	Contents Value Factor	Contents Value	Business Income ($/day)	Lost Wages ($/day)
401 Escobar	Retail - Auto Parts Emporium	COM2	1 Story, without Basement	4,225	$94.31	$398,476.69	100%	$398,476.69	$282.13	$122.38
500 Estudillo	Garage - auto repair storage yard	COM3	1 Story, without Basement	1,623	$70.90	$115,070.61	100%	$115,070.61	$691.90	$261.57
724 Marina Vista	Retail - Printing services	IND2	1 Story, without Basement	5,501	$94.31	$518,821.37	100%	$518,821.37	$232.30	$47.86

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

MP_A Scenario Loss Estimation Analysis for Commercial/Industrial Structures[1]

Alhambra Creek Channel Improvements

Address	Structure Elevation (ft msl)	Water Surface Elevation (ft msl)	Depth of Flooding (ft)	Structure DDF (% of BRV)	Structure Damage	Contents DDF (% of contents value)	Contents Damage	Loss of Function (days)	Loss of Business Income	Lost Wages
401 Escobar St	12.28	12.20	-0.08	8%	$32,994	12%	$49,491	8.3	$2,336	$1,013
500 Estudillo St	11.42	12.20	0.78	13%	$14,844	19%	$22,266	12.9	$8,926	$3,374
724 Marina Vista	11.99	12.20	0.21	10%	$52,142	15%	$78,212	10.1	$2,335	$481

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

MP_A Scenario Loss of Business Income and Lost Wages Calculations[1]

Alhambra Creek Channel Improvements

Address	HAZUS Building Type	Area (sf)	Income, Output, and Wage Recapture Factor[2]	Owner Income per Day[3] ($/sf)	Output per Day[4] ($/sf)	Business Income[5] ($/day)	Wages per Day[6] ($/sf)	Lost Wages[7] ($/day)	Functional Downtime[8] (days)	Total Lost Business Income	Total Lost Wages
401 Escobar	COM1	4,225	87%	$0.06	$0.45	$282.13	$0.22	$122.38	8.3	$2,336	$1,013
500 Estudillo	COM3	1,623	51%	$0.13	$0.73	$691.90	$0.33	$261.57	12.9	$8,926	$3,374
724 Marina Vista	IND2	5,501	98%	$0.25	$1.85	$232.30	$0.44	$47.86	9.6	$2,218	$457

Note

1 Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.
2 The Recapture Factors were taken from Table 14.16 HAZUS99 Earthquake Table of Recapture Factors in the HAZUS Flood Model Technical Manual.
3 Owner Income per Day was taken from Table 14.14 Proprietor's Income in the HAZUS Flood Model Technical Manual. This value was inflated to 2008 dollars.
4 Output per Day was taken from Table 14.14 Proprietor's Income in the HAZUS Flood Model Technical Manual. This value was inflated to 2008 dollars.
5 Business Income was determined by adding the Owner Income and Output per Day and multiplying the sum by the square footage and 1 minus the Recapture Factor. For example, the Business Income for 704 Petaluma was ($0.14 per square foot + $0.73 per square foot) x 6,783.75 square feet x (1-0.51).
6 Wages per Day was taken from Table 14.14 Proprietor's Income in the HAZUS Flood Model Technical Manual. This value was inflated to 2008 dollars.
7 Lost Wages were determined by multiplying the Lost Wages per Day by the square footage and 1 minus the Recapture Factor. For example, the Lost Wages for 704 Petaluma was $0.33 per square foot x 6,783.75 square feet x (1-0.51).
8 Functional Downtime was determined using the Depth Damage Functions from the FEMA BCA Riverine Full Data Module.

MP_A Scenario Economic Impact of Road/Bridge Closure[1]
Alhambra Creek Channel Improvements

Road/Bridge Closure	Vehicles per Day	Cost per Vehicle Hour	Delay Time (hours)	Duration of Closure (days)	Total Cost of Delay
Marina Vista Avenue Closure	4,153	$32.23	0.083	0.08	$888.77

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

Appendix E:

Hilltop Green Flood Mitigation Project

Project: 1203-0027

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List of Figures and Tables

Appendix E:

Project: 1203-0027
Hilltop Green Flood Mitigation Project

E.1 General Project Information

E.1.1 Project Location

As illustrated in Figure E.1, the Hilltop Green Flood Mitigation Project is located in the City of Richmond, Contra Costa County, CA. More specifically, the project site, located in Hilltop Green Park, is surrounded by a residential subdivision and adjacent to Interstate 80.

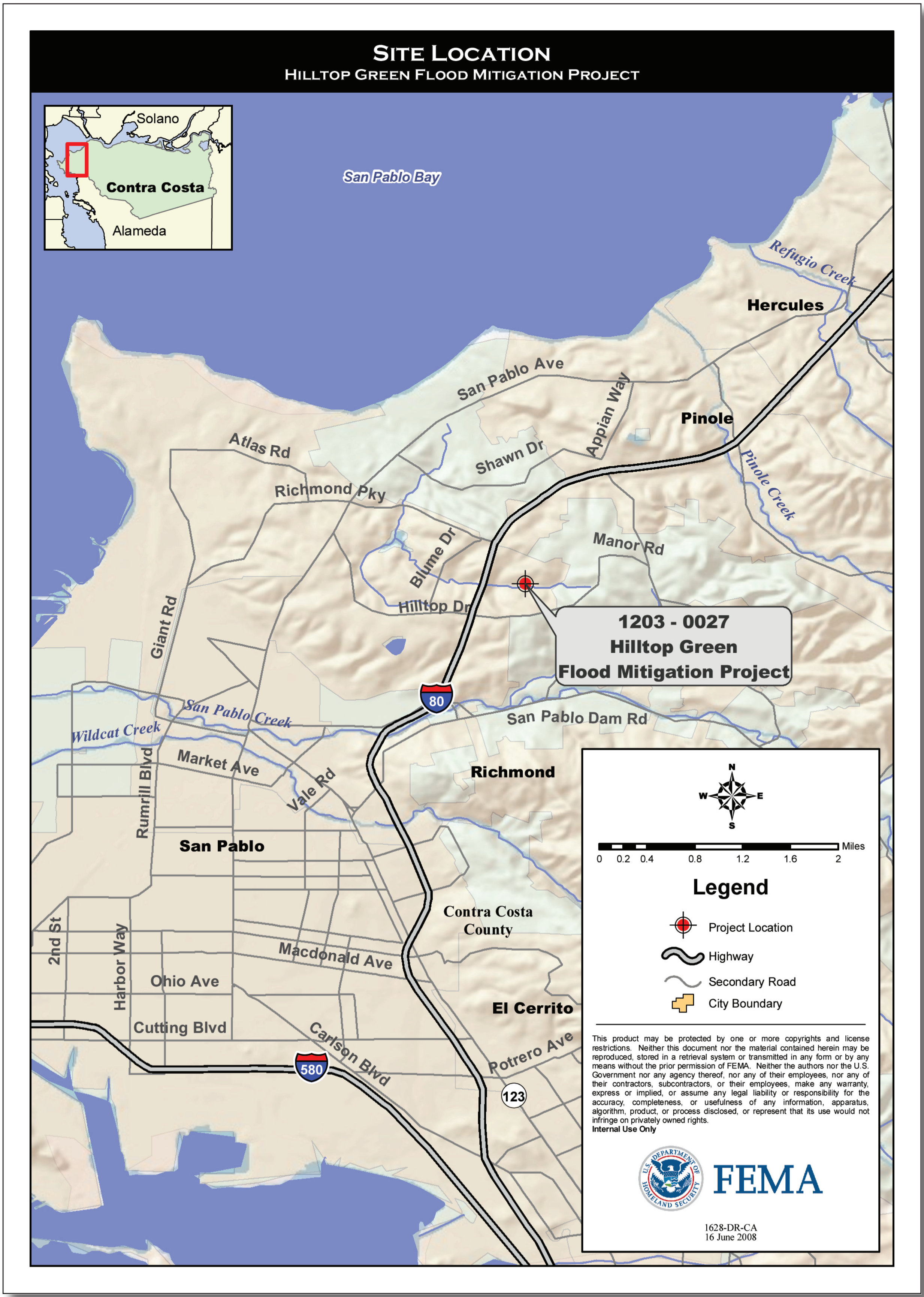
E.1.2 Project Description

The West County Wastewater District pump station is located at Hilltop Green Park. With bowl-shaped topography, the park slopes down to the pump station, which is situated at the park's lowest elevation (Figures E.2 and E.3). The storm drain system consists of a runoff collection system in the surrounding area of the pump station with outflow traveling along Parkway Drive, under Interstate 80, and emptying into Garrity Creek. The runoff collection is a drop inlet connected to a 42-inch-diameter RCP with the outflow transitioning into a 54-inch-diameter RCP and crossing under Interstate 80 in a 60-inch corrugated metal pipe.

Storm events in 1982 and 1997 flooded the pump station. The flooding resulted in a power outage and subsequent system failure. Insufficient capacity of the creek channel and storm drain outlet were factors in the flooding of the station. Additionally, lack of curbing or a trash guard along the storm drain outlet caused clogging and water backup. Flooding conditions contributed to damages to the pump station controls, variable frequency drives, and emergency generator. As a result of the power outage and consequent pump failure, public health could have been placed at risk. Sewage overflowed onto the ground and into stormwater conveyance systems. According to West County Wastewater District's personnel, the raw sewage overflow from the 1997 storm event drained through the existing stormwater systems and was captured in a small detention area. The sewage overflow was then pumped to the wastewater treatment plant. The damage costs from the 1997 storm event were $191,257 (2008 dollars).

The 1997 event flooded the pump station to a depth of 2.5 feet. According to the District Engineer, for West County Wastewater

Figure E.1


SITE LOCATION
HILLTOP GREEN FLOOD MITIGATION PROJECT
Solano
Contra Costa
Alameda
San Pablo Bay
Refugio Creek
Hercules
San Pablo Ave
Appian Way
Pinole
Pinole Creek
Atlas Rd
Shawn Dr
Richmond Pky
Manor Rd
Blume Dr
Hilltop Dr
1203 - 0027
Hilltop Green
Flood Mitigation Project
Giant Rd
80
San Pablo Creek
Wildcat Creek
San Pablo Dam Rd
Market Ave
Vale Rd
Richmond
Rumrill Blvd
San Pablo
Contra Costa
County
2nd St
Harbor Way
Macdonald Ave
Ohio Ave
El Cerrito
Cutting Blvd
Carlson Blvd
Potrero Ave
580
123
N
W
E
S
Miles
0 0.2 0.4 0.8 1.2 1.6 2
Legend
Project Location
Highway
Secondary Road
City Boundary
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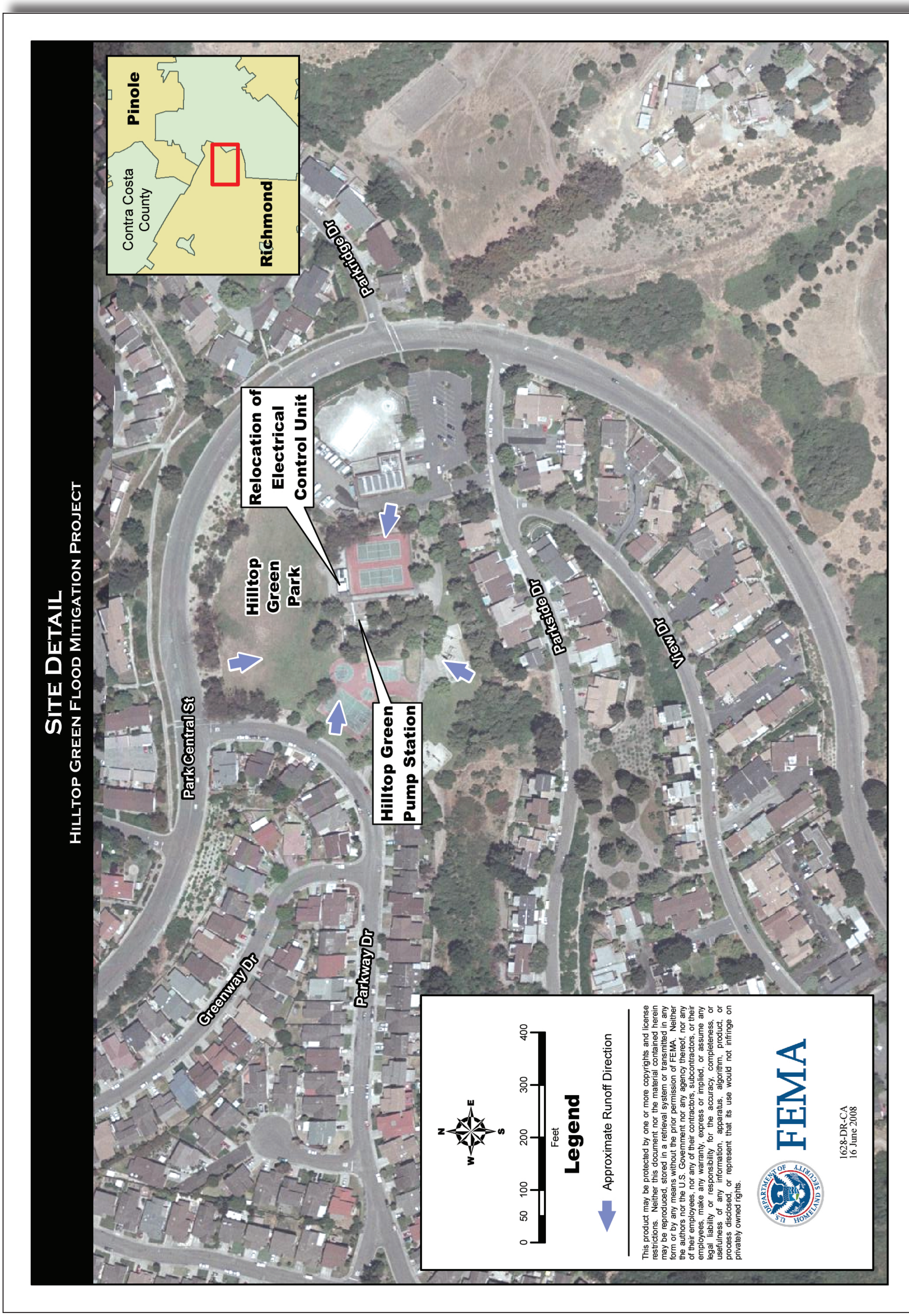
SITE DETAIL
HILLTOP GREEN FLOOD MITIGATION PROJECT
Pinole
Contra Costa County
Richmond
Parkridge Dr
Relocation of Electrical Control Unit
Hilltop Green Park
Park Central St
Hilltop Green Pump Station
Parkside Dr
View Dr
Parkway Dr
Greenway Dr
N
E
S
W
0 50 100 200 300 400
Feet
Legend
Approximate Runoff Direction
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16 June 2008

Figure E.2

District, a 13-year storm event had previously completely inundated the pump station. The FFE of the pump station is 185 feet above msl. The District analyzed topography within the park to determine the highest possible flood elevation before floodwaters would naturally discharge out of the park. The study revealed that protection against a 100-year flood event existed above an elevation of 200 feet msl for critical pump station controls and flood-sensitive equipment.

Project improvements included the relocation of all the pump station electrical control systems, phase shift transformers, and emergency generator. A new structure was built to house this equipment approximately 30 feet from the pump station and 19 feet above the original floor. The new facility's final floor elevation is 204 feet msl. This elevation is 4 feet above the 100-year event protected elevation of 200 feet msl. The new building was equipped with a waterproof enclosure for the electrical controls and a quick-acting, watertight exterior door. Conduit was routed from the electrical enclosure to the existing submersible pumps. New curbing was also installed to reduce clogging of the drop inlet at the storm drain (Figure E.4).

E.1.3 Project Funding and Construction Time Line

In 1998, the HMGP grant application was approved for a project cost of $173,600 (1998 dollars), with a Federal share of $136,019 (1998 dollars). The remaining costs were funded by local sources including Contra Costa County and West County Wastewater District. The Hilltop Green Flood Mitigation Project HMGP grant was approved March 18, 1998, and the project was completed July 30, 1999. The final project cost was $248,520 (2008 dollars).

Figure E.3

E.2 Data Collection

The LAT conducted a detailed review of the project file for the Hilltop Green Flood Mitigation Project, noting the data that were available and the data that required additional research. Additionally, the LAT collected site-specific information related to site condition (topography, drainage features, structure details, and equipment relocation) during the initial site visit. Personnel from the West County Wastewater District provided site-specific information related to past flooding, costs of previous damages, and background regarding the sewage overflows that occurred during the downtime of the pump station.

No previous studies were available for the project area; therefore, all data required for the Physical Parameter Analysis had to be collected. The USGS DEM was used to provide topographic data. Hydrologic and hydraulic data were collected from the design drawings, site visits, and gage data review. The project's MP_A scenario was defined using the design and topographic data collected.

E.3 Physical Parameter Analysis

E.3.1 Storm Event Analysis

To identify the candidate storm event, weather information was obtained from two sources: NOAA/National Climatic Data Center and the CDEC. The rainfall data indicated that the event that occurred on December 31, 2005, was the most severe event that occurred after project completion. This event yielded approximately 3.16

Figure E.4

inches of precipitation in a 12-hour period. The precipitation data for this project were obtained from the Richmond City Hall CDEC station located at latitude 37.933 and longitude -122.350. This station is approximately three to four miles from the Hilltop Green/ West Contra Costa Sanitary District. Using the intensity-duration-frequency curves obtained from the Windows (based) Intensity-Duration-Frequency Version 3 (WinIDF3) database issued by the California Department of Transportation (1998), the estimated event had a recurrence interval between 10 and 25 years. This interval is consistent with the 14-year event calculation provided by Contra Costa County.

Based on the damage information provided in the HMGP application, the District Engineer indicated that damages would likely have occurred for the MP_A scenario for a storm event with a 5-year recurrence interval. Further, it was noted in the project file that the pump station was completely inundated during previous events of 13-year and longer recurrence intervals.

E.3.2 Flow Parameter Analysis

E.3.2.1 Hydrologic Analysis

The peak flow representing the MP_A scenario for Hilltop Green was developed using the Modified Rational Method and Hydraflow Hydrographs 2004 by Intelisolve. The model was compared to the information provided in the HMGP application pertaining to the January 1997 storm. The estimated peak flow for the December 31, 2005, storm event was one cfs.

E.3.2.2 Hydraulic Analysis

A hydraulic model representing the MP_A scenario was not available. Due to the small size and shape of the affected area, detailed topography was not needed. The topography of the contributing drainage area is bowl-shaped and slopes down to the pump station where the storm drain is located. This elevation is the lowest in the total drainage area. Based on information in the project file and on the site characteristics verified during the site visit, the basic geometry of the catchment basin was used to determine the height of the flood through volume calculations. Using a simplified method to calculate the volume of water in the basin for the December 31, 2005, storm event, flooding would have inundated the pump station and electronic equipment to a depth of 3.5 feet.

E.3.2.3 Flood Boundary Analysis

The hydraulic analysis indicated that the lift station and pump station control unit would be inundated by more than three feet of flooding in the MP_A scenario. Based on the flood inundation, losses avoided could be calculated. A flood boundary analysis was unnecessary for this project, because only a determination of whether or not the pump station would have flooded was required; the entire inundated area was not relevant for the Loss Estimation Analysis. Figure E.5 illustrates the flood inundation for the West County Wastewater District pump station located in Hilltop Green Park.

E.4 Loss Estimation Analysis

MP_A damages were determined using historical damage records for a flood event in 1997, similar in magnitude to the event of interest in 2005. The elevation of the new electrical controls above the 100-year flood elevation was completed July 30, 1999. The 2005 event was less severe than a 20-year event; therefore, no MP_C damages occurred. The loss estimation details are provided in Table E.1 and discussed in the following subsections.

E.4.1 Physical Damage

Physical damage for this project included impacts to the pump station, electrical controls, and other equipment, as well as the environmental impacts of sewage overflow. Physical damage costs were calculated using historical damage data. These data were obtained from West County Wastewater District flood cost records for the 1997 storm event. Historical flood costs for physical damage included equipment repair, replacement and rental, and environmental impacts (such as water quality testing).

Total estimated physical damage for the MP_A scenario were calculated to be $132,891. Since the project was completed on July 30, 1999, no damages have occurred. Therefore, the total losses avoided for physical damage were $132,891.

E.4.2 Loss of Function

According to *What Is a Benefit?*, loss of function impacts are "the losses, costs and direct economic impacts that occur when physical damages are severe enough to interrupt the function of a building or other facility" (FEMA, 2001). The Hilltop Green Flood Mitigation Project is related to a sanitary sewer pump station; therefore, utility service is lost when the pump station is not operating. The loss of function for this particular project is based on an estimated operating budget for the pump station. The Sanitary District Engineer estimated the annual operating budget to be $66,056 per year, or $181 per day, and provided a functional downtime from the 1997 flood event of 8 days and 30 minutes. The functional downtime for the 2005 event


MPA Scenario Physical Parameter Analysis
Hilltop Green Flood Mitigation Project
Flood Depth
Hilltop Green Park
Park Central St
Parkway Dr
Parkside Dr
Pinole
Contra Costa County
Richmond
N
E
S
W
0
25
50
100
150
200
Feet
Legend
Flood Depth
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Figure E.5

Table E.1

Loss Estimation Analysis Results
Hilltop Green Flood Mitigation Project

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 or collected data.
Contents	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Roads and Bridges	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Infrastructure	$131,848	$0	**$131,848**	• Flood depth at pump station estimated to be three feet. • Based on historical damages during 1997 event detailed in the project file (flood depth = 2.5 ft).
Landscaping	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Environmental Impacts	$1,043	$0	**$1,043**	• Includes environmental testing of water quality. • Based on historical damages during 1997 event detailed in the project file (flood depth = 2.5 ft).
Vehicles/Equipment	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Subtotal	***$132,891***	***$0***	***$132,891***	
Loss of Function				
Displacement Expense	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Loss of Rental Income	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Loss of Business Income	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Lost Wages	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Disruption Time for Residents	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Loss of Public Services	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Economic Impact of Utility Loss	$1,452	$0	**$1,452**	• Based on estimated annual operating budget ($66,056) and functional downtime (8 days, 30 minutes) for the 1997 event.
Economic Impact of Road/Bridge Closure	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Subtotal	***$1,452***	***$0***	***$1,452***	
Emergency Management				
Debris Cleanup	$19,533	$0	**$19,533**	• Based on historical damages during 1997 event detailed in the project file (flood depth = 2.5 ft).
Governmental Expense	$38,833	$0	**$38,833**	• Based on historical damages during 1997 event detailed in the project file (flood depth = 2.5 ft).
Subtotal	***$58,366***	***$0***	***$58,366***	
Total	***$192,709***	***$0***	***$192,709***	

[1] All amounts rounded to the nearest dollar

of interest was assumed to be equal to the 1997 event because the events were of similar magnitude. Therefore, the economic impact of utility loss for the MP_A scenario was $1,452 ($181 per day x 8.02 days). No damages to the pump station have occurred since the project was completed. Therefore, the total losses avoided for loss of function were $1,452.

E.4.3 Emergency Management

Emergency management costs in the records for the 1997 storm event included overhead and labor costs and site cleanup. For the MP_A scenario, emergency management costs totalled $58,366. This total includes $19,533 for debris cleanup and $38,833 for governmental expense. Since project completion on July 30, 1999, no MP_C damages have occurred. Therefore, the total losses avoided for emergency management costs were $58,366.

E.4.4 Results Summary

For the December 31, 2005, event of interest, losses avoided due to the completion of the mitigation project total $192,709. When compared to the project investment of $248,520, this project yields an ROI of 78 percent. This ROI only reflects the losses avoided for one event of interest; therefore, the ROI is expected to increase as additional storm events test the project's effectiveness over its useful life.

Appendix F:

Broadway Culvert replacement

Project: 1203-0034

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Appendix F:

Project: 1203-0034

Broadway Culvert Replacement

F.1 General Project Information

F.1.1 Project Location

As illustrated on Figure F.1, the Broadway Culvert Replacement project is located near the City of Olivehurst, Yuba County, CA. More specifically, the project site is located on Lateral #15, which is the main north/south drainage canal. The residential subdivision located approximately two miles north (upstream) of the project site is prone to frequent flooding.

F.1.2 Project Description

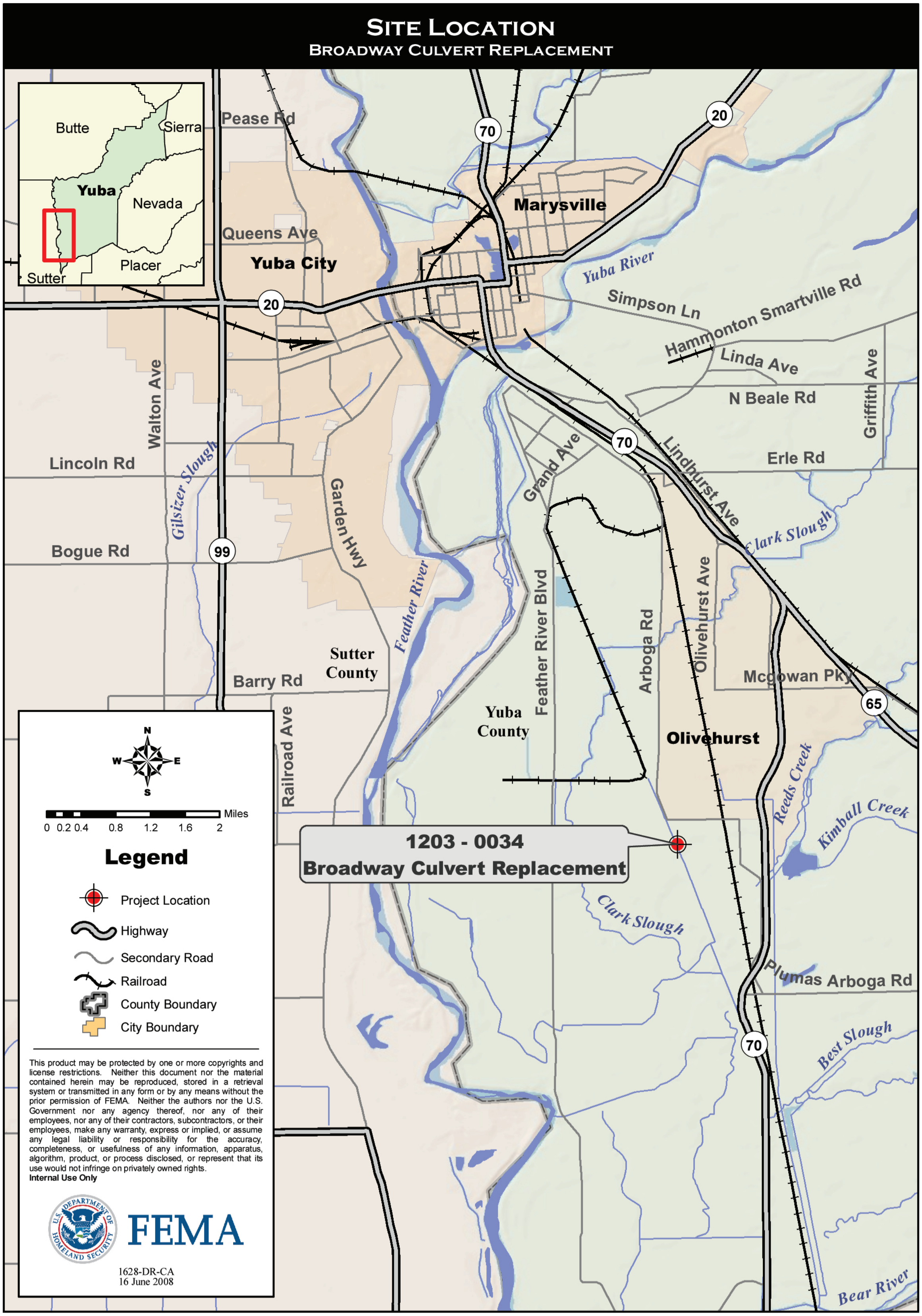
The Broadway Culvert Replacement project is a small component of a large flood control project outlined in the *Revised South Yuba Master Drainage Plan,* dated March 1991 (MHM, 1991). This master plan recommended projects that would alleviate recurring flooding impacting the communities of Linda and Olivehurst in Yuba County.

The Broadway Culvert is located on Lateral #15 within the community of Arboga. Lateral #15 is the main north-south drainage canal for Reclamation District 784. The lateral carries stormwater from the developed areas of Linda, Yuba County Airport, and western Olivehurst south to Pump Station #6. At Pump Station #6 the flow is pumped over a levee to the Bear River.

Lateral #15 runs north-south along the Old Pacific Rail Road and is used to convey stormwater runoff from more developed areas located to the east and prevent flooding of agricultural land to the west (Figure F.2). The existing Broadway Street culvert was undersized and created a downstream obstruction that caused stormwater to back up in the northern portion of Lateral #15 and flood adjacent properties.

Flooding caused by the backwater effect at Lateral #15 has caused repetitive damage to properties along Butterfly Lane, Buttercup Lane, and Sunny Road. Floods were recorded in 1950, 1955, 1964, 1972, 1974, 1983, 1986, 1995 (1044-DR-CA and 1046-DR-CA), and in January 1997 (1155-DR-CA). The HMGP project file indicates that structures in the project area had up to 0.5 feet of flooding in 1955 and 1997, up to 1 foot of flooding in 1986, and up to 1.5 feet of flooding in 1995.

Figure F.1


SITE LOCATION
BROADWAY CULVERT REPLACEMENT
Butte
Sierra
Yuba
Nevada
Placer
Sutter
Pease Rd
Queens Ave
Yuba City
Marysville
Yuba River
Simpson Ln
Hammonton Smartville Rd
Linda Ave
N Beale Rd
Griffith Ave
Erle Rd
Lindhurst Ave
Clark Slough
Walton Ave
Lincoln Rd
Gilsizer Slough
Bogue Rd
Garden Hwy
Grand Ave
Feather River
Feather River Blvd
Arboga Rd
Olivehurst Ave
Mcgowan Pky
Sutter County
Yuba County
Olivehurst
Barry Rd
Railroad Ave
Reeds Creek
Kimball Creek
1203 - 0034
Broadway Culvert Replacement
Clark Slough
Plumas Arboga Rd
Best Slough
Bear River
20
70
99
65
N
W
E
S
Miles
0 0.2 0.4 0.8 1.2 1.6 2
Legend
Project Location
Highway
Secondary Road
Railroad
County Boundary
City Boundary
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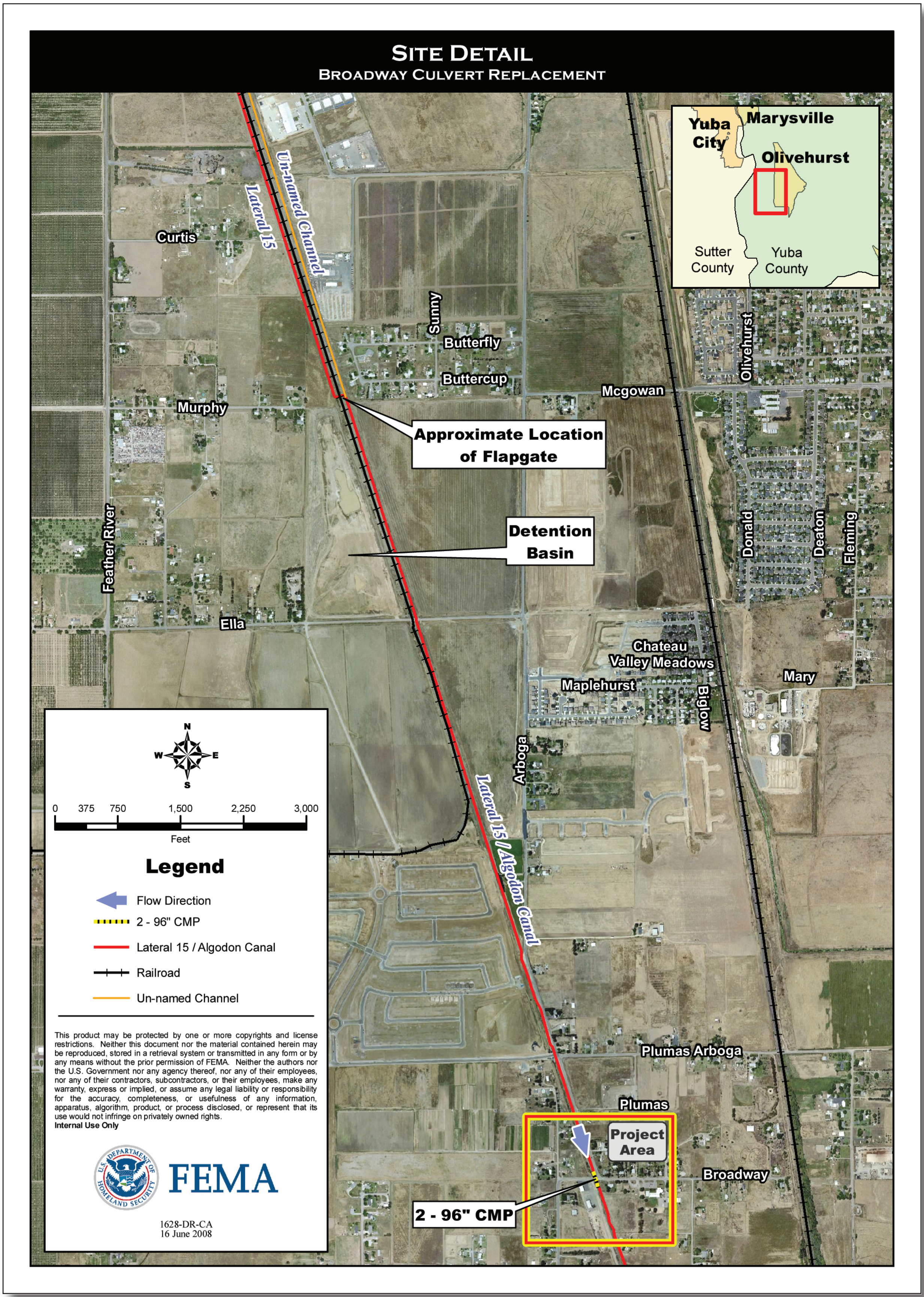
16 June 2008

Figure F.2


SITE DETAIL
BROADWAY CULVERT REPLACEMENT
Yuba City
Marysville
Olivehurst
Sutter County
Yuba County
Un-named Channel
Lateral 15
Curtis
Sunny
Butterfly
Buttercup
Olivehurst
Mcgowan
Murphy
Approximate Location of Flagpate
Detention Basin
Feather River
Donald
Deaton
Fleming
Ella
Chateau Valley Meadows
Maplehurst
Biglow
Mary
Arboga
Lateral 15 / Algodon Canal
Plumas Arboga
Plumas
Project Area
Broadway
2 - 96" CMP
N
W
E
S
0
375
750
1,500
2,250
3,000
Feet
Legend
Flow Direction
2 - 96" CMP
Lateral 15 / Algodon Canal
Railroad
Un-named Channel
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Project improvements included replacement of the existing 72-inch-diameter by 38-foot-long RCP with dual 96-inch-diameter by 95-foot-long corrugated metal pipes (CMPs) and creating rock slope protection at the inlet and outlet (Figure F.3). A new flapgate was also installed on a culvert located at the end of Buttercup Lane. The canal was dredged to remove accumulated silt and debris. According to the project file, these alterations increased flood protection from a 3-year event to a 100-year event.

F.1.3 Project Funding and Construction Time Line

An application for HMGP funding for the Broadway Culvert Replacement project was submitted to FEMA in 1998. The HMGP application was made for $100,000 (1998 dollars), of which FEMA contributed $75,000. The final project cost was $104,006 ($138,961 in 2008 dollars). The grant was approved on March 18, 1998, and the project was completed on September 29, 1998.

F.2 Data Collection

The LAT reviewed the HMGP project file and found that additional data were needed. The LAT conducted an initial site visit to gather site-specific information related to past flooding, and assess the site conditions (topography, drainage features, and structure types).

The following documents were provided by Yuba County and their engineering consultant:

- *Reclamation District 784 Master Drainage Plan*, prepared by Mead and

Figure F.3

Hunt, September 2002.

- FEMA's *Flood Insurance Study for Yuba County, California - Unincorporated Areas*. November 17, 1981.

These documents contained much of the hydrologic and hydraulic information used for the study.

F.3 Physical Parameter Analysis

F.3.1 Storm Event Analysis

The DWR CDEC was used to identify candidate storm events. Two gage stations were used in the analysis of the peak flow for the December 31, 2005, storm event, Wheatland 2 NE and Bear River at Camp Far West Dam (CFW). The Wheatland 2 NE gage station is located approximately nine miles southeast of the Broadway Culvert, at latitude 39.028 and longitude -121.390. The CFW gage is located approximately 13 miles west of the Broadway Culvert, at latitude 39.0500 and longitude -121.3170. The CFW gage was more appropriate to the project site because the gage located near Wheatland was at a much higher elevation. The CFW gage recorded 2.4 inches of rainfall in 6 hours and 3.4 inches of rainfall in 24 hours during the December 31, 2005, event. Based on the precipitation-duration-frequency-depth curves from DWR, the CFW station recorded a 25-year rainfall event for the 24 hour duration.

F.3.2 Flow Parameter Analysis

F.3.2.1 Hydrologic Analysis

Several hydrologic analysis methods were considered for this project; however, the calculated peak flow using some of these methods was significantly high according to Yuba County. The watershed for Lateral #15 includes various laterals and detention basins that delay the flow carried through Lateral #15. A lack of information regarding these additional laterals and detention made the hydrologic analysis difficult. The best method, based on the information obtained for the project, for determining the flow at the Broadway Culvert used the witnessed WSE during the December 31, 2005, storm event. The final hydrology was based on the observed field WSE obtained by Yuba County Maintenance Yard staff during the storm event. According to the County Engineer, Emergency Field Crews recall the dual culvert at Broadway flowing half full. The timing of the field observation suggests that this flow was not the peak flow event. One foot was added to the observed WSE to simulate the peak flow of the event. The corresponding flow, calculated using Federal Highway Administration HY-8 software

(2007), was determined to be 350 cfs.

F.3.2.2 Hydraulic Analysis

Both the MP_A and MP_C scenarios were modeled using 350 cfs. Detailed topography representing the MP_A and MP_C scenarios in the project area was not available; therefore, information from the project file and data collected during a site visit were used to verify and modify the 1.0-meter vertical digital topography purchased from a third-party vendor. The MP_A scenario indicated a backwater effect that would have caused overtopping at the Buttercup/Butterfly residential area. Another culvert, approximately 1.5 miles upstream of Broadway, appeared to contribute to the flooding in the Buttercup/Butterfly community. At Ella Street, the right bank of Lateral #15 is lower in elevation and has a smaller cross-section. The excess flow would overtop the bank and flood the area north of Ella Street. The area of greatest impact would be the Buttercup/Butterfly community because a 2- to 3-foot berm located along Buttercup Lane creates a small basin that would inundate the residential structures within that neighborhood. Based on project assumptions and data collected for analysis, the flow would be sufficient to flood the community. The area is extremely flat; therefore, the flood depth in this community would be zero to 1.25 feet. These depths are consistent with depths observed during historical events in this area.

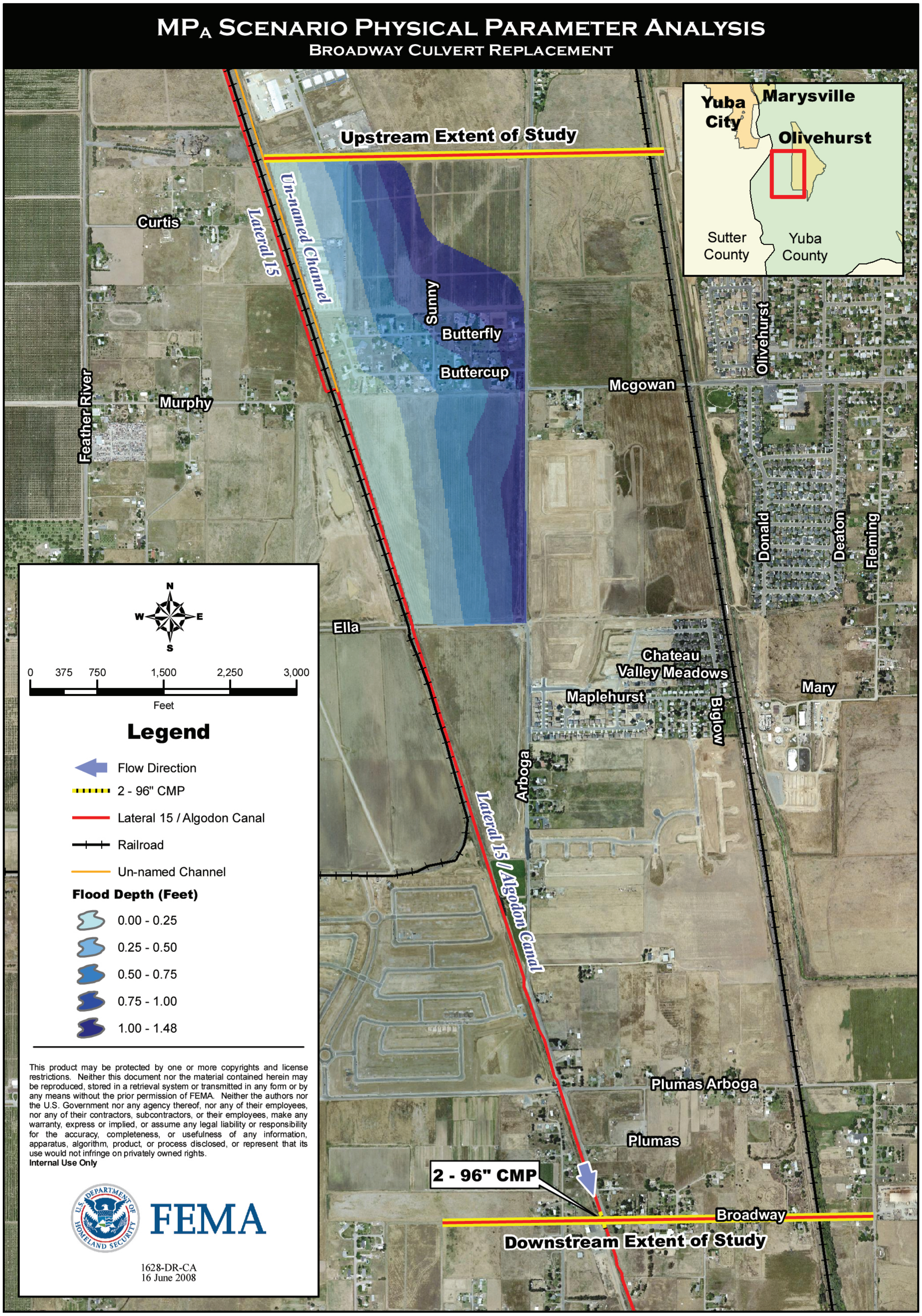
The hydraulic analysis indicated that, if the Broadway Culvert had not been replaced and upgraded, out-of-bank flooding would have occurred. Therefore, losses avoided would be expected for this project.

F.3.2.3 Flood Boundary Analysis

Based on the results of the hydraulic modeling, flood boundary analyses were conducted to determine the level of damage for both the MP_A and MP_C scenarios. No existing flood boundary analysis was available for either the MP_A or MP_C scenario. The analyses were performed using the hydraulic model for the December 31, 2005, storm event and the available topographic data. The hydraulic model for the MP_A scenario indicated overbanking immediately upstream of Ella Street. The hydraulic model for the MP_C scenario indicated the December 2005 storm event would have been contained in Lateral #15 (the model was verified by Yuba County and no damages were documented for the actual storm event). Yuba County Emergency Field Crews confirmed that no flooding was observed during this storm event.

Figure F.4 details the flood inundation boundaries resulting from this analysis for the MP_A scenario. The mapping indicates that 39 residences and 1 commercial facility (inclusive of several buildings)

Figure F.4


MPA Scenario Physical Parameter Analysis
Broadway Culvert Replacement
Upstream Extent of Study
Downstream Extent of Study
Marysville
Yuba City
Olivehurst
Sutter County
Yuba County
Un-named Channel
Lateral 15
Lateral 15 / Algodon Canal
Curtis
Sunny
Butterfly
Buttercup
Mcgowan
Murphy
Feather River
Olivehurst
Donald
Deaton
Fleming
Ella
Chateau Valley Meadows
Maplehurst
Biglow
Mary
Arboga
Plumas Arboga
Plumas
2 - 96" CMP
Broadway
N
W
E
S
0
375
750
1,500
2,250
3,000
Feet
Legend
Flow Direction
2 - 96" CMP
Lateral 15 / Algodon Canal
Railroad
Un-named Channel
Flood Depth (Feet)
0.00 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.48
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were within the flood boundary. The depth of flooding at these structures was determined using topographic data.

A site visit was conducted to estimate the structure elevations for each structure within the identified flood boundary for use in the flood boundary analysis. The structures were elevated approximately one foot above grade. Based on the flood boundary analysis and data collected in the field, losses avoided could be calculated for the 39 residential structures and 1 commercial property within this project area.

F.4 Loss Estimation Analysis

The Physical Parameter Analysis indicated that losses could be calculated for the December 31, 2005, storm event for the MP_A scenario. No damage occurred in the MP_C scenario. Loss estimation details are provided in Table F.1 and discussed in the following subsections.

F.4.1 Physical Damage

Physical damage costs were calculated for the structure and contents of the impacted residential structures and the industrial facility and damages to the impacted roadways. Detailed historical damages for these individual structures were not available in the project file. The structure and contents damages for the MP_A scenario were calculated by determining:

- **Structure Type** - Structure type was determined using real estate information available on the Internet and verified during a site visit. All structures were one-story buildings without basements.
- **Area** - The area of each structure was estimated in GIS using aerial photographs and building footprint information.
- **Structure Elevation** - Structure FFEs were determined using topographic data, structure elevation data collected in the field, and foundation height guidance in HAZUS.
- **Building Replacement Value** - BRVs were determined for each residential structure using Marshall & Swift and for the industrial facility using RSMeans.
- **Contents Value** - The contents values were determined using FEMA BCA guidance (30 percent of the BRV for residential structures [FEMA 2005, 2006b]) and guidance in the *HAZUS-MH MR3 Technical Manual* (150 percent of the BRV for industrial structures [FEMA 2006a]).
- **Appropriate Depth-damage Functions** - The depth-damage

curves for the FEMA BCA Riverine Full Data Module were used.

Based on the MP_A scenario flood depths at each structure, the physical damages to structures and contents were estimated to be $1,205,594 for the MP_A scenario. Details of the calculations can be found in Attachments F.1 through F.4. As indicated in the project file and verified by MP_C hydraulic modeling, no flooding or damages followed the project implementation.

Physical damage to the impacted roadways was determined based on previous damages during historical flood events. DSRs from historical events were reviewed to calculate physical damage for Butterfly Lane, Buttercup Lane, and Sunny Road. The physical damage for these impacted roadways was estimated to be $122,903. As indicated in the project file and verified by MP_C hydraulic modeling, no flooding or damages followed the project implementation.

Total estimated physical damage was $1,328,497 for the MP_A scenario. No damage was predicted for the MP_C scenario. Therefore, the losses avoided for physical damage was $1,328,497.

F.4.2 Loss of Function

Loss of function was calculated for displacement expense, disruption time for residents, loss of business income, and lost wages. The loss of function impacts for the MP_A scenario were estimated based on the flood depths at each structure. Details of the calculations can be found in Attachments F.1 through F.5.

The economic impact of a road closure was not estimated for this project location. The impacted roadways, Buttercup Lane, Butterfly Lane, and Sunny Road, were in residential areas that typically evacuate or displace and were not through streets regularly used by non-residents. Because the residents of these roads would be displaced, the economic impacts of these road closures would have to be calculated for the location to which the residents were displaced. For example, if a resident was displaced to a location that increased his or her typical commute, this increase in commute could be included in the calculation of economic impacts of road closures. The Commute may increase for some residents but decrease for others, so this impact was not calculated.

Using FEMA BCA Flood Depth-Damage Curves for Displacement Time and EMI guidance for disruption time, loss of function costs were calculated for the residential structures and their occupants for the MP_A scenario. Displacement expense was calculated using the FEMA standard values. Rental costs of $1 per square foot per month for temporary housing, $500 per month for utilities, and other rental costs were assumed. A one-time cost of $500 was assumed

Table F.1 Part 1 of 2

Loss Estimation Analysis Results
Broadway Culvert Replacement

Loss Type	MP_A Scenario Losses[1]	MP_C Scenario Losses[1]	Losses Avoided[1]	Comments
Physical Damage				
Structure	$635,142	$0	**$635,142**	• 39 residential structures were impacted; all were one-story buildings with no basements. • One industrial facility, encompassing eight buildings was impacted; all were one-story buildings with no basements. • Structure damages were estimated using depth-damage curves from the FEMA BCA Full Data Flood Module. • BRVs were based on Marshall & Swift (residential) and RSMeans (industrial).
Contents	$570,452	$0	**$570,452**	• The contents of 47 structures were impacted. • Contents value for residential structures was estimated at 30% of the BRV based on the FEMA BCA. • Contents value for industrial structures was estimated based on HAZUS-MH. • Contents damages were estimated using depth-damage curves from the FEMA BCA Full Data Flood Module.
Roads and Bridges	$122,903	$0	**$122,903**	• Estimated using historical data provided in DSRs for events of similar magnitude.
Infrastructure	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Landscaping	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Environmental Impacts	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Vehicles/Equipment	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Subtotal	***$1,328,497***	***$0***	***$1,328,497***	
Loss of Function				
Displacement Expense	$48,159	$0	**$48,159**	• Residents from 39 homes were displaced in the MP_A scenario. • Displacement from the industrial facility was not calculated based on the assumption that the business would not be displaced by short-term closure.
Loss of Rental Income	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Loss of Business Income	$16,370	$0	**$16,370**	• Daily business income was calculated based on HAZUS-MH guidance. • Functional downtime was estimated using depth-damage curves from the FEMA BCA Full Data Flood Module.
Lost Wages	$3,373	$0	**$3,373**	• Daily lost wages were calculated based on HAZUS-MH guidance. • Functional downtime was estimated using depth-damage curves from the FEMA BCA Full Data Flood Module.
Disruption Time for Residents	$165,387	$0	**$165,387**	• Over 94 residents were affected in the MP_A scenario. • Disruption costs were determined using the national average per-hour wage identified in *What Is a Benefit?* ($21.16 per hour). • Disruption time was calculated using EMI guidance.
Loss of Public Services	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.

Continued

Table F.1 Part 2 of 2

Loss Estimation Analysis Results
Broadway Culvert Replacement

Loss Type	MP_A Scenario Losses[1]	MP_C Scenario Losses[1]	Losses Avoided[1]	Comments
Loss of Function (Continued)				
Economic Impact of Utility Loss	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Economic Impact of Road/Bridge Closure	$0	$0	**$0**	• Not predicted, not indicated in project file or collected data.
Subtotal	***$233,289***	***$0***	***$233,289***	
Emergency Management				
Debris Cleanup	$8,141	$0	**$8,141**	• Estimated using historical data provided in the project file.
Governmental Expense	$33,922	$0	**$33,922**	• Estimated using historical data provided in the project file.
Subtotal	***$42,063***	***$0***	***$42,063***	
Total	***$1,603,849***	***$0***	***$1,603,849***	

[1] All amounts rounded to the nearest dollar

for moving costs for each impacted structure. Displacement time was determined using the depth-damage curves from the FEMA BCA Full Data Riverine Flood Module.

For disruption time, FEMA provides national average wage of $21.16 per hour. The disruption time was calculated based on EMI guidance with 40 hours, plus an additional 8 hours for every 1 percent in building damage for each adult occupant. Each residence was assumed to have two adult inhabitants (based on 2000 California Census data).

Disruption time and displacement expense for residents in the project area were estimated to be $213,546 for the MP_A scenario. The MP_C scenario involved no disruption or displacement. Therefore, losses avoided due to the loss of function associated with residential structures were $213,546.

Loss of function for the industrial structures impacted in the MP_A scenario was calculated using the FEMA BCA Flood Depth-Damage Curves for Loss of Function Time. The calculations included loss of business income and lost wages. The depth-damage curves relate the functional downtime to the type of structure and the depth of flooding. The functional downtime was then multiplied by the business income per day to determine the loss of business income and multiplied by the lost wages per day to determine lost wages. The business income for each structure was determined using *HAZUS-MH MR3 Technical Manual* Tables 14.14 - Proprietor's Income and 14.16 - HAZUS99 Earthquake Table of Recapture Factors. The business income per square foot per day was determined using the HAZUS building code for each structure and Table 14.14 from the *HAZUS-MH MR3 Technical Manual*. This value was multiplied by the structure area and recapture factor for the appropriate HAZUS label. Lost wages were calculated in a similar manner, using the same tables in HAZUS. The calculations for loss of business income and lost wages are provided in Attachment F.5.

For the MP_A scenario, lost business income and was estimated to be $16,370, and lost wages were estimated to be $3,373. As no structures were impacted in the MP_C scenario, no losses occurred. Therefore, losses avoided for the industrial facility total $19,743.

The total losses avoided for loss of function for all structures in this project area were estimated to be $233,289.

F.4.3 Emergency Management

Emergency management costs are those costs related to response and recovery activities and include debris cleanup and governmental costs. The project file indicated that typical debris cleanup costs were approximately $8,141 and governmental costs were approximately $33,922. For the MP_A scenario, the approximate cost for emergency management was assumed to be similar to historical records, so costs were estimated to be $42,063. For the MP_C scenario, no flooding occurred in the project area. Therefore, losses avoided associated with emergency management costs were estimated to be $42,063.

F.4.4 Results Summary

For the December 31, 2005, event of interest, losses avoided due to the completion of the mitigation project totalled $1,603,849. When compared to the project investment of $138,961, this project yields an ROI of 1,154 percent. The ROI only reflects the losses avoided for one event of interest. Therefore, the ROI is expected to increase as additional storm events test the project's effectiveness over its useful life.

MP_A Scenario Impacted Residential Structure Information[1]

Broadway Culvert Replacement

Address	FEMA BCA Building Type	Area (sf)	BRV ($/sf)	Total BRV	Contents Value Factor	Contents Value	Displacement Expense			Disruption Costs ($/person/hour)
							Rental ($/sf/mo)	Monthly ($/mo)	One-time ($/mo)	
1331 Butterfly Ln	1 story, without basement	1544	$93.00	$143,592.00	30%	$43,077.60	$1.00	$500.00	$500.00	$21.16
1341 Butterfly Ln	1 story, without basement	1203	$93.00	$111,879.00	30%	$33,563.70	$1.00	$500.00	$500.00	$21.16
1342 Buttercup Ln	1 story, without basement	1080	$93.00	$100,440.00	30%	$30,132.00	$1.00	$500.00	$500.00	$21.16
1353 Buttercup Ln	1 story, without basement	1700	$93.00	$158,100.00	30%	$47,430.00	$1.00	$500.00	$500.00	$21.16
1356 Buttercup Ln	1 story, without basement	3104	$93.00	$288,672.00	30%	$86,601.60	$1.00	$500.00	$500.00	$21.16
1357 Butterfly Ln	1 story, without basement	2949	$93.00	$274,257.00	30%	$82,277.10	$1.00	$500.00	$500.00	$21.16
1369 Buttercup Ln	1 story, without basement	1288	$93.00	$119,784.00	30%	$35,935.20	$1.00	$500.00	$500.00	$21.16
1370 Butterfly Ln	1 story, without basement	1216	$93.00	$113,088.00	30%	$33,926.40	$1.00	$500.00	$500.00	$21.16
1372 Buttercup Ln	1 story, without basement	1680	$93.00	$156,240.00	30%	$46,872.00	$1.00	$500.00	$500.00	$21.16
1373 Butterfly Ln	1 story, without basement	3066	$93.00	$285,138.00	30%	$85,541.40	$1.00	$500.00	$500.00	$21.16
1385 Buttercup Ln	1 story, without basement	1720	$93.00	$159,960.00	30%	$47,988.00	$1.00	$500.00	$500.00	$21.16
1386 Butterfly Ln	1 story, without basement	1200	$93.00	$111,600.00	30%	$33,480.00	$1.00	$500.00	$500.00	$21.16
1388 Buttercup Ln	1 story, without basement	2078	$93.00	$193,254.00	30%	$57,976.20	$1.00	$500.00	$500.00	$21.16
1389 Butterfly Ln	1 story, without basement	1440	$93.00	$133,920.00	30%	$40,176.00	$1.00	$500.00	$500.00	$21.16
1403 Buttercup Ln	1 story, without basement	1446	$93.00	$134,478.00	30%	$40,343.40	$1.00	$500.00	$500.00	$21.16
1404 Butterfly Ln	1 story, without basement	1189	$93.00	$110,577.00	30%	$33,173.10	$1.00	$500.00	$500.00	$21.16
1405 Butterfly Ln	1 story, without basement	1624	$93.00	$151,032.00	30%	$45,309.60	$1.00	$500.00	$500.00	$21.16
1420 Buttercup Ln	1 story, without basement	1600	$93.00	$148,800.00	30%	$44,640.00	$1.00	$500.00	$500.00	$21.16
1426 Butterfly Ln	1 story, without basement	1600	$93.00	$148,800.00	30%	$44,640.00	$1.00	$500.00	$500.00	$21.16
1427 Buttercup Ln	1 story, without basement	1189	$93.00	$110,577.00	30%	$33,173.10	$1.00	$500.00	$500.00	$21.16
1442 Butterfly Ln	1 story, without basement	1302	$93.00	$121,086.00	30%	$36,325.80	$1.00	$500.00	$500.00	$21.16
1442 Buttercup Ln	1 story, without basement	2654	$93.00	$246,822.00	30%	$74,046.60	$1.00	$500.00	$500.00	$21.16
1443 Butterfly Ln	2 story, without basement	2839	$78.00	$221,442.00	30%	$66,432.60	$1.00	$500.00	$500.00	$21.16
1443 Buttercup Ln	1 story, without basement	1314	$93.00	$122,202.00	30%	$36,660.60	$1.00	$500.00	$500.00	$21.16
1458 Butterfly Ln	1 story, without basement	1468	$93.00	$136,524.00	30%	$40,957.20	$1.00	$500.00	$500.00	$21.16
1459 Buttercup Ln	1 story, without basement	1462	$93.00	$135,966.00	30%	$40,789.80	$1.00	$500.00	$500.00	$21.16
1474 Butterfly Ln	1 story, without basement	1320	$93.00	$122,760.00	30%	$36,828.00	$1.00	$500.00	$500.00	$21.16

Continued

MP_A Scenario Impacted Residential Structure Information[1]
Broadway Culvert Replacement

Address	FEMA BCA Building Type	Area (sf)	BRV ($/sf)	Total BRV	Contents Value Factor	Contents Value	Displacement Expense			Disruption Costs ($/person/hour)
							Rental ($/sf/mo)	Monthly ($/mo)	One-time ($/mo)	
1474 Buttercup Ln	1 story, without basement	1468	$93.00	$136,524.00	30%	$40,957.20	$1.00	$500.00	$500.00	$21.16
1475 Buttercup Ln	1 story, without basement	1314	$93.00	$122,202.00	30%	$36,660.60	$1.00	$500.00	$500.00	$21.16
1490 Butterfly Ln	1 story, without basement	1410	$93.00	$131,130.00	30%	$39,339.00	$1.00	$500.00	$500.00	$21.16
1490 Buttercup Ln	1 story, without basement	1468	$93.00	$136,524.00	30%	$40,957.20	$1.00	$500.00	$500.00	$21.16
1491 Butterfly Ln	1 story, without basement	1400	$93.00	$130,200.00	30%	$39,060.00	$1.00	$500.00	$500.00	$21.16
1491 Buttercup Ln	1 story, without basement	1367	$93.00	$127,131.00	30%	$38,139.30	$1.00	$500.00	$500.00	$21.16
4260 Sunny Rd	1 story, without basement	1600	$93.00	$148,800.00	30%	$44,640.00	$1.00	$500.00	$500.00	$21.16
4276 Buttercup Ln	1 story, without basement	2304	$93.00	$214,272.00	30%	$64,281.60	$1.00	$500.00	$500.00	$21.16
4292 Buttercup Ln	1 story, without basement	1080	$93.00	$100,440.00	30%	$30,132.00	$1.00	$500.00	$500.00	$21.16
4301 Buttercup Ln	1 story, without basement	2180	$93.00	$202,740.00	30%	$60,822.00	$1.00	$500.00	$500.00	$21.16
4310 Buttercup Ln	1 story, without basement	1988	$93.00	$184,884.00	30%	$55,465.20	$1.00	$500.00	$500.00	$21.16
4331 Sunny Rd	1 story, without basement	1274	$93.00	$118,482.00	30%	$35,544.60	$1.00	$500.00	$500.00	$21.16

Note
[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

MP_A Scenario Impacted Industrial Structure Information[1]
Broadway Culvert Replacement

Address	Structure Information	HAZUS Building Type	FEMA BCA Building Type	Area (sf)	BRV ($/sf)	Total BRV	Contents Value Factor	Contents Value	Business Income ($/day)	Lost Wages ($/day)
4476 Skyway Dr	lumber yard									
	building 1	IND2	1 story, without basement	4,919	$40.79	$200,671.11	150%	$301,006.66	$207.74	$42.80
	building 2	IND2	1 story, without basement	4,873	$40.79	$198,759.95	150%	$298,139.93	$205.76	$42.39
	building 3	IND2	1 story, without basement	5,745	$40.79	$234,359.87	150%	$351,539.80	$242.61	$49.99
	building 4	IND2	1 story, without basement	5,604	$40.79	$228,588.94	150%	$342,883.40	$236.64	$48.75
	building 5	IND2	1 story, without basement	2,250	$40.79	$91,791.57	150%	$137,687.36	$95.02	$19.58
	building 6	IND2	1 story, without basement	2,177	$40.79	$88,812.42	150%	$133,218.63	$91.94	$18.94
	building 7	IND2	1 story, without basement	1,543	$40.79	$62,955.64	150%	$94,433.46	$65.17	$13.43
	building 8	IND2	1 story, without basement	4,768	$40.79	$194,487.96	150%	$291,731.94	$201.34	$41.48

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

MP_A Scenario Loss Estimation Analysis for Residential Structures[1]

Broadway Culvert Replacement

Address	Structure Elevation (ft)	Water Surface Elevation (ft)	Depth of Flooding (ft)	Structure DDF (% of BRV)	Structure Damage	Contents DDF (% of contents value)	Contents Damage	Displacement Time (days)	Displacement Expense	Disruption Time (hours)	Disruption Costs
1331 Butterfly Ln	56.93	57.43	0.50	12%	$16,513	5%	$7,431	31.0	$2,612	132	$5,586
1341 Butterfly Ln	57.22	57.43	0.21	10%	$11,244	5%	$5,060	13.0	$1,239	120	$5,095
1342 Buttercup Ln	56.21	57.43	1.22	16%	$15,829	7%	$7,123	76.1	$4,507	166	$7,029
1353 Buttercup Ln	56.99	57.43	0.44	11%	$17,707	5%	$7,968	27.3	$2,501	130	$5,485
1356 Buttercup Ln	56.24	57.43	1.19	16%	$44,802	7%	$20,161	74.2	$9,409	164	$6,947
1357 Butterfly Ln	57.36	57.43	0.07	9%	$25,643	4%	$11,539	4.3	$999	115	$4,858
1369 Buttercup Ln	57.16	57.43	0.27	10%	$12,398	5%	$5,579	16.7	$1,498	123	$5,197
1370 Butterfly Ln	57.44	57.43	-0.01	9%	$10,076	4%	$4,534	0.0	$0	111	$4,709
1372 Buttercup Ln	56.7	57.43	0.73	13%	$19,764	6%	$8,894	45.3	$3,789	114	$5,976
1373 Butterfly Ln	57.51	57.43	-0.08	8%	$23,609	4%	$10,624	0.0	$0	106	$4,496
1385 Buttercup Ln	57.33	57.43	0.10	10%	$15,196	4%	$6,838	6.2	$959	116	$4,909
1386 Butterfly Ln	57.56	57.43	-0.13	8%	$8,738	4%	$3,932	0.0	$0	103	$4,344
1388 Buttercup Ln	56.92	57.43	0.51	12%	$22,321	5%	$10,044	31.6	$3,217	132	$5,603
1389 Butterfly Ln	57.65	57.43	-0.22	7%	$9,401	3%	$4,231	0.0	$0	96	$4,069
1403 Buttercup Ln	57.5	57.43	-0.07	8%	$11,256	4%	$5,065	0.0	$0	107	$4,527
1404 Butterfly Ln	57.69	57.43	-0.26	7%	$7,364	3%	$3,314	0.0	$0	93	$3,948
1405 Butterfly Ln	57.8	57.43	-0.37	6%	$8,564	3%	$3,854	0.0	$0	85	$3,612
1420 Buttercup Ln	57.37	57.43	0.06	9%	$13,838	4%	$6,227	3.7	$760	114	$4,841
1426 Butterfly Ln	57.81	57.43	-0.38	6%	$8,303	3%	$3,736	0.0	$0	85	$3,582
1427 Buttercup Ln	57.67	57.43	-0.24	7%	$7,563	3%	$3,404	0.0	$0	95	$4,009
1442 Butterfly Ln	57.94	57.43	-0.51	4%	$5,340	2%	$2,403	0.0	$0	75	$3,186
1442 Buttercup Ln	57.6	57.43	-0.17	7%	$18,438	3%	$8,297	0.0	$0	100	$4,222
1443 Butterfly Ln	58.09	57.43	-0.66	2%	$3,765	1%	$1,694	0.0	$0	54	$2,268
1443 Buttercup Ln	57.84	57.43	-0.41	5%	$6,489	2%	$2,920	0.0	$0	82	$3,491
1458 Butterfly Ln	58.06	57.43	-0.63	3%	$4,546	1%	$2,046	0.0	$0	67	$2,820
1459 Buttercup Ln	58	57.43	-0.57	4%	$5,262	2%	$2,368	0.0	$0	71	$3,003
1474 Butterfly Ln	58.19	57.43	-0.76	2%	$2,652	1%	$1,193	0.0	$0	57	$2,424

Continued

MP_A Scenario Loss Estimation Analysis for Residential Structures[1]
Broadway Culvert Replacement

Address	Structure Elevation (ft)	Water Surface Elevation (ft)	Depth of Flooding (ft)	Structure DDF (% of BRV)	Structure Damage	Contents DDF (% of contents value)	Contents Damage	Displacement Time (days)	Displacement Expense	Disruption Time (hours)	Disruption Costs
1474 Buttercup Ln	58.05	57.43	-0.62	3%	$4,669	2%	$2,101	0.0	$0	67	$2,851
1475 Buttercup Ln	58.18	57.43	-0.75	2%	$2,750	1%	$1,237	0.0	$0	58	$2,455
1490 Butterfly Ln	58.34	57.43	-0.91	1%	$1,062	0%	$478	0.0	$0	46	$1,967
1490 Buttercup Ln	58.28	57.43	-0.85	1%	$1,843	1%	$829	0.0	$0	51	$2,150
1491 Butterfly Ln	58.38	57.43	-0.95	0%	$586	0%	$264	0.0	$0	44	$1,845
1491 Buttercup Ln	58.31	57.43	-0.88	1%	$1,373	0%	$618	0.0	$0	49	$2,058
4260 Sunny Rd	57.15	57.43	0.28	10%	$15,475	5%	$6,964	17.4	$1,715	123	$5,214
4276 Buttercup Ln	56.57	57.43	0.86	13%	$28,498	6%	$12,824	53.3	$5,484	146	$6,196
4292 Buttercup Ln	57.06	57.43	0.37	11%	$10,898	5%	$4,904	22.9	$1,708	127	$5,366
4301 Buttercup Ln	57.31	57.43	0.12	10%	$19,463	4%	$8,758	7.4	$1,165	117	$4,943
4310 Buttercup Ln	56.25	57.43	1.18	15%	$28,546	7%	$12,846	73.5	$6,597	164	$6,920
4331 Sunny Rd	57.94	57.43	-0.51	4%	$5,225	2%	$2,351	0.0	$0	75	$3,186

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

MP_A Scenario Loss Estimation Analysis for Industrial Structure[1]
Broadway Culvert Replacement

Address	Structure Elevation (ft msl)	Water Surface Elevation (ft msl)	Depth of Flooding (ft)	Structure DDF (% of BRV)	Structure Damage	Contents DDF (% of contents value)	Contents Damage	Loss of Function (days)	Loss of Business Income	Lost Wages
4476 Skyway Dr										
building 1	56.98	57.43	0.45	11%	$22,575	25%	$50,795	11.3	$2,337	$481
building 2	56.78	57.43	0.65	12%	$24,348	28%	$54,783	12.3	$2,521	$519
building 3	56.58	57.43	0.85	13%	$31,053	30%	$69,869	13.3	$3,215	$662
building 4	56.38	57.43	1.05	14%	$32,917	32%	$74,063	14.4	$3,408	$702
building 5	56.18	57.43	1.25	16%	$14,687	36%	$33,045	16.0	$1,520	$313
building 6	57.58	57.43	-0.15	8%	$6,794	17%	$15,287	7.7	$703	$145
building 7	57.38	57.43	0.05	9%	$5,823	21%	$13,103	9.2	$603	$124
building 8	57.18	57.43	0.25	10%	$19,935	23%	$44,854	10.3	$2,064	$425

Note

[1] Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.

MP_A Scenario Loss of Business Income and Lost Wages Calculations[1]

Broadway Culvert Replacement

Address	HAZUS Building Type	Area (sf)	Income, Output, and Wage Recapture Factor[2]	Owner Income per Day[3] ($/sf)	Output per Day[4] ($/sf)	Business Income[5] ($/day)	Wages per Day[6] ($/sf)	Lost Wages[7] ($/day)	Functional Downtime[8] (days)	Total Lost Business Income	Total Lost Wages
4476 Skyway Dr											
building 1	IND2	4919	98%	$0.27	$1.85	$207.74	$0.44	$42.80	11.3	$2,337	$481
building 2	IND2	4873	98%	$0.27	$1.85	$205.76	$0.44	$42.39	12.3	$2,521	$519
building 3	IND2	5745	98%	$0.27	$1.85	$242.61	$0.44	$49.99	13.3	$3,215	$662
building 4	IND2	5604	98%	$0.27	$1.85	$236.64	$0.44	$48.75	14.4	$3,408	$702
building 5	IND2	2250	98%	$0.27	$1.85	$95.02	$0.44	$19.58	16.0	$1,520	$313
building 6	IND2	2177	98%	$0.27	$1.85	$91.94	$0.44	$18.94	17.7	$703	145
building 7	IND2	1543	98%	$0.27	$1.85	$65.17	$0.44	$13.43	9.2	$603	$124
building 8	IND2	4768	98%	$0.27	$1.85	$201.34	$0.44	$41.48	10.3	$2,064	$425

Note

1 Original calculations were performed in spreadsheet format; therefore, numbers may not calculate as presented due to rounding.
2 The Recapture Factors were taken from Table 14.16 HAZUS99 Earthquake Table of Recapture Factors in the HAZUS Flood Model Technical Manual.
3 Owner Income per Day was taken from Table 14.14 Proprietor's Income in the HAZUS Flood Model Technical Manual. This value was inflated to 2008 dollars.
4 Output per Day was taken from Table 14.14 Proprietor's Income in the HAZUS Flood Model Technical Manual. This value was inflated to 2008 dollars.
5 Business Income was determined by adding the Owner Income and Output per Day and multiplying the sum by the square footage and 1 minus the Recapture Factor. For example, the Business Income for 704 Petaluma was ($0.14 per square foot + $0.73 per square foot) x 6,783.75 square feet x (1-0.51).
6 Wages per Day was taken from Table 14.14 Proprietor's Income in the HAZUS Flood Model Technical Manual. This value was inflated to 2008 dollars.
7 Lost Wages were determined by multiplying the Lost Wages per Day by the square footage and 1 minus the Recapture Factor. For example, the Lost Wages for 704 Petaluma was $0.33 per square foot x 6,783.75 square feet x (1-0.51).
8 Functional Downtime was determined using the Depth Damage Functions from the FEMA BCA Riverine Full Data Module.

Acronyms:

ADH
Arroyo del Hambre

BCA
Benefit-Cost Analysis

BRV
Building Replacement Value

CADD
Computer Aided Design and Drafting

CDEC
California Data Exchange Center

cfs
cubic feet per second

CFW
Camp Far West

CLOMR
Conditional Letter of Map Revision

CN
Curve Number

Corp Yard
Napa Corporation Yard

DDF
depth-damage function

DEM
Digital Elevation Model

DSR
Damage Survey Report

DWR
California Department of Water Resources

EMI
Emergency Management Institute

EOC
Emergency Operations Center

FCD
Flood Control Headquarters - Contra Costa County

FEMA
Federal Emergency Management Agency

FFE
first floor elevation

FIRM
Flood Insurance Rate Map

FIS
Flood Insurance Study

FMA
Flood Mitigation Assistance

ft
foot (feet)

GIS
Geographic Information System

GPS
Global Positioning System

H&H
hydrologic and hydraulic

HAZUS-MH
Hazards U.S. - Multihazard

HEC-RAS
Hydrologic Engineering Center - River Analysis System

HMGP
Hazard Mitigation Grant Program

IDF
intensity-duration-frequency

in
inch(es)

LA
Losses Avoided

LAT
Loss Avoidance Team

lidar
Airborne Light Detection and Ranging Systems

LOMR
Letter of Map Revision

m
meter

MAP
mean annual precipitation

MHHW
mean high-higher water

MP_A
Mitigation Project Absent

MP_C
Mitigation Project Complete

MR3
Maintenance Release 3

msl
mean sea level

NFIP
National Flood Insurance Program

NOAA
National Oceanic and Atmospheric Administration

NRCS
Natural Resources Conservation Service

NWS
National Weather Service

OES
(California) Governor's Office of Emergency Services

PA
Public Assistance

PDM
Pre-Disaster Mitigation

PI
Project Investment

PW
Project Worksheet

PWA
Philip Williams Associates

RCP
reinforced concrete pipe

RFC
Repetitive Flood Claims

ROI
Return on Investment

SCS
Soil Conservation Service

SRL
Severe Repetitive Loss

TIN
Triangular Irregular Network

USACE
U.S. Army Corps of Engineers

USGS
U.S. Geological Survey

WSE
water surface elevation

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http://cdec.water.ca.gov/

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http://www.fhwa.dot.gov

Google Earth:
http://earth.google.com/

Google Maps:
http://maps.google.com/

HEC-RAS:
http://www.hec.usace.army.mil/software/hec-ras/

Hydraulic Reference:
http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

Marshall & Swift:
http://www.marshallswift.com/

Yuba County Community Development and Services Agency - Planning Department Specific Plans:
http://www.co.yuba.ca.us/Departments/Community%20Development/Planning/Specific%20Plans/Plumas%20Lake/

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